

REPORT ON PROJECT SUMMARIES AND CASE STUDIES



August 2013

Projects funded by Innovative Bridge Research and Construction Program (1998-2005) and Innovative Bridge Research and Deployment Program (2006-2009)

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EXECUTIVE SUMMARY

Background

The Innovative Bridge Research and Construction (IBRC) Program was established under Transportation Equity Act for the 21st Century (TEA-21) in 1998 as a 6-year program that provided direction and funding to help State and local highway agencies defray the cost of incorporating innovative materials and technologies in bridge repair, rehabilitation, replacement, and new construction. This program was extended for another two years as a result of TEA-21 continuing resolutions.

Following the IBRC program, the Innovative Bridge Research and Deployment (IBRD) program was established under SAFETEA-LU to encourage highway agencies to more rapidly accept the use of new innovative materials, technologies, and practices. The general program goals of IBRD were similar to the goals of IBRC Program with the intent to promote and demonstrate innovation in its broadest sense to move market-ready technologies into conventional practice.

Under these two programs, over 400 innovative projects have been funded in 50 States, Puerto Rico and District of Columbia with a total award exceeding \$139 million dollars.

Many innovative technologies such as the use of high performance materials, the use of glass and carbon fiber-reinforced polymers, and implementing innovative construction techniques such as accelerated bridge construction using prefabricated bridge elements have been promoted, implemented, and successfully deployed with this funding. Case studies, professional publications, and reports through the media were published for many of these projects highlighting numerous positive achievements.

Project Data Collection

A systematic approach was developed to organize the data of these various projects that were funded in part by the IBRC and IBRD programs. The overall goal of the organization was to summarize and evaluate each project based on information provided by the State Bridge offices and FHWA State Division offices. Data was assembled from multiple sources and by a variety of methods. First, all available information with respect to funded projects and project history was provided by the FHWA. The information was reviewed and cross referenced with the FHWA's website and the 2008 IBRC and IBRD progress report. Based on these sources, a database was generated and sorted based on the project name and corresponding technology.

The status of each project was then established by contacting each State DOT and FHWA State Division offices. A contact report form was developed to document the correspondence with the States. Technical information was gathered by e-mail and phone calls to the best extent reasonably possible, but was ultimately contingent upon State participation. Each State was generally very responsive and an approximately 80% capture rate was achieved. This capture rate reflects the facts that many projects had been successfully closed out and archived, others are ongoing or were still ongoing at the time of the report request. In some instances, the original project coordinator had retired or the knowledgeable staff had moved on to different careers.

Project Summaries

The project reports were returned by the States. Based on those reports, a recommended list of projects for developing project summary sheets was created. At the same time, each project was sorted based on the technology or technologies being implemented. Recommendations for summary reports were based on: (1) level of completeness of the information reported by the State, (2) impact of the technology implemented, and (3) the reported lessons learned while implementing the technology. A summary sheet was generally not recommended only when very limited information was available for a project. Approximately 300 summary sheets were completed for this report.

Based on the information received, a series of 11 General Technology categories were determined for classifying all projects. Each technology is summarized in the report with a general description and includes any necessary sub-categories. These general categories include:

- High Performance Concrete
- Fiber Reinforced Polymers
- Self Consolidating Concrete
- High Performance Steel
- Accelerated Bridge Construction
- Reinforcing Bars
- Monitoring
- Coatings and Corrosion
- Foundations
- Deck Coatings
- Other Technologies (Miscellaneous)

Several of these technologies are now in common use or are under additional development specifically as a result of the IBRC and IBRD programs.

Project Case Studies

For these technologies, 50 projects were selected as candidates for development of a detailed case study. These 50 projects were selected as a broad selection from all of the 11 general technology categories and were based on the data obtained from the States. To that end a minimum of three (3) and a maximum of five (5) from each technology were recommended, with an attempt to capture each of the subcategories. Thus, each subcategory had at least one Summary Sheet. From this list a maximum of 30 were selected for development.

To assist with the final Case Study selection process, the case studies were ranked. Projects were first rated on a scale of 1-5 based on the positive impact of the technology on the project. The second rating from 1-5 was based on having sufficient data reported by the state to populate a case study. Any ties were settled by quality of the information in the Summary Sheets. The projects which were considered the 30 most viable candidates were each selected for a complete case study. Each project case study is a four to eight page document highlighting the project and technology.

Program Results

The case studies show that the IBRC and IBRD programs overall demonstrated new and viable technologies that are currently being implemented on a regular basis for modern construction. The results achieved by the IBRC and IBRD programs provide a solid and tangible step in tackling several of the problems associated with America's infrastructure. In 2009, ASCE's annual report card estimated the 5-year shortfall in funding for roads and bridges at \$549.5 billion for the entire United States. Traditional methods of construction are not expected to be the only answer to solve this problem. Arguments have been presented that some of the traditional methods are at least partly the reason for the existing poor conditions on some bridges. Thus, a new and more innovative means of design and construction needs to be part of the equation and the IBRC and IBRD programs has provided a vehicle for this innovation.

All 30 projects used for the case studies produced positive results and in many cases were critical in developing the innovative technology for future use in the State and/or region. Additionally, numerous projects that were part of the two programs, but were not selected for the final 30 case studies, also showed many other encouraging benefits. Several examples are highlighted below.

High Performance Concrete (HPC) was used for the deck design in the construction of the Wacker Drive Viaduct project. As reported, it provided an excellent long-term solution for the City of Chicago. This high profile project in the heart of downtown Chicago was very successful and received positive media attention. Based on the success of this project, the Chicago Department of Transportation has been implementing HPC on several bridge decks since the success of the original Wacker Drive Viaduct reconstruction project. HPC is now in general use throughout the United States.

Self Consolidating Concrete (SCC) was used in conjunction with High Performance Steel (HPS) slender tube arches for the Ravenna Viaduct in Ravenna Nebraska. This new system eliminated the need of a center pier. This slender arch system is only possible because of new high performance steel and SCC, and new theories recognizing the increased strength of confined concrete. The results achieved on this project formed the basis for standardizing the system for future applications. This provides a new solution for a low clearance design or to eliminate piers and can be applied to any bridge in the United States which may need to meet similar requirements.

The Cottonwood Creek Bridge in Hutto, Texas utilized Accelerated Bridge Construction (ABC) in almost every major component of the structure. Precast concrete elements included the abutments, bent cap, and the slab beam which incorporated an integral deck. The use of ABC led to a 33 day construction schedule that is a much shorter timeframe than traditional bridge construction techniques. Based on the success of this replacement project, the Texas Department of Transportation developed standard bridge details for the decked slab beam for state-wide use for rapid replacement requirements. ABC is now a nationally recognized initiative. Almost any project with time sensitive constraints can benefit from this technique. Moreover, the ABC concept has proven to reduce project costs even when the accelerated schedule is not a priority.

One of the most publicized IBRD projects was the Neal Bridge project in Maine. It incorporated an experimental design which made use of concrete-filled Fiber Reinforced Polymer (FRP)

arches. This was the first ever bridge of its kind to be constructed in the United States, and bridges which have since utilized this innovative technology have become to be known as “bridge-in-a-backpack”. The State of Maine gained valuable insight into this new bridge technology and how to implement it. As a result, five more similar projects have been completed in Maine, becoming a regular construction technique. This technology could be applied in many States across the nation and demonstrates the capabilities of using FRP in bridge design. This type of structure is designed to span smaller features and is ideal for local agencies looking for a relatively inexpensive and quickly constructed bridge, of which, are thousands of bridges that fit this description.

Built in 2000, the Rollins Road Bridge incorporated several innovative technologies in its design. The bridge utilized Carbon Fiber Reinforced Polymer (CFRP) reinforcement in the concrete deck, High Performance Concrete (HPC) in both the girders and deck, and instrumented the entire bridge with a Structural Health Monitoring (SHM) system designed to record the bridge’s long-term performance. Restoration and long term durability of bridge decks are important for bridge life. Monitoring devices are increasingly considered for evaluating bridges. Based on this project, the New Hampshire Department of Transportation has routinely used HPC in decks and prestressed girder design. Additionally, the CFRP used in the bridge deck is performing very well.

Gray County, located in north Texas, utilized an innovative deicing overlay to provide a safer riding surface during winter travel. This deicing system utilizes “charged” aggregates which store deicing materials that automatically leach out of its surface when the roadway comes into contact with ice or snow. The epoxy-aggregate deicing overlay is activated by weather conditions, thus the deicing capabilities are instantly achieved. After five years of service, there has been a significant decrease in both traffic accidents and the amount of deicing chemicals traditionally seen at this bridge site. The Texas Department of Transportation has been very satisfied with the results, and based on the performance of this bridge site, three other sites have utilized this technology.

Each of these successful projects which are now being used as common construction techniques would not have come to fruition or would not have been established nearly as quickly without the funding provided by the IBRC and IBRD programs. The additional funds were able to provide a tipping point to overcome the initial costs commonly associated with implementing new or untested technologies. Taking this burden off the local owners greatly facilitated demonstrating these technologies and has proven to lead to useful construction materials and techniques.

1. SUMMARY SHEETS

1.1. ALABAMA

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** AL-97 Bridge over I-65 near City of Letohatchie**State:** AL **Federal-Aid Project #:** _____ **Fiscal Year:** 2004 **Funds Awarded:** \$400,000.00**Fund Status:** \$78639.00 Expended **Project Status:** Initiated**Associated Project Names**

Repair of Girder Ends on I-565 NBI

Project: Change / Associated

Reallocated from / to:

SR 81 over Uphapee Creek

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Bonded Reinforcement on surface of Concrete T-Beams

Technology Description: Fiber-reinforced polymer (FRP) laminates are being used to effectively strengthen reinforced concrete members. A flexural application for this material is for strengthening of bridges. The existing bridge was found to be deficient for certain types of truck loadings. Fiber-reinforced polymer (FRP) strips were selected to use in the strengthening scheme. Strips or sheets are bonded to the concrete surface with an epoxy

Project Information**Positive Results:**

- Project is ongoing
- Initial laboratory study and modeling indicates FRP is able to provide added bending moment capacity
- Able to evaluate most accurate modeling methods for FRP strengthening

Negative Results:

- Project is ongoing
- None of the PE-debonding models correlated with the existing NSM tests

Lessons Learned:**Barrier to implementation of Technology:** Project is ongoing

Analytical results show that spacing the strips fairly evenly across the cross section should effectively control service-level cracking while minimizing debonding interaction between the strips.

Internal or External Reports:

" NEAR-SURFACE MOUNTED, FIBER-REINFORCED POLYMER STRIPS FOR NEGATIVE-MOMENT STRENGTHENING OF CONCRETE BRIDGES—DESIGN METHODOLOGY" Masters thesis presents the results from the initial evaluation of FRP reinforcing application, selection of the proper modeling techniques to predict the strength gain of the concrete beams, and recommendations for the field application of the technology on the Letohatchie Bridge.

Publications, Presentations, or, Construction Studies:

None to date.

Additional Comments:

Technology used on Other Projects: Yes, FRP reinforcement is being used on another IBRD projects and shows promise as an effective repair and strengthening technique.

Plans on Reuse of Technology: Yes if field results match structural analysis. FRP reinforcement has the potential to be highly beneficial for repair of concrete structures.

Applicability to other States: Should be available for general use to all states.

If the strengthening scheme proves to be effective for this bridge, it could be used to strengthen other bridges that were constructed using the same ALDOT standard design.

10/30/08: Formal agreement with research consultant signed July 21 2008 to proceed with development of the project. Research Project 930-745.

Project was delayed by the State and research consultant due to other higher priority projects were finished.

3/30/2010

Research project 930-745S:

Contract Amount \$250,003

Start Date 10/1/2008

Anticipated Completion Date 9/30/2011

Quarterly Progress Report:

10/1/2009-12/31/2009

Time Expended 25%

Funds Expended \$78,639 (31%)

Work Accomplished:

- Design of Strength Verification test almost complete
- Formwork for test specimens completed and strain gages installed
- Continue working on finite element model to compare with load tests

NBI Structure Number 008847

SR97 over I-65 near City of Letohatchie

Lowndes County

Alabama

State DOT Contact: George H Conner

Phone: 334-242-6272

E-mail: connerg@dot.state.al.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** BB Comer Southbound Bridge US 431 over Tennessee River**State:** AL **Federal-Aid Project #:** IBRCPF-0035(505) **Fiscal Year:** 2005 **Funds Awarded:** \$400,000.00**Fund Status:** \$298,498.60 Expended **Project Status:** InitiatedAssociated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Self Consolidating Concrete in Drilled Shafts**Technology Description:** Carbon fiber reinforced polymer (CFRP) strips were externally bonded to the girder soffits to enhance the positive moment capacity of the spans.Project InformationPositive Results:

Project is ongoing

SCC in the experimental castings appeared to have uniform elevels of consolidation between the annulus and cover regions.

Negative Results:

Project is ongoing

Lessons Learned:

Barrier to implementation of Technology: Project is ongoing

Problems were found when placing the SCC in two of the production shafts.

Internal or External Reports:

“Quarterly progress report - Evaluation of High-Performance Drilled Shaft Concrete on the B.B. Comer Bridge” attached highlights progress up to placement of the initial production shafts and included steps for completion of the project.

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Nono to date.

Plans on Reuse of Technology: Project Ongoing

Applicability to other States: Results will be usable for any state wishing to investigate us of SCC for drilled shafts.

10/30/08: Design of SCC mix underway. Special Provisions are being developed for the test drilled shafts. Testing plans are being developed.

Research Project 930-688S, 30% complete.

3/30/2010 Status:

Research Project 930-688S has been funded under Alabama Project IBRCF-0035(505)

Project Started 11-1-2006

Project Funds Expended \$298,498.60

Projected Completion Date 8-30-2010

Construction Project BRF-0035(502) was used to construct actual test shafts to be exhumed for destructive testing as part of the research project.

Work completed to date see attached Research Report 930-688S for this IBRC project

Major Items remaining are non-destructive testing and preparing the final report.

I have requested a copy of a presentation made at the 53rd Annual Alabama Transportation Conference about the result of the research and testing on the drilled shafts.

State DOT Contact: Lindy Blackburn

Phone: 334-206-2203

E-mail: blackburnl@dot.state.al.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** County Rte. 409 over Short Creek**State:** AL **Federal-Aid Project #:** IBRCP-ACGBBRZ-4811(200) **Fiscal Year:** 2000 **Funds Awarded:** \$500,000.00**Fund Status:** Expended**Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: HPC Prestressed Girders

Technology Description: Use of stronger concrete to increase span length of standard AASHTO Prestressed girder shapes. Final strengths of the HSP were in the range of 9000psi

Project Information**Positive Results:**

Demonstrated HPC girders can be used to increase span lengths for local road bridges eliminating the need for a center pier in the creek. Construction time was reduced by 6-8 weeks due to spanning the creek.

Negative Results:

Heavier girders were more difficult to set. Deck elevation adjustments were required due to more camber than predicted on the plans.

Lessons Learned:

Barrier to implementation of Technology: None. This form of concrete is available.

HPC can benefit local road agencies, decreasing construction times and eliminating piers. The biggest challenge on this project was setting the 135ft long girders. The experienced contractor was able to overcome this challenge. Also of note is that 135ft is the practical limit for girder transportation.

A second challenge was the camber of the center span for the project. There is evidence on this project that, with the longer spans and higher concrete strengths, the camber will become less predicable. On this project, the excessive camber forced a 3/4" raise in the alignment at the center of the bridge that was tapered to zero at the ends.

Internal or External Reports:

"Marshall County Commission" August 10, 2004 internal report prepared by the County Engineer is attached.

**Publications, Presentations, or, Construction Studies:**

None

Additional Comments:

Technology used on Other Projects: None to date

Plans on Reuse of Technology: Yes. Will be used where appropriate, in particular where standard AASHTO shapes can be used to eliminate substructure units.

Applicability to other States: Suggested for use in all states where conditions are such that additional substructure units can be eliminated.

10/30/08: Construction Project completed April 26, 2005.

County supplemented the project with \$391,035.48 of Federal-aid Off-system bridge funds.

3/30/10:

Construction Project IBRCP-ACGBBRZ 4811(200) was completed on 4/26/2005 and all IBRC funds were expended.

NBI Structure Number 018564

State DOT Contact: Robert Pirando

Phone: 256-571-7712

E-mail: ncaeng@yahoo.com

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Repair of Girder Ends on I-565 NBI Str. No.# 015821 Huntsville, AL**State:** AL **Federal-Aid Project #:** IBRCPF-STPAAF-1565(306) **Fiscal Year:** 2003 **Funds Awarded:** \$400,000.00**Fund Status:** \$373,939.00 Expended **Project Status:** Initiated**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Bonded Repair to Prestressed Concrete Girder Ends

Technology Description: Cracks were discovered on prestressed bulb-tee beams near diaphragms cast to make the spans continuous. An externally bonded FRP reinforcement repair system was designed for the girders to strengthen them, limit further crack growth, and prevent additional cracks.

Project Information**Positive Results:**

- Project is ongoing
- FRP is able to accomplish three objectives with one system – provide added bending moment capacity; provided adequate shear resistance; shift future cracking to a more benign location on the span.

Negative Results:

- Project is ongoing
- None to date

Lessons Learned:

Barrier to implementation of Technology: Project is ongoing

Internal or External Reports:

"CRACKING AND REPAIR OF PRESTRESSED CONCRETE BRIDGE GIRDERS MADE CONTINUOUS FOR LIVE LOADS" Intermediate Report: details preliminary engineering and analysis for application of the FRP reinforcement. Results of application and effectiveness have not yet been made available.

Publications, Presentations, or, Construction Studies:

None to date.

Additional Comments:

Technology used on Other Projects: Yes, FRP reinforcement is being used on another IBRD project "AL -97 Bridge over I-65 near City of Letohatchie" which is also still under study.

Plans on Reuse of Technology: Yes if field results match structural analysis. FRP reinforcement has the potential to be highly beneficial for repair of concrete structures.

Applicability to other States: Should be available for general use to all states.

3/30/10 Status:

Research Project 930-601 10/1/2009-12/31/2009:

- Scheduled load test of repaired bridge for 5/20-21/2010
- 86% complete

Preliminary Project IBRCP I565(302)

- Design 100% complete

Construction Project IBRCPF-STPAAF I565(306):

- Repairs to girder ends 100% complete
- Work accepted by ALDOT 1/15/2010

IBRC Funds:

- Awarded \$400,000.00
- Current Balance \$26,060.62

State DOT Contact: George H Conner

Phone: 334-242-6272

E-mail: connerg@dot.state.al.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** SR 81 over Uphapee Creek**State:** AL **Federal-Aid Project #:** IBRCP-SP00(002) **Fiscal Year:** 2000 **Funds Awarded:** \$299,400.00**Fund Status:** \$299,400.00 Expended **Project Status:** Completed**Associated Project Names**

Surles Road Bridge Over Bedsole	Project: Change / <u>Associated</u>	Reallocated from / to:
Repair of Girder Ends on I-565	Project: Change / <u>Associated</u>	Reallocated from / to:
AL-97 Bridge over I-65	Project: Change / <u>Associated</u>	Reallocated from / to:

Technology Implemented: FRP Bonded Reinforcement to Concrete Tee Girders

Technology Description: Carbon fiber reinforced polymer (CFRP) strips were externally bonded to the girder soffits to enhance the positive moment capacity of the spans.

Project Information**Positive Results:**

Strengthening of existing structures using externally bonded FRP strip can be achieved quickly and easily, however it is can be prohibitively messy and require extensive cleanup.

Design can be achieved using basic principles of structure mechanics and reinforced concrete design.

Lab test show that keeping bridge open to traffic during epoxy curing does not result in degradation in flexural strength

Negative Results:

Very messy procedure.

Did not restore as much strength as anticipated.

Lessons Learned:

Barrier to implementation of Technology: For FRP Laminates to be attractive for repairs the installation process must be efficient and economical for state DOT's and the repair must remain effective for many years after the installation. However, considering long term costs, it can be cost effective relative to other types of repairs.

Determining adequate anchorage requirements is difficult. FRP added did not provide enough reliable strength to remove all load postings from the bridge. The work is excessively messy with most tools needing to be discarded upon completion.

A typical installation should consist of no more than the following: access to the repair area through scaffolding, boom truck, etc; a crew of four to six men; job truck with a portable work surface; personal protective equipment for dealing with chemical substances.

Internal or External Reports:

“REPAIR OF THE UPHAPEE CREEK BRIDGE WITH FRP LAMINATES” This Final Report details the design and installation of the FRP, as well as the analysis methods, lab testing, and field testing of the FRP system.

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Yes, see related projects *AL-97 over I-65 near City of Letohatchie* and *Repair of girder ends on I-565*.

Plans on Reuse of Technology: Yes, this technology is potentially cost competitive to other repair and strengthening techniques for concrete bridges .

Applicability to other States: The FRP repair application is applicable to all states with concrete bridges in need of similar types of strengthening or repair.

Additional Project Notes:

10/30/08: Project complete. Final Research Report is being developed.

The State did not properly charge this project with researchers expenditures. They were misdirected by mistake to another state project. On 8-25-08 the State Office Engineer advised that the error will be corrected. When done the full amount awarded will be expended.

3/30/10:

Project IBRCP- SP00(002) Completed and all funds have been expended.

Final Research Report 930-466-2 is attached.

Project is closed

State DOT Contact: Gregg Conner

Phone: 334-242-6272

E-mail: connerg@dot.state.al.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Surles Road Bridge over Bedsole Creek**State:** AL **Federal-Aid Project #:** IBRCP-BRZ-2100(201) **Fiscal Year:** 2000 **Funds Awarded:** \$126,500.00**Fund Status:** Expended**Project Status:** Completed**Associated Project Names**

NBI Str. No 018178

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Timber / FRP Glue-Laminated Beam

Technology Description: The intent is to increase the capacity of the glue laminated timber beams with FRP

Project Information**Positive Results:**

Demonstrated the capability of adding FRP laminates to glue laminated timber to extend the span length to 75' while meeting the HS-20 design load.

Negative Results:

Costs were higher than expected and comparable to the cost of AASHTO prestressed concrete girders.

Lessons Learned:**Barrier to implementation of Technology:** overall costs comparable to prestressed girders with increased handling and inspection difficulties. Does not appear to be practical for routine application. Performance untested and long term durability not yet determined. Not currently recommended for future use.

Timber coated in thick creosote layer making handling and inspection difficult.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: No.

Plans on Reuse of Technology: No, see "Lessons Learned".

Applicability to other States: none

10/30/08: Construction Project completed April 1 2002.

2000 award \$126,000 was de-allocated at end of 2000 and reallocated in 2001 and an additional allocation was awarded in 2001 of \$50,000 to fully fund the original request in 2000. County supplemented the project with \$68,836.24 of Federal-aid Off-system bridge funds.

3/30/10:

Construction Project IBRCP-BRZ 2100(201) has been completed 4/1/2002 and all funds have been expended.

NBI Structure Number 018178

State DOT Contact: Benjamin Sanders

Phone: 334-335-2874

E-mail: CCHD@TROYCABLE.NET

1.2. ALASKA

FHWA IBRC/IBRD Project Summary Report FormProject Name: Kodiak Harbor Channel# 1189State: AK Federal-Aid Project #: Not Reported Fiscal Year: 2000 Funds Awarded: \$20,000.00Fund Status: Expended Project Status: CompletedAssociated Project Names

Statewide Seismic Retrofit

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Monitoring Seismic Bearings

Technology Description: Survey reflectors were permanently mounted to the Friction Pendulum bearings to monitor thermal performance and verify friction resistance. Survey points will be used to monitor displacements after seismic events. This project is considered a supplement to the Friction Pendulum bearings study and is not a new technology, but is instead a traditional monitoring system of a new technology. For information on the Friction Pendulum Technology, see the associated "Statewide Seismic Retrofit" project.

Project InformationPositive Results:

- Able to document performance of seismic isolation bearings on the Kodiak Near Island Bridge.
- By contract, finish coats were not required on the bearings
- The condition of the wind-lock bolts, rubber seals, grout pads, anchor bolts, and sole plates have been consistently noted as good
- Internal inspections have consistently reported the internal surfaces are clean and dry
- Six months after installation, rubbing marks were found where the pendulum has slid over the stainless steel dish, thus showing signs of movement. These signs are consistent with the survey data showing the thermal expansion and contraction of the bridge.
- No permanent deformations have been noted in the inspections
- Thermal movements have been accommodated

Negative Results:

- The paint system on the exterior of the bearings has shown a constant trend of deterioration through the inspections.
- Within 6 months of installation, rust was forming on the exterior surfaces of the bearings. With each successive inspection, further deterioration of the paint system was noted.
- The last inspection noted freckle rust and paint system failing on nearly every bearing inspected.
- Some of the grout pads have minor shrinkage cracks.
- In the last inspection, one of the rubber seals was bulged on the left side near the windlock. However, there were no signs that the bulge was causing any problems.
- Bearing number 2 on Pier 4 was found to have what appears to be a dried glue drip inside, but no signs of leakage.

Lessons Learned:

Barrier to implementation of Technology: None, the installation and performance of the Friction Pendulum bearings has been satisfactory. However, to date there have been no seismic events with a large enough magnitude close enough to the bridge site to validate the seismic performance of the Friction Pendulum bearings.

Internal or External Reports:

See "Final Report Friction Pendulum™ Bearing Replacement For Kodiak Harbor Channel Bridge No. 1189" attached to associated Project:

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Monitoring with survey equipment is common practice

Plans on Reuse of Technology: Will continue to use standard monitoring techniques.

Applicability to other States: Will determine applicability after bearings have been monitored during an earthquake event

State DOT Contact: Richard A Pratt, PE

Phone: (907) 465-8890

E-mail: Richard.pratt@alaska.gov

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Parks Highway Susitna River Bridge Repairs**State:** AK **Federal-Aid Project #:** BH-0A4-2(6) **Fiscal Year:** 2006 **Funds Awarded:** \$200,000**Fund Status:** Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Polyester Concrete Overlay

Technology Description: Polyester concrete overlays are similar to other overlays with the exception that they only require 2 to 3 hours to cure before returning traffic to the roadway. The unusual aspect of using polyester concrete for this application is the harsh temperature conditions present in Alaska.

Project Information**Positive Results:**

Construction Comments: Polyester concrete will give the bridge deck a longer life, versus an asphalt or microsilica concrete overlay.

We were able to put traffic on the new polyester concrete overlay with 1.5 to 2 hours, which helped lessen the impact the project had on the traveling public.

Negative Results:

Construction Comments: Initial materials cost were significantly more than traditional overlay materials used.

Materials used are very specialized and not available in the state of Alaska, making any potential repairs quite costly.

Lessons Learned:

Barrier to implementation of Technology: Cost of overlay in Alaska due to lack of supply

Construction Comments: Preparation of the deck surface as well as the application of the polyester concrete are very specialized tasks, which require both workers and inspectors who have had extensive experience working with these materials. Make sure the contractor provides a resume for all workers involved in the deck preparation and polyester lay down process, showing past experience.

Internal or External Reports:

September 2006 "Experimental Feature Work Plan, Polyester Concrete Overlay of the Susitna River Bridge"

**Publications, Presentations, or, Construction Studies:**

Additional Comments:

Technology used on Other Projects: None to date

Plans on Reuse of Technology: Not reported

Applicability to other States: Polyester overlay is used in other states such as California and Washington due to the quick cure time.

Construction Comments provided by: Mr. Ted Meyer (907-244-7138).

State DOT Contact: Drew Sielback
E-mail: Drwe.Sielbacj@alaska.gov

Phone: 907-465-6942

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Statewide Seismic Retrofit**State:** AK **Federal-Aid Project #:** Not Reported **Fiscal Year:** 2000 **Funds Awarded:** \$330,400.00**Fund Status:** Expended **Project Status:** Completed**Associated Project Names**

Kodiak HRBR CHNNL# 1189

Project: Change / Associated

Reallocated from / to:

Technology Implemented: **Friction Pendulum Bearings**

Technology Description: Friction Pendulum isolation bearings were installed on the Kodiak River Bridge to replace seismically vulnerable tall rocker bearings. Friction Pendulum bearings use a combination of a concave surface and friction to isolate the superstructure from ground motion while using friction as a seismic dampener.

The retrofit of the bridge was successful and implemented standard superstructure jacking procedures.

Project Information**Positive Results:**

Bearings have been in service for approximately 10 years, and they appear to be performing as designed.

Negative Results:

None to date.

Lessons Learned:

Selection of paint system was inadequate for exposed portions of the bearing.

Barrier to implementation of Technology: Seismic Performance still untested; therefore technology has not been proven successful.

Internal or External Reports:

Copy of "Final Report Friction Pendulum™ Bearing Replacement For Kodiak Harbor Channel Bridge No. 1189" attached.

**Publications, Presentations, or, Construction Studies:**

None

Additional Comments:

Technology used on Other Projects: Benicia-Martinez bridge in California

Plans on Reuse of Technology: once the performance has been subjected to a seismic event, the technology will be evaluated for future use based on its success or failure relative to other bearings.

Applicability to other States: technology could be applicable to other states with seismic concerns where superstructure isolation is practical. Bearings have been used in buildings in various locations, and on the Benicia-Martinez bridge in California, for example.

Excerpt of conclusion from attached paper: *"The installation and performance of the Friction Pendulum bearings on the Kodiak Harbor Channel Bridge has been satisfactory. Once the installation plan was approved, removal of the old bearings and installation of the new bearings progressed without problems. With the exception of the paint system on the exterior surfaces of the bearings, no other problems have been noted. To date, thermal movements have been accommodated and no seismic events with sufficient magnitude have occurred."*

State DOT Contact: Richard A Pratt, PE
 E-mail: Richard.pratt@alaska.gov

Phone: (907) 465-8890

1.3. ARIZONA

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I-40 Sunshine BNSFRR OP WB MP 237.10**State:** AZ **Federal-Aid Project #:** 040-D(016) **Fiscal Year:** 2004 **Funds Awarded:** \$400,000.00**Fund Status:** \$400,000.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Concrete, Low Corrosion Steel in Deck Slab

Technology Description: An existing concrete slab was removed and a new concrete slab using silica fume high performance concrete with low corrosion steel was constructed. The design performance criteria for the bridge deck were: Durability under freeze-thaw exposure; Lower permeability to salt penetration; Lower shrinkage potential; Reduced steel corrosion

Project Information**Positive Results:**

Develop a HPC mix design using laboratory tests of various batches. Field trial batches were conducted at a ready mix plant near the bridge site to simulate job conditions such as concrete batching, travel time, plastic and hardened concrete properties. Test result indicated that a concrete mix design with 0.41 water/cement ratio and 5 percent silica fume by weight of cement provided overall optimum performance against project requirements. A special performance specification was written for this pilot project. Currently the new deck is under monitoring for its performance and the data collection will be used for future study which is underway.

Negative Results:

Since this is a pilot project and HPC was never implemented in AZ before. A lot of trial batches were tested to satisfy the HPC requirements such as aggregate properties and conditions, controlling air content loss of pumped concrete on deck, a short of schedule that prevented refinement of the HPC mix and field practices and small size of demonstration slab not properly simulating the deck placement conditions.

Lessons Learned:

Barrier to implementation of Technology: None.

1. Aggregates quality and conditions will impact the quality of HPC mix to meet field performance requirements.
2. Ready mix supplies in Arizona need to make the transition from their current practice of concrete batching based on slump to batching based on Water/Cement ratio.
3. Concrete slump and air content at the batch plant may need to be higher than required on-deck to compensate for losses during transportation and pumping.

The upfront investment in dollars and resources can be justified when ADOT considers the reduced maintenance and extended service life of bridge decks using HPC technology.

Internal or External Reports:

“Implementing HPC on the Sunshine Bridge Project; Final Report 538” This report presents the research work from a pilot program regarding the feasibility of implementing high performance concrete on Arizona bridge decks, using the Sunshine Bridge in Holbrook, Arizona as a test case.

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: No.

Plans on Reuse of Technology: Yes, HPC can be implemented successfully on future bridge projects based on the test results and experience gained from the Sunshine Bridge project to date.

Applicability to other States: HPC is currently used in many other states. This was a pilot program for the first application in the state of Arizona. The use of HPC in bridges by other state DOTs with similar climate and service conditions has reduced maintenance and increased the service life of structures..

State DOT Contact: Pe-Shan Yang
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FHWA IBRC/IBRD Project Summary Report Form

Project Name: Virgin River Gorge Structure #7 Interstate 15, MP 22.55 Crossing Virgin River
State: AZ **Federal-Aid Project #:** 015-A(200) **Fiscal Year:** 2006 **Funds Awarded:** \$200,000.00
Fund Status: \$200,000.00 Expended **Project Status:** Completed

Associated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Innovative Construction Phasing and Erection Techniques

Technology Description: The erection time and cost for the two new steel plate girders were reduced by using field assembled track-moving steel gantries for girder pick-up and drop in a very confined work zone. Segments of girder were picked up from truck bed at each abutment then delivered to designated locations by the rolling gantry system moving along channel-shaped tracks temporarily attached to the bridge deck on each side of the 10-ft wide construction opening.

Project Information**Positive Results:**

Single lane of I-15 traffic in each direction was maintained at all times during connection of existing 496-ft long, three-span northbound and southbound bridges. Temporary concrete barriers were placed on each side of the work zone to provide safety for traveling public and construction crew.

Negative Results:

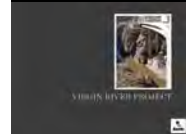
None.

Lessons Learned:

Barrier to implementation of Technology: None.

In order to facilitate the erection of field splices, diaphragms and lateral bracings, also for the safety of construction crew working over deep canyon, a 14-ft wide temporary wooden walkway was constructed on bottom flanges of the deeper existing plate girders located at each side of the opening. This walkway provided adequate work spaces on both sides and below the new girders.

These innovative erection techniques ensured the smooth and safe construction process and lead this project to earn the 2008 Arizona DOT Partnering Award.

Internal or External Reports:**Publications, Presentations, or, Construction Studies:**

"Virgin River Project"

Attached presentation shows pictures of the bridge replacements for the Virginia River project, including Structure #7. The presentation has pictures but is not descriptive of the project.

Additional Comments:

Technology used on Other Projects: No.

Plans on Reuse of Technology: Yes, if suitable project is found

Applicability to other States: Yes, states should consider alternate construction techniques. The initial cost may be higher, but the overall cost and impact on the traveling public is reduced.

State DOT Contact: Pe-Shen Yang
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Phone: 610-712-8606

1.4. ARKANSAS

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** State Hwy 245 Bridge over Interstate 30 (Texarkana)**State:** AR **Federal-Aid Project #:** NH-IBRC-30-1(143)2 **Fiscal Year:** 2004 **Funds Awarded:** \$347,500.00**Fund Status:** \$347,500.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: HPC in Bridge Rails and Deck Slab

Technology Description: High Performance concrete was used for a bridge deck targeting properties for longevity including increased compressive strength, decreased permeability, reduced shrinkage, and freeze-thaw resistance.

Project Information**Positive Results:**

The major positive result of the study is a crack free bridge deck. Another positive result is the familiarization of a local ready mix plant to high-performance concrete (HPC). The HPC mixture contained 50% slag cement that experienced a slow strength gain (which is a positive) and had low permeability. Finally, the benefits of immediate wet curing procedures were observed (no plastic shrinkage cracking).

Negative Results:

The concrete's placement is a potential negative. Due to the fresh air content requirement, the HPC was placed by bucket which prolonged the placement time. For future HPC decks, concrete placement by pump is recommended.

Lessons Learned:

Barrier to implementation of Technology: The concrete mix still needs to be refined. Proper construction practices also need to be established since it is not the mix alone that determines the final properties

For future HPC projects, we recommend testing the concrete's permeability at 90 days of age, removing the maximum compressive strength requirement at 56 days (and possibly implementing a maximum compressive strength at 7 days), and increasing the fresh air content requirement to 6+2% (from 6 +/-1%).

Recommendations include:

- Keep the w/c ratio low, large amount of coarse aggregate, and addition of slag to decrease permeability
- Lowering cementitious material content below 518 lb/yd³ results in an unusable mix
- Silica fume helps offset reduction of cement
- Proper AEA dosages improve freeze/thaw durability
- Construction techniques are just as important as mix design – allow sections to cure as long as possible before beginning adjacent pours.
- Investigate the use of pumping for concrete placement.

Internal or External Reports:**Publications, Presentations, or, Construction Studies:**

“State Hwy 245 Bridge over Interstate 30 (Texarkana)” The attached report highlights the research project and installation of the HPC.

Additional Comments:

Technology used on Other Projects:

Plans on Reuse of Technology: Will be reevaluated for future projects.

Applicability to other States: Recommend states develop their own procedures for mix design and application based on their specific construction and geographic needs. HPC has proven benefits and is applicable to any state using concrete in bridges.

State DOT Contact: Chris Hanning
Chris.hanning@arkansashighways.com

Phone: 501-569-2074

HDR Contact Name: Duncan Paterson

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** State Hwy 49 over I-40 (Brinkley)**State:** AR **Federal-Aid Project #:** BRN-IBRC-40-5(144)216 **Fiscal Year:** 2005 **Funds Awarded:** \$282,000.00**Fund Status:** \$282,000.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: HPS in I-GirdersTechnology Description: High performance steel was used in place of standard steel for I-girders**Project Information****Positive Results:**

The major positive result of this project was the cost savings from using High Strength Steel. High Strength Steel allowed for the design of slightly smaller girders and a slightly wider girder spacing. These girders accommodated the proper clearance without spreading the embankment footprints out, which would have required more right-of-way to be acquired.

Negative Results:

The only negative aspect discovered with using High Strength Steel was the additional work required of the steel fabricator to use special welding procedures, which were approved by AHTD prior to fabrication. Since small girders could be used with this project, additional camber was needed when fabrication of the girders was done, which cost slightly more, but was offset with cost savings listed above.

Lessons Learned:

Barrier to implementation of Technology: None apparent. Even with special procedures for welding, the process of working with HPS was very similar to using standard steel.

Normal construction monitoring was sufficient to determine if project was successful. No additional inspection during construction was required with the use of High Strength Steel.

Although cost savings were achieved though materials, it was slightly offset by additional camber and special welding procedures. These need to be considered when doing a cost comparison analysis.

Internal or External Reports:**Publications, Presentations, or, Construction Studies:**

Additional Comments:

Technology used on Other Projects:

Plans on Reuse of Technology: Yes, use of HPS will be advantageous for certain types of girder construction in the future.

Applicability to other States: Can be used by all states where HPS steel is available.

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Phone: 501-569-2074

1.5. CALIFORNIA

No Project Summary Reports were generated for this State.

1.6. COLORADO

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Castlewood Canyon Bridge, SH 83 over Cherry Creek**State:** CO Federal-Aid Project #: BR 0831-085 Fiscal Year: 2003 Funds Awarded: \$400,000.00**Fund Status:** \$400,000.00 Expended **Project Status:** CompletedAssociated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: CFRP wrap repair of historic arch

Technology Description: Carbon fiber wraps were used to reinforce an existing arch bridge as a repair and strengthening to meet increased traffic loads. The FRP scheme was used to provide longitudinal reinforcement for flexural enhancement and transverse reinforcement for confinement, shear enhancement, and protection from concrete deterioration and steel corrosion. FRP was externally bonded to the substrate.

Project InformationPositive Results:

The project was highly successful by demonstrating: (a) the first use of carbon wraps in Colorado for arch rehabilitation by CDOT; (b) the use of precast slabs, and column, caps by splice connections to accelerate construction. The project used the "BPI DoughNUT" termination system.

Carbon wraps have continued to be used on pier cap repairs since the Castlewood project. Additionally, the State will utilize accelerated slab construction on other projects. The project was also showcased at FHWA Bridge meeting in Colorado Springs during construction.

Negative Results:

None other than commented below. During construction there were block out problems with concrete leaking in the pintle holes.

Lessons Learned:

Barrier to implementation of Technology: long term effectiveness and resistance to deterioration unproven. Carbon fiber wraps can be very expensive and total replacement costs should be compared. The Contractor offered to replace the wrapped arch with a new structure and this was not pursued by CDOT in fear of the historic impacts of the project.

Additional lessons:

- Bond between FRP and substrate is critical factor in order to increase load carrying capacity
- FRP can provide good protection against aggressive environmental conditions but is dependent upon proper bonding
- The epoxy breaks down at 446°F and deteriorates under fire. Special treatments can be applied to increase fire endurance
- Degradation of the pull-off strength must be considered in the specifications related to the structural design

Internal or External Reports:Publications, Presentations, or, Construction Studies:

"Evaluation of the FRP-Retrofitted Arches in the Castlewood Canyon Bridge, Report No. CDOT-DTD-R-2005-01"

Authors: Delchi Fafach, Benson Shing, Sunyoung Chang, Yunping Xi

(<http://www.coloradodot.info/programs/research/pdfs/2005/castlewood.pdf/view>)

Additional Comments:

Technology used on Other Projects:

Plans on Reuse of Technology: Will evaluate long term durability of the wrap based on ongoing monitoring of the wrap. The monitoring will be important for evaluating the effectiveness of the CFRP repair, the performance of the corrosion inhibitor, and long term performance of the arch.

Applicability to other States: applicable to other states. Results of the monitoring will be used to demonstrate whether or not this is a worthwhile procedure. States can use those results and evaluate the process for their own use.

State DOT Contact: Mike Mohseni

Phone: 303-513-4300

E-mail: Mansour.mohseni@dot.state.co.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I-225 & Parker Rd. Phase III**State:** CO **Federal-Aid Project #:** SP 2254-062 **Fiscal Year:** 2000 **Funds Awarded:** \$400,000.00**Fund Status:** \$400,000.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Carbon FRP prestress deck panels and glass fiber reinforcement and implementation of HPCTechnology Description: Fiberglass reinforcement in place of traditional steel concrete reinforcing bars**Project Information****Positive Results:**

Colorado first used carbon fiber reinforcing in prestress panels and glass fiber reinforcement in the safety barrier and bridge rail. A temporary barrier was installed with glass fiber reinforcing and it was removed easily compared to steel reinforcing. The permanent bridge rail with the glass reinforcing has been hit and appears to be functioning satisfactory. HPC was also used

Negative Results:

It was unfortunate the test carbon fiber panels were not cast to the correct strength of concrete though they performed satisfactorily. There was controversy with the acceptance of the carbon reinforced panels due to cracking and possible debonding at the ends. The panels that were accepted by a licensed engineer. Not all of the carbon fiber strand was used in the project. The supplier Leadline of the carbon fiber had a special machine to aid the precast fabricator to anchor the carbon fiber strand for jacking. Leadline had a high cost for this machine and the fabricator ended up splicing the strand with .6" diameter steel strand for anchorage in the bed. The coupler caused a twist in the carbon strand making it difficult for strand alignment. The glass fiber reinforced barrier had more pronounced cracking compared to the reinforced steel barrier. The Contractor ordered the glass reinforcing material and had difficulty meeting his time schedule as the bars required preforming. The HPC mix continues to experience cracking.

Lessons Learned:

Barrier to implementation of Technology: material is very costly and further investigation is needed to evaluate life-cycle costs. CFRP bars are much more fragile than steel reinforcing and must be handled with extra care.

special equipment is needed for materials as Leadline's machine, a negotiated price should be established prior to bidding or a contract developed. This will take special contracting procedures and a finding of the public's interest

Internal or External Reports:

"Studies on the Use of High-Performance Concrete and FRP Reinforcement for the I-225/Parker Road Bridge, Report No. CDOT-DTD-R-2003-13" Authors: P. Benson Shing, Yunping Xi
<http://www.coloradodot.info/programs/research/pdfs/2003/hpcparker.pdf/view>

Publications, Presentations, or, Construction Studies:

“Evaluation of a Bridge Deck with CFRP Prestressed Panels under Fatigue Load Cycles” by Benson Shing, Kerri Borlin, Gero Marzahn, Department of Civil, Environmental & Architectural Engineering, University of Colorado Boulder, CO September 2003 (<http://www.coloradodot.info/programs/research/pdfs/2003/bridgedeckcrfppanels.pdf/view>)

Publications, Presentations, or, Construction Studies (cont'd):

“The Behavior of Fiber Reinforced Polymer Reinforcement in Low Temperature Environmental Climates”, By Renee Cusson, and Yungping Xi, University of Colorado Boulder October 2002 (<http://www.coloradodot.info/programs/research/pdfs/2003/frp.pdf/view>)



“EVALUATION OF FRP PRESTRESSED PANELS/SLABS FOR I-225 / PARKER ROAD PROJECT, Report No. CDOT-DTD-R-2001-14” Authors: Reuben Zylstra, P. Benson Shing, Yunping Xi, (<http://www.coloradodot.info/programs/research/pdfs/2001/frpprestressedpanel.pdf/view>)

Additional Comments:

Technology used on Other Projects: Yes, associated project: *Denver Parks O'Fallon Park Bridge*

Plans on Reuse of Technology: No, Glass FRP is overly expensive and difficult to work with. The benefits of FRP deck do not outweigh the inconvenience of using it and construction techniques are not sufficiently established. The HPC mix continues to crack excessively.

Applicability to other States: suggest that other states avoid using this technology.

State DOT Contact: Aziz Khan

Phone: 303-757-9522

E-mail: aziz.khan@dot.state.co.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I-25NB over Purgatoire River I-25; I-25NB over Main Street**State:** CO **Federal-Aid Project #:** IM-0251-166 **Fiscal Year:** 2004 **Funds Awarded:** \$247,300.00**Fund Status:** \$247,300 Expended **Project Status:** Complete**Associated Project Names**

I-25 over Great Western RR

Project: Change / Associated

Reallocated from / to:

Alternate name: *Trinidad Project*Project: Change / Associated

Reallocated from / to:

Technology Implemented: Study of SCC

Technology Description: SCC was used for the construction of Abutments and pier columns. SCC used for this application is high-flow that requires no vibration and can penetrate heavy reinforcement and complex framework.

Project Information**Positive Results:**

Project implemented the first use in the field of SCC successfully. Appearance of abutment wall and pier wall was excellent

Negative Results:

None noted

Lessons Learned:

Barrier to implementation of Technology: None. SSC was poured as a repair while subjected to normal traffic loads.

The ready mix company complained about the use of the material as they were not familiar. The specifications should have required a 1-2 hr training for the ready mix company and contractor before work was to proceed.

Vibrations from traffic loads can cause loss of bond strength on the order of 20% and compared to bond that is not subject to vibration during the pouring and curing process. Divert heavy truck traffic for at least four hours after the pour has been completed.

A slump flow ranging from 26 to 30 inches is recommended to secure proper placement with complete girder encapsulation.

Internal or External Reports:**Publications, Presentations, or, Construction Studies:**

“Study on the Use of Self-Consolidating Concrete for the Repair of the Mead Bridges on I-25, Report No. CDOT-2007-1” **Authors:** Panos Kiouisis, Brent Whitcomb

(<http://www.coloradodot.info/programs/research/pdfs/2007/meadbridge.pdf/view>)

Additional Comments:

Technology used on Other Projects: Yes, The technology has been used at the I-25 Meade bridges and the Trinidad Project.

Plans on Reuse of Technology: Yes, it is a good technology for the proper applications where standard concrete will not work. Results were very positive for the Abutment and Pier applications.

Applicability to other States: results of the repairs are applicable to other states. Use of SCC allowed for this solution to be possible. Use of SCC in the abutments and piers is recommended based on results of this study..

State DOT Contact: Aziz Khan
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Phone: 303-757-9522

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Denver Parks O'Fallon Park Bridge over Bear Creek**State:** CO **Federal-Aid Project #:** CE10590 **Fiscal Year:** 2001 **Funds Awarded:** \$499,759.00**Fund Status:** \$499,759 Expended**Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Deck Panel and Glass fiber reinforcement**Technology Description:** FRP Deck panel and FRP reinforcement was evaluated for use in place of a traditional bridge deck. Lightweight and designed to be mor durable.**Project Information****Positive Results:**

Successfully built Glass Panel bridge and glass fiber reinforced bridge. Bridge appears to be performing satisfactorily even though there is usually one trash truck on the structure weekly as it serves the Denver parks area.

Negative Results:

Workers did not like working with glass reinforced fiber as the fibers were irritating to the skin. CDOT has not used this technology since this project. Difficult to adjust glass reinforcing in field.

Lessons Learned:

Barrier to implementation of Technology: Every environmental parameter tested in the study resulted in a degradation of GFRPs to a certain extent. From the strength aspect, the worst degradation was a 35% reduction of tensile strength of the GFRP subjected to the ponding of 1M NaOH (1 mole solution of sodium hydroxide) solution. From the stiffness point of view, the worst degradation was a 32% reduction of Young's modulus of the GFRP subjected to the ponding of 3% Ca(Cl₂) solution. Comparing the effect of environmental temperature with the effect of mechanical loading, it is very clearly that the effect of temperature is dominant. Therefore, in addition to the mechanical fatigue loading test performed in this project, a larger scale cyclic temperature test for the FRP panel is very necessary and important for evaluating the long-term performance of the panel. The significant degradations in terms of the tensile strength and the stiffness must be considered in the specifications related to the structural design of bridge decks if the GFRP is to be used widely for bridge decks in the state of Colorado. The monitoring process of the bridge deck should be continued. The results obtained so far provide valuable information and can be compared to the strains that will be collected in the future to evaluate the long-term performance of the bridge deck.

Internal or External Reports:**Publications, Presentations, or, Construction Studies:**

"Evaluation of GFRP Deck Panels for the O'Fallon Park Bridge, Report No. CDOT-DTD-R-2004-2"

Authors: Guido Camata, P. Benson Shing

<http://www.coloradodot.info/programs/research/pdfs/2004/ofallanpark.pdf/view>

"Long-Term Durability of Fiber-Reinforced Polymers (FRPs) and In-situ Monitoring of FRP Bridge Decks at O'Fallon Park Bridge, Report No. CDOT-DTD-R-2004-03"

Authors: Yunping Xi, Sun-Young Chang, Andi Asiz, Yue Li

<http://www.coloradodot.info/programs/research/pdfs/2004/ofallan2.pdf/view>

Additional Comments:

Technology used on Other Projects: Yes, similar Project for IBRC is *I-225 & Parker Rd. Phase III*.

Plans on Reuse of Technology: None, to date, material is too expensive and difficult to work with. Cost is also excessive.

Applicability to other States: conclusions of this study are available to other states interested in using FRP.

State DOT Contact: Aziz Khan

Phone: 303-757-9522

E-mail: Aziz.khan@dot.state.co.us

FHWA IBRC/IBRD Project Summary Report Form

Project Name: Pedestrian Underpass on SH7 (Arapahoe Ave) @ Bear Canyon Cr
State: CO **Federal-Aid Project #:** STU 0071-025 **Fiscal Year:** 2006 **Funds Awarded:** \$78,000.00
Fund Status: \$78,000 Expended **Project Status:** Complete

Associated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Demonstrated Xypex admixture to seal concrete

Technology Description: Xypex is a concrete admixture intended to act as a water sealant

Project InformationPositive Results:

None. The product does not work

Negative Results:

The culvert experienced cracking and the Xypex admixture did not seal water and the culvert is leaking

Lessons Learned:**Barrier to implementation of Technology:** The product does not work

CDOT should have inquired nationally about the use of the product for highway applications before pursuing study.

Internal or External Reports:Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: No.

Plans on Reuse of Technology: No. See negative results

Applicability to other States: not recommended to other states.

10/30/08: The IBRC Project is completed. The County of Boulder is suing the manufacturer.

State DOT Contact: Aziz Khan

Phone: 303-757-9522

E-mail: Aziz.khan@dot.state.co.us

1.7. CONNECTICUT

No Project Summary Reports were generated for this State.

1.8. DISTRICT OF COLUMBIA

No Project Summary Reports were generated for this State.

1.9. DELAWARE

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** BR 26 ON FOULK RD OVER NAAMAN'S CREEK**State:** DE Federal-Aid Project #: EBRN-N203(4) Fiscal Year: 2001 Funds Awarded: \$0(reallocation)**Fund Status:** \$91,200 Expended**Project Status:** CompleteAssociated Project Names

BR 172B, Ramp J I95 Service Area

Project: Change / AssociatedReallocated from / to: \$91,200**Technology Implemented:** CFRP reinforcement in precast concrete beams

Technology Description: A study performed by University of Delaware in conjunction with the DOT using bonded CFRP wraps to strengthen concrete box beams as a repair or to mitigate further deterioration.

Project InformationPositive Results:

- If the CFRP plates are successfully bonded to the beams that it will lead to an increase in flexural capacity
- The plates may also reduce the size of cracking which forms on the tension faces of beams due to a variety of serviceability issues

Negative Results:

- Shear forces at the ends of the attached plates induced a delamination and peel-type failure between the plate and the beam
- Beams will fail in a more brittle manner than under reinforced beams with steel rebar and this behavior should be studied further

Lessons Learned:**Barrier to implementation of Technology:** None, however no real world application was performed, testing was done at the UniversityInternal or External Reports:

"Rehabilitation of Cracked Adjacent Concrete Box Beam Bridges"

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Split off of 1-712B project

10/30/08: Complete

Originally agreed to take \$150,000 from the 1-712B project. Final split with the deobligated money on this project was to be added up to \$350,000 award. This contract scope changed from a superstructure replacement to a rehabilitation using CFRP. Actual final costs were \$91,200.

State DOT Contact: Jiten Soneji

Phone: 302-760-2299

E-mail: Jiten.soneji@state.de.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** BR 119 on SR 82 over Red Clay Creek**State:** DE **Federal-Aid Project #:** EBHOS-N261(2) **Fiscal Year:** 2000 **Funds Awarded:** \$220,000.00**Fund Status:** \$208,552,77 Expended**Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Stainless clad rebar and CFRP Rehab

Technology Description: CFRP are bonded to steel to strengthen steel plate girders. MMXF rebar was used instead of stainless due to availability issues.

Project Information**Positive Results:**

Comparison of diagnostic load test results both before and after rehabilitation of the Ashland Bridge show that the use of advanced composite materials were effective in causing a decrease in live load strain experienced by the rehabilitated floor beam. Floor beam strains decreased by 5.5% due to the CFRP plate application.

Negative Results:

MMXF short term behavior appears to be the same as regular rebar.

Lessons Learned:

Barrier to implementation of Technology: None for CFRP, results were overall positive. MMXF is being evaluated for long term durability – short term results match regular rebar.

In future rehabilitation using CFRP plates it would be recommended that the joint locations of the plates be looked at in more detail. It would be preferred that the staggered joints of the plate sections do not occur at the location of maximum moment as was the case in the Ashland Bridge. This location is not desirable because the plates may be vulnerable at this joint. It is a possibility that the large strains occurring at the maximum moment region would induce peeling of the plates. This peeling would then make the plates less effective thus comprising the integrity of the entire rehabilitation.

Internal or External Reports:

"STAINLESS CLAD REBAR AND CFRP REHAB EVALUATION FOR BRIDGE 1-119"

Chajes, et al.

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Yes, see IBRC project *BR 712B, Ramp J, I95 Service AREA*.

Plans on Reuse of Technology: CFRP – yes, will reuse for strengthening for appropriate applications. MMXF – not yet, awaiting long term studies.

Applicability to other States: CFRP study indicates technology will work for steel beam or girder strengthening.

10/30/08: Complete

State DOT Contact: Jiten Soneji

Phone: 302-760-2299

E-mail: Jiten.soneji@state.de.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** BR 712B, Ramp J, I95 Service Area, Newark**State:** DE **Federal-Aid Project #:** EBRN-N056(22) **Fiscal Year:** 2001 **Funds Awarded:** \$350,000.00**Fund Status:** \$200,000 Expended**Project Status:** Complete**Associated Project Names**

BR26 on Foulk Rd Over Naaman Project: Change / Associated

Reallocated from / to: \$150,000**Technology Implemented:** MMXF rebarTechnology Description: MMXF non-corrosive reinforcing for concrete reinforce beams.**Project Information****Positive Results:**

MMXF is has nearly 2x the yield point of standard steel rebar. No issues for field application of the rebar. Both MMFX beams failed in the desired mode. For both beams, the MMFX rebar yielded prior to failure.

Negative Results:

MMXF short term behavior appears to be the same as regular rebar.

Lessons Learned:

Barrier to implementation of Technology: MMXF is being evaluated for long term durability – short term results match regular rebar.

While both MMFX beams reached relatively high deformation states before failing, neither displayed as much ductility as the standard beam. The MMFX2 beam did display more ductility than the MMFX4 beam which was closer to being over-reinforced. Since MMFX has a yield strength close to twice that of regular steel, designers must be careful to not design beams that are over-reinforced when using MMFX as a direct replacement for standard steel reinforcement.

Internal or External Reports:

“MMFX Rebar Evaluation for I-95 Service Road Bridge 1-712-B” Chajes, et.al.

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Yes, see IBRC project *BR 119 on SR82 over Red Clay Rd.*

Plans on Reuse of Technology: MMXF – not yet, awaiting long term studies.

Applicability to other States:

10/30/08: Complete

This project was initially awarded \$350,000. The project was agreed upon to be split. This project was to get \$200,000. Bridge 1-026 was to get \$150,000. In the end the full \$350,000 was obligated..

State DOT Contact: Jiten Soneji

Phone: 302-760-2299

E-mail: Jiten.soneji@state.de.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Bridge 2-008F, Frederica**State:** DE **Federal-Aid Project #:** EBROS-K010(2) **Fiscal Year:** 1999 **Funds Awarded:** \$450,000**Fund Status:** \$450,000 Expended **Project Status:** Complete**Associated Project Names**

Bridge I-680

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Concrete BeamsTechnology Description: 2-Span prestressed concrete adjacent box beam bridge with HPC in Beams and the deck.
HPC is low permeability and high strength**Project Information****Positive Results:**

Longer span lengths are possible. Can reduce the number of piers and number of girders required. Material installed successfully and performing well

Negative Results:

None to date.

Lessons Learned:**Barrier to implementation of Technology:**

Low permeability and high strength concrete can be obtained with locally available materials. The excess cooling heat can have an effect on the prestressing strands depending on the timing of the release. Short term creep and shrinkage were underestimated by the AASHTO and PCI equations, but this is attributed to the fact that these occur over a much shorter timeframe for HPC. Long term effects are much more consistent with predictions.

Internal or External Reports:

“High Performance Concrete for Bridge 8F in Frederica”

**Publications, Presentations, or, Construction Studies:**

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

10/30/08: Work complete

Documentation for the transfer of money from this project to 2-008F was approved on June 2, 1999.

State DOT Contact: Jiten Soneji

Phone: 302-760-2299

E-mail: Jiten.soneji@state.de.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Churchman Road over I-95**State:** DE Federal-Aid Project #: IMON056(16) Fiscal Year: 2002 Funds Awarded: \$500,000.00**Fund Status:** \$500,000 Expended **Project Status:** CompleteAssociated Project Names*Smiths Bridge*Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Steel (HPS) Girders

Technology Description: HPS was used for main structural members. Steel type used was HPS Grade 70W and evaluated for strength and deflection criteria (deflection based on reduced required section for strength)

Project InformationPositive Results:

System was able to handle much larger DL than a traditional beam design due to HPS, resulting in material savings. More difficulty arose from the fact that the bridge is skewed than the use of HPS.

Negative Results:

Major retrofit of the lateral force resisting system led to large delays.

Lessons Learned:

Barrier to implementation of Technology: None

Lab test should be conducted on gauges prior to installation in the field. At least two test gauges should be installed in a controlled environment with steady temperature and no solar effects, on the same material that will be instrumented in the study. The final phase of lab testing should be to record data daily over a period of one week while the material is outside, subject to both temperature change and sun effects. This lab data will help to differentiate between strains due to thermal variation and strains due to dead load. Placement of gauges on each side of the web would allow for the quantification of strains due to torsion and axial force individually. All diaphragms should be designed as primary members and should be aligned normal to the girders requiring bracing.

Internal or External Reports:

“MONITORING OF THE CHURCHMAN’S ROAD BRIDGE OVER I-95” Winterling et.al.

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Yes, for appropriate span applications.

Applicability to other States: HPS is a good tool for any state, but attention is needed for use in skewed bridges since live and dead load deflection become larger and more important to address.

10/30/08: Complete

There was extensive coordination and FHWA approval to transfer this money to 1-009 but It was never done. The money expended was on Churchman's Road.

State DOT Contact: Jiten Soneji

Phone: 302-760-2299

E-mail: Jiten.soneji@state.de.us

1.10. FLORIDA

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Hillsboro Canal Bridge**State:** FL Federal-Aid Project #: _____ Fiscal Year: 2005 Funds Awarded: \$300,000.00**Fund Status:** \$300,000 Expended **Project Status:** Complete**Associated Project Names**Hillsboro Canal Bridge-
MonitoringProject: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Deck Panel

Technology Description: Fiber reinforced deck panel for bridge

Project InformationPositive Results:

Completing the installation allowed us to learn about and address construction and design issues associated with these decks

Negative Results:

There were initial problems with installation we believe have been addressed..

Lessons Learned:**Barrier to implementation of Technology:** Further study of deck

At the time of this report, the study is ongoing to determine the durability of a deck system of this type.

Internal or External Reports:Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported.

Applicability to other States: Not Reported.

10/30/08: Project in 10% completion status

10/30/09: Installation is 100% complete

State DOT Contact: Marc Ansley

Phone: 850-921-7111

E-mail: Marc.ansley@dot.state.fl.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Hillsboro Canal Bridge – Monitoring**State:** FL **Federal-Aid Project #:** _____ **Fiscal Year:** 2006 **Funds Awarded:** \$200,000.00**Fund Status:** (not reported)**Project Status:** Initiated**Associated Project Names**

Hillsboro Canal Bridge

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Deck Panel

Technology Description: This portion of the funding is being used to monitor the Fiber reinforced deck panel for bridge in the field.

Project InformationPositive Results:

The installation is complete and the monitoring has begun. We have also completed the field work for the initial bridge test.

Negative Results:

Some minor problems with the data volume being generated by initial monitoring setup

Lessons Learned:**Barrier to implementation of Technology:** Further study of deck

Preliminary information indicates that the deck has very local characteristics with little load distribution. This is not bad but contrast markedly with other deck systems.

Internal or External Reports:

In development

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported.

Applicability to other States: Not Reported.

10/30/09: Installation of monitoring devices.

State DOT Contact: Marc Ansley

Phone: 850-921-7111

E-mail: Marc.ansley@dot.state.fl.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Jensen Beach Causeway – MMFX**State:** FL Federal-Aid Project #: Not reported Fiscal Year: 2001 Funds Awarded: \$0(reallocated)**Fund Status:** \$417,250 Expended **Project Status:** CompleteAssociated Project Names

US1.Key Deer N Channel

Project: Change / Associated

Reallocated from / to: \$289,000

Sr679 over Burnces Pass

Project: Change / Associated

Reallocated from / to:

Technology Implemented: MMFX Reinforcing

Technology Description: All sixteen spans of Bridge 890146 were used for the evaluation of the MMFX bars. Eight of the sixteen spans (spans 1-8) of the bridge were constructed with MMFX bars and the other eight (spans 9-16) were constructed using ASTM A-615 standard black rebar.

Project InformationPositive Results:

- Long range material study in corrosive environments.
- Possible increase in service life of structures with slight increase in cost.
- There is no evidence of any conditions that may promote corrosion

Negative Results:

- No difference in corrosion resistance has been observed between MMFX rebars and standard rebars on the bridge deck application

Lessons Learned:**Barrier to implementation of Technology:** proof of concept. No difference between normal and MMFX rebar to dateInternal or External Reports:

“2008 FIELD EVALUATION OF MMFX AND 2101LDX STAINLESS STEEL REINFORCEMENT INITIAL PERFORMANCE REPORT”

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported.

Applicability to other States: Not Reported

10/30/08: The Jensen Beach Causeway bridge is 100% completed.

Per John Hooks' e-mail dated 4/30/01, The US1/Key Deer bridge and the Burnces Pass bridge were deleted from IBRC database and replaced with the Jensen Beach Causeway bridge.

State DOT Contact: Contact not listed

Phone: _____

E-mail: _____

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Jensen Beach Causeway – Stainless**State:** FL Federal-Aid Project #: Not reported Fiscal Year: 2001 Funds Awarded: \$0(reallocated)**Fund Status:** \$417,250 Expended **Project Status:** Complete**Associated Project Names**

US1.Key Deer N Channel

Project: Change / Associated

Reallocated from / to: \$128,250

Sr679 over Burnces Pass

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Stainless Steel Reinforcing

Technology Description: For the evaluation of the 2101LDX stainless steel reinforcement, two of the substructure piers of Bridge 890145 were used. Stainless steel was used for the construction of the two columns and the footer.

Project InformationPositive Results:

- Long range material study in corrosive environments.
- Possible increase in service life of structures with slight increase in cost.
- There is no evidence of any conditions that may promote corrosion

Negative Results:

- No difference in corrosion resistance has been observed between MMFX rebars and standard rebars on the bridge deck application

Lessons Learned:

Barrier to implementation of Technology: proof of concept. No difference between normal and stainless rebar to date.

Internal or External Reports:

“2008 FIELD EVALUATION OF MMFX AND 2101LDX STAINLESS STEEL REINFORCEMENT INITIAL PERFORMANCE REPORT”

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported.

Applicability to other States: Not Reported

10/30/08: The Jensen Beach Causeway bridge is 100% completed.

Per John Hooks' e-mail dated 4/30/01, The US1/Key Deer bridge and the Burnces Pass bridge were deleted from IBRC database and replaced with the Jensen Beach Causeway bridge.

State DOT Contact: Contact not listed

Phone: _____

E-mail: _____

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Key Royale Drive Bridge over Bimini Bay**State:** FL **Federal-Aid Project #:** (N/A) **Fiscal Year:** 2004 **Funds Awarded:** \$400,000.00**Fund Status:** \$400,000 Expended **Project Status:** CompletedAssociated Project Names

None

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Concrete in Piles

Technology Description: Six piles with highly reactive supplementary cementitious materials (SCM) and fender piles were used to construct bridge. Corrosion sensors were embedded in the bridge piles for periodic future monitoring.

Project InformationPositive Results:

- Piles with highly reactive supplementary cementitious materials (SCM) were driven for the Key Royale Bridge. Six different SCM were used to construct the bridge and fender piles to allow monitoring under realistic exposure conditions at real time rather than accelerated corrosion testing in laboratory conditions. Corrosion sensors were embedded in the bridge piles for periodic future monitoring. Removable fender piles were also installed with the same mixtures and will be removed in 15-20 years to be examined for ingress of chlorides and corrosion damage. In addition, durability segments were constructed using the same concrete and prestressing strand as the fender piles. These segments were hung from the fender piles for consistent exposure conditions and instrumented with corrosion sensors and temperature sensors for long-term corrosion and temperature monitoring. These segments will also be cored for evaluating the chloride ion penetration and concrete hydration over time.
- Embedded Data Collectors (EDCs) were also installed in the bridge piles for monitoring pile driving. Reduced strain and acceleration, pile driving stresses, and static pile capacities collected from EDC were compared to the data collected from the conventional monitoring system, Pile Driving Analyzer (PDA). CAPWAP analyses were performed on PDA data to separate the skin and tip resistances. The results of CAPWAP analyses were also compared to the EDC's results. It was found that the plastic properties, volume of voids, and absorption were not significantly affected by the implementation of any of the mineral admixtures.
- At 28 days, each mixture exhibited nearly equal compressive strength in which the silica fume mixtures showed the highest. However, at 365 days each mixture containing mineral admixtures were nearly equal.
- Poisson's ratio appeared to be unaffected by the use of mineral admixtures
- The use of mineral admixtures improved the resistance to shrinkage. Each mixture exhibited lower linear shrinkage than the control.
- The surface resistivity was greater increased when compared to the control
- The chloride ion penetrability was significantly improved

Negative Results:

- Initial cost of concrete piles is higher than that of normal concrete. Cost of EDC is higher than the conventional PDA cost.

Lessons Learned:

Barrier to implementation of Technology: None

- It was also found that ACI's equation overestimated the MOR for nearly all mixtures, with the 7 day test showed the greatest amount of overestimation.
- The metakaolin mixture showed the best results for modulus of elasticity (MOE), as they were nearly equal to the control at all ages. The silica fume mixtures displayed the lowest MOE at 7 days, and the highest at 365 days.
- Based on the results from the decision matrix, the most efficient proportions of mineral admixtures to be used in conjunction with 18% fly ash were: 30% slag, 10% metakaolin, 12% ultrafine fly ash, and 9% silica fume.

Internal or External Reports:

“IMPLEMENTATION OF HIGHLY REACTIVE POZZOLANS IN THE KEY ROYALE BRIDGE REPLACEMENT”

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

10/30/08: Project is in 96% completion status

Monitoring has been performing.

State DOT Contact: Charles Ishee

Phone: 352-955-6667

E-mail: Charles.ishee@dot.state.fl.us

1.11. GEORGIA

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I-75 @ SR 37/Adel (FM 1500 ft West to 650 ft East I-75) - Cook County**State:** GA **Federal-Aid Project #:** IM-STP-75-1(193) 01 **Fiscal Year:** 2000 **Funds Awarded:** \$656,039.04**Fund Status:** \$0.00 Expended**Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Steel in Plate Girders

Technology Description: High performance steel was used in place of standard steel for Plate girders

Project Information**Positive Results:**

The Georgia DOT wanted to use High Performance Steel for a highway bridge taking advantage of the higher yield strength of 70,000 psi. The bridge was a two span continuous plate girder bridge that utilized welded construction for the field splices. This was done successfully for this structure and the bridge is now constructed and open to traffic

Negative Results:

None

Lessons Learned:

Barrier to implementation of Technology: HPS steel can be used successfully without any apparent problems for highway bridges. Field welding does not present any special problems using this material. In addition, the HPS material was readily available from the suppliers for this project.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: No, HPS was not used on other Georgia projects.

Plans on Reuse of Technology: Yes, this project was a successful application of High Performance Steel for a continuous steel plate girder utilizing field welded spliced plate girders for a highway bridge.

Applicability to other States: Yes, this technology is applicable to all states.

State DOT Contact: Paul V. Liles, Jr.
E-mail: pliles@dot.ga.gov

Phone: 404-631-1882

FHWA IBRC/IBRD Project Summary Report Form

Project Name: I-85 @ SR 34 Ramp Reconstruction Southeast Quadrant - Coweta County
State: GA **Federal-Aid Project #:** IM-85-1(356)01 **Fiscal Year:** 2005 **Funds Awarded:** \$265,000.00
Fund Status: \$0.00 Other **Project Status:** Initiated

Associated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Lightweight High Performance Concrete in PSC Girders

Technology Description: Lightweight high performance concrete used in a highway bridge to demonstrate the feasibility of using this concrete in prestressed girders.

Project InformationPositive Results:

None

Negative Results:

None

Lessons Learned:

Barrier to implementation of Technology: High performance, high strength lightweight concrete can be used for PSC beams in Georgia but careful attention needs to be paid to the elastic modulus and camber considerations in the design of these beams.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None at this time

Additional Comments:

Technology used on Other Projects: Lightweight HPC was not used on other Georgia projects

Plans on Reuse of Technology: Unable to determine, report were not included.

Applicability to other States: This application is applicable to all states.

Additional Project Notes:

The GA DOT wanted to use lightweight high performance concrete in a highway bridge to demonstrate the feasibility of using this concrete in prestressed girders

State DOT Contact: Paul V. Liles, Jr.

Phone: 404-631-1882

E-mail: pliles@dot.ga.gov

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** SR 92 over Noonday Creek Bridge Rehabilitation – Cherokee County**State:** GA **Federal-Aid Project #:** STP00-M002-00(072) **Fiscal Year:** 2000 **Funds Awarded:** \$154,148.41**Fund Status:** \$154,148.41 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Project

Technology Description: Fiber-reinforced polymer (FRP) composites are being used to effectively strengthen a concrete T-beam bridge.

Project Information**Positive Results:**

The Georgia DOT wanted to strengthen a concrete T-beam bridge using FRP Composites. The bridge was a posted highway bridge before the strengthening. After the strengthening, the bridge was no longer required to be posted.

Negative Results:

None

Lessons Learned:

Barrier to implementation of Technology: FRP Strengthening is an acceptable means of strengthening a concrete highway bridge. It can be done at a reasonable cost with very little interruption of existing highway traffic.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Yes, FRP technology was used on other Georgia projects.

Plans on Reuse of Technology: Yes, FRP Composites can be used to strengthen existing concrete highway bridges.

Applicability to other States: Yes, this technology is applicable to all states.

Additional Project Notes:

FRP Composites can be used to strengthen existing concrete highway bridges.

State DOT Contact: Paul V. Liles, Jr.
E-mail: pliles@dot.ga.gov

Phone: 404-631-1882

1.12. HAWAII

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Honolua Stream Bridge**State:** HI **Federal-Aid Project #:** BR-030-1(37) **Fiscal Year:** 2005 **Funds Awarded:** \$300,000.00**Fund Status:** \$28,500.00 Expended **Project Status:** Initiated**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Deck Panel

Technology Description: Application of Fiber Reinforced Polymer (FRP) composite for use in bridge. BridgeComposites to provide a FRP-concrete hybrid bridge superstructure that meets AASHTO design criteria.

Project Information**Positive Results:**

Although the research has just begun the light weight of the FRP superstructure may be advantageous to any rehabilitation or upgrade of the structure. The old bridge is on CRM abutments which may not allow an increase in the loading to the abutments.

Negative Results:

None at this time

Lessons Learned:

Barrier to implementation of Technology

None at this time.

Internal or External Reports:

“Progress Report on Honolua Bridge Superstructure Design” This is a progress report; the anticipated RTA is for November 2011.

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: No

Plans on Reuse of Technology: Cannot be determined at this time

Applicability to other States: Cannot be determined at this time.

Additional Project Notes:

10/30/08: PS&E being developed. Construction 2009.

3/15/10: Project under design, tentative RTA anticipated in November 2011.

State DOT Contact: Dean Takiguchi
E-mail: dean.takiguchi@hawaii.gov

Phone: 808-692-7614

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Kahoma Stream Bridge on Lahaina Bypass**State:** HI **Federal-Aid Project #:** NH-030-1(35) **Fiscal Year:** 2009 **Funds Awarded:** \$350,000.00**Fund Status:** \$73,324.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to: {\$}

Technology Implemented: Structural Health Monitoring Using Smart Sensor Technology

Technology Description: Various instrumentation devices are used to monitor stress and movement in the bridge

Project InformationPositive Results:

Being able to collect and analyze live monitoring data to evaluate structural health and reliability of this unique innovative inverted precast arch bridge. Application of instruments and initial monitoring was successful.

Negative Results:

Difficulty in reliability and applying results to conventional concrete bridges.

Lessons Learned:

Barrier to implementation of Technology: concrete as noted above.

Internal or External Reports:

None at this time.

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: No

Plans on Reuse of Technology: Cannot be determined at this time

Applicability to other States: Cannot be determined at this time.

Additional Project Notes:

3/15/10: Time elapsed and work completed to date = 31%. Completion date is May 31, 2012.

State DOT Contact: Paul Santo, State Bridge Engineer
E-mail: paul.santo@hawaii.gov

Phone: 808-692-7610

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** North Kahana Stream Bridge**State:** HI **Federal-Aid Project #:** BR-083-1(53) **Fiscal Year:** 2004 **Funds Awarded:** \$400,000.00**Fund Status:** \$285,046.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Self Consolidated Concrete in Drilled Shafts

Technology Description: The 4-hour retarded Self Consolidated Concrete (SCC) mixture was used in the SCC trial shaft and SCC load test shaft at the bridge project to verify that SCC would meet the project specifications and provided adequate flow and filling properties for the drilled shafts.

Project Information**Positive Results:**

- Use of SCC is ideal for drilled shaft applications; densifies concrete around reinforcing steel cage and minimizes defects in drilled shaft concrete.

Negative Results:

- Challenge of long delivery time of concrete to job site may require flexibility in dosage and adjusting mix design.
- Based on the observations made during the test shaft construction at the N. Kahana Bridge site, the self-consolidating concrete used for this project is not considered suitable for the production shafts.

Lessons Learned:

Barrier to implementation of Technology: Bridge is under construction, so instrument installation and monitoring phase not yet complete.

Internal or External Reports:

"Trial Placement of Ameron mixture 4539 SCC". The research study is 80% completed;



"Preliminary Report on N. Kahana Bridge SCC Trial Shafts"

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: No

Plans on Reuse of Technology: Cannot be determined at this time

Applicability to other States: Cannot be determined at this time.

Additional Project Notes:

10/30/08: To be advertised in summer 2008, construction begins 2009.

3/15/10: Research study is 80% completed and time elapsed is 85%, PI submitted no-cost time extension request. Initial end of contract was 1/31/10.

A more detailed evaluation of this concrete mixture will be possible after the 28 day strength and segregation tests are completed. Creep and shrinkage results will also be evaluated once they are available

State DOT Contact: Paul Santo , State Bridge EngineerPhone: 808-692-7610E-mail: Paul.santo@hawaii.gov

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Route 19 / Kealakaha Stream Bridge**State:** HI Federal-Aid Project #: _____ Fiscal Year: 2000 Funds Awarded: \$691,947.00**Fund Status:** \$682,000.00 Expended **Project Status:** CompletedAssociated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Fiber optic instrumentation for seismic, dynamic loads

Technology Description: Develop a dynamic deflection monitoring system using fiber optic strain gauges for the Kealakaha stream bridge. Verify the mathematical model using electrical resistance strain gauges and select the fiber optic strain gauge system to be used in future verification tests. Strain measurements from gauges placed along the bridge will be used to obtain the girder curvature, which will then be used to mathematically determine the deformed shape of the bridge.

Project InformationPositive Results:

Initially to have been the first fiber optic instrumented bridge at the time of inception/design.

Negative Results:

Instrumentation required supplemental funding by HDOT due to delay in implementation of construction VECP

Lessons Learned:

Barrier to implementation of Technology: Two-year delay in construction was unanticipated, delaying implementation of technology for future applications.

Internal or External Reports:

“SEISMIC MONITORING OF DYNAMIC BRIDGE DEFORMATIONS USING STRAIN MEASUREMENTS”

“Computer Modeling of the Proposed Kealakaha Stream Bridge”

This report was prepared in May 2003. Up to date, the research study is 70% complete.

Publications, Presentations, or, Construction Studies:"SEISMIC INSTRUMENTATION OF THE KEALAKAHA BRIDGE"Additional Comments:

Technology used on Other Projects: No

Plans on Reuse of Technology: Cannot be determined at this time.

Applicability to other States: Cannot be determined at this time.

Additional Project Notes:

10/30/08: Under construction ~55% complete, completion date September 2009. VECP delayed NTP.

3/10/10: Bridge is near completion of construction, research study is 70% complete, new completion date is now 6/30/11.

To develop an accurate yet economical fiber optic strain gauge system for use in the Kealakaha Stream Bridge Project, several strain gauge systems were tested on a 1/37th scale model of the bridge. First the "ideal 24" strain gauge system was analyzed, producing results that agreed well with the measured and theoretical deflections. To reduce costs, a 12-gauge system was investigated. Thus, 12 gauges were selected.

The results agreed well with the measured values and the SAP2000 model result. The results of dynamic tests illustrate the importance of using fiber optic strain gauges capable of high frequency monitoring rather than the weldable electrical resistance strain gauges

When installed on the bridge, in the event of ground shaking which exceeds the minimum trigger threshold set for the instrumentation, the data loggers will record the readings on all instruments at 0.01 second intervals, with a back memory of 10 seconds prior to the triggering event. Recording will continue until the motion decreases below a predetermined switch-off threshold. The instrumentation will be available immediately should aftershocks occur soon after the initial quake.

State DOT Contact: Paul Santo , State Bridge Engineer

Phone: 808-692-7610

E-mail: Paul.santo@hawaii.gov

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Salt Lake Blvd. Bridge over Halawa Stream**State:** HI **Federal-Aid Project #:** BR-7311(4) **Fiscal Year:** 2003 **Funds Awarded:** \$360,886.00**Fund Status:** \$310,329.66 Expended **Project Status:** CompletedAssociated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Carbon Fiber Reinforced Polymer (CFRP) shear strengthening of prestressed girders

Technology Description: The objective of this study was to evaluate the performance of CFRP L-shaped stirrups as a shear retrofit applied over existing shear cracks, particularly under cyclic loading conditions. The research was performed to provide guidance for the shear retrofit to be performed on cracked AASHTO girders in the Salt Lake Boulevard Bridge.

Project InformationPositive Results:

Shear cracking in prestressed girders were repaired with FRP wrap retrofit.

- During cyclic loading, the CarboShear-L stirrups contributed significantly to control the width of the existing shear cracks.
- The CarboShear-L stirrups were relatively easy to install in laboratory conditions and the same could be expected for field conditions
- The CarboShear-L stirrup retrofit system also increased the beam stiffness and reduced beam deflections.

Negative Results:

Issues of bond between FRP and concrete and anchorage to girder critical to success of retrofit.

- Results of the beam test were inconclusive.

Lessons Learned:

Barrier to implementation of Technology: Further laboratory testing should be performed on full-scale AASHTO bridge girder with CarboShear-L stirrups and FRCC filler blocks applied over existing shear cracks to verify performance of the full-scale retrofit.

Repair of the existing shear cracks through epoxy injection would likely improve the beam service load performance, but did not appear to be necessary to ensure adequate performance of the CarboShear-L stirrup retrofit.

Internal or External Reports:

“Test of Cracked Prestressed Concrete T-Beam Retrofitted for Shear using CFRP L-Shaped Plates”

This report was prepared in December 2008. The Research Monitoring Study completion is scheduled for 10/31/12.

Publications, Presentations, or, Construction Studies:Additional Comments:

Technology used on Other Projects: No

Plans on Reuse of Technology: Cannot be determined at this time.

Applicability to other States: Cannot be determined at this time.

Additional Project Notes:

Bridge is owned by the City & County of Honolulu, project was coordinated with the City and their design consultant.

10/30/08: Under construction completion date December 2008

3/10/10: Construction project completed 1/28/09. Research monitoring study to be completed by 10/31/12, 80% complete to date.

State DOT Contact: Paul Santo , State Bridge Engineer

Phone: 808-692-7610

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1.13. IDAHO

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I-15 Bridge over Center Street IC**State:** ID **Federal-Aid Project #:** IM-15-1(121)69 **Fiscal Year:** 2004 **Funds Awarded:** \$260,000.00**Fund Status:** \$260,000.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Polyester Concrete Overlay

Technology Description: Using polyester concrete overlay as protection system on bridge deck.

Project Information**Positive Results:**

This was the first use of polyester concrete in Idaho. The product was successfully placed and appears to be performing well. The product was placed very close to the minimum ambient temperature placement range. The product bonded well to the Portland cement concrete and has maintained its skid resistance.

Negative Results:

Product was more expensive relative to other deck protection systems.

Lessons Learned:

Barrier to implementation of Technology: Ensuring the contractor has experience with mixing and placement of this product is essential.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: No.

Plans on Reuse of Technology: Yes, where applicable.

Applicability to other States: Yes, where applicable.

Additional Project Notes:

10/30/08: Bid 12-2005. Bridge is complete & open to traffic.

The project was a success. ITD learned a lot from using this product. ITD developed a highly refined special provision for polyester concrete overlays. The product was costly to use because it required a specialty contractor. The product will be evaluated for use with other overlay products to extend the life of bridge decks and prevent chloride intrusion.

State DOT Contact: Matt Farrar
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Phone: 208-334-8538

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** SR 21 over Mores Creek @ New York Gulch

State: ID **Federal-Aid Project #:** STP-BR-3290(108) **Fiscal Year:** 2002 **Funds Awarded:** \$32,200.00

Fund Status: \$32,200.00 Expended **Project Status:** Completed

Associated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: MMFX Rebar

Technology Description: MMFX microcomposite reinforcement used in deck and parapet construction instead of traditional epoxy coated rebars.

Project InformationPositive Results:

The iron workers and ITD construction inspectors reported that MMFX was much easier to place than epoxy coated rebar. Since there are no protective coatings, there is no susceptibility to damage and therefore no need for scratch/ding repair. Iron workers can work at much more rapid pace when handling material since they do not need to be as concerned with damaging protective coatings. Verbal field reports were very positive. Product has been in place for a few years now and seems to be performing well.

Negative Results:

Proprietary product that is more expensive than epoxy bars.

Lessons Learned:

Barrier to implementation of Technology: none at this time, comparison will come after the bridge has been in service for a few years.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Yes, throughout the state.

Plans on Reuse of Technology: Yes, where applicable.

Applicability to other States: Yes, where applicable.

Additional Project Notes:

10/30/08: Bid 12-2001 Bridge Complete & Opened to Traffic

MMFX steel used in all deck and parapet reinforcing. MMFX (and other corrosion resistant rebar products) are being evaluated and used on bridges in areas of the state with harsh climates (high moisture and winter salt usage). Once bridges have been in service for a number of years, ITD will compare the benefits versus cost of using stainless steel and other corrosion resistant systems to the traditional epoxy coated system.

State DOT Contact: Matt Farrar
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Phone: 208-334-8538

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** State Hwy. 200 over Mosquito Creek**State:** ID **Federal-Aid Project #:** BR-5120(106) **Fiscal Year:** 2005 **Funds Awarded:** \$151,000.00**Fund Status:** \$151,000.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: SafeLaneTechnology Description: Using SafeLane surface overlay on bridge project instead of other deicing systems.**Project Information****Positive Results:**

Verbal reports from ITD construction inspectors indicate the product was placed with no problems. District maintenance personnel indicate not many deicing chemicals were used in the past couple winters in this area (mild weather) so no reported efficiency gains in regards to Magnesium-Chloride deicing operations.

Negative Results:

None at this time. Will continue to evaluate product over several more winters. Other states have expressed concerns with aggregate becoming polished, thus skid resistance decreases.

Lessons Learned:

Barrier to implementation of Technology: No construction challenges. Product was easy to install. Will continue to monitor performance over next few years to determine pros and cons of product

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: No.

Plans on Reuse of Technology: Yes, where applicable.

Applicability to other States: Yes, where applicable.

Additional Project Notes:

10/30/08: Bid 01-2006. Bridge is complete and open to traffic.

The product is being evaluated over several winter seasons. It has been in place for a couple of winters and performed well. The product is much easier to maintain than other deicing systems such as Rainbird emitters.

State DOT Contact: Matt Farrar
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Phone: 208-334-8538

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Sunnyside Road (I-15B) Interchange over I-15**State:** ID **Federal-Aid Project #:** NH-15-3(106)113 **Fiscal Year:** 2003 **Funds Awarded:** \$400,000.00**Fund Status:** \$400,000.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Steel (HPS) Girders**Technology Description:** High performance steel (HPS) used in on bridge project instead of Grade 50 weathering steel.**Project Information****Positive Results:**

This was one of the state's first uses of HPS. No significant fabrication issues arose. The project worked through the development of an HPS specification that ITD can use on future HPS projects.

Negative Results:

HPS product was more expensive relative to Grade 50 weathering steel

Lessons Learned:

Barrier to implementation of Technology: No fabrication issues arose and development of HPS specification was effective. Project was very helpful to work through first time issues in Idaho for HPS.

A cost/benefit analysis is important to justifying the additional cost of this product to additional service life.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Yes, throughout the state.

Plans on Reuse of Technology: Yes, where applicable.

Applicability to other States: Yes, where applicable.

Additional Project Notes:

10/30/08: Bid 05-2004. Bridge is complete and opened to traffic.

Project was a success. Special provisions for HPS were developed on this project that can be used on future projects. The girders are expected to provide more longevity and durability than traditional girders.

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Phone: 208-334-8538

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Westmond Bridge; US 95 over BSFRR

State: ID **Federal-Aid Project #:** BRF-5110(107) **Fiscal Year:** 2003 **Funds Awarded:** \$50,000
Fund Status: \$50,000.00 Expended **Project Status:** Completed

Associated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: MMFX Rebar (Stainless Clad originally envisioned)

Technology Description: MMFX microcomposite reinforcement used in construction instead of traditional epoxy coated rebars.

Project Information**Positive Results:**

Ironworkers and ITD reported ease of placement. The contractor was able to accelerate this portion of construction and make up some time because no repair was needed to coating systems.

Negative Results:

Limited number of manufacturers limits the availability of suppliers. Small production issues can cause substantial delays on projects since there are very few suppliers that can produce this material.

Lessons Learned:

Barrier to implementation of Technology: none at this time, comparison will come after the bridge has been in service for a few years.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Yes, throughout the state.

Plans on Reuse of Technology: Yes, where applicable.

Applicability to other States: Yes, where applicable.

Additional Project Notes:

10/30/08: Bid 02-2003. Bridge is complete and open to traffic.

Stainless steel clad reinforcing steel was originally specified for this project. However, timely delivery issues arose from the manufacturer. In order to save the project's schedule, MMFX rebar was substituted.

This project was a success. MMFX (and other corrosion resistant rebar products) are being evaluated and used on bridges in areas of the state with harsh climates (high moisture and winter salt usage). Once bridges have been in service for a number of years, ITD will compare the benefits versus cost of using stainless steel and other corrosion resistant systems to the traditional epoxy coated system.

State DOT Contact: Matt Farrar
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Phone: 208-334-8538

1.14. ILLINOIS

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** 170 FR 2.5 ME 115/70 To Bond Co. Line**State:** IL Federal-Aid Project #: 0701(176) Fiscal Year: 2000 Funds Awarded: \$58,800.00**Fund Status:** \$58,800.00 Expended **Project Status:** Completed**Associated Project Names**Corenzo Rd. over I-55; I-80
Kean Ave.Project: Change / Associated

Reallocated from / to:

Technology Implemented: HPC Deck

Technology Description: Using high performance concrete (HPC) for transportation structures.

Project InformationPositive Results:

No construction problems noted.

Negative Results:

- Immediate results not favorable enough to implement technology fully on a statewide basis.
- Increased transverse bridge deck cracking after one year in service.

Lessons Learned:

Barrier to implementation of Technology: Positive results difficult to determine until bridges go through several years of service

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

"HIGH PERFORMANCE CONCRETE FOR TRANSPORTATION STRUCTURES"

Additional Comments:

Technology used on Other Projects: Yes, throughout the state of Illinois.

Plans on Reuse of Technology: No, initial results were not favorable.

Applicability to other States: unable to determine, study report is incomplete.

Additional Project Notes:

10/30/08: Projects constructed 2 bridge decks.

2000 IBRC funds constructed 7 structures, 2002 IBRC funds constructed 17 structures. All structures are combined into one report.

State DOT Contact: Doug Dirks

Phone: 217-782-7208

E-mail: Doug.Dirks @illinois.gov

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Adeline Rd, Freeport Rd, Eagle Pt. Road**State:** IL Federal-Aid Project #: 000S(083)-2 Fiscal Year: 1999 Funds Awarded: \$122,000.00**Fund Status:** \$122,000.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: HPC Deck Slab Overlays

Technology Description: Using high performance concrete (HPC) in deck overlays construction.

Project InformationPositive Results:

No problems noted. Successful microsilica overlays

Negative Results:

Delays in award notification required State to complete the project with other state funds and then substitute IBRC funds.

Lessons Learned:**Barrier to implementation of Technology:** This was not a highly rated project, but it got selected. In general, it was not really an innovative ideaInternal or External Reports:

None

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Yes.

Plans on Reuse of Technology: Yes, where applicable.

Applicability to other States: Yes, where applicable.

Additional Project Notes:

Rehabilitation – high performance (HPC) concrete – microsilica concrete for strength, early strength and permeability used in the deck overlay

State DOT Contact: Doug Dirks

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Babylon Bridge over Spoon River, Lee Township**State:** IL **Federal-Aid Project #:** 0057(022) **Fiscal Year:** 2004 **Funds Awarded:** \$400,000.00**Fund Status:** \$187,200.00 Reallocated
\$227,700.00 Deobligated **Project Status:** Completed**Associated Project Names**High Road over Long Run Creek Project: Change / Associated Reallocated from / to: \$100,000.00Pleasant Ridge Rd / Little Canteen Ck. Project: Change / Associated Reallocated from / to: \$87,200.00**Technology Implemented:** FRP Bridge Deck and Hillman composite bridge system

Technology Description: The deck is comprised of only fiber reinforced polymer (FRP)

Project Information**Positive Results:**

None – Project was not constructed.

Negative Results:

Excessive cost of material and material availability became major issues for implementation. The initial project was intended to demonstrate the viability of FRP in construction, but actually working with the material in fabrication became unworkable.

Lessons Learned:**Barrier to implementation of Technology:** Ensure that local agency is truly ready to implement the technology. Ensure there are no outstanding issues that could halt the project, such as environmental concerns.**Internal or External Reports:**

None.

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: No

Plans on Reuse of Technology: N/A

Applicability to other States: N/A

Additional Project Notes:

10/30/08: Stalled due to lack of matching funds and increased cost materials.

\$100,000 was removed from this project and applied the High Road project (2006)

\$87,200 was removed from this project and applied to the Fairview Heights FRP project.

Original Scope: New 4 span bridge of approximately 400 feet, including at least 2 galvanized steel trusses will bridge Spoon River and the primary floodPlain.

State DOT Contact: Mark Gawedzinski

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I-39 over Kishwaukee River**State:** IL **Federal-Aid Project #:** 0391(006) **Fiscal Year:** 1999 **Funds Awarded:** \$150,000.00**Fund Status:** \$150,000.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Health Monitoring and FRP Bonded Reinf.

Technology Description: Continuous monitoring for two years of the Kishwaukee bridge using the Health Monitoring System (HMS) to validate that the design and retrofit strategy performed on the bridge arrested the crack growth.

Project Information**Positive Results:**

Effective Health Monitoring system installed. Successful data collection for retrofit analysis

Negative Results:

Anticipated FRP bonded reinforcement was eliminated from the project.

Lessons Learned:

Barrier to implementation of Technology: Health monitoring results resulted in design of an external post-tensioning system on the structure in lieu of FRP sheets.

Internal or External Reports:

“MONITORING OF THE I-39 KISHWAUKEE BRIDGE” This research report details the finding of the continuous monitoring of the Kishwaukee bridge using HMS.

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: No

Plans on Reuse of Technology: Yes, where applicable

Applicability to other States: Yes, where applicable

Additional Project Notes:

Original Scope:

Rehabilitation – Twin segmental concrete box girder bridges (1090' long x 42' wide); 3 NDE Technologies to monitor cracks in twin post-tensioned segmental box girders; carbon fiber reinforced polymer (FRP) composite sheets will be applied inside the boxes.

Final Scope:

Continuous monitoring of the Kishwaukee Bridge using the HMS. The instrument response provided needed information for real-time inspection and planned maintenance and rehabilitation. The measurements collected from this project were used to infer possible structural changes and to guide retrofit strategies for compromised components, ensuring the bridge's integrity and stability into the future.

State DOT Contact: Mark Gawedzinski

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** High Road Bridge carrying High Road over Long Run Creek**State:** IL Federal-Aid Project #: 0197(097) Fiscal Year: 2006 Funds Awarded: \$250,000.00**Fund Status:** \$250,000.00 Expended **Project Status:** CompletedAssociated Project NamesBabylon Bridge over Spoon
RiverProject: / AssociatedReallocated / to: \$100,000.00**Technology Implemented:** Hybrid-Composite Beams

Technology Description: Self-consolidating concrete for the compression reinforcement, high strength steel wire fibers for the tension reinforcement, and an FRP composite box for the shell

Project InformationPositive Results:

Successful project. Technology being considered in neighboring State

Negative Results:

None, other than cost

Lessons Learned:

Barrier to implementation of Technology: Costs were much higher than expected.

Project not well documented other than being very successful.

Internal or External Reports:Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: No.

Plans on Reuse of Technology: Yes, technology was a success.

Applicability to other States: Yes, this technology is being considered in neighboring states

Additional Project Notes:

Project initially awarded \$150,000, but an additional \$100,000 was reallocated to this project from another IBRD candidate project.

10/30/08: Beams were load tested this spring. June 17 2008 beams were installed at the project location.

Money was moved from the Babylon Bridge project (2004) to this project due to inactiveness of the Babylon Bridge Project.

State DOT Contact: Mark Gawedzinski

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I-474 over W. Pottstown Road**State:** IL **Federal-Aid Project #:** 4747(100) **Fiscal Year:** 2000 **Funds Awarded:** \$45,000.00**Fund Status:** \$45,000.00 Expended **Project Status:** Completed**Associated Project Names**

1474 FR 174 to Illinois River

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Metalizing Concrete Beam Ends

Technology Description: Using "sprayed-on" galvanic cathodic protection systems as a means of extending the life of precast prestressed concrete I-beams. The Illinois Department of Transportation conducted an evaluation of three different types of zinc-based metals as anodes for galvanic cathodic protection.

Project Information**Positive Results:**

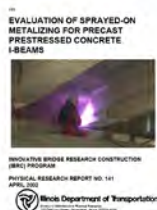
None

Negative Results:

Evaluation of the three different types of "spray on" anodes for galvanic cathodic protection indicate that the systems do not offer any improved amount of protection to the pre-stressing strands when compared to beams that were not treated. Results from the corrosion potential surveys indicate that the systems are not protecting the steel. It appears that the anodes do not develop enough current necessary to drive the ion exchange to arrest the corrosion process.

Lessons Learned:

Barrier to implementation of Technology: Until the current demand can be addressed, it would not be beneficial to the Department to pursue additional galvanic cathodic protection research.

Internal or External Reports:

"EVALUATION OF SPRAYED-ON METALIZING FOR PRECAST PRESTRESSED CONCRETE I-BEAMS"

This research report details the evaluation of sprayed-on metalizing for precast prestressed concrete I-beams

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: No.

Plans on Reuse of Technology: No, results indicated that system did not protect the steel.

Applicability to other States: Not at this time, driving current demand needs to be addressed.

Additional Project Notes:

10/30/08: Completed.

Report can also be found at <http://www.dot.il.gov/materials/research/pdf/141.pdf>

State DOT Contact: Mark Gawedzinski

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I-55/I-70 Poplar Street Complex**State:** IL **Federal-Aid Project #:** C-98-083-97 **Fiscal Year:** 1999 **Funds Awarded:** \$99,000.00**Fund Status:** \$99,000.00 Expended **Project Status:** Completed**Associated Project Names**IL 83 and US 45 over the
Wisconsin Central RR in
Lake Villa, ILProject: Change / Associated

Reallocated from / to:

Technology Implemented: HPS**Technology Description:** To develop a high performance 70W steel (HPS) less expensive than the presently used construction steel. Also assist in marketing of the steel for infrastructure applications.**Project Information****Positive Results:**

Good results. Improved structural steel with not much added expense. Improved toughness and weldability.

- NUCu 70W steel is now included in the ASTM A710 Standard. The steel was used for rehabilitation of a bridge in Illinois and its use is planned for another bridge.
- NUCu steel because of the advantages given in this report should find increased infrastructure use in bridges, posts, signs, railings, etc. as well as for applications in other fields.

Negative Results:

None

Lessons Learned:

Barrier to implementation of Technology: Further marketing activities by FHWA are warranted.

Internal or External Reports:

“Development and Commercialization of High-Performance Steel” This final report details the development and commercialization of high performance steel.

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Yes, IL83 and US 45 over the Wisconsin Central RR in Lake Villa, IL.

Plans on Reuse of Technology: Yes, this technology is cost-effective, easier to weld and has the best weathering resistance.

Applicability to other States: Yes, this high-performance steel is applicable to all states.

Additional Project Notes:

Replacement-Several interchange bridges (total of 58 spans, 98' average length x variable widths) – Replacement steel bridges; two-girder steel superstructures w/ floor beams; high performance (HPS 70W) steel developed @ Northwestern University.

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** IL 104 over Brush Cr. 3E. of Kincaid & E of I-55**State:** IL **Federal-Aid Project #:** 0753(025) **Fiscal Year:** 2000 **Funds Awarded:** \$49,960.00**Fund Status:** \$49,960.00 Expended **Project Status:** CompletedAssociated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: HPC DeckTechnology Description: Using high performance concrete (HPC) for transportation structures.
Research program funded for design mixProject InformationPositive Results:

Successfully built with no construction problems.

Negative Results:

As with other HPC decks, transverse cracks developed after one year of service.

Lessons Learned:**Barrier to implementation of Technology:** Excessive cracking see lessons learned below.

The use of High Performance Concrete (HPC) for IDOT transportation structures was the subject of a three-year study that involved field investigation, laboratory experiments, analysis and modeling work. The field study was based on IDOT projects and involved instrumentation and analysis of six HPC bridge decks. The laboratory component used methods developed at UIUC for characterizing early age thermal, shrinkage, creep, and cracking behavior. Modeling included the use of material models to analyze and predict creep and shrinkage behavior and a finite element model to investigate structural and material interaction in IDOT bridges.

The different bridge structures and concrete bridge deck materials were examined extensively in this project, and their relationship to concrete bridge deck cracking was established. A primary finding of the study, that HPC mixtures used by IDOT are not significantly different from OPC, is relevant for this discussion. IDOT HPC proportioning strategies resulted in many of the benefits of HPC, such as low permeability, but without the drawbacks of some HPC materials. It is common to find HPC materials with very low w/c ratios around 0.30 and high additions of silica fume. These factors will significantly increase autogenous shrinkage and heat evolution and could potentially cause cracking.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

"HIGH PERFORMANCE CONCRETE FOR TRANSPORTATION STRUCTURES"

Additional Comments:

Technology used on Other Projects: Yes, throughout the state of Illinois.

Plans on Reuse of Technology: No, initial results were not favorable.

Applicability to other States: unable to determine.

Additional Project Notes:

10/30/08: Projects constructed 2 bridge decks.

2000 IBRC funds constructed 7 structures, 2002 IBRC funds constructed 17 structures. All structures are combined into one report.

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FHWA IBRC/IBRD Project Summary Report Form

Project Name: IL 83 and US 45 over the Wisconsin Central RR in Lake Villa, IL; IL 49S over I-74; IL 49N over I-74

State: IL **Federal-Aid Project #:** 0866(005) **Fiscal Year:** 2003 **Funds Awarded:** \$331,000.00

Fund Status: \$331,000.00 Expended **Project Status:** Completed

Associated Project Names

I-55/I-70 Poplar Street Bridge

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Steel

Technology Description: Using Copper alloy steel known as ASTM A710 Grade B high-performance Steel (HPS) in bridge construction.

Project InformationPositive Results:

Successful project. Need to monitor long-term to adequately assess results.

- The steel is strong, tough, easy to fabricate and doesn't have to be painted.
- The steel is easy to weld and has high-impact toughness at low temperature.

Negative Results:

None

Lessons Learned:

Barrier to implementation of Technology: None

Internal or External Reports:

"Researchers design high performance Steel" Northwestern University Press Release

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Yes, I-55/I-70 Poplar Street Complex

Plans on Reuse of Technology: Yes, this technology is cost-effective, easier to weld and has the best weathering resistance

Applicability to other States: Yes, this high-performance steel is applicable to all states.

Additional Project Notes:

Funding comments: There were problems with FHWA deallocation of unobligated IBRC funds nationwide and this in turn delayed subsequent reallocation of funds. This caused two of the three bridges to fall out of the construction project due to timing. Therefore, only the District 1 structure near Lake Villa, IL was constructed using HPS..

Bridge replacements: 3 Multi-span steel girders bridges; high performance steel in the new superstructures: ASTM Aa1010 (Duracorr), a low chromium stainless steel, Grade 50; a high-performance, hot-rolled Grade 50 carbon steel; and ASTM A710 Grade B-a

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Jacksonville, S Fayette Street over Town Brook**State:** IL **Federal-Aid Project #:** 00D6(053) **Fiscal Year:** 1999 **Funds Awarded:** \$170,000.00**Fund Status:** \$170,000.00 Expended **Project Status:** CompletedAssociated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Deck

Technology Description: Using fiberglass reinforced polymer (FRP) composite in bridge deck construction. The experimental FRP composite material selected for this project was "DuraSpan TM" from Martin Marietta Composites.

Project InformationPositive Results:

The construction of the bridge deck was expedited. The entire deck surface was delivered and placed on the bridge in one day. The material is easy to work with and easy to place. The use of angle irons for fillets and grout dams worked well. The use of pre-cut shear stud pockets in the FRP panels worked well.

Negative Results:

The application was costly.

The 3rd annual performance survey reveals the following:

- The angle iron welded to the top flange of the steel girders as a fillet has started to rust in some areas.
- Settlement of the approach pavement was noted at both ends of the structure.
- A crack has developed in the HMA surface at the north end of the structure where the structure abuts the approach pavement

Lessons Learned:

Barrier to implementation of Technology: None reported

Internal or External Reports:

"Fiberglass Reinforced Polymer Composite Bridge Deck Construction in Illinois" This construction report details the planning, design, construction methods and cost for the replacement of the single span structure on South Fayette street over the Town Brook.

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Yes, on Pleasant Ridge Road over little Canteen Creek.

Plans on Reuse of Technology: Yes, where applicable.

Applicability to other States: Yes, the FRP panels are applicable to all states with similar replacement projects.

Additional Project Notes:

Replacement single span steel beam bridge (50' long x 23' wide); fiber reinforced polymer (FRP) composite deck on replacement bridge. The experimental FRP composite material selected for this project was "DuraSpan TM" from Martin Marietta Composites. The construction of the bridge took place between September and December of 2001.

IDOT 1st annual performance survey: was completed in December 2002. No problems or forms of distress were found on the structure. Some minor settlement of the approach pavement was noted at both the north and south ends of the structure.

IDOT 3rd annual performance survey: completed in December 2004. No problems or forms of distress were found on the FRP composite bridge deck. The angle iron welded to the top flange of the steel girders as a fillet has started to rust in some areas. Settlement of the approach pavement was noted at both ends of the structure. A crack has developed in the HMA surface at the north end of the structure where the structure abuts the approach pavement

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Pleasant Ridge Rd. over Little Canteen Creek**State:** IL **Federal-Aid Project #:** 9149(003) **Fiscal Year:** 2005 **Funds Awarded:** \$392,200.00**Fund Status:** \$377,200.00 Expended **Project Status:** Initiated**Associated Project Names**Babylon Bridge over Spoon
RiverProject: Change / AssociatedReallocated from / to: \$87,200.00**Technology Implemented:** FRP Deck PanelTechnology Description: Using fiberglass reinforced polymer (FRP) deck panel in bridge construction.**Project Information****Positive Results:**

Successfully installed, but not completed to date.

Negative Results:

Panels did not fit together real well. Very expensive at over \$700 per sq.ft. Fabrication in Colorado was delayed due to problems with internal funding of the fabricator. Project delayed several years.

Lessons Learned:**Barrier to implementation of Technology:** Ensure fabricator has resources to completely fabricate the bridge. Ensure that the project is on track relating to other aspects, such as ROW, etc. Needed to add load testing to the bridge since there is no real good acceptance criteria. When listing suppliers of FRP deck panels, make sure they are all capable.**Internal or External Reports:**

Not completed, panels were installed march 2010.

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Yes, on Jacksonville, S Fayette Street over Town Brook.

Plans on Reuse of Technology: Unable to determine.

Applicability to other States: Unable to determine.

Additional Project Notes:

This project was originally awarded \$305,000. With high bids, an additional \$72,200 was transferred to this project from the Babylon Bridge Project. Subsequently an additional \$15,000 was transferred to this project from the Babylon Bridge Project to provide funding for a five year evaluation program by Wiss, Janey, and Elsner.

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Quincy 18th Street over Cedar Creek**State:** IL Federal-Aid Project #: 5058(021) Fiscal Year: 1999 Funds Awarded: \$450,000.00**Fund Status:** \$450,000.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Galvanized Rebar and Structural Steel

Technology Description: Using galvanized rebars (substructure and deck) and galvanized structural steel (steel girders) in bridge construction.

Project InformationPositive Results:

Project built successfully and is performing well.

Negative Results:

Problems with some of the steel passing bend test for acceptance. Galvanizing seems to make reinforcing steel more "brittle", but acceptable. High cost makes technology implementation a low priority.

Lessons Learned:**Barrier to implementation of Technology:** IDOT quality assurance report recommend the following:

- Reject # 8 bars due to their failure to meet the required ASTM A615 Table 3 bend test
- Galvanized rebars should not be bent in the field due to the likelihood of delamination of the zinc coating. All bars should be bent to final shape before they are galvanized.
- Chemical composition of steel intended to be galvanized should be controlled.
- Contract plans and specifications using galvanized load-carrying structural members should receive a materials review at least two months in advance before sealing of the plans.

Internal or External Reports:Report titled: "Analysis of Galvanized Reinforcing Bars for the 18th Street Bridge, City of Quincy, Illinois". No electronic version availablePublications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: No.

Plans on Reuse of Technology: Yes, where applicable.

Applicability to other States: Yes, where applicable.

Additional Project Notes:

IDOT: Investigative Report for Quality Assurance June, 2001: Analysis of Reinforcing Bars for the 18th street Bridge, City of Quincy, Illinois: Recommendations:

- Reject # 8 bars due to their failure to meet the required ASTM A615 Table 3 bend test. The Contractor should provide a credit for this pay item in accordance with Article 105.03 of IL DOT Standard Specifications for Road and Bridge Construction.
- Consider a credit for deficient abnormal galvanizing of the # 8, # 9, and # 10 rebars due to lack of iron-free eta zinc on the surface of the zinc coating. Since this layer comprises about 30% of a typical zinc coating, only 30% is eligible for credit.
- Chemical composition of steel intended to be galvanized should be controlled by improved specifications and technical provisions on any future acquisition of rebars and structural steel acquired by the contractor for this project. For future projects, controls on steel composition with restrictions on carbon, phosphorus and silicon would help to minimize formation of gray or matted iron-rich zinc coatings. Control of other elements like hydrogen and copper would also minimize the potential for steel embrittlement.
- Galvanized rebars should not be bent in the field due to the likelihood of delamination of the zinc coating. All bars should be bent to final shape before they are galvanized.
- Contract plans and specifications using galvanized load-carrying structural members should receive a materials review at least two months in advance before sealing of the plans; receipt of plans before letting of the project for bid may be too late for alteration of any design errors.

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Wacker Dr. Viaduct**State:** IL **Federal-Aid Project #:** _____ **Fiscal Year:** 1999 **Funds Awarded:** \$2.2 million**Fund Status:** \$2.7million Expended **Project Status:** Completed**Associated Project Names**City of Chicago Wacker Dr. to
Franklin St.Project: Change / AssociatedReallocated from / to: \$500,000.00**Technology Implemented:** HPCTechnology Description: Using high performance concrete (HPC) in bridge construction.**Project Information****Positive Results:**

Chicago DOT very pleased with results. CDOT has been implementing HPC on all bridge decks since the Wacker project.

Negative Results:

None noted

Lessons Learned:**Barrier to implementation of Technology:** With these specifications, it was very difficult for IDOT to issue a "Materials Certification" for the project. Therefore, there were delays in closing out the project.

One goal of the specifications is to obtain concrete that has only moderate early-age strength and that continues to gain strength over time. In conjunction with this later-age strength gain, permeability should decrease. The field-cast HPC specimens had moderate early strengths, and are continuing to gain strength over time. The freeze-thaw results were excellent through 276 cycles. The charge passed in the rapid chloride permeability test continues to decrease over time. The 3-month chloride penetration results by ponding were borderline, but the 6-month results were below specifications. The one-year ponding tests are in progress. The scaling results were good except for popouts. Shrinkage has leveled off at less than 400 microstrain through 239 days, and is well below the 600 microstrain specification

Special attention is required to avoid interference between post-tensioning ducts, and care must be exercised to avoid damage, misalignment and blockage of ducts during construction

Internal or External Reports:

“WACKER DRIVE VIADUCT RECONSTRUCTION: Evaluation of Epoxy Resins for Bonding Concrete Segments”

“Tasks 1E and 2C: Evaluation of HPC Mixes for Performance and Durability Characteristics”

“Tasks 1C and 2B: Raw Materials Testing”

“Task 3: Latex-Modified Concrete Overlay”

“Literature Review of High Performance Concrete”

“Task 9: Prototype Testing ”

“Trial Overlay Removal and Replacement”

These final reports detail the evaluation and testing of high performance concrete in bridge construction.

Publications, Presentations, or, Construction Studies:Additional Comments:

Technology used on Other Projects: Yes, throughout Chicago.

Plans on Reuse of Technology: Yes, where applicable.

Applicability to other States: Yes, where applicable.

Additional Project Notes:

New bridge – Multiple span, reinforced concrete structure (2.5 +/- mile long x 100'-120' wide) on concrete columns; replace superstructure w/ multi-span, precast, post-tensioned, segmental concrete deck slabs of high performance (HPC) concrete

Project Partners: WISS, JANNEY, ELSTNER, ASSOCIATES, INC., and The University of Illinois at Chicago..

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1.15. INDIANA

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** 21st Street over I-465**State:** IN Federal-Aid Project #: _____ Fiscal Year: 2005 Funds Awarded: \$400,000.00**Fund Status:** \$400,000.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Concrete, U Beam Girders

Technology Description: Using high performance concrete (HPC) in the construction of prestressed girders and bridge decks.

Project Information**Positive Results:**

The research related to this project is currently underway, but the structure (21st Street over I-465) is now complete and open to traffic. On a preliminary basis, there are several positive results:

- The use of high-performance concrete in the prestressed girders (f'_{ci} = 8000 psi and f'_c = 10,000 psi) was achieved without difficulty at the precast concrete plant. In fact, strengths in excess of 8,000 psi were achieved in less than 24 hours. There were no problems in placing the concrete.
- The use of a QC/QA concrete mix in the deck (f'_c = 5000 psi) was also achieved without difficulty. Both trial mixes and actual placement occurred without any problems.
- Research on live load distribution factors has found that improved distribution factors can be obtained for exterior girders using simple modeling rather than use of the level rule as prescribed by AASHTO. This change has the potential of resulting in improved economy for this girder type.
- Continuing research on the shear strength of U-beam and the influence of debonding on shear strength are expected to impact not only the continued application of U-beams, but prestressed girder products in general.

Negative Results:

There are no known negative results.

Lessons Learned:**Barrier to implementation of Technology:**

- Sub-contractors can greatly influence the success and timing of a project. Since the girder type was new for this project, new forms were acquired by the precaster. The setup of the new precast bed as well as difficulties in the first time placing strand and reinforcement for this girder type led to delays in the construction of the girders. These delays were compounded by the onset of cold weather that delayed deck placement until the following construction season.
- Contractors do not always read the specifications. It became apparent as the girder precasting was about to commence that the precaster had not read the specifications which required a trial mix and approval of that mix before casting of the girders. It was fortunate that this was discovered prior to tensioning and casting of the first girder.

Internal or External Reports:

None at this time.

Publications, Presentations, or, Construction Studies:

Pavelchak, M., Frosch, R.J., and Kreger, M.E., "Experimental Assessment of the Effectiveness of Commercially Available Prestressed Strand Debonding Products", American Concrete Institute, Fall Convention, New Orleans, LA, November 10, 2009. (Unable to provide)

Additional Comments:

Technology used on Other Projects: No, none mentioned for this state

Plans on Reuse of Technology: Cannot be determined at this time, research is ongoing

Applicability to other States: Cannot be determined until research is still underway.

Additional Project Notes:

10/30/08: Project under construction.

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** County Bridge #153**State:** IN **Federal-Aid Project #:** _____ **Fiscal Year:** 2002 **Funds Awarded:** \$475,000.00**Fund Status:** \$475,000.00 Expended **Project Status:** Initiated**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Fiber Reinforced Polymer Deck PanelTechnology Description: Fiber reinforced polymer (FRP) deck panels used in bridge construction.**Project Information****Positive Results:**

Unclear at this time; bridge deck installed November 2009, but cold weather prevented installation of the wearing surface. As of 3/25/10, the wearing surface had yet to be installed.

Negative Results:

Generally unclear at this time (see above); however, this project experienced considerable delays which might be attributed to unfamiliarity with the FRP Deck on the part of the engineers, contractors, county officials responsible for processing the necessary paperwork, etc.

Lessons Learned:**Barrier to implementation of Technology:**

- Difficult to do the letting when the price of the FRP deck is fluctuating so much.
- Some manufacturers/vendors don't remain in business for long; materials' testing is a challenge.
- Manufacturers/vendors have to be involved early on to resolve technical issues.

Internal or External Reports:**Publications, Presentations, or, Construction Studies:**

Additional Comments:

Technology used on Other Projects: No, none mentioned for this state

Plans on Reuse of Technology: unable to determine, report is in progress and wearing surface has not been installed.

Applicability to other States: Yes this technique is applicable and has been used by other states.

Additional Project Notes:

See "Positive Results" for general update (project not complete at time of report).

Research funding will be depleted by May 2010; this is after numerous no-cost extensions and at least one request (granted) for supplemental funding from the Joint Transportation Research Program at INDOT/Purdue Research Program.

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Thayer Road over I-65**State:** IN **Federal-Aid Project #:** IN/JTRP-2006/15 **Fiscal Year:** 2000 **Funds Awarded:** \$85,000.00**Fund Status:** \$66,116.30 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP reinforcement in deck slab

Technology Description: Fiber reinforced polymer (FRP) bars used as reinforcement in bridge deck construction. The behavior of the FRP reinforced bridge deck is assessed and compared with its design assumptions. The findings of this study provide design tools and behavioral data that will assist in the future development and deployment of this technology.

Project Information**Positive Results:**

There were several positive results from this project:

1. The research on bond strength of FRP reinforcement developed a bond model that unifies and improves the design of steel and FRP reinforcement for development and splice lengths. This bond model has gained acceptance with ACI Committee 440 and is likely to be implemented into the 440.1, "Guide for the Design and Construction of Structural Concrete Reinforced with FRP bars." In addition due to the general applicability, this bond model has the potential of being adopted by the AASHTO design specifications and the ACI building code.
2. The implementation on the Thayer Road bridge occurred without any difficulties. While the contractor originally had perceptions of difficulties in using FRP reinforcement, it was found that using this reinforcement type actually reduced construction time and reduced some construction costs. The following benefits were discovered due to the lightweight of the material: 1) it was possible for a single individual to move and place the reinforcement (cranes were not required), 2) it was much easier to lay out the reinforcement because the reinforcement was much easier to manipulate, 3) the reinforcement could be tied together in a mat much easier, and 4) damage to epoxy coated reinforcement did not have to be repaired. These factors led to a decrease in reinforcement placement time and costs associated with placement..
3. To-date, the bridge deck is responding as expected and no problems have been experienced. The positive experience of this project should lead to consideration of use on other projects where long-term durability is of concern.

Negative Results:

There are no known negative results from either the use of this project or that developed over the course of the project.

Lessons Learned:

Barrier to implementation of Technology: The primary lesson learned is that contractors can be resistant to change. There was a general perception that the use of a different reinforcement type would increase both construction cost and time and the bids reflected this fact. While there is an increased cost from use of a higher cost reinforcing material, these costs can be somewhat mitigated through reduced crew and construction time which was achieved from much easier handling of the material. At the end of the project, the contractor indicated that his original perceptions were wrong and that use of this material can reduce costs in several areas including materials transport, material handling, and reinforcement placement.

Internal or External Reports:

“FHWA/IN/JTRP-2006/15 IMPLEMENTATION OF A NON-METALLIC REINFORCED BRIDGE DECK” This final report (Volume 1&2) details the design, construction and performance evaluation of FRP bar reinforcing concrete decks.

Publications, Presentations, or, Construction Studies:

Pay, A.C. and Frosch, R.J. “Bond Behavior of Lap Spliced Fiber-Reinforced Polymer (FRP) Bars,” New Developments and Techniques in Bond and Development of Reinforcement, American Concrete Institute, Fall Convention, Boston, MA, September 28, 2003.

Additional Comments:

Technology used on Other Projects: None mentioned for this state.

Plans on Reuse of Technology: Yes, the results were very positive.

Applicability to other States: Yes, This technology is applicable to all states, where long-term durability if of concern.

Additional Project Notes:

10/30/08: Project completed

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** US 30 over Jain Creek (extra coating thickness)**State:** IN **Federal-Aid Project #:** _____ **Fiscal Year:** 2003 **Funds Awarded:** \$200,000.00**Fund Status:** \$200,000.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Extra thick epoxy coated reinforcementTechnology Description: Applying coating thickness of up to 21 mils on epoxy-coated No. 5 and No. 9 bars in order to evaluate the performance in bond to normal-weight concrete.**Project Information****Positive Results:**

The main findings of the experimental program are as followed:

- For each bar size specimen designed for $1/2 f_y$ ($1/2$ of yield stress), the stress at failure obtained using beam theory analysis at the Failure Load, were similar when comparing the Bundled Bar with the Single Splice specimens.
- Increasing the coating thickness up to 21 mils resulted in ratios of test to calculated values at failure greater than 1.0 when the calculated values was determined using the AASHTO LRFD (2004) Specifications and the ACI 318-05 Code. ACI 318-05 calculated values resulted in an average test/calculated ratio greater than the average for test/calculated ratios using the AASHTO LRFD (2004) Specifications. The No. 9 single splice bars however, were slightly lower for ACI than for AASHTO.
- The specimens containing bars with coatings thickness in the range of 18-21 mils did not show significantly different deflections at failure when compared to those of the companion specimens with bars having a coating thickness range of 12-15 mils.
- For the No. 9 Bundled Bar specimens designed for $1/2 f_y$, the increase in coating thickness resulted in a reduction in the average crack spacing and average crack width with thicker coatings.
- For the No. 9 single bar splices the increase in coating thickness resulted in a reduction in the average crack width. The reduction was less significant than that observed in the No. 9 Bundled Bar specimens. Furthermore, the increase in coating thickness resulted in no change in the average crack spacing.
- For the No. 5 Single Splice specimens designed for $1/2 f_y$, the increase in coating thickness resulted in an increase of average crack spacing and average crack width for thicker coating thicknesses.
- Bundling of bars resulted in an increase of the average crack spacing compared to that observed in Single Splice specimens only in the case of the No. 9 bar specimens with 12-15 mils coating thickness. In the other three cases considered, No. 5 bar specimens with 12-15 mils coating thickness, No. 5 bar specimens with 18-21 mils coating thickness and No. 9 bar specimens with 18-21 mils coating thickness, bundling of bars resulted in a decrease in the average crack spacing when compared to similar Single Splice specimens. The largest reduction was observed in the No. 5 bar specimens with coating thickness in the range of 18-21 mils.

As a result of this project, INDOT already increase the minimum epoxy coating thickness although not to the extent of 18 mils. The change in minimum epoxy thickness influences the range of allowable thickness for quality control.

Negative Results:

No negative results are expected based on consultations with fabricators, INDOT engineers and bridge designers during the execution of the project

Lessons Learned:

Barrier to implementation of Technology: The use of the current provisions for development and splice length of epoxy-coated bars in tension in both the AASHTO LRFD (2004) and ACI 318-08 is supported by the test findings of the experimental program up to a coating thickness not to exceed 21 mils. However, since the ACI 318-08 specifications consider the critical parameters of cover and transverse reinforcement, the authors encourage the Indiana Department of Transportation to use these provisions in the design of development and splice length of bars with coating thickness up to 18 mils.

A monitoring plan for a future concrete bridge deck to be built in Indiana using coated bars with thickness of coating up to 18 mils includes three stages. First, prior to construction sampling of the reinforcement, specifically coating thickness, and number of defects upon arrival to the job site and after placement is recommended. In addition, contractor, coater and epoxy powder manufacturer will be collected. Concrete specifications (w/c, air content and strength) will be documented together with epoxy-coated reinforcing steel specifications, quality assurance test results and inspection records including coating patching requirements and material and site storage length and conditions. During construction in the second stage, the number of defects after casting of the concrete will be evaluated using the same technique as in the "Methods of Corrosion Protection and Durability of Concrete Bridge Decks Reinforced with Epoxy-Coated Bars – Phase I" JTRP study. It is also proposed to determine relevant concrete material properties using established sampling techniques.

The third stage is the monitoring of the deck performance in-service conditions. The long-term performance should be monitored with a combination of regularly scheduled visits to obtain chloride levels in the concrete at various depths, survey for delaminating and obtain cores to inspect the concrete and the reinforcement. Remote surveillance using corrosion (Embedded Corrosion Instrument, ECI) transducers in combination with a fully automated data acquisition system is also suggested for implementation as means to determine the conditions in the concrete deck. The ECI has the capability to monitor linear polarization resistance, open circuit potential, resistivity, chloride ion concentration and temperature.

Internal or External Reports:

“Deck Replacement - Use of Extra Coating Thickness Epoxy-Coated Bars” This Final Report details the evaluation of the performance in bond to normal-weight concrete of epoxy-coated bars with coating thickness up to 21 mils using No. 5 and No. 9 bars.

Publications, Presentations, or, Construction Studies:

Hasan, Hendy O., Cleary, D.B., and Ramirez, J.A., (1995) "Field Evaluation of Concrete Bridge Decks Reinforced with Epoxy-Coated Steel in Indiana," Transportation Research Record, National Research Council, No. 1476, July, pp. 155-161.

Samples, L. M., and Ramirez, J. A., "Field Investigation of Concrete Bridge Decks in Indiana- Part 1: New Construction and Initial Field Investigation of Existing Bridge Decks," Concrete International, American Concrete Institute, February 2000, pp. 53-56.

Additional Comments:

Technology used on Other Projects: No, none mentioned for this state

Plans on Reuse of Technology: Yes, although not to the extent of 18 mils coating thickness.

Applicability to other States: Yes, this technique is applicable to all states.

Additional Project Notes:

10/30/08: New candidate project being proposed. Research portion of project is complete.

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FHWA IBRC/IBRD Project Summary Report Form

Project Name: US-50 Bridge over Tanners Creek and Service Road, Lawrenceburg
State: IN **Federal-Aid Project #:** _____ **Fiscal Year:** 2004 **Funds Awarded:** \$300,000.00
Fund Status: \$200,000.00 Expended **Project Status:** Initiated

Associated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Full Depth, Precast Bridge Deck System

Technology Description: Developed a new full depth precast bridge deck system and conducted laboratory testing and on a full-scale prototype bridge under both cyclic and static loading.

Project Information

Positive Results: Extensive research conducted in the laboratory demonstrated the following:

- The new system improves constructability and durability by eliminating penetrations in the deck that are commonly used in other full-depth precast solutions. New connections were developed for connection of the deck to the girder as well as for connecting adjacent panels
- Through the full-scale prototype bridge, both its constructability and structural performance were verified
- This new deck system can be constructed extremely quickly and has the potential of providing a significant tool for the rapid construction and replacement of bridges.

Negative Results:

No negative results have been experienced in the laboratory.

Lessons Learned:

Barrier to implementation of Technology: None at this time. A field study should be implemented to further evaluate the constructability and long-term performance of the structure.

Internal or External Reports:

“INNOVATIVE BRIDGE CONSTRUCTION PROGRAM: IMPLEMENTATION OF FULL-DEPTH BRIDGE DECK PANELS IN INDIANA” This Draft Final Report details the research conducted on the implementation of a full depth precast bridge deck panels.

Publications, Presentations, or, Construction Studies:

Price, S. and Frosch, R.J., “Innovative Connection Details for Full-Depth Precast Bridge Deck Panels for use on Prestressed Concrete Girders, American Concrete Institute, Spring Convention, San Antonio, TX, March 16, 2009.

Price, S. and Frosch, R.J., “A New Connection System for Precast Bridge Deck Panels on Concrete Girders, 2009 Prestressed/Precast Concrete Institute, Annual Convention, San Antonio Texas, September 13, 2009.

Additional Comments:

Technology used on Other Projects: No, none mentioned for this state

Plans on Reuse of Technology: Cannot be determined at this time, only laboratory testing has been accomplished.

Applicability to other States: Cannot be determined until field demonstration is complete.

Additional Project Notes:

10/30/08: New candidate project being proposed. Research portion of project is complete.

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Phone: 765-463-1521 ext. 248

1.16. IOWA

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** 100th Avenue over Little Soap Creek, Keokuk Township**State:** IA **Federal-Aid Project #:** IBRC-C090(046) **Fiscal Year:** 2003 **Funds Awarded:** \$300,000.00**Fund Status:** \$300,000.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: UHPC**Technology Description:** Ultra high performance concrete (UHPC) used in a bridge replacement project. A monitoring program was implemented to document the performance of this innovative product.**Project Information****Positive Results:**

The successfully completed goal of the project was to advance state-of-the-art in concrete bridge construction technology by designing and constructing the first UHPC bridge in the United States, as well as to promote the use of UHPC both nationally and internationally. Additionally, experience was gained in using advanced materials in Iowa, and recommended design procedures for shear design for UHPC beams were developed. A load test was conducted to failure on a full-size UHPC prestressed beam.

Negative Results:

High cost of material.

Lessons Learned:

Barrier to implementation of Technology: The current cost of UHPC is very prohibitive, restricting widespread use of UHPC in bridge construction in Iowa, unless bridge units are optimized to reduce the amount of UHPC required.

Internal or External Reports:

“Ultra High Performance Concrete Highway Bridge” This Report details the experience gained in designing, testing, mixing and casting the ultra high performance concrete.

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Yes

Plans on Reuse of Technology: Yes, where applicable.

Applicability to other States: Yes, where applicable.

Additional Project Notes:

Project Opened to Traffic: May 5th, 2006

This project was conducted in conjunction with Iowa State University and the Center for Transportation Research and Education (CTRE)

Principal Investigator:
Brent Phares

Student Researcher:
Brian Degen

State DOT Contact: Ahmad Abu-Hawash
E-mail: Ahmad Abu-Hawash@dot.iowa.gov

Phone: 515-239-1393

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** 136th Ave. over Buffalo Creek

State: IA	Federal-Aid Project #: IBRC-C010(58)	Fiscal Year: 2005	Funds Awarded: \$400,000.00
		2007	\$300,000.00

Fund Status: \$554,260.62 Expended**Project Status:** Initiated**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: UHPC PI girder bridge

Technology Description: Ultra high performance concrete (UHPC) PI section to be used in a bridge project. The design work is adapting the optimized test section that was developed by FHWA and MIT with modification. The load test will be conducted once the bridge is complete.

Project Information**Positive Results:**

- The goal was to optimize the shape of UHPC and test it in the field. The 2nd generation PI Girder has shown much improved live load distribution and the bridge continues to perform well.
- This bridge appears to be performing well and is within the general design parameters
- All measured strain levels below cracking strain
- Minimal cracking observed
- The PI girders provided a new and effective option for bridge superstructures
- The design approach for the bridge was appropriately conservative in consideration of the relatively new geometry and materials
- Models can be developed cost-effectively and provide a useful tool for designers in predicting behavior, anticipating locations of concern, evaluating details, and identifying global changes in bridge performance through subsequent load tests.

Negative Results:

- Cost of proprietary UHPC product

Lessons Learned:

Barrier to implementation of Technology: In order for UHPC to be implemented widely around the state and the nation, the shape of the girder needs to be optimized in order to reduce material and other construction costs.

- Future designs could utilize longer spans, lower live load distribution factors, and most likely dispense with transverse mild steel reinforcement in the deck of the girders.
- With the decrease in cost of UHPC and fiber reinforcement in North America (\$2000/yd³ as of 2007 according to Vande Voort, Suleiman and Sriharan 2008), UHPC pi-girder bridges will become a more viable option
- If cracking of the UHPC is used as a criterion to limit stresses for durability considerations, relatively simple, linear-elastic finite element models can provide a highly useful tool in predicting behavior of the UHPC pi-girders.
- Models can be developed cost-effectively and provide a useful tool for designers in predicting behavior, anticipating locations of concern, evaluating details, and identifying global changes in bridge performance through subsequent load tests. The verification of these models is of particular significance for future designs employing the distinctive UHPC pi-girder.
- The pi-girders have lateral distribution factors ranging from 0.62 for exterior girders and 0.75 for interior girders. The design value of 1.0 was, therefore, conservative.
- The bridge did not behave as if perfectly simply supported as assumed in design. The concrete diaphragms at the piers appear to have provided some degree of continuity between the end spans and pi-girder span. However, the 2009 test showed that the UHPC centerspan appeared to have lost some degree of rotational restraint.
- The bridge did not behave as if perfectly simply supported as assumed in design. The concrete diaphragms at the

piers appear to have provided some degree of continuity between the end spans and pi-girder span. However, the 2009 test showed that the UHPC centerspan appeared to have lost some degree of rotational restraint.

- Based on the measured live load strains and allowing for a 5 cm (2 in.) asphalt overlay and an impact factor of 1.33, the girder length could be increased to roughly 20 meters (65ft) without cracking for Interim 2008 AASHTO specified loads.
- Construction strains induced by tightening of the HSS members are significant in the webs -- often of similar magnitude to the strains recorded during live load tests. Tighter fabrication tolerances for diaphragms members may be appropriate.
- The maximum measured dynamic amplification factor was 1.15 for speeds up to 25 mph. The specified AASHTO dynamic amplification factor of 1.33 is conservative for this bridge.
- The steel diaphragms are not overly effective in improving the live load distribution between pi-girders for service level loads. However, when the midspan diaphragm was active the maximum live load strains on the bulbs were reduced by roughly 6%.
- The steel diaphragm at midspan is not effective in decreasing the vertical web strain.
- The use of ready-mix trucks in UHPC batching can provide compressive material strengths of 28 ksi.

Internal or External Reports:



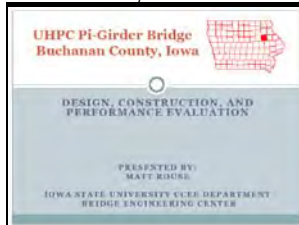
“Design of Buchanan County, Iowa, Bridge Using Ultra High

Performance Concrete and PI Girders” This Report details the design work to date, the Final Report is being written.



“Design, Construction, and Field Testing of an Ultra-High Performance Concrete Pi-Girder Bridge”

Publications, Presentations, or, Construction Studies:



“UHPC Pi-Girder Bridge Buchanan County, Iowa”



“Buchanan County constructs a bridge using ultra-highperformance concrete girders”



"Iowa's ultra-high performance concrete implementation"



2009 PCI Bridge Design Awards

Additional Comments:

Technology used on Other Projects: Yes, previous bridge project south of Ottumwa, Iowa

Plans on Reuse of Technology: Cannot be determined at this time.

Applicability to other States: Cannot be determined at this time.

Additional Project Notes:

\$300,000 additional funds allocated in FY 2007

Project opened to traffic: November 26, 2008

This project is being conducted in conjunction with Iowa State University and the Center for Transportation Research and Education (CTRE)

Principal Investigator:
Brent M. Phares

Co-Principal Investigators:
Terry J. Wipf
Matt Rouse

State DOT Contact: Ahmad Abu-Hawash

Phone: 515-239-1393

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** 215 Avenue Bridge over Lime Creek

State: <u>IA</u>	Federal-Aid Project #: <u>IBRC-C028(041)</u>	Fiscal Year: <u>2001</u>	Funds Awarded: <u>\$285,000.00</u>

Fund Status: <u>\$265,440.93 Expended</u>	Project Status: <u>Completed</u>

Associated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Glulam

Technology Description: Fiber reinforced polymer (FRP) plates bonded to the tension laminate to reinforce glued-laminated timber girders.

Project Information**Positive Results:**

This project showed that using FRP plates to strengthen glulam bridges is an economically viable method for constructing bridges. Good aesthetics.

- The overall bridge structural performance under static live loading is adequate and within specified limits.
- Initial test results do not indicate a significant increase in stiffness resulting from the presence of the FRP reinforcement on the girders.

Negative Results:

High cost of material. Delaminations occurred on one beam during construction, but were found to not significantly affect the beam strength.

Lessons Learned:

Barrier to implementation of Technology: May be appropriate in a park setting where the increase cost is justified by the increased aesthetics of the timber bridge. Otherwise, concrete slab bridges are significantly less expensive.

Challenges arose during erection due, in part to the fact that shop drawings were not part of the project plans

Internal or External Reports:

“Evaluation of a Timber Bridge for the Secondary Road System Using FRP Reinforced Glued Laminated Girders” This Final Report details the fabrication inspection and installation of the FRP plates bonded to the glued-laminated timber girders, as well as the condition inspection and static field-load testing of the system.

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: No

Plans on Reuse of Technology: Yes, in a park or rustic setting.

Applicability to other States: Yes, where applicable.

Additional Project Notes:

Road opened to traffic in Fall 2004

This project was conducted in conjunction with Iowa State University and the Center for Transportation Research and Education (CTRE)

Principal Investigators:

Terry J. Wipf

Brent M. Phares

Student Researchers:

Jake Bigelow

Travis Hosteng

State DOT Contact: Ahmad Abu-Hawash
E-mail: Ahmad Abu-Hawash @dot.iowa.gov

Phone: 515-239-1393

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Iowa 24 over Goddard Creek

State: <u>IA</u>	Federal-Aid Project #: <u>IBRC-24-</u>	Fiscal Year: <u>2003</u>	Funds Awarded: <u>\$205,000.00</u>
	<u>2(12)</u>	<u>2004</u>	<u>\$135,000.00</u>

Fund Status: \$281,219.58 Expended**Project Status:** Completed**Associated Project Names**

4th ave over Ralston creek

Project: Change / AssociatedReallocated from / to: \$135,000.00**Technology Implemented:** **FRP deck slab**

Technology Description: Fiber reinforced polymer (FRP) composite bridge was installed as a new temporary bridge system. This new structure is 35percent lighter than the steel alternative and potentially easier to transport.

Project Information**Positive Results:**

None reported

Negative Results:

Project failed due to delamination of the FRP deck and elevation inconsistencies. Bridge was removed from service.

- Moisture had infiltrated the deck panel and was beginning to result in deterioration of the styrofoam bottles and the top layers of FRP were delaminated.

Lessons Learned:

Barrier to implementation of Technology:

Internal or External Reports:

“Testing and Evaluation of the Iowa DOT FRP Temporary Bypass Bridge” This Final Report details the testing and evaluation of the FRP Temporary Bypass Bridge.

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: No

Plans on Reuse of Technology: No.

Applicability to other States: No, this system did not perform well.

Additional Project Notes:

Project opened to traffic in Spring 2007, but removed from service a short time later due to damage along the edges and delaminating of the top layer.

\$135,000 additional funds were allocated to this project on 9/9/03 after IBRC-3715(619) (4th ave over Ralston creek) was cancelled.

This project was conducted in conjunction with Iowa State University and the Center for Transportation Research and Education (CTRE)

Co-Principal Investigators:

Terry J. Wipf

Brent M. Phares

Investigators:

Travis K. Hosteng

Doug L. Wood

State DOT Contact: Ahmad Abu-Hawash
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Phone: 515-239-1393

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** 24th St. over I-80/I-29 Council Bluffs**State:** IA **Federal-Aid Project #:** IM-080-1(308) **Fiscal Year:** 2005 **Funds Awarded:** \$400,000.00**Fund Status:** \$124,349.78 Expended **Project Status:** Initiated**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Concrete precast Deck slabs using accelerated construction techniques**Technology Description:** Prestressed precast deck panels longitudinally post tensioned on steel girders and accelerated bridge construction techniques were investigated in the laboratory.**Project Information****Positive Results:**

This project used accelerated construction which resulted in a reduction in construction time of approximately 50% when compared with an equivalent structure using traditional construction methods.

Laboratory results concluded;

- No difficulty in installing the shear studs in the precast panel pockets were foreseen by the contractor or encountered by the research team.
- The waterproof duct tape and butyl rubber methods of grout proofing the ductsplices were both found to be acceptable.

Negative Results:

Sequential nature of construction operations limits the reduction in construction time that can be achieved.

Lessons Learned:

Barrier to implementation of Technology: From Laboratory testing;

- Conducting the bend test on the four studs in the corners of the precast panel pockets was easily done with a straight pipe. Bending the center two studs was more difficult than the corner studs; however, the studs can be easily bent if a pipe pre-bent in an "S" shape is used.
- Sandblasting the surface of the concrete /grout joint was the most effective surface treatment for resistance to shear.

Internal or External Reports:

“24th Street Bridge over I80/I29, Council Bluffs, Iowa” This Report details the laboratory testing and evaluation of the prestressed precast deck panel installation on the steel girders. The Final Report is being prepared,

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: No

Plans on Reuse of Technology: Cannot be determined at this time.

Applicability to other States: Cannot be determined at this time.

Additional Project Notes:

Construction completed in 2009.

This project was conducted in conjunction with Iowa State University and the Center for Transportation Research and Education (CTRE)

Principal Investigator:

Brent M. Phares

Co-Principal Investigator:

Terry J. Wipf

Start Date: 3/01/07

Scheduled Completion Date: 6/30/10

State DOT Contact: Ahmad Abu-Hawash

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** 4th Ave. over Ralston Creek

State: IA	Federal-Aid Project #:	IBRC- 3715(619)	Fiscal Year:	2000 2001	Funds Awarded:	\$75,000.00 \$60,000.00
Fund Status:	\$135,000.00 Reallocated		Project Status:	Withdrawn		

Associated Project Names

24-2(12) Winneshiek County in FY 2003 (Iowa 24 over Goddard Cr.) Project: Change / Associated Reallocated from / to: {\$135,000.00}

Technology Implemented: FRP Deck Panels

Technology Description: A temporary FRP deck bridge was designed and developed to replace existing steel temporary bridge with the Iowa Department of Transportation.

Project Information**Positive Results:**

None

Negative Results:

- Shortly after traffic was allowed on the bridge, Iowa DOT inspectors noticed that the transverse edge at the end of one of the panels was showing signs of significant damage at the approach end of the bridge due to elevation of the backwall being approximately 1 in lower than the deck panel
- Shortly after the steel plates were installed, inspection found that the top layer of FRP and the wearing surface had debonded on one of the deck panels over approximately half of the panel surface area
- water and debris had entered through holes in the top layer of FRP near the lifting lug locations and was thought to be potentially deteriorating the foam bottles that comprised the core of the panels

Lessons Learned:

Barrier to implementation of Technology: Although test results indicated that the bridge showed no signs of reduced stiffness and was adequately distributing the loads, as a result of this deterioration of the south deck panel, the bridge was immediately closed, removed, and replaced

Internal or External Reports:

"Testing and Evaluation of the Iowa DOT FRP Temporary Bypass Bridge" The Final Report is for the funded project.

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Yes, funds were re-allocated to IBRC-24-2(12) Winneshiek County in FY 2003.

Plans on Reuse of Technology: No

Applicability to other States: No

Additional Project Notes:

Funding contribution from city was going to be too great so the project was discontinued.

10/30/08: Project closed. Funding de-allocated in FY03.

\$135,000 re-allocated to IBRC-24-2(12) Winneshiek County in FY 2003. This was a FRP slab detour bridge.

State DOT Contact: Ahmad Abu-Hawash
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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** 53rd Ave. over Crow Creek Bettendorf

State: <u>IA</u>	Federal-Aid Project #: <u>IBRC-0587(20)</u>	Fiscal Year: <u>1999</u>	Funds Awarded: <u>\$220,000.00</u>
		<u>2001</u>	<u>\$75,000.00</u>

Fund Status: \$294,559.80 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: **FRP**

Technology Description: Constructing one span of a three span bridge with fiber reinforced polymer (FRP) deck panels. Perform short-term live load testing and long term monitoring.

Project Information**Positive Results:**

The goal of the project was to demonstrate the use of lightweight, stronger than steel, easier to handle FRP panels in bridge construction. After two years of field monitoring, the deck was performing as expected.

Negative Results:

Transverse cracking was visible after one year of service; however there was no significant loss of stiffness in the FRP deck. Central girders may not have achieved full composite action with FRP deck panels.

Lessons Learned:

Barrier to implementation of Technology: Minor de-bonding of the wearing surface from deck panels occurred.

- Observed deterioration is likely due to structural behavior effects and not loading effects.

Internal or External Reports:

“Evaluation of the Bettendorf Bridge, Iowa” This Final Report details the design and installation, as well as the field testing and monitoring of the FRP deck panels.

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Yes

Plans on Reuse of Technology: Yes, where applicable

Applicability to other States: The FRP Technology is applicable to all states in need of similar strengthening.

Additional Project Notes:

10/30/08: Construction complete. Project is active in FMIS due to unexpended balance of \$440.20

\$220,000 was allocated in 1999 and \$75,000 was allocated in 2001

This project was conducted in conjunction with Iowa State University and the Center for Transportation Research and Education (CTRE)

Principal Investigator:

Terry J. Wipf

Co-Principal Investigators:

Fouad S. Fanous

Brent M. Phares

Wally Mook from the City of Bettendorf was also involved.

Scheduled Completion Date: 2/28/06

State DOT Contact: Norm McDonald

Phone: 515-239-1206

E-mail: Norm.McDonald@dot.iowa.gov

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Boone County Bridge (ID 85-25-031) 120th Street over Squaw Creek**State:** IA **Federal-Aid Project #:** IBRC-CO008 **Fiscal Year:** 2004 **Funds Awarded:** \$400,000.00
(39)—8E-08**Fund Status:** \$399,526.08 Expended **Project Status:** Completed**Associated Project Names**Madison County Bridge (14B-
551-100) 290th Street over
unnamed creekProject: Change / Associated

Reallocated from / to:

Technology Implemented: **High Performance Concrete in Deck Slab, accelerated construction techniques****Technology Description:** Precast concrete elements and accelerated bridge construction techniques were investigated in the laboratory and at the bridge project site.**Project Information****Positive Results:**

By using accelerated construction techniques, the construction time of the project was reduced significantly when compared to an equivalent structure. This project was a step in the Iowa DOT's continuing effort to implement accelerated bridge construction techniques in Iowa. Future projects will explore the use of these techniques on higher traffic routes

Negative Results:

Requirements for sequential work, such as cast in place joints and post-tensioning add time to the critical path.

Lessons Learned:**Barrier to implementation of Technology:** Precast elements ended up being critical path – intermediate completion dates should be in contract documents for projects that include precast elements.

Communication in Accelerated Construction is very important – construction or fabrication issues need to be resolved quickly, and it is necessary to use electronic distribution for documents.

Internal or External Reports:**“Precast Concrete Elements for Accelerated Bridge Construction”****“ACCELERATED CONSTRUCTION IN IOWA”****“Design and Evaluation of Accelerated Bridge Construction”**

These Reports details the design, laboratory testing, field testing and evaluation of the accelerated bridge construction techniques.

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Yes

Plans on Reuse of Technology: Yes, where applicable.

Applicability to other States: Yes, where applicable.

Additional Project Notes:

This project was conducted in conjunction with Iowa State University and the Center for Transportation Research and Education (CTRE)

Principal Investigator:
Terry J. Wipf

Co-Principal Investigators:
Brent M. Phares
F. Wayne Klaiber
Mike D. LaViolette

Research Assistant:
Matthew Becker

Construction completed: December 2006

State DOT Contact: Ahmad Abu-Hawash
E-mail: Ahmad Abu-Hawash@dot.iowa.gov

Phone: 515-239-1393

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** County Bridge ID 86 on local road**State:** IA **Federal-Aid Project #:** IBRC-C011(86) **Fiscal Year:** 2006 **Funds Awarded:** \$200,000.00**Fund Status:** \$0.00 Expended**Project Status:** Initiated**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Accelerated construction using precast elements

Technology Description: Using precast elements and accelerated bridge construction techniques to reduce construction time.

Project InformationPositive Results:

The goals of this project include evaluating the 2nd generation of precast elements, reducing construction time by 66% using accelerated construction, and comparing abutment systems on ease of installation and performance. While the contract listed 10 working days as the time frame for the construction of the bridge, the actual work took only 5 days, showing the great amount of potential that exists for saving user costs by using accelerated construction.

Negative Results:Lessons Learned:

Barrier to implementation of Technology: With proper incentive and design, entire precast bridges can be built very rapidly.

Internal or External Reports:

The report is not completed at time of submittal.

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Yes

Plans on Reuse of Technology: Yes, where applicable.

Applicability to other States: Yes, where applicable.

Additional Project Notes:

This project is conducted in conjunction with Iowa State University and the Center for Transportation Research and Education (CTRE)

Principal Investigator:

Brent M. Phares

Co-Principal Investigator:

Terry J. Wipf

Project let 4/21/09.

Bridge construction complete: 9/15/09

State DOT Contact: Ahmad Abu-Hawash
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Phone: 515-239-1393

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** East 12th Street over I-235**State:** IA **Federal-Aid Project #:** IM-235-2(331) **Fiscal Year:** 2002 **Funds Awarded:** \$320,000.00**Fund Status:** \$320,000.00 Expended **Project Status:** CompletedAssociated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: HPS

Technology Description: High performance steel (HPS) used in the construction of Iowa's first HPS bridge. Use innovative Structural Health Monitoring (SHM) techniques to continuously monitor the performance of HPS in bridge application over two year period.

Project InformationPositive Results:

By using a continuous Structural Health Monitoring (SHM) System, HPS was determined to be a viable option for use in Iowa bridges. Additionally, the SHM system functions well and recommendations have been made to improve the system for future use on other projects.

Negative Results:

Problems with fiber-optic sensors, which included:

- Optical loss
- Interference between sensors
- Large strain range of sensors
- Large compressive drop
- Backscatter

Lessons Learned:

Barrier to implementation of Technology: As this bridge is located over a major roadway (I-235), coordination with traffic was difficult and needs to be considered for future work.

- Use surface-mountable sensors.
- Use at least a 3 mm jacket on the cable.
- Use mechanical splices to splice adjacent fiber strands.
- If bare FBGs are used, test different types of epoxy for the best adhesion.
- Separate the wavelengths of adjacent sensors by at least 5 nm.
- Cover sensors and splices such that they are accessible for visual inspection. (This is only necessary if access to sensors will be available after installation.
- Data collection and processing system that requires little user intervention but still provides the beneficial information of the current system would enhance the capabilities of the current system.

Internal or External Reports:

"Remote Continuous Evaluation of a Bridge Constructed Using High-Performance Steel" This Final Report documents the design and construction of the bridge, summarizes the monitoring system in place, describes the data management system, and documents the structural performance of the bridge.

Publications, Presentations, or, Construction Studies:Additional Comments:

Technology used on Other Projects: No

Plans on Reuse of Technology: Yes, where applicable.

Applicability to other States: Yes, where applicable.

Additional Project Notes:

Bridge opened to traffic: March 23, 2004

Structural Health Monitoring continued for 2 years after construction.

This project was conducted in conjunction with Iowa State University and the Center for Transportation Research and Education (CTRE)

Principal Investigator:
Terry J. Wipf

Co-Principal Investigators :
Brent M. Phares
Lowell F. Greimann

Research Assistants:
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Justin Doornink
Ping Lu

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Hwy. E64 over Small Creek East of US 63**State:** IA **Federal-Aid Project #:** IBRC-C086(057) **Fiscal Year:** 2002 **Funds Awarded:** \$170,000.00**Fund Status:** \$163,469.40 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Steel-free concrete bridge deck**Technology Description:** Steel free deck (SFD) system, consisting of a composite fiber reinforced concrete (FRC) that doesn't contain internal reinforcement, was used for the construction a single span steel-girder bridge deck.**Project Information****Positive Results:**

The steel-free bridge deck design performed satisfactorily on steel girders and is feasible for use on prestressed, pretensioned concrete beam bridges. Future work should investigate the potential for use of this deck system on other bridge types. The steel free deck performed well when load tested, the results were within specification limits.

- Girder deflections at mid-span were well below the limitations for serviceability.

Negative Results:

Conventional reinforcement was required in the deck overhang areas.

Lessons Learned:

Barrier to implementation of Technology: Trial batches to refine the mix design for the Fiber-reinforced concrete is beneficial.

Internal or External Reports:

“Evaluation of a Single-span Steel-girder Bridge Using a Steel-free Deck System” This Final Report details the design, installation, field and laboratory testing of the SFD system.

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: No

Plans on Reuse of Technology: Yes, where applicable.

Applicability to other States: Yes, where applicable.

Additional Project Notes:

Project opened to traffic: Summer 2004

This project was conducted in conjunction with Iowa State University and the Center for Transportation Research and Education (CTRE)

Principal Investigator:

Terry J. Wipf

Co-Principal Investigators:

Brent M. Phares

F. Wayne Klaiber

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Van W. Robbins

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I-A-92 over Walnut Creek**State:** IA **Federal-Aid Project #:** IBRC-0921(055) **Fiscal Year:** 2002 **Funds Awarded:** \$130,000.00**Fund Status:** \$116,082.82 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP strengthening of steel girders**Technology Description:** Carbon fiber reinforced polymer (CPRP) plates were added to the bottom flange of steel girders to strengthen overstressed beams.**Project Information****Positive Results:**

This project demonstrated that overstressed beams could be adequately strengthened by the addition of CFRP plates to the bottom flange of steel girder bridges cost effectively. A load test was conducted that confirmed the increase in strength resulting from the addition of the CFRP plates.

Negative Results:

Additional studies are required to understand failure mechanisms, to determine behavior characteristics such as; fire resistance, long term creep, degradation of bond forces and to develop design standards.

Lessons Learned:**Barrier to implementation of Technology:**

Initially the technology was time consuming to install due to learning the installation process, however procedures could be developed that decrease the amount of time required for installation. Additionally, special care must be taken to ensure galvanic induced corrosion does not occur between the steel girder and the carbon fibers.

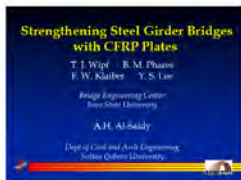
More strength possibly could have been obtained by removing the load from the beams before installing the plates.

Internal or External Reports:

“Evaluation of A Steel Girder Bridge Strengthened Using FRP Plates” This Final Report details the design, installation and field testing of the strengthening system.

Publications, Presentations, or, Construction Studies:

"Strengthening Steel Girder Bridges with Carbon Fiber-Reinforced Polymer Plates"



"Strengthening Steel Girder Bridges with CFRP Plates"

Additional Comments:

Technology used on Other Projects: No

Plans on Reuse of Technology: Yes, where applicable.

Applicability to other States: Yes, where applicable.

Additional Project Notes:

Installation Complete: June 2003

This project was conducted in conjunction with Iowa State University and the Center for Transportation Research and Education (CTRE)

Principal Investigator:

Terry J. Wipf

Co-Principal Investigators:

Brent M. Phares

F. Wayne Klaiber

Student Researcher:

Yoon-Si Lee

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Madison County Bridge (14B-551-100) 290th Street over unnamed creek**State:** IA **Federal-Aid Project #:** IBRC-C061(076) **Fiscal Year:** 2004 **Funds Awarded:** \$200,000.00**Fund Status:** \$200,000.00 Expended **Project Status:** Completed**Associated Project Names**Boone County Bridge (ID 85-25-031) 120th street over Squaw CreekProject: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Concrete Box beams using accelerated construction techniques

Technology Description: Precast concrete elements and accelerated bridge construction techniques were investigated in the laboratory and at the bridge project site.

Project Information**Positive Results:**

The goal of using Accelerated Construction was to reduce construction time to 50% or less of an equivalent project not using AC. The project successfully completed this by finishing construction in 4 ½ weeks whereas the typical construction time would have been 2 months.

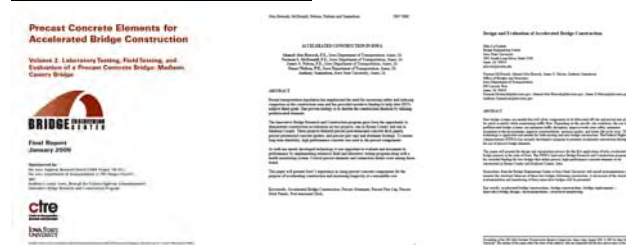
Negative Results:

Some indication of corrosion on prestressing strand.

Lessons Learned:

Barrier to implementation of Technology: Precast elements ended up being critical path – intermediate completion dates should be in contract documents for projects that include precast elements.

Communication in Accelerated Construction is very important – construction or fabrication issues need to be resolved quickly, and it is necessary to use electronic distribution for documents.

Internal or External Reports:

“Precast Concrete Elements for Accelerated Bridge Construction”

“ACCELERATED CONSTRUCTION IN IOWA”

“Design and Evaluation of Accelerated Bridge Construction”

These Reports details the design, laboratory testing, field testing and evaluation of the accelerated bridge construction.

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Yes

Plans on Reuse of Technology: Yes, where applicable.

Applicability to other States: Yes, where applicable.

Additional Project Notes:

Construction completed in 2007

Project was awarded in FY 2004 but funds were allocated in FY 2005.

This project was conducted in conjunction with Iowa State University and the Center for Transportation Research and Education (CTRE)

Co-Principal Investigators:

Terry J. Wipf

Brent M. Phares

F. Wayne Klaiber

Student Researcher:

Ryan P. Bowers

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Rt. 141 over Willow Cr.**State:** IA **Federal-Aid Project #:** IBRD-141-5(12) **Fiscal Year:** 2000 **Funds Awarded:** \$230,000.00**Fund Status:** \$229,893.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Post-Tensioning

Technology Description: Carbon fiber reinforced polymer (CFRP) post-tensioning bars were installed on the exterior of steel girders to strengthen an existing, structurally deficient, steel girder bridge. The strengthening system was monitored to document the performance and long term impact.

Project Information**Positive Results:**

This project resulted in the P-T system improving overall live-load carrying capacity. The use of P-T CFRP bars to strengthen the SD bridge proved to be viable and effective in this case. No special equipment or training was required for installation

- The addition of the P-T strengthening system had a negligible impact on changing the stiffness of the bridge. This indicates that the live load distribution characteristics are virtually the same before and after the installation of the P-T strengthening system.
- The P-T system generates strain opposite to those produced by dead and live loads and thereby improves the overall live load carrying capacity of the bridge.
- Based upon an analysis performed using the HS-20 truck, it was found that the P-T strengthening system reduced dead and live load induced moments by approximately 3% to 5%, thus allowing the bridge to carry additional live load.

Negative Results:

The addition of the P-T strengthening system had a negligible impact on changing the stiffness of the bridge. This indicates that the live load distribution characteristics are virtually the same before and after the installation of the P-T strengthening system.

An average loss of 2.6 kips of P-T force (per location) occurred over two years of service. Therefore, long-term monitoring on the P-T strengthening system maybe needed for further assessment.

Lessons Learned:

Barrier to implementation of Technology: Long term losses need to be monitored and assessed.

The use of the P-T CFRP bars to strengthen the structurally deficient bridge described in this project was proved to be a viable, effective, and practical solution. However, the CFRP P-T bars used in this project may not be applicable where larger overstresses need to be reduced. In such a case, a bar with increased capacity may be needed.

Internal or External Reports:

“EVALUATION OF POST-TENSION STRENGTHENED STEEL GIRDER BRIDGE USING FRP BARS” This Final Report details the design and installation of the FRP bars, as well as the analysis methods, lab testing and field testing of the FRP system.

Publications, Presentations, or, Construction Studies:Additional Comments:

Technology used on Other Projects: Not reported.

Plans on Reuse of Technology: Not reported.

Applicability to other States: Results demonstrate that this can be used on other small projects.

Additional Project Notes:

Installation of post-tensioning – November 2001

Final load test – June 2003

This project was conducted in conjunction with Iowa State University and the Center for Transportation Research and Education (CTRE)

Principal Investigator:

Terry J. Wipf

Co-Principal Investigator:

Brent M. Phares

Investigator:

F. Wayne Klaiber

Research Assistant:

Yoon-Si Lee

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** US 20/South Beaver Creek Project. NHSX-520-5(78)**State:** IA **Federal-Aid Project #:** NHSX-520-5(78)—3H-38 **Fiscal Year:** 2001 **Funds Awarded:** \$200,000.00**Fund Status:** \$140,396.39 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: MMFX Reinforcement in Deck Slab

Technology Description: To investigate corrosion prevention through the use of corrosion-resistant alloys. The corrosion resistance of MMFX micro-composite steel reinforcement, a high-strength, high-chromium steel reinforcement was installed to determine whether MMFX reinforcement, in fact, provides superior corrosion resistance to epoxy-coated mild steel reinforcement in bridge decks.

Project Information**Positive Results:**

The project goal was to compare the corrosion resistance of MMFX reinforcing bars with other reinforcing bars. Laboratory tests which accelerated corrosion were used to compare MMFX reinforcing bars with uncoated bars, epoxy-coated bars, and epoxy-coated with intermittent exposure. In laboratory tests MMFX performed similarly to epoxy-coated steel. Long term monitoring of epoxy coated and MMFX reinforcement is ongoing in the bridge decks of twin bridges.

Laboratory results, under accelerated conditions, exhibited yield strengths approximately twice those required for Grade 60 mild reinforcement.

Negative Results:

Se Lessons Learned. Corrosion is forming on the bars in the field.

Lessons Learned:

Barrier to implementation of Technology: Damage due to handling and transportation is not an issue with MMFX reinforcement.

As the bridges have shown no signs of corrosion, long term monitoring is needed to determine the long term effect of corrosion on MMFX.

Internal or External Reports:

“Evaluation of Corrosion Resistance of Different Steel Reinforcement Types” This Final Report details the evaluation of corrosion resistance of different steel reinforcement types.

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: No

Plans on Reuse of Technology: Cannot be determined at this time, monitoring is on going.

Applicability to other States: Yes, reinforcing is an issue for all reinforced concrete

Additional Project Notes:

\$59,603.61 de-allocated in FY 2006.

Bridge opened to traffic: August 2003

Project was conducted in conjunction with Iowa State University and the Center for Transportation Research and Education (CTRE)

Principal Investigator:

Terry J. Wipf

Co-Principal Investigators:

Brent M. Phares

Fouad S. Fanous

Student Researchers:

Yoon-Si Lee

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1.17. KANSAS

No Project Summary Reports were generated for this State.

1.18. KENTUCKY

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I-65 Bridge over Main St. Louisville**State:** KY **Federal-Aid Project #:** 126 **Fiscal Year:** 2004 **Funds Awarded:** \$140,000.00**Fund Status:** \$140,000.00 Expended **Project Status:** Completed**Associated Project Names**I-65 over Jacob, Broadway, and
Gray StreetsProject: Change / Associated

Reallocated from / to:

Technology Implemented: Carbon FRP Fabric

Technology Description: Carbon fiber reinforced polymer (CFRP) fabric was wrapped around reinforced concrete pedestal to repair deterioration.

Project Information**Positive Results:**

Monitoring of the bridge's pedestals is on going. The repair was successful.

Negative Results:

None

Lessons Learned:

Barrier to implementation of Technology: This retrofit method works.

Internal or External Reports:

No report on file at this time.

Publications, Presentations, or, Construction Studies:

None at this time.

Additional Comments:

Technology used on Other Projects: Yes, see related project I-65 over Jacob, Broadway, and Gray Streets.

Plans on Reuse of Technology: Yes, This repair method will be used in the future on bridges with similar deficiencies.

Applicability to other States: Yes, this technology is applicable to all states in need of similar types of strengthening or repair.

Additional Project Notes:

Reinforced concrete pedestals at the pier caps, supporting steel girders, were deteriorating at an alarming rate. The deteriorated concrete was removed and the pedestals were reshaped and wrapped with carbon FRP fabric.

This IBRC project was combined, under the same Federal-Aid Project #: 126, with an IBRC project awarded in 2003 and entitled "I-65 over Jacob, Broadway, and Gray Streets".

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I-65 over Jacob, Broadway, and Gray Streets**State:** KY **Federal-Aid Project #:** 126 **Fiscal Year:** 2003 **Funds Awarded:** \$305,000.00**Fund Status:** \$305,000.00 Expended **Project Status:** Completed**Associated Project Names**I-65 Bridge over Main
St.LouisvilleProject: Change / Associated

Reallocated from / to:

Technology Implemented: Carbon FRP Fabric strengthening of prestressed concrete bridge girdersTechnology Description: Carbon fiber reinforced polymer (CFRP) fabric was bonded to the web and bottom flange of the beams to halt the crack formation and expansion.Project InformationPositive Results:

Monitoring of the bridge is ongoing. The repair was successful.

Negative Results:

None

Lessons Learned:

Barrier to implementation of Technology: Proper application of the CFRP fabric is highly recommended. The fabric at two of the more than 100 locations started to peel due to improper surface preparation

Internal or External Reports:

No report on file at this time.

Publications, Presentations, or, Construction Studies:

None at this time.

Additional Comments:

Technology used on Other Projects: Yes, see related project I-65 bridge over Main St., Louisville.

Plans on Reuse of Technology: Yes, This repair method will be used in the future on bridges with similar deficiencies.

Applicability to other States: Yes, this technology is applicable to all states in need of similar types of strengthening or repair.

Additional Project Notes:

Prestressed concrete bridge girders experienced cracks at the ends of the beams at more than 100 locations. The cracks were increasing in number and expanding with time. Carbon FRP fabric was bonded to the web and bottom flange of the beams to halt the crack formation and expansion.

10/30/08: Retrofit completed. Cost increased to cover monitoring and evaluation for three years (until 2010)

This IBRC project was combined, under the same Federal-Aid Project #: 126, with an IBRC project awarded in 2004 and entitled "I-65 bridge over Main St., Louisville".

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Kentucky Route 3297 over Little Sandy River**State:** KY **Federal-Aid Project #:** 114 **Fiscal Year:** 2001 **Funds Awarded:** \$105,000.00**Fund Status:** \$105,000.00 Expended **Project Status:** CompletedAssociated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Carbon FRP Fabric bonded Reinforcement

Technology Description: Carbon fiber reinforced polymer (CFRP) fabric system applied to precast concrete girders to repair and strengthen the superstructure of a shear deficient bridge.

Project InformationPositive Results:

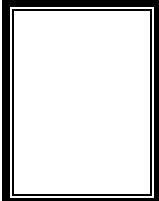
- Original solution was to replace, at a cost of ~ \$600,000, the 3-span superstructure made up of spread box beams that have experienced severe shear cracks. The superstructure was repaired using Carbon FRP Fabric.
- Monitoring of the repair showed that the repair halted the crack growth.
- The repair was conducted without stopping any traffic on the bridge.
- Due to the success of this project, this method of repair was adopted on other bridges in Kentucky.

Negative Results:

None

Lessons Learned:

Barrier to implementation of Technology: The surface preparation and proper application of the fabric are the keys to the success of this project

Internal or External Reports:

“Shear Repair of P/C Box Beams Using Carbon Fiber Reinforced Polymer (CFRP) Fabric” This Research Report details the retrofit work carried out for shear repair of P/C box beams using CFRP fabric.

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Yes, on several other projects in the state of Kentucky.

Plans on Reuse of Technology: Yes, the results were favorable.

Applicability to other States: Yes, this technology is applicable to all states and has been used in some states.

Additional Project Notes:

The FRP Fabric application was also used in Kentucky projects such as; I-65-over Jacob, Broadway and Gray Streets and I-65 bridge over Main Street, Louisville

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** KY 974 over Howard Creek in Clark County, KY**State:** KY **Federal-Aid Project #:** 125 **Fiscal Year:** 2003 **Funds Awarded:** \$400,000.00**Fund Status:** \$400,000.00 Expended **Project Status:** Completed**Associated Project Names**

KY-92 over Jellico Creek

Project: Change / AssociatedReallocated from / to: \$400,000.00**Technology Implemented:** Aluminum Bridge Deck

Technology Description: Using aluminum alloys for bridge deck construction

Project Information**Positive Results:**

- Aluminum Deck is lightweight, thus reducing the dead load and increasing the allowable live load on the bridge.
- Following the placement of the first of twelve deck panels, it took 10 minutes to place one panel on the bridge. Consequently, the placement of the deck could be completed in 2 hours and traffic could be allowed on the deck while the underside of the deck was connected to the bridge beams.
- 3 years of monitoring showed that the deck is performing as expected. There were no signs of deterioration or damage.

Negative Results:

Cost of the aluminum deck is very high and would limit its use to steel girder bridges in congested areas.

Lessons Learned:**Barrier to implementation of Technology:** Training of construction workers to lift and place Aluminum deck panels, and to conduct practice runs before placement on the actual bridge**Internal or External Reports:**

None at this time, a draft report was scheduled for submission in May 2010.

Publications, Presentations, or, Construction Studies:

Presentation titled "KY92 over Jellico Creek" is named for the original project but does discuss the KY94 over Howard Creek bridge deck project.

Additional Comments:

Technology used on Other Projects: Yes, this technology was used on the Webster County Bridge 50, Crab Orchard Creek

Plans on Reuse of Technology: Yes, the results were positive.

Applicability to other States: Yes, this technology is applicable to all states in need of similar types of repair.

Additional Project Notes:

The original project, KY-92 over Jellico Creek, was replaced with bridge on KY 974 over Howard Creek in Clark County, KY

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** KY 3302 over Sugar Tree Branch**State:** KY **Federal-Aid Project #:** 159 **Fiscal Year:** 2005 **Funds Awarded:** \$240,000.00**Fund Status:** \$10,000.00 Expended **Project Status:** Initiated**Associated Project Names**Galloway road over N. Elkhorn
Cr.Project: Change / AssociatedReallocated from / to: \$240,000.00**Technology Implemented:** FRP Stay-in-Place Forms for Deck SlabTechnology Description: Carbon fiber reinforced polymer (CFRP) stay-in-place form to be used in bridge deck slab construction.**Project Information**Positive Results:

None at this time. A preliminary study has indicated the technology will be effective and that the SIP will not corrode. FRP forms are lightweight and install similarly to normal metal SIPs.

Negative Results:

None at this time.

Lessons Learned:

Barrier to implementation of Technology: None at this time.

Internal or External Reports:

The draft report will be submitted in July 2014 once the monitoring phase of the project is complete.

Publications, Presentations, or, Construction Studies:

The presentation will be prepared in July 2014 once the monitoring phase of the project is complete.

Additional Comments:

Technology used on Other Projects: No. None noted for the state of Kentucky.

Plans on Reuse of Technology: Unable to determine at this time

Applicability to other States: Unable to determine at this time, as noted above this application has not yet been monitored.

Additional Project Notes:

The project funds were delayed due to bridge substitution.

The original technology FRP Rebars in deck slab was substituted with FRP stay-in-Place forms for deck slab.

The project name changed from Galloway Road over N. Elkhorn Cr. to KY 3302 over Sugar Tree Branch.

State DOT Contact: David Steele

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Clark County bridge located on County Road 1210 over Two Mile Creek**State:** KY **Federal-Aid Project #:** 102 **Fiscal Year:** 2000 **Funds Awarded:** \$35,000.00**Fund Status:** \$35,000.00 Expended **Project Status:** CompletedAssociated Project NamesKY595 over West Fork Silver Ck Project: Change / Associated Reallocated from / to: \$35,000.00**Technology Implemented:** Carbon FRP Rebar

Technology Description: Carbon fiber reinforced polymer (CFRP) bars were used in the construction of a concrete bridge deck. The CFRP bars were installed in the top and bottom mats in both transverse and longitudinal directions.

Project InformationPositive Results:

- Ease of handling and placement of Carbon FRP bars due to their lightweight.
- Monitoring of cracks in the deck for a period of four years showed any crack formation (primarily due to temperature and shrinkage) were below the AASHTO limits.

Negative Results:

None

Lessons Learned:

Barrier to implementation of Technology: The number of bar chairs should be doubled for FRP bars due to their low modulus of elasticity which leads to larger deflections when workers step on them during concrete placement

Internal or External Reports:

“INSPECTION AND EVALUATION OF A BRIDGE DECK REINFORCED WITH CARBON FIBER REINFORCED POLYMER (CFRP) BARS” This Research Report details the inspection and evaluation of a bridge deck reinforced with carbon fiber reinforced polymer bars.

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: No, the FRP bars were not used on other projects in the state of Kentucky.

Plans on Reuse of Technology: Yes, the results were favorable.

Applicability to other States: Yes, this technology is applicable to all states and has been used in some states.

Additional Project Notes:

The reason the KY595 over West Fork Silver Creek bridge was replaced with the Clark County bridge located on county road 1210 over Two Mile Creek is due to the fact that the KY595 bridge was replaced prior to the establishment of the budget account for this project.

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** KY 714 over Jephtha Creek**State:** KY **Federal-Aid Project #:** 158 **Fiscal Year:** 2005 **Funds Awarded:** \$150,000.00**Fund Status:** \$55,000.00 Expended **Project Status:** Initiated**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Carbon FRP Fabric

Technology Description: Carbon fiber reinforced polymer (CFRP) fabric was bonded to the web and bottom flanges of the beams to halt the crack formation and expansion.

Project Information**Positive Results:**

Monitoring of the bridge is ongoing. The repair was successful.

Negative Results:

None at this time, monitoring is on going.

Lessons Learned:

Barrier to implementation of Technology: This repair method is highly effective.

Internal or External Reports:

No report on file at this time.

Publications, Presentations, or, Construction Studies:

None at this time.

Additional Comments:

Technology used on Other Projects: Yes, this technology was used on several bridge projects in the state of Kentucky.

Plans on Reuse of Technology: Yes, This repair method will be used in the future on bridges with similar deficiencies.

Applicability to other States: Yes, the FRP fabric technology is applicable to all states in need of similar types of strengthening or repair.

Additional Project Notes:

- Prestressed concrete bridge girders experienced cracks at the ends in every span of the three span bridge. The cracks were increasing in number and expanding with time. Carbon FRP fabric was bonded to the web and bottom flanges of the beams to halt the crack formation and expansion.
- Monitoring of the bridge is ongoing. The repair was successful. This repair method will be used in the future on bridges with similar deficiencies.
- Bridge project such as I-65 over Jacob, Broadway, and Gray Street and I-65 over Main Street, Louisville also implemented the FRP fabric technology.

State DOT Contact: David Steele

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Louisa-Fort Gay Bridge**State:** KY **Federal-Aid Project #:** 118 **Fiscal Year:** 2002 **Funds Awarded:** \$195,000.00**Fund Status:** \$195,000.00 Expended **Project Status:** CompletedAssociated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Carbon FRP Laminates

Technology Description: Carbon fiber reinforced polymer (CFRP) laminates were externally installed to the bottom of the girders to halt the crack formation and expansion. Carbon FRP fabric was also applied to halt the growth of shear cracks at the ends of the girders.

Project InformationPositive Results:

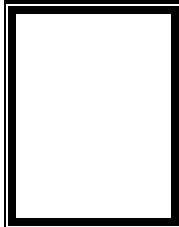
Monitoring of the bridge for a period of three years showed that the repair was successful.

Negative Results:

Contractor did not properly inject the shear cracks and the Carbon Fabric showed some bulges in the crack region. Upon inspection immediately following the fabric application of the fabric, remedial actions were taken to remedy the problem.

Lessons Learned:

Barrier to implementation of Technology: Inspection and supervision during the application of the CFRP fabric is highly recommended.

Internal or External Reports:

“INSPECTION AND EVALUATION OF A BRIDGE DECK REINFORCED WITH CARBON FIBER REINFORCED POLYMER (CFRP) BARS” This Research Report details the installation and monitoring of the FRP installed to retrofit reinforced concrete girders.

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Yes, the FRP repair application was used on KY 32 over Lytles Creek.

Plans on Reuse of Technology: Yes, the results were favorable.

Applicability to other States: Yes, this technology is applicable to all states and has been used in some states.

Additional Project Notes:

Reinforced concrete bridge girders experienced flexural cracks that were increasing in number and expanding with time. Carbon FRP laminates were bonded to the bottom of the girders to halt the crack formation and expansion.

Carbon FRP Fabric was also applied to halt the growth of shear cracks at the ends of the girder

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Scott County Rd. 5218 over North Elkhorn Creek**State:** KY **Federal-Aid Project #:** 113 **Fiscal Year:** 2001 **Funds Awarded:** \$70,000.00**Fund Status:** \$70,000.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Stainless steel clad and MMFX reinforcing steel bars

Technology Description: Stainless steel clad and micro-composite multistructural formable steel (MMFX) were used to reinforced a two-span bridge. The bridge decks were then monitored to evaluate the performance of the two different reinforcing methods.

Project Information**Positive Results:**

- Handling and placement of the stainless steel clad and MMFX reinforcing steel bars is similar to epoxy coated steel.
- Monitoring of cracks in the deck for a period of four years showed any crack formation (primarily due to temperature and shrinkage) were below the AASHTO limits.
- Analytical moment curvature analysis showed that the span reinforced with the MMFX possessed higher moment strength than the SSC deck in both positive and negative moment regions.

Negative Results:

None

Lessons Learned:**Barrier to implementation of Technology:** None

Monitoring of crack formation, location, length and width was carried out on specific intervals beginning in August 2001. As of September 23, 2005, the cracks in the decks were not measurable since the observed crack width was less than the smallest unit (1/100 in.) on the crack comparator. This is also less than the maximum allowed crack width of 0.013 in. prescribed in AASHTO Standard Specification for exterior exposure

Internal or External Reports:

“PERFORMANCE EVALUATION OF CONCRETE BRIDGE DECKS REINFORCED WITH MMFX AND SSC REBARS” This Draft Research Report details the performance evaluation of concrete decks reinforced with MMFX and SSC rebars.

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: No, none mentioned for the state of Kentucky..

Plans on Reuse of Technology: Yes, the results were favorable.

Applicability to other States: Yes, this technology is applicable to all states and has been used in some states.

Additional Project Notes:

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Webster County Bridge on KY 270, Crab Orchard Creek**State:** KY **Federal-Aid Project #:** 157 **Fiscal Year:** 2004 **Funds Awarded:** \$345,000.00**Fund Status:** \$240,000.00 Expended **Project Status:** Initiated**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Aluminum Bridge DeckTechnology Description: Using aluminum alloys for bridge deck construction. Monitoring of the bridge after deck placement.**Project Information****Positive Results:**

None at this time, monitoring started in fall 2010 following the deck placement.

Negative Results:

Cost of the aluminum deck is very high and would limit its use to steel girder bridges in congested areas.

Lessons Learned:**Barrier to implementation of Technology:** The deck placement took longer than expected due to the layout of the truss bridge floor beams and Stringers. Since detailed bridge plans were not available, detailed inspection of the bridge along with a thorough evaluation of the construction process would have helped.**Internal or External Reports:**

No report on file at this time.

Publications, Presentations, or, Construction Studies:

None.

Additional Comments:

Technology used on Other Projects: Yes, this technology was used on KY94 over Howard creek.

Plans on Reuse of Technology: Unable to determine from this project, monitoring is ongoing.

Applicability to other States: Yes, this technology is applicable to all states in need of similar types of repair.

Additional Project Notes:

- Aluminum Deck is lightweight, thus reducing the dead load and increasing the allowable live load on the bridge.
- Monitoring of the bridge started in fall 2010 following the deck placement.

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1.19. LOUISIANA

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Caminada Bay Bridge**State:** LA **Federal-Aid Project #:** 9906540 **Fiscal Year:** 2007 **Funds Awarded:** \$200,000.00**Fund Status:** \$60,000.00 Expended **Project Status:** Initiated**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: **FRP Strand: Repairing/Strengthening of bridges with post tension FRP strands & performance evaluation**

Technology Description: Fiber reinforced polymer (FRP) strands are installed to strengthen a load-posted bridge. The bridge will then be monitored.

Project Information**Positive Results:**

The project is still ongoing and as such no positive results could be reported. However, if the performance is verified through long-term evaluation, it will provide a new alternative to bridge strengthening in Louisiana.

Negative Results:

None at this time, the project is still ongoing.

Lessons Learned:

Barrier to implementation of Technology: The availability of FRP post-tensioning strands in the United States is an issue. This may cause a delay in ordering and installing the materials.

Internal or External Reports:

At the time of this report the project is still ongoing and as such no external reports have been submitted. Two interim progress reports were submitted to the Project Review Committee (PRC) but are not available.

Publications, Presentations, or, Construction Studies:

The PI gave a presentation to the PRC regarding the computation performed for strengthening of the bridge. When the study is completed, presentations of the findings will be made and a final report will be published.

Additional Comments:

Technology used on Other Projects: The FRP strands technology was not used on any other Louisiana projects.

Plans on Reuse of Technology: Unable to determine at this time.

Applicability to other States: Unable to determine at this time.

Additional Project Notes:

A load-posted bridge has been identified for the study. One concrete span and one steel span will be strengthened. Preliminary design of a bridge strengthening using FRP post-tensioning strands has been completed and presented to the PRC. The bridge will be strengthened and monitored.

The LTRC project number is LTRC 07-3ST; S.P. No. 736_99_1438. (Authorized: \$200k, expended \$51,168 as of 4/5/2010). [Original award description was Caminada Bay Bridge FY 2005].

LTRC: Louisiana Transportation Research Center is the research arm of LADOTD and manages all state and federally funded research projects.

State DOT Contact: Walid Alaywan

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Elm Grove Garden Road Bridge**State:** LA **Federal-Aid Project #:** 9906525 **Fiscal Year:** 2004 **Funds Awarded:** \$225,000.00**Fund Status:** \$225,000.00 Expended**Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: **Development of Advanced Grid Stiffened FRP Tube-Encased Concrete Columns**

Technology Description: A new type of confining device consisting of a latticework of interlacing fiber reinforced polymer (FRP) ribs that are jacketed by a FRP skin, was proposed, manufactured, tested, and modeled to encase concrete cylinders.

Project Information**Positive Results:**

A life-cycle economic analysis was conducted to evaluate the potential application of this novel column in bridge construction. It is found that:

- This new confining device outperforms the traditional FRP tubes because it develops a positive composite action with the concrete core through mechanical interlocking and it fully utilizes the load carrying capacity of the fibers.
- Advanced grid stiffened (AGS) tubes increase the elastic range of the confined concrete cylinders so that the enhanced compressive strength can actually be used in design.
- The AGS tube can be manufactured automatically using the two-axis filament winder per a pin-guided collapsible mandrel system.
- The AGS tube encased concrete cylinder can be modeled and designed using finite element analysis by considering the non-linear stress-strain constitutive law and by using the non-associative Drucker-Prager failure criterion.
- The incorporation of nanoclay increases both the fire tolerance and compressive strength of AGS tube encased concrete cylinders and with 1% nanoclay incorporation, the fire tolerance outperforms the commercially available fire-retardant additive at a concentration of 30%.
- Based on the current market price, the material cost of the AGS tube confined concrete cylinder is about twice as much as that of the traditional RC column. Considering the reduced installation cost, maintenance cost, and corrosion resistance, the cost of AGS tube confined concrete cylinders would be competitive.

Negative Results:

The project was delayed for about 8 months. The reason is that additional building-block tests and fire-tolerance tests were added in order to fully understand the development of composite action between the AGS tube and the concrete core and to find alternatives for resisting fire hazard to the polymer based AGS tube. However, it is noted that although additional tasks were conducted, the cost of this project maintained the same as the original budget.

Lessons Learned:

Barrier to implementation of Technology: A key lesson is on the implementation of this project. It is believed that the following studies must be conducted before the derived technology from this project can be applied to full-scale test:

- It is recommended that further study should be towards joining the AGS tube encased concrete cylinders with other structural elements.
- It is also recommended that dynamic and drivability tests must be conducted to verify the applicability of the novel column as piles.

Internal or External Reports:

LTRC: Louisiana Transportation Research Center is the research arm of LADOTD and manages all state and federally funded research projects.

Project Capsule – Published September 2005: <http://www.ltrc.lsu.edu/pdf/2005/05-3ST.pdf>



“Development of Advanced Grid Stiffened FRP Tube-Encased Concrete Columns”

Also, a final report has been submitted to Louisiana Transportation Research Center.

Publications, Presentations, or, Construction Studies:

The following two papers have been published.

- G. Li and R.C. Velamathy. Fabricating, Testing, and Modeling of Advanced Grid Stiffened Fiber Reinforced Polymer Tube Encased Concrete Cylinders. *Journal of Composite Materials*, Vol. 42, No. 11, pp. 1103-1124 (June, 2008).
- G. Ji, G. Li, S.-S. Pang, and W. Alaywan. Strength Enhancement of Advanced Grid Stiffened FRP Tube Confined Concrete Cylinders under Fire. *Journal of Composite Materials*, Vol. 43, No. 22, pp. 2555-2569, (October, 2009).

(these publications not available)

Additional Comments:

Technology used on Other Projects: The ASG FRP tube-encased concrete column technology has not been used on other Louisiana projects.

Plans on Reuse of Technology: Unable to determine, the Final Report has not been published.

Applicability to other States: Unable to determine, further study is recommended to verify the applicability of this new technology.

Additional Project Notes:

The LTRC project number is LTRC 05-3ST. S.P. No. 736_99_1357. (Authorized: \$225K ; Expended: \$216,434 as of 4/5/2010). [Original award description: Elm Grove Garden Road Bridge]

A problem statement was submitted to the Research Problem Identification Committee (RPIC) regarding the implementation of the findings of this study. The decision for now is to fund such study when a connection between a column made of this material and the bridge cap can be developed.

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Louisiana Route 70, Bayou Pierre Part**State:** LA **Federal-Aid Project #:** 9906526 **Fiscal Year:** 2005 **Funds Awarded:** \$400,000.00**Fund Status:** \$320,000.00 Expended **Project Status:** Initiated**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP wrapped Balsa-wood Bridge Deck

Technology Description: Fiber reinforced polymer (FRP) wrapped balsa-wood used in the bridge deck system. It is a vacuum-sealed, resin-infused balsa-wood layers wrapped with hard wires with FRP skin surfaces

Project Information**Positive Results:**

- The construction took less than two days. This is the first of its kind in Louisiana and perhaps in the world.
- The deck is performing well at this point. If the performance of this composite system is verified through long-term evaluation, it will provide a new alternative to traditional bridge decks. The actual installation took about 8 hours.

Negative Results:

None

Lessons Learned:

Barrier to implementation of Technology: Many fiber optic sensors were damaged during construction and manufacturing process.

Because it is a new system, it took longer to produce it.

The final construction of the deck was delayed.

Internal or External Reports:

Several interim progress reports were submitted.

Publications, Presentations, or, Construction Studies:

The PI gave the Project Review Committee (PRC) several presentations at different stages of the study.

Additional Comments:

Technology used on Other Projects: The FRP wrapped balsa wood was not used on other Louisiana project.

Plans on Reuse of Technology: Unable to determine.

Applicability to other States: Unable to determine, The Final Report has not been published.

Additional Project Notes:

Installation of bridge deck has been completed.

The LTRC project number is LTRC 05-5ST; S. P. No. 736 _99_1370. (Authorized: \$400K, Expended: \$184,700 as of 4/5/2010). [Original Award Description: LA 15 over Stroke Bayou].

LTRC: Louisiana Transportation Research Center is the research arm of LADOTD and manages all state and federally funded research projects.

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FHWA IBRC/IBRD Project Summary Report Form

Project Name: Structure Health Monitoring of the I-10 Twin Span Bridge Over Lake Pontchartrain
State: LA **Federal-Aid Project #:** 9906539 **Fiscal Year:** 2009 **Funds Awarded:** \$650,000.00
Fund Status: \$395,333.00 Expended **Project Status:** Initiated

Associated Project Names

Doe Slough Canal Bridge

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Element health monitoring using embedded sensor technology

Technology Description: Install a substructure and superstructure health monitoring system on selected bridge piers for short-term and long-term monitoring of the bridge. The substructure instrumentation includes strain gauges and In-Place Inclometers (IPI) installed inside the piles, and triaxial accelerometers, water pressure cells, tiltmeters, and corrosion meters installed on the pile cap.

Project InformationPositive Results:

The lateral load test was successfully conducted by pulling the M19 eastbound and westbound piers toward each other using high strength steel tendons using two 600-ton jacks. We were able to apply a maximum lateral load of 1870 kips. The corresponding maximum lateral deformation of the M19 eastbound pier cap, as measured using the laser survey, was 0.66 in. at northwest corner and 0.58 in. at southwest corner; which are in agreement with values measured from IPI inclinometers.

Negative Results:

None.

Lessons Learned:**Barrier to implementation of Technology:**

- The FB-MultiPier analyses predicted much higher lateral deformations compared to the measured values during lateral load tests. The measured were about 50% of the values predicted using the FB-MultiPier.
- The success rate of strain gauges and IPI sensors instrumentations were about 65%.

Internal or External Reports:

When the study is completed, presentations of the findings will be made and a final report will be published.

Publications, Presentations, or Construction Studies:

Abu-Farsakh, M., Yoon, S., Ha D., Marr, W., Zhang, Z., Tsai, C., Fu, Z., and Andrea, A., 2010, "Instrumentation Plan for Monitoring the New I-10 Twin Span Bridge," presented and published at the 89th TRB annual meeting, Washington, D.C.

Additional Comments:

Technology used on Other Projects: The Health monitoring system using embedded sensor was no used on other Louisiana projects.

Plans on Reuse of Technology: Unable to determine, study is on going at time of report.

Applicability to other States: Unable to determine, study is on going at time of report.

Additional Project Notes:Accomplishments:

- Completed the substructure and superstructure instrumentations.
- Installed and calibrated the OSMOS WIM system.
- Started analyzing the lateral load test data.
- Started back-calculating the p-y multipliers for FB-Multipier analysis of battered pile groups in similar soil conditions.

The LTRC project number is LTRC 07-1ST; S.P. No. 736_99_1437. (Authorized: \$650 K ; Expended: \$395,333 as of 4/5/2010). [Funding was combined for the project from two IBRCs awards originally entitled FY 2005 MPRR Bridge and FY 2005 Doe Slough Canal and Approaches along with an addition IBRC end of year redistribution award of \$250 K].

LTRC: Louisiana Transportation Research Center is the research arm of LADOTD and manages all state and federally funded research projects.

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1.20. MAINE

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Fairfield – Emery Brook Bridge**State:** ME **Federal-Aid Project #:** _____ **Fiscal Year:** 2000 **Funds Awarded:** \$350,000.00**Fund Status:** \$323,085.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Reinforced Glulamined Beams with Integral Concrete Deck

Technology Description: Fiber reinforced polymer (FRP) reinforced glulam-concrete composite bridge. The glulam girders are reinforced with E-glass fiber reinforced polymer on their tension side and connected to a reinforced concrete deck to provide composite action.

Project Information**Positive Results:**

- The steel rebar dowels used were easily manufactured, inexpensive and performed well.
- Connectors were able to withstand large shear forces.
- The bridge was successfully designed and detailed on schedule, bridge construction was completed in the fall of 2003, and the bridge was opened to traffic in May, 2004.
- According to the condition inspection performed in May 2006 and September 2007, the bridge is overall in good condition.

Negative Results:

Inspections performed two and three years later revealed loose and missing nuts at bearing seat and diaphragms and loose lag screws at the FRP termination.

Lessons Learned:

Barrier to implementation of Technology: Direct shear test should be performed with the same connection to obtain more reliable data.

Fatigue and flexural beam testing should be performed to observe the performance of the system.

Standards should be developed so results can be compared more accurately.

Consider unshored to reduce labor cost.

Internal or External Reports:

“FRP-REINFORCED GLULAM-CONCRETE COMPOSITE BRIDGE IN FAIRFIELD, MAINE: STRUCTURAL COMPONENT TESTING, ANALYSIS, DESIGN AND LOAD TESTING” This Research Report details the analysis, design and load testing of the FRP-Reinforced glulam-concrete composite bridge system.

Publications, Presentations, or, Construction Studies:

None.

Additional Comments:

Technology used on Other Projects: No, The FRP reinforced gluelam-concrete composite technology was not used on other Maine projects.

Plans on Reuse of Technology: Yes, the results were positive and the bridge is expected to equal or exceed the life span of a typical timber bridge.

Applicability to other States: Yes, This technology is applicable to all states.

Additional Project Notes:

10/30/08: Project completed. There is still \$26,914 left in contract balance for final report and long term evaluation.

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HDR Contact Name: Duncan Paterson

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Municipal Pier in Milbridge**State:** ME **Federal-Aid Project #:** _____ **Fiscal Year:** 1999 **Funds Awarded:** \$246,000.00**Fund Status:** \$246,000.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Reinforced Glulam Deck Panels

Technology Description: Fiber reinforced polymer (FRP) is adhered to the bottom of glulam panel as an adhesive to the wood substrate acting as a composite section.

Project Information**Positive Results:**

- FRP-glulam panels can be handled on the construction site in a manner and with equipment similar to that used for conventional glulam panels and prestressed concrete planks.
- The weight of the FRP-glulam panels used in this project was only one third the weight of equivalent prestressed concrete planks. This weight reduction allows for cost savings in construction
- The FRP has not shown deterioration through two years in the marine environment.
- FRP performs well with regard to structural strength.

Negative Results:

Shrinkage that occurs during curing increases the rate of deterioration and weakens the FRP.

Lessons Learned:

Barrier to implementation of Technology: FRP should be protected to increase environmental durability.
An alternative, more durable FRP should be investigated for reinforcing glulam panels.

Internal or External Reports:

“BEHAVIOR AND DESIGN OF FRP-REINFORCED LONGITUDINAL GLULAM DECK BRIDGES” This thesis details the design, testing, construction and evaluation of the FRP reinforced longitudinal glulam deck bridges.

Publications, Presentations, or, Construction Studies:

None.

Additional Comments:

Technology used on Other Projects: Yes, the FRP reinforced Glulam technology was use on several Maine projects.

Plans on Reuse of Technology: Yes, this repair application is cost-competitive and has significant advantages to other methods of repair.

Applicability to other States: This technology is applicable to all states in need of similar types of strengthening or repair.

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Neal Bridge, Pittsfield**State:** ME **Federal-Aid Project #:** _____ **Fiscal Year:** 2003 **Funds Awarded:** \$400,000.00**Fund Status:** \$400,000.00 Expended **Project Status:** Completed**Associated Project Names**Mill Pond Bridge Rt. 142, West
Branch of Carabassett RiverProject: Change / Associated

Reallocated from / to:

Technology Implemented: Concreted Filled FRP Tubes

Technology Description: A light-weight, corrosion resistant system for short to medium span bridge construction using FRP composite arch tubes that act as reinforcement and formwork for cast-in-place concrete. Also known as Bridge-in-a-Backpack™, the arch systems are lightweight, easily trans-portable and do not require the heavy equipment or large crews needed to handle the weight of traditional construction materials. In addition, the arches capitalize on their inherent properties to trans-form vertical loads to internal axial forces, the superiority of concrete in sustaining compression loads, and the versatility and strength of composite materials.

Project Information**Positive Results:**

- The materials are lighter, which means heavy placement and transport equipment isn't necessary.
- The composite materials and fibers are as strong as steel. And the whole process is quicker.
- Once the materials are fabricated and the site is ready, construction time takes a matter of days rather than weeks or months. That means shorter road closures and traffic diversions.
- The tubes require no steel reinforcing bars, or rebar, because they are stronger than steel.
- The tubes protect the concrete from water and elements, therefore extending the life of the concrete.

Negative Results:

None

Lessons Learned:

- Originally scheduled for Mill Pond Bridge for a deck replacement on a truss. The truss was deemed not historical so it was decided to replace the whole structure. Several substitution projects were identified but did not move forward.

Barrier to implementation of Technology: None

Internal or External Reports:

"Beam Finite-Element Analysis of Pressurized Fabric Tubes" July 2007



"In-Plane Load-Deflection Behavior and Buckling of Pressurized Fabric Arches" November 2009

Publications, Presentations, or, Construction Studies:

"Research Features - Bridge in a Backpack"



"Bridge-in-a-Backpack™ Brochure"

Additional Comments:

Technology used on Other Projects: Yes

Plans on Reuse of Technology: Yes, statewide program planned

Applicability to other States: This technology is applicable to all states in need of similar types of strengthening or repair.

10/30/08: The original application was for Mill Pond Bridge in Salem Twp for a light weight hollow wood composite core deck system on a truss. When the truss was deemed not historical it was decided to replace the whole structure.

Because the first four choices for bridges (Salem Twp., Arrowsic-Georgetown, South Bristol, & Naples) are now full replacements, MaineDOT has selected another alternative - Neal Bridge in Pittsfield. See 'current status' for additional information.

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** New Meadows Bridge in Sagadahoc, ME**State:** ME **Federal-Aid Project #:** _____ **Fiscal Year:** 1999 **Funds Awarded:** \$135,000.00**Fund Status:** \$135,000.00 Expended **Project Status:** complete**Associated Project Names**

Waldboro

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Advanced Engineered Lumber railroad bridge ties

Technology Description: Advanced engineered lumber (AEL), mixed hardwood glue-laminated ties were installed on one span of a railroad bridge and visually inspected two years later.

Project Information**Positive Results:**

There were no evidence of tie movement, plate cutting in the ties and tie spike pull out.

Negative Results:

- Half the ties developed cracks that parallels edge joint of the multiple width boards which coincides with J-bolt screw location.
- Large delaminations , both in length and depth were observed on the overhanging portions of the ties.

Lessons Learned:

Barrier to implementation of Technology: It is recommended that when the AEL ties are removed from service. A more detailed inspection of the bond lines should be conducted, and mechanical testing be conducted to determine the residual strength and stiffness of the ties.

Internal or External Reports:

“Final Report: Inspection of the Advanced Engineered Lumber Railroad Ties at the New Meadows Bridge” This Final Report details the inspection and findings of the advanced engineered lumber (AEL) railroad bridge ties.

Publications, Presentations, or, Construction Studies:

None.

Additional Comments:

Technology used on Other Projects: No, the advanced engineered lumber (AEL) ties technology was not used on other Maine projects.

Plans on Reuse of Technology: No, the results were not positive.

Applicability to other States: No, it is recommended that the AEL ties be removed from service at this location.

Additional Project Notes:

The original technology was FRP-Timber Bridge Railroad Ties.

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** State-wide, IBRC program (Rollins Road)**State:** ME Federal-Aid Project #: _____ Fiscal Year: 2001 Funds Awarded: \$270,000.00**Fund Status:** \$219,378.93 Expended **Project Status:** Initiated**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Concrete Filled FRP Arch System

Technology Description: Fiber reinforced polymer (FRP) arch system used in bridge construction.

Project InformationPositive Results:

This project is similar to the Neal Bridge project – a successful project. This technology has been a success for the state

Negative Results:

None at this time.

Lessons Learned:**Barrier to implementation of Technology:** The University of Maine has developed prototype FRP concrete filled arches and completed lab testing. MaineDOT is currently working with UMaine to construct demonstration projects.Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None.

Additional Comments:

Technology used on Other Projects: Yes

Plans on Reuse of Technology: Yes

Applicability to other States: can be successful for any state.

Additional Project Notes:

10/30/08: The University of Maine has developed prototype FRP concrete filled arches and completed lab testing. MaineDOT is currently working with the University to construct a demonstration bridge for Neal Bridge in Pittsfield. Delays in the prototype development

07/27/09: Approx. \$50,000 remains. The University has developed prototype FRP concrete filled arches and completed lab testing. MaineDOT is currently working with UMaine to construct a demonstration bridge (Neal Bridge in Pittsfield).

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Waldo-Hancock Bridge over Penobscot River**State:** ME **Federal-Aid Project #:** _____ **Fiscal Year:** 2004 **Funds Awarded:** \$400,000.00**Fund Status:** \$400,000.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Cable stay system (inert gas)

Technology Description: Using nitrogen charged stays to provide two forms of corrosion protection for the cable stays. The first form is an environment free of oxygen. The second form is a monitoring system to detect loss of gas pressure in the stays.

Project Information**Positive Results:**

None.

Negative Results: There were numerous problems discovered:

- More than 50% of the stays not holding pressure, leakage were extensive.
- Inability to produce a gas tight system.
- Potential repairs could not guarantee that leaks would be fully eliminated
- Concerns about longevity of repairs at the deck level.

Lessons Learned:**Barrier to implementation of Technology:** Potential long term maintenance issues were identified:

- Frequent recharging of nitrogen bottles inside the bridge, increasing with age.
- High safety risk with leaking nitrogen displacing oxygen inside the segments.
- Normal maintenance activities re much more difficult and costly.

It was decided to implement the dry air cable stay protection system instead.

Internal or External Reports:

“Inert Gas System” This Final Report details development, installation and testing of the nitrogen gas protection system for cable stays.

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: No, the cable stay inert gas system was not applied on other Maine projects

Plans on Reuse of Technology: No, the project was unsuccessful.

Applicability to other States: No, the project was unsuccessful.

Additional Project Notes:

10/30/08: Inert Gas system for cable stays on the Penobscot Narrows Bridge was installed but unsuccessful.

The dry air cable stay protection system with a suitable monitoring system is proposed to replace the inert gas system.

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Union-Washington Skidmore/Medomak

State: ME	Federal-Aid Project #:	8934.01	Fiscal Year:	1999 2002	Funds Awarded:	\$270,000.00 \$32,000.00
Fund Status:		\$211,582.00 Expended \$21,581.99 Expended	Project Status: Initiated			

Associated Project NamesUnion-Washington Skidmore Project: Change / Associated Reallocated from / to: \$270,000.00**Technology Implemented:** FRP glulamated deck system, FRP reinforced glulam deck panels

Technology Description: Fiber reinforced polymer (FRP) deck system used in bridge construction.

Project Information**Positive Results:**

- Demonstrate cost-effective bridge deck panel system for bridge deck replacement.
- Reduce maintenance and life-cycle costs with durable composite materials.
- Reduce construction time and congestion through prefabrication and modular construction.
- Develop engineering design criteria for the FRP-Glulam Composite Deck Panel system.
- FRP-glulam panels behaved more ductile than glulam panels.
- FRP composite skins are expected to extend the life of glulam panels by providing environmental protection.
- Failure load of FRP-glulam panels was approximately 35.7% higher than the corresponding one of glulam panels

Negative Results:

None at this time. A long term performance study needs to be completed.

Lessons Learned:**Barrier to implementation of Technology:**

Exposure to Chromated Copper Arsenate (CCA) preservative reduced the longitudinal tensile strength of unidirectional composite laminates.

Internal or External Reports:

“Final Report: Maine Composites Living Lab: FRP-Wood Hybrid Bridge Deck Union-Washington, Skidmore Bridge” This Final Report details the design, fabrication, installation and performance of the FRP glulam deck system over steel girders.

Publications, Presentations, or, Construction Studies:

“FRP-Glulam Panels for Highway Bridge Deck Replacement” This publication summarized the impact of the FRP gluelam deck system technology on the construction industry.

Additional Comments:

Technology used on Other Projects: Yes, the FRP glulaminate deck system was applied on other Maine projects

Plans on Reuse of Technology: Yes, the experimental and analytical study were positive, however a long term performance has not been completed

Applicability to other States: Yes, this technology is applicable to all state in need of similar repair.

Additional Project Notes:

10/30/08: The FRP reinforced glulaminate deck was constructed on steel I-beams. A construction report was completed. A final report including long term performance still needs to be completed.

In FY1999, stated there is still \$50,000 left in contract with UMaine to complete final report and long term evaluation.

Supplemental IBRC funds to complete this project. FY 1999 and FY 2002 IBRC awards in order to complete the project.

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Winterport & Beaver Cove**State:** ME **Federal-Aid Project #:** _____ **Fiscal Year:** 1999 **Funds Awarded:** \$18,000.00**Fund Status:** Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Bridge Drains

Technology Description: Fiber reinforced polymer (FRP) composite drain, grating and downspout system embedded in bridge concrete decks to replace the conventional steel drainage system.

Project Information**Positive Results:**

Installation was a success. The new drains are being monitored in the field and the maintenance required to provide constant and sufficient water drainage will be compared to that of the steel drains.

Negative Results:

None at this time, monitoring is ongoing.

Lessons Learned:

Barrier to implementation of Technology: Long Term durability needs to be proven (ongoing)

The prototype proved to be acceptable for highway bridges. The prototype design was improved and approved as a safe, functional, and durable drain system by Maine DOT. Maine DOT ordered six FRP composite drains to begin replacing damaged steel ones in concrete bridge decks. The FRP drains were fabricated and installed in three highway bridge concrete decks in the state of Maine. The long-term durability of the new down spouts should make them a more cost effective solution. The new drains are being monitored in the field and the maintenance required to provide constant and sufficient water drainage will be compared to that of the steel drains.

Internal or External Reports:

“Fiber-Reinforced Polymer Composite Drain for Highway Concrete Bridge Decks” This Draft Report details the design, testing and installation of the FRP composite bridge drain.

Publications, Presentations, or, Construction Studies:

None.

Additional Comments:

Technology used on Other Projects: The FRP bridge drains was not used on other Maine projects

Plans on Reuse of Technology: Unable to determine, monitoring is ongoing at the time of the report.

Applicability to other States: Unable to determine, monitoring is ongoing at the time of the report.

Looking to lower maintenance costs, the University of Maine in collaboration with Maine Department of Transportation (DOT) and Kenway Corporation designed, prototyped and tested a Fiber-Reinforced Polymer (FRP) composite drain, grating and downspout system to replace the corroded steel ones in bridges. Three identical prototypes were fabricated, embedded in concrete slabs, and submitted to a series of laboratory tests to ensure structural integrity and to optimize the design for long-term durability.

State DOT Contact: Dale Peabody

Phone: 207-624-3305

E-mail: Dale.Peabody @maine.gov

1.21. MARYLAND

FHWA IBRC/IBRD Project Summary Report Form

Project Name: Aa Innovative Bridge Research & Construction Program – Smart Aggregates for Monitoring Corrosion in Steel Reinforced Concrete

State: MD **Federal-Aid Project #:** SP308B4T **Fiscal Year:** 2002 **Funds Awarded:** \$315,000.00

Fund Status: \$315,000.00 Expended **Project Status:** Complete

Associated Project Names

Smart Aggregate – Distributed
Sensor Network for Monitoring
Salt Ingress in Concrete Bridge
Decks

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Smart Aggregates for Monitoring Corrosion in Steel Reinforced Concrete

Technology Description: Smart Aggregates for Monitoring Corrosion in Steel Reinforced Concrete

Project InformationPositive Results:

- The funding was used to develop, test, and evaluate a prototype sensor. After a number of years of researching and testing the concept, the initial work is complete. Field tests were performed on two bridges and the readings from the sensors were comparable to measured chlorides from destructive testing. As a result, the Johns Hopkins Applied Physics Lab has a sensor that with additional testing, they are confident will be a viable tool for transportation organizations to use to monitor corrosion in steel reinforced concrete structures. The next step of the project is to complete a final full scale testing of the sensors in the lab environment as well as field testing at multiple locations.

Negative Results:

- This project took a lot longer than originally anticipated and required additional funding for testing.

Lessons Learned:

- Source of funding needed to be identified in order to complete the remaining work once the IBRD grant ran out. At this point we are hoping that other states will become interested in the project and that Maryland can initiate a pooled fund study to complete the full scale testing of the sensors. To help generate interest, the Applied Physics Lab will present the work on this project at the International Bridge Conference in Pittsburgh in June 2010.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Not reported

Plans on Reuse of Technology: Not reported

Applicability to other States: Further study is needed to evaluate the long term benefits of embedding these sensors.

Additional Project Notes:

None

State DOT Contact: Allison Hardt

Phone: 410-545-2916

E-mail: ahardt@sha.state.md.us

FHWA IBRC/IBRD Project Summary Report Form

Project Name: Rehabilitation of Bridge No. 12016 on MD 24 over Deer Creek – Including Deck Replacement Utilizing Fiber Reinforced Polymer Deck

State: MD **Federal-Aid Project #:** BH-IBRC-1247(10)N **Fiscal Year:** 2000 **Funds Awarded:** \$40,000.00

Fund Status: \$40,000.00 Expended **Project Status:** Complete

Associated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Deck Panel and High Performance Concrete

Technology Description: Fiber-reinforced polymer composite material with a combination of a polymer matrix and a reinforcing agent used in deck panel to reduce construction time and decrease dead load

Project InformationPositive Results:

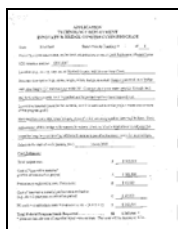
- One of the impressive advantages for the use of the FRP deck was the fast installation time. Fourteen days from the time the existing concrete deck had been removed, the new FRP bridge deck had been installed, and the bridge was ready to accept traffic. In contrast, a reinforced concrete deck would take double that time, under the best conditions, before it would be ready to accept traffic with a minimum of seven days required just for adequate curing of the concrete deck and the curbs.
- Another advantage gained from the FRP deck was the increase in the bridge rating due to the lighter weight of the FRP deck as compared to a reinforced concrete deck. The FRP deck installed on the MD 24 bridge weighed 70 lbs./sq. ft (including asphalt wearing surface) versus 115 lbs./sq. ft of a reinforced concrete deck. This large difference in weight allows the bridge to carry heavier vehicular loads.

Negative Results:

- One disadvantage is the proprietary nature of the product. There are only a small number of manufacturers of FRP bridge decks, all of whose systems vary in the method of production, the configuration and thickness of the deck and the connection details used to connect the deck to the bridge. These differences present problems for projects awarded using a competitive bid process. Projects must be designed to accommodate the deck systems of at least three FRP deck manufacturers or must rely on the contractor to submit a design for the FRP deck system of his choosing for review and approval. This is not ideal because a contractor could choose an undesirable manufacturer. It is also cumbersome and costly to provide plans accommodating three different manufacturers. Therefore, neither of these options is ideal.
- Another disadvantage is the high cost for this type of deck. This type of deck cost almost double the cost of traditional decks making it hard to justify in these tough economic times.

Lessons Learned:

- Maryland State Highway Administration's first installation of an FRP deck was a positive experience. As with any experience, there were many things learned that would certainly affect how future FRP deck projects would be approached. One practice that will definitely be repeated is to have a mandatory pre-bid meeting for all contractors considering bidding the project. This gives us the opportunity to explain the installation procedure to the contractors so they understand what is expected and feel comfortable with the work they are bidding.
- Another useful step is the requirement that a representative from the FRP deck manufacturer, involved with the design of the project, be on site during installation. This representative has valuable experience and is able to guide the contractor on how best to install the deck and offer valuable input into solving any problems that may arise. For example, as the installation of the deck panels on the MD 24 bridge progressed from one side of the bridge to the other, the actual length of the jointed panels was larger than the expected length. Erroneously, we were expecting a perfect fit. For our installation, the end support could not accommodate this growth in the panels. To solve this problem, the ends of the panels, at the abutment, were cut. This may have been a daunting task without a representative from the FRP manufacturer on site. The representative was able to arrange for the proper cutting saw to be delivered to the site immediately, in order to cut the necessary panels and properly seal the ends in a matter of hours, avoiding long delays in progress.
- Because of the problems with the growth of the joined panels and differences in the as-built bridge versus original plans, any future designs must have some degree of tolerance for differences between planned dimensions and actual field dimensions. This is especially true when the deck will be installed on an existing structure. It is rare to find an existing structure that has all member dimensions and spacing, matching the asbuilt plans. When pouring a reinforced concrete deck, it is easy to adjust for changed conditions. With an FRP deck, however, it is not as simple since the deck panels are delivered to the site already created and fabricated. Therefore, it is important to design the deck system in a way that can easily accommodate small differences between planned and actual conditions.

Internal or External Reports:

"Application of Technology Deployment" Report of Supplier Selection Process.

Publications, Presentations, or, Construction Studies:

"MEETING OF BLUE RIBBON PANEL TO SELECT FRP DECK SUPPLIER FOR BRIDGE NO. 12016 ON MD 24 OVER DEER CREEK" Report for International Bridge Conference 2002

Additional Comments:

Technology used on Other Projects: Yes

Plans on Reuse of Technology: Yes

Applicability to other States: Unknown

Additional Project Notes:

Project completed in fall 2001

State DOT Contact: J. Robert

Phone: 410-545-8327

E-mail: jrobert@sha.state.nd.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** US 1 Br #0700300 over Octoraro Creek**State:** MD **Federal-Aid Project #:** 123-1(34)N **Fiscal Year:** 2008 **Funds Awarded:** \$400,000.00**Fund Status:** \$351,000.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Clean and Paint Bridge for Evaluation of Three Different Types of Paint SystemsTechnology Description: Clean and Paint Bridge for Evaluation of Three Different Types of Paint Systems**Project Information****Positive Results:**

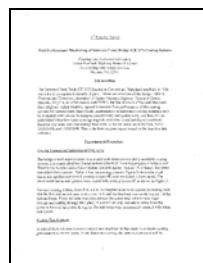
- So far the study had found that all three coatings are providing corrosion protection to the steel:
System K: 2-coat ZnMCU / Fast Polyaspartic Urethane
System J: 1-coat Waterborne Acrylic
System C: 3-coat Zn-rich Expoy / Epoxy / Urethane
- System C provided the best corrosion protection

Negative Results:

- Paint System K had some spot peeling between the finish coat and primer
- Coating J started to show mild corrosion rust at edges and corners of some of the underside structural members

Lessons Learned:

- The standard three coat Paint System C provides us with the best protection and is easily applied by the contractor.
- The manufacturer of System J can not provide the correct finish coat colors.
- With Paint System K, we think spot peeling was caused by moisture laying on the primer when it was painted.

Internal or External Reports:

"Field Performance of Octoraro Creek Bridge (CE 337) Coating Systems" Progress Reports provided throughout project timeline

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Not reported

Plans on Reuse of Technology: Not reported

Applicability to other States: the traditional 3-coat system is the preferred method

Additional Project Notes:

10/29/08: Project is complete and accepted for maintenance

State DOT Contact: Ryan M. Hughes

Phone: 410-545-8435

E-mail: rhughes1@sha.state.md.us

1.22. MASSACHUSETTS

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Franklin I-495 over MBTA Bridge, Bridge No. F-08-027**State:** MA **Federal-Aid Project #:** Not Reported **Fiscal Year:** 2000 **Funds Awarded:** \$57,500.00**Fund Status:** Unknown **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Bonded Reinforcement in P/S Slab Bridge

Technology Description: Fiber-reinforced polymer composite material with a combination of a polymer matrix and a reinforcing agent were glued to bottom of prestressed concrete beams to improve load carrying capacity of bridge

Project Information**Positive Results:**

- Fiber Reinforced Laminates were glued to the bottom of prestressed concrete beams to improve load carrying capacity of the bridge

Negative Results:

None reported

Lessons Learned:

- Recent inspection report dated July 18, 2008 has not documented any adverse findings

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

"Inspection Report" dated July 18, 2008

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

None

State DOT Contact: Unknown

Phone: _____

E-mail: _____

1.23. MICHIGAN

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** City of Southfield Bridges**State:** MI **Federal-Aid Project #:** _____ **Fiscal Year:** 1999 **Funds Awarded:** Unknown**Fund Status:** \$700,000.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: **External Sensors for Monitoring Bridge Constructed with FRP Prestressing & Rebar**

Technology Description: Two structures were monitored for deterioration due to corrosion. Structure A, which services traffic entering the subdivision, was constructed of standard AASHTO precast concrete beams, reinforced with conventional steel elements. Structure B, carrying outgoing traffic, was constructed of precast concrete double-tee beams reinforced not with steel, but with elements manufactured of carbon fiber reinforced polymer (CFRP).

Project Information**Positive Results:**

- The use of CFRP offers several distinct advantages over reinforcing steel in concrete construction, one of which is the virtual elimination of deterioration due to corrosion, a common problem among conventionally reinforced bridges. A complex system of instrumentation and monitoring devices was embedded and exterior-mounted to the structural elements of both bridges during construction.

Negative Results:

- Double tee beams are not used by MDOT.
- The high cost of CFRP reinforcement would preclude widespread use.

Lessons Learned:

- The provisions of the AASHTO specifications can be used to predict load distribution behavior of CFRP reinforced double tee beam bridge superstructure configurations.
- The measured concrete strains, deflections, and forces in the longitudinal and transverse post-tensioned tendons over a period of one year indicate that the bridge is performing as expected.
- The monitored response of the bridge also demonstrates that the unbonded post-tensioned tendons and their anchorages are intact and effectively serving within the environmental conditions encountered at the bridge.
- The results also demonstrate the integrity of the bridge in both longitudinal and transverse directions.

Internal or External Reports:

"Load Testing a CFRP-Reinforced Bridge"

<http://www.ltu.edu/cm/attach/B6FC1930-05B0-447D-98A2-05ACB25736D1/CI07Grace.pdf>
Publications, Presentations, or, Construction Studies:

Roller, J. J., and Elremaily, A. F., "Instrumentation and Structural Testing of Full-Scale Double-Tee Beam, Bridge Street Bridge, City of Southfield, Michigan," *Final Report to the City of Southfield, Michigan*, Construction Technology Laboratories, Inc., April 13, 2001, 46 pp. (Not available)

Additional Comments:

Technology used on Other Projects: Unknown

Plans on Reuse of Technology: Unknown

Applicability to other States: Unknown

Additional Project Notes:

None

State DOT Contact: Steven Kahl
E-mail: kahls@michigan.gov

Phone: 517-322-5707

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I-94 over Shook Road and C&O RR**State:** MI **Federal-Aid Project #:** _____ **Fiscal Year:** 2003 **Funds Awarded:** \$137,000.00**Fund Status:** \$137,000.00 Expended **Project Status:** CompleteAssociated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Micro-Composite Rebar

Technology Description: Micro-Composite, Multi-Structural Formable (MMFX) low-carbon, chromium bearing, reinforcing steel designed to have high corrosion resistance, strength and ductility was used on this project to reduce long-term costs by providing a service life of 75 years with little or no maintenance

Project InformationPositive Results:

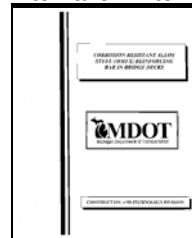
- The estimated service life is 75 years with little or no maintenance
- The MMFX steel does exhibit corrosion resistance, higher yield strength, and a lower life cycle cost of \$25,700 as compared to epoxy coated reinforcement

Negative Results:

- It is possible to have an over-reinforced deck section using MMFX due to its higher yield strength, and possible reduction of ductility at ultimate load levels.
- The available bar lengths differed from design and fabrication. During the design phase the manufacturer confirmed the ability to provide bars of 43 ft length. At the time of construction, however, the manufacturer indicated that 40 ft was the maximum length available. The contractor therefore ordered additional bars to provide lapping to make up the difference.
- The bars delivered to the site had mill scale on the surface that differed in appearance from the evaluation specimens. At this time it is unclear as to how the mill scale will affect the long-term performance of the MMFX bar.

Lessons Learned:

- The bond strength for MMFX was comparable to uncoated reinforcement, but results from flexure testing of reinforced concrete beams imply that the lap length needs further study. Therefore, the designer should reduce or eliminate lapped joints, either by mechanical splices, or requiring the contractor to supply the exact length reinforcing bars as detailed on the plan sheets.
- Due to the high yield strength, MMFX use in bridge deck construction should be limited to structures that are designed in accordance with AASHTO LRFD code, and for 75 ksi steel reinforcement design yield strength, in highly congested urban areas, when life cycle costs are justified.

Internal or External Reports:

"CORROSION RESISTANT ALLOY STEEL (MMFX) REINFORCING BAR IN BRIDGE DECKS"

http://www.michigan.gov/documents/mdot/MDOT_Research_Report_R1499_209781_7.pdf
Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Unknown

Plans on Reuse of Technology: Unknown

Applicability to other States: Unknown

Additional Project Notes:

None

State DOT Contact: Steven Kahl
E-mail: kahls@michigan.gov

Phone: 517-322-5707

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I94EB & WB over Riverside Drive**State:** MI **Federal-Aid Project #:** 13081-75047A **Fiscal Year:** 2009 **Funds Awarded:** \$400,000.00**Fund Status:** \$400,000.00 Expended **Project Status:** Initiated**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: **Low Nickel Austenitic (200 series) Stainless Steel and Microcomposite Reinforcement**

Technology Description: Stainless steel reinforcement was placed in the deck and microcomposite steel in the substructure. The stainless and microcomposite reinforcement is expected to provide a 100 year service life, reducing maintenance and rehabilitation needs for a high volume (61,000 vehicles/day) freeway

Project Information**Positive Results:**

- The stainless and microcomposite reinforcement is expected to provide a 100 year service life, reducing maintenance and rehabilitation needs for a high volume (61,000 vehicles/day) freeway.
- Using stainless and microcomposite steel in this structure resulted in a significant life cycle cost savings of \$889,000 in 2009 dollars.

Negative Results:

- Although unrelated to the selection and use of stainless and microcomposite steel reinforcement, unanticipated settlement of the eastbound structure during stage 1 construction resulting in extended construction delays and additional costs to stabilize the existing structure to maintain mobility. This additional cost was not factored in the life cycle analysis, but would tend to increase the LCC savings for the stainless and microcomposite reinforcement use.

Lessons Learned:

- Specifying stainless and microcomposite reinforcement is appropriate and highly recommended in specific cases where life cycle costs and other factors as identified above support its use.
- Consideration of stainless steel reinforcement should also be given in situations of unusual construction difficulty (poor soil conditions, high traffic volumes, limited access) or to minimize environmental impacts.

Internal or External Reports:

None at this time

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Unknown

Plans on Reuse of Technology: Unknown

Applicability to other States: Unknown

Additional Project Notes:

None

State DOT Contact: Steven Kahl

Phone: 517-322-5707

E-mail: kahls@michigan.gov

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I96 over I-69 BR (Lansing Rd)**State:** MI **Federal-Aid Project #:** _____ **Fiscal Year:** 1999 **Funds Awarded:** Unknown**Fund Status:** \$37,000.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to: {\$}

Technology Implemented: FPR Bonded Reinforcement for Column Repair

Technology Description: Experiments were conducted to assess the effects of using glass and carbon FRP wraps, with fibers oriented in the hoop direction, for rehabilitating corrosion-damaged bridge columns

Project Information**Positive Results:**

- The results of the accelerated corrosion experiment indicate that wrapping reduced the corrosion depth in the reinforcing bars by 46% to 59% after 190 days of testing.
- Both glass and carbon wraps are equally effective in slowing down corrosion.
- The durability of the repair using carbon and glass wraps was assessed using accelerated freeze-thaw testing, and no significant loss in axial load carrying capacity was observed after 300 cycles of freeze-thaw.

Negative Results:

None

Lessons Learned:

- Although unbonded wraps reduce stress concentrations in the FRP, they are less effective in reducing the corrosion rate than bonded wraps. It is postulated that this is due to the ingress of water along the unbonded FRP-concrete interface.
- The semi-empirical expression developed by Restrepo was found to be effective in predicting the axial load capacity of wrapped cylinders.

Internal or External Reports:

Ronald S. Harichandran, MDOT Research Report RC-1386 "Repair of Corrosion-Damaged Columns Using FRP Wraps", Michigan State University, December 2000.

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Unknown

Plans on Reuse of Technology: Unknown

Applicability to other States: Unknown

Additional Project Notes:

None

State DOT Contact: Steven Kahl

Phone: 517-322-5707

E-mail: kahls@michigan.gov

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** M-15 Over Gooding Creek**State:** MI **Federal-Aid Project #:** 79031-48321A **Fiscal Year:** 2000 **Funds Awarded:** \$156,000.00**Fund Status:** \$153,433.06 Expended**Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Rebar in Deck SlabTechnology Description: Aramid FRP Rebar used in deck slab design to significantly reduce corrosion**Project Information**Positive Results:

- Aramid fiber reinforcement was used in the bridge deck, equivalent US size #3 and #4 bars

Negative Results:

- The cost to use Aramid fiber reinforcement was \$21 per ft, compared to standard epoxy coated reinforcement cost of \$0.61 per ft

Lessons Learned:

- Aramid fiber as reinforcement is costly and not likely supported by life cycle analysis.
- Other readily available corrosion resistant materials such as stainless steel are more cost effective.
- Aramid reinforcement must be prefabricated and cannot be field modified, and is very sensitive to field handling.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Unknown

Plans on Reuse of Technology: Unknown

Applicability to other States: Unknown

Additional Project Notes:

10/30/08: Completed 10-31-00

This project has 2 entries in the IBRC database, this one and another for \$4k, making a total allocated amount of \$160,000. No documentation of this split has been found. Assumption is that the \$156k was for construction and \$4k was for evaluation. The obligated amount does not reflect this split.

State DOT Contact: David Juntunen

Phone: 517-322-5688

E-mail: juntunend@michigan.gov

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** M-43 Bridge over Sebewa Drain

State: MI	Federal-Aid Project #: 23041-53262A	Fiscal Year: 2004	Funds Awarded: \$58,000.00

Fund Status: \$58,000.00 Expended
\$58,000.00 Reallocated

Project Status: Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Clad Stainless Steel Rebars in Deck Slab

Technology Description: Solid stainless reinforcement was installed in the bridge deck, which will provide an estimated 100 year service life

Project Information**Positive Results:**

None

Negative Results:

- The intent was to use clad stainless steel reinforcement, but the manufacturer was unable to deliver. Therefore a substitution with stainless reinforcement was necessary. Because the manufacturer was unable to supply the clad reinforcement, they substituted the order with solid stainless reinforcement at no additional charge.

Lessons Learned:

- The use of stainless clad reinforcement is limited due to the supply issue. The manufacturer has recently been stockpiling inventory in the US to avoid this in the future. The smallest reinforcement size available is US #5 because of the manufacturing limitations, and with length of 39.5 ft due to shipping limitations. This information must be accounted for when designing the structure.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Unknown

Plans on Reuse of Technology: Unknown

Applicability to other States: Unknown

Additional Project Notes:

10/30/08: completed 9-2-05

State DOT Contact: Steven Kahl

Phone: 517-322-5707

E-mail: kahls@michigan.gov

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** M-50 Bridge over Grand River**State:** MI **Federal-Aid Project #:** 38071-57079A **Fiscal Year:** 2004 **Funds Awarded:** \$200,000.00**Fund Status:** \$200,000.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Self Consolidated Concrete in Concrete Box Girders

Technology Description: The M-50/US-127 Bridge over the Grand River, B02 of 38071 (Jackson, Michigan) features SCC prestressed box beams on half of its structure (3 beams). The demonstration project considered the evaluation of three different mix design approaches to SCC together with a reference normally consolidated concrete mix (NCC)

Project Information**Positive Results:**

- To evaluate long-term performance, a field monitoring system composed of thermocouples and strain gages was placed on the SCC beams and one of the NCC beams at different cross-sections along their lengths and one year of recorded data, from December 2005 to December 2006, has been studied. The data shows that while some variations exist in the initial strain levels of the girders (due to concrete variations such as shrinkage and elastic modulus), the variation of strain once the bridge was in service seems to be very similar for all girders.

Negative Results:

- Implementing SCC in a precast facility is not as simple as changing the concrete mix design. Extensive work is required to develop a mix design and certain modifications to current casting operations are required to use SCC effectively. Further, time is necessary to gain the experience that will allow SCC to be used most efficiently

Lessons Learned:

- The use of SCC in the production of box beams reduced the production time an average of 61% compared to using NCC. Because the beam casting process was so much faster with SCC, concrete batches needed to be produced nearly continuously. The use of void hold downs were required to maintain the desired cross section dimensions.
- Evaluation of true long-term performance will require acquisition of data for several more years before more sound conclusions on the long-term behavior of SCC prestressed elements can be reached.

Internal or External Reports:

"EXPERIMENTAL EVALUATION AND FIELD MONITORING OF PRESTRESSED BOX BEAMS FOR SCC DEMONSTRATION BRIDGE"

http://www.michigan.gov/documents/mdot/MDOT_Research_Report_RC1489_209837_7.pdf

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Unknown

Plans on Reuse of Technology: Unknown

Applicability to other States: Unknown

Additional Project Notes:

10/30/08: completed 10-21-05

State DOT Contact: Steven Kahl
E-mail: kahls@michigan.gov

Phone: 517-322-5707

HDR Contact Name: Duncan Paterson

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Parkview over US131**State:** MI **Federal-Aid Project #:** 39014-89325A **Fiscal Year:** 2009 **Funds Awarded:** \$80,000.00**Fund Status:** \$80,000.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Installation of Sensors for Structural Health MonitoringTechnology Description: Installation of sensors for structural health monitoring of full depth precast deck panels and substructure elements for rapid bridge construction**Project Information****Positive Results:**

- A sensor-based bridge health monitoring system was developed and deployed for the newly constructed Parkview Bridge in Kalamazoo, Michigan. This system adopted rapid bridge construction techniques using precast concrete technology. Sensors were installed at strategic locations and connected to a remote computer workstation via telephone lines. Continuous bridge condition data are being collected in real time, archived in the laboratory computer workstation, and analyzed to assess the structural performance and integrity. This continuous information can greatly increase bridge safety for its users by providing early warning signs before a failure occurs.
- A methodology for assessing the savings in time and cost associated with adopting Rapid Bridge Construction (RBC) techniques was developed and used in this research project. A comparison study was carried out to assess the performance of RBC technique at the Parkview Bridge. The RBC technique was found to save bridge construction time and consequently realize savings in reduced user delay costs. This user cost and time saving is significant enough that it justifies the relatively high initial cost of the RBC technique.

Negative Results:

- The precast deck panels were fabricated and erected onto the superstructure and found to have misaligned post tensioning ducts, necessitating removal and recasting of the deck panels. This added approximately seven weeks to the project. The high skew added complexity to the geometry and contributed to the alignment issue. Installing 200 sensors necessitated over 20,000 ft of wiring and concomitant connections.

Lessons Learned:

- For complex geometry such as high skew, precast components must be carefully constructed and alignment match up assured before transport and placement. Wireless sensor capability may be beneficial when high density sensor networks are installed, removing the complication of wiring connections and related construction issues.

Internal or External Reports:

Abudayyeh, O., MDOT research report RC1536, "A Sensor Network System for the Health Monitoring of the Parkview Bridge Deck," Western Michigan University, Kalamazoo, MI, January 2010. (not available)

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Unknown

Plans on Reuse of Technology: Unknown

Applicability to other States: Unknown

Additional Project Notes:

None

State DOT Contact: Steve Kahl

Phone: 517-322-5707

E-mail: kahls@michigan.gov

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** EB I-496 over CSX RR & Holmes SD Rd. R12-3**State:** MI **Federal-Aid Project #:** 33045-51396A **Fiscal Year:** 2001 **Funds Awarded:** \$270,000.00**Fund Status:** \$270,000.00 Expended**Project Status:** Complete**Associated Project Names**WB I-496 over CSX RR and
Holmes SD Rd. R12-4Project: Change / Associated

Reallocated from / to:

Technology Implemented: Stainless-clad reinforcing bars

Technology Description: Stainless steel reinforcement was placed in the deck and a corrosion monitoring probe was placed on the adjacent structure for performance evaluation comparison of the epoxy coated reinforcement used therein

Project Information**Positive Results:**

- The stainless reinforcement is expected to provide a 100 year service life, reducing maintenance and rehabilitation needs for a high volume (66,000 vehicles/day) urban freeway
- Future projects using stainless steel reinforcement will use an engineer's estimate reflective of market prices as opposed to historical unit prices, due to the infrequent use

Negative Results:

- The intent was to use clad stainless steel reinforcement, but the manufacturer was unable to deliver. Therefore a substitution with stainless reinforcement was necessary. This also increased the cost of the innovative material, resulting in the entire fund allocation expenditure on the material and no monitoring funds.
- Incorrect engineer's estimate of stainless steel reinforcement costs. The engineer's estimate used on this project was taken from a previous project that required fabrication of special mechanical splices, significantly increasing the cost by 75%. The estimate was carried forward to this project resulting in the contractor submitting a bid price of \$3.87/lb. In 2001 material costs were around \$2.00/lb, so an appropriate estimate would have been \$2.50/lb.

Lessons Learned:

- The use of stainless clad reinforcement is limited due to the supply issue. The manufacturer has recently been stockpiling inventory in the US to avoid this in the future. The smallest reinforcement size available is US #5 because of the manufacturing limitations, and with length of 39.5 ft due to shipping limitations. This information must be accounted for when designing the structure.

Internal or External Reports:**Publications, Presentations, or, Construction Studies:**

None

Additional Comments:

Technology used on Other Projects: Unknown

Plans on Reuse of Technology: Possibly, future recommendations for projects given

Applicability to other States: Unknown

Additional Project Notes:

None

State DOT Contact: Steven Kahl

Phone: 517-322-5707

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1.24. MINNESOTA

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I-394 Over Dunwoody Boulevard**State:** MN **Federal-Aid Project #:** _____ **Fiscal Year:** 1999 **Funds Awarded:** \$86,000.00**Fund Status:** \$86,000.00 Expended **Project Status:** Completed**Associated Project Names**I94 and Glenwood Ave I35 at
Maryland AveProject: Change / Associated

Reallocated from / to:

Technology Implemented: CP Anodes

Technology Description: By use of electrochemical chloride extraction (ECE), negatively charged chloride ions are driven away from negatively charged rebar and potentially out of the concrete to re-passivate the rebar and reduce the rate of corrosion

Project Information**Positive Results:**

- A research report was written documenting the installation of the system and the results and conclusions. The title and location of that report is listed below. The study showed that it is possible to install such a system and operate it for an extended period of time with positive results. The system was successfully installed on several piers and then activated for several months. The data collected showed measureable results of chloride extraction. The system was deactivated at the conclusion of the project but data has continued to be collected on a regular basis to monitor the corrosion rate. It appears from this data that the rate of corrosion has been reduced as a result of the system.

Negative Results:

- Although the ECE process reduced average chloride levels in the treated structures by approximately 50%, several locations still had chloride concentrations in excess of the established corrosion threshold following ECE treatment.
- Resistivity probe failures that occurred at some of these locations indicated corrosion within the treated structures could still occur, despite re-passivation of the reinforcing steel following ECE treatment. Continued monitoring of the installed instrumentation is required to evaluate the long-term effectiveness of ECE treatment and concrete wrapping/sealing as a corrosion mitigation technique.

Lessons Learned:

- MnDOT would consider installing a similar system on future projects.
- Use larger-scale embeddable corrosion monitoring probes that can more closely model the corrosion rates of the reinforcing steel, such as the "3LP" or "polarization resistance" techniques, in unwrapped structures, or a galvanic corrosion cell containing an embedded anode and cathode, for wrapped structures.
- Extensively monitor one or two treated structures that report high initial chloride concentrations and large areas of active corrosion potential. By collecting chloride samples and installing corrosion monitoring instruments at several locations, more specific conclusions on the effectiveness of the treatment on the entire structure could be drawn (i.e. 10-15 sample and instrument locations per column, or more, as opposed to three).

Internal or External Reports:

"Evaluation of Electrochemical Chloride Extraction (ECE) and Fiber Reinforced Polymer (FRP) Wrap Technology" Mark Chauvin, Carol Shield, Catherine French, William Smyrl; 2000.

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: not reported

Plans on Reuse of Technology: Would be considered on future projects

Applicability to other States: Results are applicable to other states.

Additional Project Notes:

Work completed June 2000

State DOT Contact: Erik Wolhowe

Phone: 651-366-4505

E-mail: Erik.Wolhowe@state.mn.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Glen Road over TH61, City of Newport**State:** MN **Federal-Aid Project #:** _____ **Fiscal Year:** 2002 **Funds Awarded:** \$500,00.00**Fund Status:** \$500,000.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Strength High Performance Steel Girders

Technology Description: The effects of using a high strength/high performance steel girders over the traditional Grade 50W as a means of reducing the cost of materials

Project Information**Positive Results:**

- The goals of this project were to observe the benefits of using High Performance Steel (HPS), particularly in the material savings resulting from the higher strength properties, fabrication time, construction time, and future maintenance costs. The HPS was being compared to ASTM A709 Grade 50W steel which was the common choice of steel.
- The project showed that HPS (ASTM A709 HPS Grade 70W) had positive benefits in each of the areas studied. There were cost savings primarily because less material was needed. The HPS material is about 40% stronger than the Grade 50W material so less material was needed to provide the required strength. The material costs were slightly higher, but not enough to offset the savings from reduction in pounds of steel.
- The fabrication time and the construction time were no different from the Grade 50W steel.
- The material was supplied to the fabricator without delay.
- The future maintenance costs are still being evaluated, but it appears that these costs are similar to the Grade 50W material
- No research report was written documenting the installation of the system and the results and conclusions.

Negative Results:

None

Lessons Learned:

- Because of the positive results of this project, MnDOT is using this material whenever the HPS can reduce the amount of steel.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Yes

Plans on Reuse of Technology: Yes, MnDOT is using this material whenever the HPS can reduce the amount of steel

Applicability to other States: Yes

Additional Project Notes:

10/30/08: Complete

State DOT Contact: Erik Wolhowe
E-mail: Erik.Wolhowe@state.mn.us

Phone: 651-366-4505

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Innovative Bridge Research**State:** MN **Federal-Aid Project #:** _____ **Fiscal Year:** 2000 **Funds Awarded:** \$290,000.00**Fund Status:** \$290,000.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Use of Large Diameter High Density Polyethylene Pipe Under Shallow Fill**Technology Description:** The effects of using thermoplastic pipe under shallow cover and repeated highway live loads**Project Information****Positive Results:**

- A research report was written documenting the installation of the system and the results and conclusions. The title and location of that report is listed below. The study showed that it is possible to install such large diameter polyethylene pipes under shallow fill and have them perform under a repeated lived load.
- Under moderate live loads for a period of 3.5 years the pipe has performed well. No deterioration has been noted in the condition of the pipe. The response to live loads at depths of fill of 1.5 ft and 2.5 ft was minimal

Negative Results:

- Due to the high coefficient of thermal expansion and the temperature extremes in the Minnesota environment, the pipe expansion and contraction did cause the pavement surface to become rough, eventually cracking the pavement over the pipes. Cracking over the pipes at a depth of 1.5 ft of fill was substantial.

Lessons Learned:

- The cracking was significantly reduced over the pipes with 2.5 ft of fill, and the pavement performance was much better. As a result, the recommended minimum depth of cover is the maximum of 2 ft or 0.5 times the pipe diameter. At this minimum depth, the pipe structural performance will be excellent, and the effect on roadway performance should be minimal if installed according to the recommended practice.

Internal or External Reports:

"Performance of Thermoplastic Pipe Under Highway Vehicle Loading" Timothy McGrath; 2005.

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Unknown

Plans on Reuse of Technology: Unknown

Applicability to other States: Unknown

Additional Project Notes:

10/30/08: Project complete.

Original approved project included the following: Rehabilitation of I-35W under 6th St. Ramp to I-94, Minneapolis, using microsilica HPC concrete deck - \$260,000; New Bridge, TH100 under 36th Ave. using stainless steel clad bars - \$30,000.

State DOT Contact: Erik Wolhowe
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Phone: 651-366-4505

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Lexington Ave Bridge**State:** MN **Federal-Aid Project #:** _____ **Fiscal Year:** 2001 **Funds Awarded:** \$500,000.00**Fund Status:** \$500,000.00 Expended **Project Status:** Complete**Associated Project Names**I-35 over Miss. River & TH 62
over I-35WProject: Change / Associated

Reallocated from / to:

Technology Implemented: Prefabricated Fusion Bonded Epoxy Coated Rebar

Technology Description: Prefabricated fusion bonded epoxy coated rebar used as reinforcement in concrete deck to reduce corrosion

Project Information**Positive Results:**

- Use of fusion bonded rebar gives the opportunity for long range performance comparisons. So far no distress is noted in the deck that is related to the rebar.

Negative Results:

- There were quite a large number of corroded locations especially at the cut ends. To date this has not been a problem in the deck performance. Extent of impact difficult to determine short term, will need a longer range time frame unless destructive analysis such as coring is used to investigate condition of the rebar.

Lessons Learned:

- Keep tighter inspection or process control on cut ends and requirements for repair coating of such areas.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

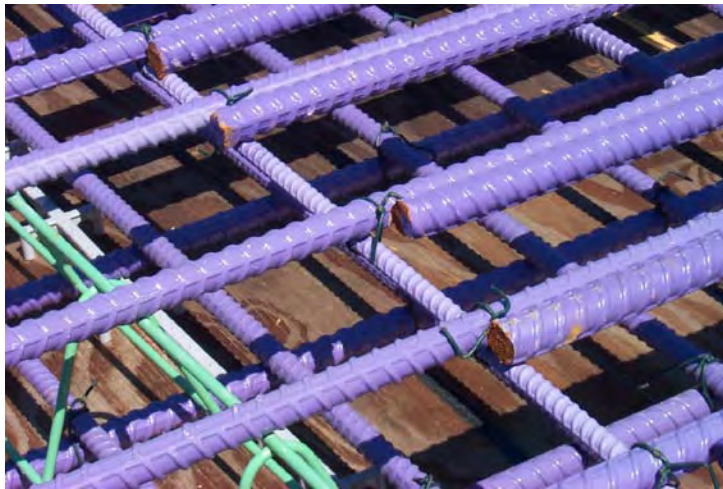
Technology used on Other Projects: Not reported

Plans on Reuse of Technology: Not anticipated

Applicability to other States: not recommended at this point.

Additional Project Notes:

Photos of corroded rebar ends attached.



State DOT Contact: Paul Kivisto
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Phone: 651-366-4563

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Low Cracking Concrete Deck Mix – Diamond Lake Road over I-35W**State:** MN **Federal-Aid Project #:** _____ **Fiscal Year:** 2005 **Funds Awarded:** \$200,000.00**Fund Status:** \$200,000.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Concrete Mix for the Deck Modified to Limit Deck CrackingTechnology Description: Low cracking concrete deck mix with significantly less cement developed by Kansas UniversityProject InformationPositive Results:

- Used a low cracking concrete deck mix developed by Kansas University. Mix has much less cement than typical deck mixes. This was first placement in Minnesota, and while we experienced some issues with this placement, we learned a lot of lessons that helped make later placements a success.

Negative Results:

- Experienced extensive deck cracking. Concrete set up very rapidly in the ready mix trucks. Water/cement ratio was much too low.

Lessons Learned:

- Important to keep the water/cement ratio between 0.43 and 0.45 (on this placement it was down near 0.35).
- Learned not to use different admixtures from the trial placement to the actual deck placement (trial placement went well).

Internal or External Reports:

"Field Contract Report" Contact report for Bridge 27V84 Deck Placement.

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not planned

Applicability to other States: not recommended at this time.

Additional Project Notes:

10/30/08: Project completed using regular Mn/DOT construction funds. Award never allocated.

State DOT Contact: Paul Kivisto
E-mail: Paul.Kivisto@state.mn.us

Phone: 651-366-4563

FHWA IBRC/IBRD Project Summary Report Form

Project Name: TH610 from 0.6 Mi. W. Fernbrook Ln. to 0.1 Mi. W. 93rd Ave. in Maple Grove
State: MN **Federal-Aid Project #:** _____ **Fiscal Year:** 2003 **Funds Awarded:** \$400,000.00
Fund Status: \$400,000.00 Expended **Project Status:** Complete

Associated Project Names

Stillwater Bridge, TH 36 over the
St. Croix River

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Precast Deck Panels to Speed Construction

Technology Description: Precast deck panels used to significantly benefit speed of construction

Project InformationPositive Results:

- We learned there are still many issues related to cracking on precast deck panels. Definitely did increase the speed of construction.

Negative Results:

- Reflective cracking over most of the panels on each of the 3 bridges they were used on. Decks had to be sealed with methacrylate upon completion.

Lessons Learned:

- Mn/DOT will be hesitant to use partial depth precast panels (stay-in-place deck forms) unless there is a significant benefit to speed of construction.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Unknown

Plans on Reuse of Technology: MnDOT will be hesitant to use partial depth precast panels unless there is a significant benefit to the speed of construction

Applicability to other States: Unknown

Additional Project Notes:

10/30/08: Three bridge decks were constructed with precast panels

State DOT Contact: Paul Kivisto
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Phone: 651-366-4563

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** TH8 Over Center Lake Channel 0.8 Miles E of Center City**State:** MN **Federal-Aid Project #:** _____ **Fiscal Year:** 2004 **Funds Awarded:** \$400,000.00**Fund Status:** \$400,000.00**Project Status:** Complete**Associated Project Names**

TH 8 over Center Lake Channel,

TH 72 over Tamarac River near

Waskish

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Precast Concrete Inverted T-Beam for Rapid Construction

Technology Description: Precast concrete inverted T-beams were used to shorten construction time by eliminating the need for erecting falsework and forms to cast a bridge on site

Project Information**Positive Results:**

- This "inverted tee" bridge superstructure type was identified in an AASHTO 2004 technology scanning trip. The "Poutre Dalle" precast system was used in France to shorten construction time by eliminating the need for erecting falsework and forms to cast a bridge on site. Using the same concept, Mn/DOT engineers with assistance from the precast concrete industry and the University of Minnesota adapted the idea for use in Minnesota. To date, Mn/DOT has built seven bridges using this system.
- The inverted tee system uses precast, pretensioned beams placed in tight contact which allows rapid completion of the superstructure. The inverted tees are topped with a cast-in-place deck that is poured directly on the tee beams with no need for additional formwork. For a conventional concrete slab span bridge, construction time would be approximately 11-12 weeks. Utilizing the precast inverted tee system, construction time can be shortened to approximately 6 weeks.

Negative Results:

- Some longitudinal cracking of the deck above the panel joints was noted. The design has since been modified, and the 2 most recently constructed bridges have not indicated any longitudinal cracks to date.

Lessons Learned:

- The inverted tee superstructure system is a very viable bridge type for spans less than about 45 feet. It can be rapidly constructed without the need for falsework on the underside of the bridge. It has been successfully implemented in metropolitan and rural areas of the state.
- Some longitudinal cracking of the deck above the panel joints was noted. The design has since been modified, and the 2 most recently constructed bridges have not indicated any longitudinal cracks to date.

Internal or External Reports:

"Monitoring and Analysis of Mn/DOT Precast Composite Slab Span System (PCSSS)"

Publications, Presentations, or, Construction Studies:

MnDOT and the FHWA hosted a "Precast Slab System Workshop" on September 8, 2005 to discuss the success of the new superstructure system. Refer to the following website for details:

<http://www.fhwa.dot.gov/bridge/prefab/slab.cfm>

Additional Comments:

Technology used on Other Projects: Yes, MnDOT has used this system on several bridges

Plans on Reuse of Technology: In a future NCHRP project, the laboratory specimen will be used to further investigate the effect of the changes in the precast section design on durability and composite action

Applicability to other States: Unknown

Additional Project Notes:

10/30/08: Completed

Beltrami County project added

State DOT Contact: Edward B. Moore
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Phone: 513-933-6587

1.25. MISSISSIPPI

No Project Summary Reports were generated for this State.

1.26. MISSOURI

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Bridge A6358, HPS, Route 54 over Osage River**State:** MO **Federal-Aid Project #:** 0543(128) **Fiscal Year:** 2002 **Funds Awarded:** \$500,000.00**Fund Status:** \$500,000 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to: {\$}

Technology Implemented: High Performance Steel (HPS)

Technology Description: 70ksi HPS used for the main structural bridge girders

Project Information**Positive Results:**

HPS can be a good material choice for certain applications.

Negative Results:

Deflections can often control the design and still require deeper sections, thus increasing costs

Lessons Learned:

Barrier to implementation of Technology: None.

Good agreement between estimated and actual deflection response. AASHTO deflection estimates are conservative.

Experimental deflection and strain data were verified to be consistent with each other and allowed to evaluate the actual girder distribution factors. The comparison between experimental and theoretical results based on the AASHTO LRFD Bridge Design Specifications (AASHTO, 1998) allowed establishing the safety of the structure, although pointing out a significant drop in the expected behavior of one of the external girders, which may call for further assessment

Internal or External Reports:

“In-situ Load Testing of Bridge A6358 (Part 1) and of Bridge A6101 and Bridge A6102 (Part 2)”

Multiple Report File completed by the state: Includes NDE testing of deflections

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects:

Plans on Reuse of Technology: where applicable

Applicability to other States: HPS is a good material. Deflections need to be better understood to take completed advantage of the material.

State Project Number: J6P0649

Federal Project Number: 0543(128)

Construction Authorizaton: 11/08/2002

Project Closed. Last FMIS Date: 1/24/2008

State DOT Contact: Bill Stone

Phone: 573-526-4238

E-mail: William.stone@MoDOT.mo.gov

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Adelaide Ave over I70, A5960, Inverset Bridge System with HPC**State:** MO **Federal-Aid Project #:** 0705(273) **Fiscal Year:** 1999 **Funds Awarded:** \$650,000.00**Fund Status:** \$650,000 Expended**Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: HPC Deck utilizing Inverset Bridge System

Technology Description: Inverset is a method of precasting composite bridge decks on beam units or partial span deck units for accelerated bridge construction. High performance concrete was used to limit future maintenance needs by limiting cracking, increasing freeze/thaw durability, and increased scaling resistance.

Project Information**Positive Results:**

Segmental construction was faster, shorter construction time.

The contractor designed high performance concrete exhibits good or excellent resistance to chloride penetration, deterioration from freezing and thawing and scaling. These properties suggest the bridge deck concrete will be very durable.

Negative Results:

The deck had cracks with widths in excess of those allowed by the special provisions, as well as other defects relating to lifting and setting the units onto the substructure. Finishing and patching of these defects was substandard in many respects. Though not causing structural deficiencies, the defects will most certainly contribute to future maintenance and repair costs over and above those originally expected

Lessons Learned:

Barrier to implementation of Technology: Construction techniques that produce a satisfactory result

Workforce and laborers' unfamiliarity with the InversetTM product led to delays in completing the bridge units. Following the initial placement of the bridge units, a period of fine-tuning was expected. Various sized shim plates had to be fabricated and installed between the girders and bearing plates to adjust for vertical differences at the edges and corners of adjacent units. Some of the units also needed to be moved slightly (longitudinally and transversely) to achieve uniform joints gaps in between units. Following the fine-tuning process there were still some concerns with the overall fit of the bridge. Other concerns were raised as voids were found between the bottom of the concrete deck and the top of the I-girders and gaps were noticed between the deck and end diaphragms.

The finishers at times had trouble finishing the low w/cm HPC around the hanging apparatus necessary for the InversetTM formwork. At other times a rise in ambient and concrete temperatures would cause difficulty in supplying HPC with the specified air content. Loads were rejected due to insufficient air content.

it should be noted that the last seven bridge units were completed in 16 calendar days. This production rate is consistent with the expected production rate at the beginning of the project. It seems as the workers became familiar with the product, they were able to achieve better production

A few ends of the steel girders and some diaphragm connection plates were flame cut soon after erection of the superstructure to aid in the lengthy fit-up process. Although primarily located in low stress regions, the steel did require grinding and painting to bring the work up to specification.

Internal or External Reports:

None for publication at this time. Partially complete paper attached:

“Construction Phase Report Replacement Deck Using Inverset Deck with High Performance Concrete (HPC)”

Publications, Presentations, or, Construction Studies:Additional Comments:

Technology used on Other Projects: Not reported

Plans on Reuse of Technology: If limiting conditions are similar to this project it would be considered as an option (see below)

Applicability to other States: Lessons learned are appropriate for all. Other States can consider using this technology.

When determining what type of structure should replace the original bridge, two factors were key. The first being the need to replace the bridge as quickly as possible to minimize the inconvenience and detour time to the many trucking companies which operated on Hall Street, and the second was the design vertical clearance limitation of 15'4". The Inverset™ Bridge System was chosen because it could meet those requirements.

State DOT Contact: John Wenzlick

Phone: 573-751-1039

E-mail: John.Wenzlick@MoDOT.mo.gov

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Big Bend NB over I-44**State:** MO **Federal-Aid Project #:** 0444(134) **Fiscal Year:** 2004 **Funds Awarded:** \$25,000.00**Fund Status:** \$25,000 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Galvanic Cathodic Protection Applied Over Concrete Repairs

Technology Description: An Aluminum-Zinc-Indium Arc Sprayed Galvanic Anode (CORRSPRAY) cathodic protection system was applied over concrete repairs to the superstructure and substructure of three bridges.

Project InformationPositive Results:

System seems to be performing.

Negative Results:

No proof that system will work long term and cost is 3 times that of normal concrete repair techniques.

Lessons Learned:

Barrier to implementation of Technology: no long term proof of performance

Took more surface preparation than at first expected. Heavy sandblast to remove curing compound used in concrete repairs.

After the concrete repairs were made and cured the application of the arc sprayed aluminum-zinc-indium anode went very smoothly. It is probably a good idea to thoroughly sand blast any curing compound that is used off of the surface before attempting to apply the arc sprayed anode

Internal or External Reports:

"Construction Report: Arc Spray Galvanic Anode for Bridge Substructures"

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: no

Plans on Reuse of Technology: if system outperforms traditional repair by three times longer life, then system will be justified. Cost will reduce with larger and more frequent projects.

Applicability to other States: Construction techniques and results can be applied to other states.

This product replaced the epoxy coating at some locations to provide a more active way of preventing continued corrosion of the rebar and protect the new concrete patches from coming out. It will be directly compared to the epoxy coating to determine the better repair.

HX20

10/30/08: Closed

State Project Number: J611612;

MO Site Manager Contract ID Number: 041217-602

State DOT Contact: John Wenzlick

Phone: 573-751-1039

E-mail: John.Wenzlick@MoDOT.mo.gov

FHWA IBRC/IBRD Project Summary Report Form

Project Name: Farm Road-148 Bridge over Pearson Creek, Green County, Bridge 1480230
State: MO **Federal-Aid Project #:** B039(024) **Fiscal Year:** 2004 **Funds Awarded:** \$32,000.00
Fund Status: \$32,000 Expended **Project Status:** Complete

Associated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Internally reinforced FRP grid systemTechnology Description: Replace the concrete deck using a low weight, high performance Glass FRP composite deckProject InformationPositive Results:

The use of very large-size and lightweight modular stay-in-place panels, comprising a double-layer grating with epoxy-bonded form plates and designed for improved constructibility, eliminates the need of formwork and on-site tying of reinforcing bars. The five-day redecking resulted in over 70% reduction in deck construction time, with a similar reduction in labor cost.

Laboratory testing demonstrated the structural adequacy of gridform reinforced slabs under design service loads, and of a first post/deck connection configuration

Bridge has performed extremely well so far per researcher Dr. John Myers.

Negative Results:

A conservative cost estimate for the deck as-built is \$409/m² (\$38/ft²), of which \$280/m² (\$26/ft²) from the prototype FRP panels delivered to the site. The amount increases to \$483/m² (\$44.9/ft²) including the cost of the open post railing (\$271/m, \$82.6/ft)

Lessons Learned:

Barrier to implementation of Technology: Long term performance evaluation, cost, complexity of barrier design.

The construction operations were planned with the contractor parties to minimize the amount of time and work

Internal or External Reports:

Compilation of related papers:

“Development and Field Testing of an FRP Composite Bridge Deck Comprising of Guard Rail System for bridge 1480230, Greene County, MO”

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: not reported

Plans on Reuse of Technology: the technology has potential for use as a durable SIP form.

Applicability to other States: Much of this research was initiated by other states and is being investigated by other states. Yes, the technology is applicable.

Project still Active in FMIS as of 4/8/2010.
Latest FMIS date 10/31/2007

Construction Complete.

Federal Aid Project Number: B039(024)

Anticipated long term testing was to be funded by City of Springfield. That funding is no longer available.

Researcher Contact: Dr. John J Myers, PE, jmyers@mst.edu, 573-341-6618

State DOT Contact: Bill Stone

Phone: 573-526-4328

E-mail: William.Stone@MoDOT.mo.gov

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Route Y, Boone-Callaway County, Deck Replacement, Bridge N0038**State:** MO **Federal-Aid Project #:** S346(002) **Fiscal Year:** 2004 **Funds Awarded:** \$108,200.00**Fund Status:** \$108,200 Expended **Project Status:** CompleteAssociated Project Names

US 69 Bridge over I-35

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP reinforcement in Deck

Technology Description: FRP reinforcing in a bridge deck. FG in top mat, Graphite in bottom mat, fibers in concrete mix

Project InformationPositive Results:

Workability was not a problem.

Negative Results:

Getting the graphite bars in a timely manner was an issue due to availability. Graphite bars are very expensive

Lessons Learned:**Barrier to implementation of Technology:** Works best in decks, because only straight bars are available. Reluctant to use in the bridge rail because this hasn't been crash tested.Internal or External Reports:<http://www.modot.mo.gov/services/OR/byDate.htm>Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

The US 69 Bridge over I-35 project was changed to this project.

State project Number: J5S0847

Bridge Number N0038, Fed. ID: 6723

Project is Closed. Last FMIS date 5/23/2008

Supposedly Bridge N0886, Route OO, Miller County was also included in study, but all dollars shown as spent on this project.

State DOT Contact: Bill Stone

Phone: 573-526-4238

E-mail: William.Stone@MoDOT.mo.gov

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Route 224 over Route 13, HPS, Bridge A6101**State:** MO **Federal-Aid Project #:** 0133(043) **Fiscal Year:** 2001 **Funds Awarded:** \$126,000.00**Fund Status:** \$126,000 Expended **Project Status:** Complete**Associated Project Names**

A6358

Project: Change / Associated

Reallocated from / to:

Technology Implemented: HPS in Steel Plate GirdersTechnology Description: HPS for GirdersProject InformationPositive Results:

HPS is a viable option for strength.

MoDOT Bridge A6101 uses HPS70W in the design of the 138 ft – 138 ft two-span, five girder bridge. Design calculations show that using HPS only in the highly stressed regions (hybrid design) led to a superstructure steel weight savings of nearly 17% and an estimated cost savings of approximately 11% compared to a conventional 50ksi bridge.

Negative Results:Lessons Learned:**Barrier to implementation of Technology:**

Deflections measured as expected. L/1000 was met.

The deflections can control and require a deeper section to meet deflection requirements. This makes use of HPS less advantageous. The maximum measured deflections for an equivalent HS20 loading match closely to the AASHTO method of estimating deflections. The MoDOT approach significantly over-estimates the measured deflections. The conservative serviceability procedures used by some states, such as MoDOT, will cause many HPS designs to be controlled by deflection, such as A6101 was, instead of strength parameters, which negates the benefit of using higher strength materials.

Like in many progressive states, the future of HPS is promising in Missouri. HPS70W is a superior steel that can lead to more economical bridges than conventional 50ksi designs. HPS can produce significant savings, especially when used in hybrid designs with 50W or HPS50W. However, the conservative serviceability procedures used by some states, such as MoDOT, will cause many HPS designs to be controlled by deflection, such as A6101 was, instead of strength parameters, which negates the benefit of using higher strength materials

Internal or External Reports:

“PERFORMANCE AND SERVICEABILITY OF HPS GIRDERS, MO 224, LAFAYETTE COUNTY:”



“ High Performance Steel Produces Durable and Economical Girders:”



“In-situ Load Testing of Bridge A6358:”**“IN-SITU LOAD TESTING OF BRIDGE A6101 & A6102:”**

A6101



A6102

Publications, Presentations, or, Construction Studies:**Press Release:****“Missouri's Builds First HPS Bridge”****Additional Comments:**

Technology used on Other Projects: See associated Project A6358

Plans on Reuse of Technology: Yes, where appropriate

Applicability to other States: See comments on limiting conditions and additional DOT constraints. Project is applicable to other States.

QX20

10/30/08: Closed

State Project Number: J4P1102F;

MO Site Manager Contract ID Number: 010420-402

State DOT Contact: John Wenzlick**Phone:** 573-751-1039**E-mail:** John.Wenzlick@MoDOT.mo.gov

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Route I-44 Galvanic Shields: XP Embedded Galvanic Zinc Anodes on various bridges**State:** MO **Federal-Aid Project #:** 0444(126) **Fiscal Year:** 2001 **Funds Awarded:** \$118,000.00**Fund Status:** \$118,000 Expended**Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Galvashield XP™ Embedded Galvanic Anodes**Technology Description:** Anodes to Inhibit Corrosion in Bridge Decks. Approximately 4350 “Galvashield XP” anodes were installed on 26 bridges.**Project Information****Positive Results:**

Construction went very easily in that all is needed after the repair area is ready for new concrete is to attach the anodes to the rebar around the perimeter of the patch.

Negative Results:

The only way now that the effectiveness of the Galvashield XP anodes can be confirmed is in the long range (5-10 years or more) to observe how well the concrete patches perform.

Lessons Learned:

Barrier to implementation of Technology: Unable to verify performance so far.

It was planned to monitor the output of the anodes at three locations to verify that current was flowing and protecting the rebar around it with cathode action. There is no dispute that there is a ring anode effect when new non-salt contaminated patches are put in next to existing heavily contaminated concrete. The question was whether the Galvashield XP anodes would provide enough current flow to the rebar to keep them from corroding and if enough current could be maintained over the expected life of the patches ten to twenty years into the future. Because of the way the six test locations were wired, with only a single XP anode per location being monitored, it is MoDOT's opinion that no useful data can any longer be gathered. Since after only two years the current output is so low it can't be read there is no longer a way to verify if rebar corrosion is being halted or not.

The only way to prove now if the anodes are effective is to observe the condition of the patches in the future. This will however be simplified since three of the bridge under-deck locations have side by side bridge overhangs where one side the anodes were left out and the other side installed. If the one side starts deteriorating faster than the other it will show the Galvashield XP anodes are at least slowing down corrosion of the reinforcing steel and deterioration of the concrete.

Internal or External Reports:

Project Report: “Construction Report: Galvashield XP™ Embedded Galvanic Anodes to Inhibit Corrosion in Bridge Decks”

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: it is our opinion that no more should be invested in this type of anode until we can verify through observation of the concrete patches on these bridges whether or not the Galvashield XP anodes tested will produce enough cathodic protection current over a long period to stop the rebar from corroding and the concrete from deteriorating

Plans on Reuse of Technology: No currently (see above)

Applicability to other States: See comments on limiting conditions and additional DOT constraints. Project is applicable to other States.

10/30/08: Closed

State Project Number: J611298

MO Site Manager Contract ID Number: 001215-601

State DOT Contact: John Wenzlick

Phone: 573-751-1039

E-mail: John.Wenzlick@MoDOT.mo.gov

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** RT 412 FRM RT B/Z to 2.3 mi. W**State:** MO **Federal-Aid Project #:** 4121(004) **Fiscal Year:** 2000 **Funds Awarded:** \$45,000.00**Fund Status:** \$45,000 Expended**Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: **High Performance Concrete in Deck Slab and HPC Prestressed Concrete I-beams**

Technology Description: A prestressed high performance concrete (HPC) highway bridge was constructed in Missouri utilizing concrete with 56 day strength of up to 86 MPa (12,500 psi). The utilization of HPC allowed for larger girder spacing and longer spans than typically used in conventional prestressed concrete bridges.

Project Information**Positive Results:**

With the increase of concrete strength, the maximum span capacity is increased for various cross sections by up to 33%. A shallower MoDOT section using higher-strength concrete can be more cost effective than a deeper section with a lower strength concrete. This is useful for replacement of existing bridges or new bridges with clearance requirements.

The HPC deck proved to be a durable mix with low shrinkage, good scaling resistance and low chloride permeability.

Negative Results:

Prediction of long-term camber was off considerably. See report.

Lessons Learned:

Barrier to implementation of Technology: none

Predicting the camber at erection can be good. The measured erection and long-term cambers were substantially lower than the cambers estimated during design by up to 40%.

Creep and shrinkage were found to be lower than predicted using ACI Committee 209 Guidelines. Fit curves represent the measured data well and were recommended for estimation of creep coefficient and shrinkage strain.

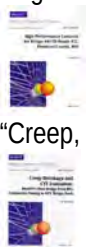
In some cases, the stresses observed in concrete after release were higher than predicted stresses, even exceeding allowable stresses. One of the reasons was the effect of restraint from the casting bed.

The actual bridge live load distribution coefficients by field load testing were found to be comparable to the live load distribution factors calculated using the AASHTO LRFD specifications (1994), but significantly lower than those factors calculated using the AASHTO standard specification (1996). The distribution factors recommended by AASHTO (1996) appeared to be overly conservative based on the live load test herein. Therefore, the AASHTO specification design codes are generally too conservative for the live load distribution factor calculation and subsequently the load rating in terms of strength limit requirements using these design guides. The AASHTO LRFD specification appears appropriate for HPC bridges is recommended instead.

For all MoDOT sections using 12.7 mm (0.5 in.) diameter Grade 270 strand at 51 mm (2 in.) centers, the maximum useful concrete compressive strength was in the range of 69 to 83 MPa (10,000 to 12,000 psi). Above this strength level, sufficient prestressing force can not be supplied within the cross section to take advantage of any higher concrete compressive strengths

Internal or External Reports:

"High Performance Concrete for Bridge A6130-Route 412, Pemiscot County, MO"



"Creep, Shrinkage and CTE Evaluation: MoDOT's New Bridge Deck Mix Companion Testing to HPC Bridge Deck"

Publications, Presentations, or, Construction Studies:Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Yes, HPC has good value in these higher strengths

Applicability to other States: results apply to other states. Technology is available for wider use.

10/30/08: Closed

State Project Number: J0P0600B;

MO Site Manager Contract ID Number: 000915-X01

State DOT Contact: John Wenzlick

Phone: 573-751-1039

E-mail: John.Wenzlick@MoDOT.mo.gov

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Rt 64 1.5 Mi SW of Pomme De Terre Lake, Hickory CO, Bridge Deck Replacement**State:** MO **Federal-Aid Project #:** S935(002) **Fiscal Year:** 2000 **Funds Awarded:** \$160,000.00**Fund Status:** \$160,000 Expended**Project Status:** Complete**Associated Project Names**

Rt 6.8, Sullivan City

Project: Change / Associated

Reallocated from / to:

Rt 86 at Neosho – Replace Bridge

Project: Change / Associated

Reallocated from / to:

Rt 86 over Hickory Creek

Project: Change / Associated

Reallocated from / to:

Technology Implemented: ABC with Precast deck panels

Technology Description: Deck replacement was done with Precast Concrete panels for an accelerated timeline with limited traffic interruptions and night lane closures.

Project Information**Positive Results:**

Benefits of fast construction using precast deck panels to redeck bridge realized. Bridge is in tourist / vacation setting over Pomme De Terre Lake. The nighttime closures to perform work, while returning the bridge to traffic during day hours proved very valuable.

Closing the bridge would have caused a 30-mile detour.

Negative Results:

The cost differential on this bridge using prefabricated sections, it was \$62.04/sq.ft. versus MoDOT's average cost of \$28.32 /sq.ft for replacing a deck by conventional methods.

Lessons Learned:

Barrier to implementation of Technology: None

On-Site precast operation was a success with some learning curve items to overcome. See reports.

The contractor had to cast 162 precast sections and had only one 10-foot panel rejected. Because of forming on a long casting bed by continuous spans, the longitudinal alignment of the in place sections was almost perfect.

Internal or External Reports:Reports available on the web at: <http://library.modot.mo.gov/RDT/reports/Ri04027/BRF05MAR.pdf>, NemoBridge.mpg (205 MB), nemo bridge.mpg (205MB), OR06003.pdf

“Deck Replacement with Precast Concrete Segments”



“Deck Replacement with Precast Concrete Segments”

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects:

Plans on Reuse of Technology: yes, where applicable. Would need similar constricting conditions to justify increased construction costs.

Applicability to other States: yes

This project is a substituted for original project: Rt 86 2.1 Mi W of Rt 59 at Noesho, Replace Bridge over Hickory Creek.
FA Project # 0861(004), State Job # J7U0537

10/30/08: Original Project : Closed This Project: Closed

Federal Aid Project Number: S935(002)

State Project Number: J8S0654

Substituted MO Site

State DOT Contact: Bill Stone

Phone: 573-526-4238

E-mail: William.Stone@MoDOT.mo.gov

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Rt. 6 .8Mi to .2 MI W Sullivan City (In Galt, MO)**State:** MO **Federal-Aid Project #:** 0062(035) **Fiscal Year:** 2000 **Funds Awarded:** \$185,000.00**Fund Status:** \$165,754.96 Expended**Project Status:** Complete**Associated Project Names**

Rt 64 – Pomme De Terre

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Stainless Steel Rebar in Deck

Technology Description: Stainless Steel reinforcing bars were used in the bridge deck

Project Information**Positive Results:**

Construction went well. The project was available. Used Plastic coated tie wires as would be used with epoxy coated reinforcement.

Time will tell on performance of the Stainless Steel rebar.

Negative Results:

Initial cost of Stainless Steel, otherwise none.

Lessons Learned:

Barrier to implementation of Technology: none

How to economically insulate SS rebar from the abutment black steel rebar would be beneficial. Used epoxy coated rebar to tie to black steel.

It has turned out that the high cost testing equipment and unavailability of the inventor have caused the fiber optic chloride sensors never to be used. No NDT testing has been done on the epoxy rebar, either, because the electrical impedance testing has never been used successfully outside of the laboratory. It was necessary therefore to rely on visual inspection of the surface of the concrete deck and old non-destructive as well as destructive testing techniques to evaluate the bridge decks. This has not yielded as much data as was hoped. There was not enough data or a good algorithm found to make a life-cycle cost analysis either

Internal or External Reports:

“Evaluation of Stainless Steel Reinforcement in Bridge Decks”

**Publications, Presentations, or, Construction Studies:**

“Evaluation of Stainless Steel Reinforcement Construction Report”



Additional Comments:

Technology used on Other Projects: no

Plans on Reuse of Technology: Yes, pending long term outcome of bridge deck

Applicability to other States: results will apply if successful over long term

QT90 Funds

Project closed 2004.

State Job Number J4U0932.

State DOT Contact: John Wenzlick

Phone: 573-751-1039

E-mail: John.Wenzlick@MoDOT.mo.gov

FHWA IBRC/IBRD Project Summary Report Form

Project Name: SB Interstate 255 over the Missouri River, and Bridge L0534 over Chariton River, Adair County at Novinger, MO.

State: MO **Federal-Aid Project #:** Not Reported **Fiscal Year:** 2006 **Funds Awarded:** \$130,000.00

Fund Status: \$78,600 Expended **Project Status:** Completed

Associated Project Names

TBD – funds remaining to be used for scour monitoring methods using temperature sensors

Project: Change / Associated

Reallocated from / ☐ to: \$51,400

Technology Implemented: Scour Monitoring using Sonar

Technology Description: A river channel-bed monitor composed of a single-beam transducer was installed on a bridge crossing the Chariton River near Prairie Hill, Missouri (structure L-344) as a pilot study to evaluate channel-bed change in response to the hydrologic condition.

Project InformationPositive Results:

The data from the sonar unit looks good. It monitors scour and backfill from flooding. USGS collects data automatically and it is available on their website. Data is collected every 15 minutes.

Throughout data collection periods, Chariton River locations near Prairie Hill and Novinger reflected bed changes as much as 13 feet and 5 feet. Nearly all of the bed changes correlated well with the hydrographic record at these locations.

Based on manufacturing specifications and independent depth measurements, the monitored channel bottom was typically within 0.5 foot of the physical measurement and never varied more than 1 foot during substantial hydrologic events.

Negative Results:

None

Lessons Learned:**Barrier to implementation of Technology:**

At I-255 it is believed that drift has damaged the upstream monitor. How to better protect from drift in future installations would be of benefit.

Internal or External Reports:

Results of Sonar monitoring:



“Real-Time River Channel-Bed Monitoring at the Chariton and Mississippi Rivers in Missouri”

Proposed Thermal Monitoring technology report:



“Remote Health Monitoring for Asset Management”

Publications, Presentations, or, Construction Studies:Additional Comments:

Technology used on Other Projects: Initial pilot study was expanded to include more scour prone bridges

Plans on Reuse of Technology: yes

Applicability to other States: results show sonar sensors are accurate means of measurement

This project has not been obligated in FMIS at time update of information on 7/30/08.

This project administered by Organization Results, not construction contract.

Original funds awarded \$130,000.

Funds this project: \$ 78,600

Balance for Pile project: \$51,400

Balance of funds is to be used on a scour monitoring method employing a pile with temperature sensors driven alongside the bent to be monitored. The research to develop the pile has been completed outside IBRD. Balance of funds here is to be used to fabricate the pile and installation/ monitoring.

State DOT Contact: No State contact is available

Phone: _____

E-mail: _____

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Southview Drive over Carter Creek, Rolla, MO**State:** MO **Federal-Aid Project #:** 5200(910) **Fiscal Year:** 2002 **Funds Awarded:** \$60,000.00**Fund Status:** \$60,000 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Pre- and Post-stressing and Rebars

Technology Description: research project was undertaken to evaluate the use of post-tensioned FRP for bridge-deck construction. The type of structure selected for this project is a four-span continuous concrete slab having GFRP bars for top and bottom mats and CFRP reinforcement for internal post-tensioning of the bridge deck

Project Information**Positive Results:**

FRP portion of widening working well.

Negative Results:

The only way now that the effectiveness of the Galvashield XP anodes can be confirmed is in the long range (5-10 years or more) to observe how well the concrete patches perform.

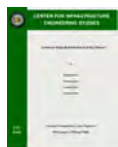
Lessons Learned:

Barrier to implementation of Technology: Further investigation must be done in this field to improve and refine the techniques related to the post-tensioning of bridge-decks using CRFP.

Experience working with FRP post-tensioning is needed. Future projects should ensure experienced personnel are obtained for this aspect of the work.

The real advantage in the use of FRP materials as reinforcement of a bridge deck is seen through its increased durability, mainly due to the absence of corrosion. To better show this advantage, a barrier with GFRP reinforcement was built on the new "FRP side" to have a comparison over time with the steel reinforced concrete barrier on the opposite side, which was going to be built after the FRP bridge deck installation

Utilizing FRP in the form of reinforcing bars allows for the use of many steel-RC concrete practices. The fabrication and installation details were nearly identical to the methods regularly utilized for steel-reinforced slabs.

Internal or External Reports:

Project Summary Report: "Southview Bridge Rehabilitation in Rolla, Missouri"

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: paper presents a good cross section of work that has been tested to date.

Project Closed.

Federal Aid Project Number: 5200(910)

This project consisted of PE and research.

State DOT Contact: John Wenzlick

Phone: 573-751-1039

E-mail: John.Wenzlick@MoDOT.mo.gov

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** State Route T Bridge over Fiddle Creek**State:** MO **Federal-Aid Project #:** S576(014) **Fiscal Year:** 2004 **Funds Awarded:** \$35,000.00**Fund Status:** \$35,000 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Precast pier caps on super elevated, skewed bridgeTechnology Description: Use of concrete precast pier caps to reduce construction time**Project Information****Positive Results:**

- Project was a success
- Workers safety can be improved, since it can be assumed that four or more workers would be required to perform elevated work for several days with traditional cast-in-place construction.
- Two workers on top of the beam cap seemed adequate during grouting process. The time spent by these two workers grouting was less than would be required for forming, pouring concrete and stripping forms.
- A lot was learned about the design and construction of precast beams. The project was thoroughly documented, pictured, and video taped throughout the entire process
- The additional design requirements of the beam-column connection worked well with traditional designed cast-in-placed beams. The fabricator recommended only minor changes to the reinforcing layout.
- New construction techniques were developed or existing techniques were employed in new ways
- Forming and pouring concrete for the beam cap are eliminated through the use of precast beam caps

Negative Results:

- The goal of reducing construction time was largely not realized on this project due to the inexperience with using precast beam caps. If more experienced workers had been used, it can be concluded that construction would have in fact been reduced.
- The fabricator had to develop forms and a precasting bed from scratch
- A method to pump grout through an inlet tube and ensure all outlet tubes were completely full had to be created
- The pressurized grouting presented a unique challenge, which required the contractor to employ a subcontractor

Lessons Learned:**Barrier to implementation of Technology:** Inexperience of workers

- Additional notes or the addition of a bridge special provision may have avoided some of the problems encountered.
- Future use of precast beam caps should go more smoothly based on the experience gained from this pilot project
- Best use of this precast option would be on projects where time considerations exceed those of costs, however due to limited availability of contractor experience, it should be considered if this would completely eliminate any time savings.
- Projects with a large number of bents (piers) would be the ideal project for this type of technology
- Transportation of beam caps needs to be considered
- The design process does not need major changes
- The congestion of the reinforcement cage should be considered and spiral confinement reinforcement should be detailed so it does not interfere with the shear stirrups
- Grout tubes should extend to the top of the beam cap and do not require a change in diameter
- The design and placement of lifting tubes should consider that the lifting force will not be purely vertical and edge distance to the lifting tubes is important to prevent cracking.
- A note on the plans allowing the shifting of reinforcement to clear the grout tubes should be added.
- The estimate in the costs of the beam caps should take into account that they are a specialty item

Internal or External Reports:

"Report on Precast Beam Cap Pilot Project"

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Unknown

Plans on Reuse of Technology: not if cost remain the same as for this project

Applicability to other States: Wide applicability as the technology has potential to be used on any bridge project that would require multiple bents (piers), and had an emphasis on construction completion time

10/30/08: Closed

Federal Aid Project Number: S576(014);

State project Number: J6S1056;

MO Site Manager Contract ID Number: 050218-606

State DOT Contact: John WenzlickPhone: 573-751-1039E-mail: John.Wenzlick@MoDOT.mo.gov

FHWA IBRC/IBRD Project Summary Report Form

Project Name: X0596 Rte. C over Creek, P0962 Rte. B over Creek, T0530 Rte. M over Crooked Creek, Y0298 Rte. U over Creek, and X0945 Rte. C over river

State: MO **Federal-Aid Project #:** 9900(589) **Fiscal Year:** 2003 **Funds Awarded:** \$250,000.00

Fund Status: \$250,000 Expended **Project Status:** Complete

Associated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Fiber reinforced polymer (FRP) strengthening

Technology Description: Project is intended to validate the use of fiber-reinforced polymer (FRP) materials as a means to strengthen existing concrete bridges that are considered structurally deficient

Project InformationPositive Results:

Increased stiffness was achieved from FRP strengthening.
High end surveying equipment was found adequate for static load testing vs. conventional sensors.
The capability of near-field microwave NDT&E techniques for quick, on-site, real-time and repeatable detection of disbonds between CFRP laminates and concrete bridge members has been demonstrated.

Negative Results:

Some bridges exhibited a loss of stiffness over time.
Unable to answer the question: How do we determine if the strengthening is still working over time?

Lessons Learned:

Barrier to implementation of Technology: Long term effect still not fully understood

For strengthening of RC bridges with FRP in the field where limited manpower exists for installation, mechanically or adhesively fastened pre-cured plates appear to be a promising technology. For short span structures as few as two individuals can install the strengthening system and this technique appears ideal for county level agency installation.

The load carrying ability of FRP may be affected by surface preparation of the concrete substrate, fiber alignment, air voids created during installation of the externally bonded sheets, and delaminations and disbonds which could occur and progress over time. As part of the installation procedure, preparation of the concrete substrate was extremely important.

The apparent increase in stiffness achieved by adding FRP strengthening is primarily attributed to the restraint of concrete cracks from opening. Overall, there has been no dramatic increase in the deflection of the tested bridges.

Internal or External Reports:

Final Project Report: vol.1: , vol.2: , vol.3: , vol.4: , vol.5: 
“Preservation of Missouri Transportation Infrastructures: Validation of FRP Composite Technology”

Publications, Presentations, or, Construction Studies:

Press releases:



“Preservation of Missouri Transportation Infrastructure - Validation of FRP Composite Technology Through Field Testing”



“Missouri’s FRP Composite Strengthening Field Tests Enter Third Year”

Additional Comments:

Technology used on Other Projects: This was a multiple project study.

Plans on Reuse of Technology: Study has been used to draft AASHTO Specs. Plans are to use this technology when appropriate as a repair technique

Applicability to other States: Study has been used to draft AASHTO Specs. Anticipate this will be used by other states.

The value of chloride initiation concentration can have a significant effect on the prediction of life expectancy of FRP strengthened bridges. The prediction accuracy of bridge life expectancy will be limited until the value, or distribution, of the chloride initiation concentration or physical evidence of the steel loss level is better defined.

10/30/08: Closed

Federal Aid Project Number: 9900(589)

Project included research.

State DOT Contact: John Wenzlick

Phone: 573-751-1039

E-mail: John.Wenzlick@MoDOT.mo.gov

1.27. MONTANA

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I-15/I-90 over BNSF RR**State:** MT **Federal-Aid Project #:** _____ **Fiscal Year:** 2005 **Funds Awarded:** \$362,000.00**Fund Status:** Unknown**Project Status:** InitiatedAssociated Project Names

Butte Area Structures

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Steel in Box Girders

Technology Description: The effects of using a High Performance Steel girders as a means of reducing the cost of materials

Project InformationPositive Results:

- Extends the knowledge base for future designs applying continuous for live load details particularly for steel girder construction. Extended knowledge base of design engineer in regards to continuous for live load applications for steel can be applied similarly to concrete.

Negative Results:

- Local fabricator was not able to handle the heavier tub sections
- Funding delays resulted in technology not as cutting edge as when first looked at
- Local fabricator not able to handle heavier section therefore went to an out-of-state fabricator

Lessons Learned:

- Currently shop drawings are being reviewed
- Bottom flange needs to be extended beyond web 1 ½" per industry standard in lieu of ¾" in order to allow ample space for automatic welding

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Unknown

Plans on Reuse of Technology: Unknown

Applicability to other States: Unknown

Additional Project Notes:

10/30/08: Expected letting date January-2011

State DOT Contact: Dave Johnson

Phone: 406-444-6261

E-mail: dfjohnson@mt.gov

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Three Structures on Secondary Rt. 243**State:** MT **Federal-Aid Project #:** _____ **Fiscal Year:** 2002 **Funds Awarded:** \$250,000.00**Fund Status:** Unknown**Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Reinforced Concrete Deck

Technology Description: Long-term monitoring for three different methods of construction for reinforced concrete decks including High Performance Concrete

Project Information**Positive Results:**

- The performance to date of the empirical reinforcement design demonstrates that this design philosophy has merit.
- All measured tension strains were significantly below those levels that would be expected to cause cracking in the decks
- All three decks exhibited similar stiffnesses and load flow behaviors, based on the GDFs experimentally determined for each bridge.
- Linear superposition worked well for all three bridge decks, indicating that all three decks were still behaving linear-elastically.
- All three decks responded similarly regardless of the speed at which the liveload was applied.

Negative Results:

None

Lessons Learned:

- Empirical design has limited cost savings on a narrow structure due to the additional reinforcement that is needed for the exterior overhangs.
- The site provided similar environments for the three structures but would choose a higher traffic volume location to accelerate the live load impacts.
- Based on all of the information obtained to-date, the HPC deck potentially will offer the most cost effective performance of the three deck configurations

Internal or External Reports:

"EVALUATING CONCRETE BRIDGE DECK PERFORMANCE"

http://www.mdt.mt.gov/research/docs/research_proj/threedecks/final_report.pdf
Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: During the course of this research project, four other laboratory studies were conducted to evaluate certain aspects of material and deck performance in a controlled environment

Plans on Reuse of Technology: Recommendations for Future Work were given, which would indicate the possibility of reuse

Applicability to other States: Unknown

Additional Project Notes:

10/30/08: Constructed

State DOT Contact: Dave Johnson

Phone: 406-444-6261

E-mail: dfjohnson@mt.gov

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** US 2 over Middle Fork Flathead River Essex**State:** MT Federal-Aid Project #: _____ Fiscal Year: 2001 Funds Awarded: \$459,000.00**Fund Status:** Unknown **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Solid Stainless Steel RebarsTechnology Description: Stainless steel reinforcement designed to resist corrosion**Project Information****Positive Results:**

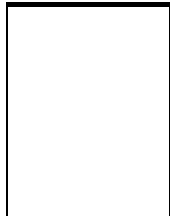
- The newly built bridge has many transverse deck cracks present not related to the use of the stainless steel reinforcement. The use of the stainless steel reinforcement in an extreme environment, i.e. heavy snows and magnesium chloride, will provide an excellent opportunity to observe performance of stainless steel in this aggressive environment.

Negative Results:

- Stainless steel rebar delivered but did not meet ASTM specification for bar deformation.

Lessons Learned:

- Only imported steel available at time of project letting
- Project site is a highly sensitive area with Glacier National Park @ east approach and Flathead National Forest @ west approach in addition to the Middle Fork of the Flathead River being a wild and scenic river. Therefore it is critical to get in and stay out and stainless steel rebar should critical assist in this bridge management philosophy

Internal or External Reports:

"EVALUATING CONCRETE BRIDGE DECK PERFORMANCE"



"IBRC PROJECTS INVOLVING CORROSION-RESISTANT REINFORCEMENT"

Also available:

http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_SMO/FDOT_BD440_rpt.pdf<http://www.tfrc.gov/structur/pubs/06078/ibrcprojects.htm>

Publications, Presentations, or, Construction Studies:

"APPENDIX E FHWA Project Number MT-01-01 TEA-21 INNOVATIVE BRIDGE CONSTRUCTION PROGRAM - Evaluation Report"

<http://www.tfhr.gov/structur/pubs/06078/hrt06078e.htm>

Additional Comments:

Technology used on Other Projects: Used on various projects throughout the United States

Plans on Reuse of Technology: Unknown

Applicability to other States: Corrosion resistant rebar has been approved for use in 27 different states, 20 either completed the project as planned or used an alternate innovative reinforcement

Additional Project Notes:

10/30/08: Constructed

State DOT Contact: Dave Johnson

Phone: 406-444-6261

E-mail: dfjohnson@mt.gov

1.28. NEBRASKA

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** 262nd Street Bridge over I-80**State:** NE **Federal-Aid Project #:** NHI-80 9 **Fiscal Year:** 2004 **Funds Awarded:** \$400,000.00
9(8224)**Fund Status:** \$400,000.00 Expended**Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Steel in Box Girders**Technology Description:** High Performance Steel in Box Girders used to reduce material cost and interruption to traffic**Project Information****Positive Results:**

- Steel boxes constructed such that they behave simple for dead loads and continuous for live loads.
- Innovative pier connection detail that eliminates the need for continuation of the bottom flanges and thus eliminates the need for field welding
- Slab cast on site over each box prior to girder placement.
- Constant bottom flange thickness due to double composite action made possible by pouring concrete inside the steel boxes near the pier. Although the concrete contribution was ignored in strength calculations the benefit of bracing of the bottom flange was considered.
- Use of HPWS (70 ksi)
- Eliminates the need for field splices
- Reduced interruption to traffic
- Improved worker safety
- The resulting moments are such that one could utilize the same cross section for an entire span
- The reduction in negative moment over the pier often results in reducing the number of cross frames

Negative Results:

- A reinforced concrete diaphragm at the pier is required
- Closure pour is required
- Overlay is required
- Negative moment reinforcement in the deck must be turned down into the concrete diaphragm at the pier resulting in congestion
- Reinforcement in the deck must be headed at the closure pour for development length and was somewhat congested
- More expensive construction

Lessons Learned:

- Find more user friendly details for developing reinforcing steel at the piers and closure pour
- Refined construction processes could further enhance speed of construction

Internal or External Reports:

None available. Final report pending completion of technology.

Publications, Presentations, or, Construction Studies:

None currently available at time of report.

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

None

State DOT Contact: Fouad Jaber

Phone: 402-479-3967

E-mail: fouad.jaber@nebraska.gov

FHWA IBRC/IBRD Project Summary Report Form

Project Name: Folded Steel Plate Bridge Technology: Research, Design, Construction and Monitoring

State: NE **Federal-Aid Project #:** STPD-BR-79-2(108) **Fiscal Year:** 2005 **Funds Awarded:** \$550,000.00

Fund Status: \$181,789.21 Expended **Project Status:** Initiated

Associated Project Names

Wagon Tongue Creek on
Highway N-79

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Folded Steel Plate Bridge Technology

Technology Description: Folded Steel Plate Bridge Technology used to reduce labor costs

Project InformationPositive Results:

- Use of Folded Steel Plate Technology almost eliminates the labor associated with girder fabrication
- Folded steel plate girder concept uses very thin plates for short span bridges. For instance for 50 ft. long simple span bridge, one only need plate that is 3/8 inches in thickness.
- To avoid painting and issues related to corrosion, A1010 steel could be used. A1010 is almost a stainless steel and it does not corrode. The alternatives are use of A1010, A572 Grade 50, HPS-70W, HPS100W or HPS-50W steel.
- Girder geometry will be an "Inverted Steel Box" shape. This shape is more stable much easier to inspect, compared to conventional box sections.
- The compression element of the girders will be stiffened using a small "bump" which eliminates the need for using expensive stiffeners.

Negative Results:

None

Lessons Learned:

None

Internal or External Reports:

"Constructability Testing of Folded Plate Girders"

Publications, Presentations, or, Construction Studies:

"A New Ear for Short Span Bridges" Article for Steel Bridge News

Additional Comments:

Technology used on Other Projects: Yes

Plans on Reuse of Technology: Yes, this is an award winning project

Applicability to other States: this is a good innovative application that should gain traction with other states.

Additional Project Notes:

None

State DOT Contact: Fouad Jaber
E-mail: fouad.jaber@nebraska.gov

Phone: 402-479-3967

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Nebraska Highway 68 over the BNSF Railroad in Ravenna**State:** NE **Federal-Aid Project #:** 68-2(102) **Fiscal Year:** 2003 **Funds Awarded:** \$400,049.00**Fund Status:** \$400,049.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: SCC GirdersTechnology Description: Use of Self-Consolidating Concrete Girders to reduce labor costs**Project Information****Positive Results:**

- The arch itself was constructed using high strength steel tubes filled with high strength shrink-compensating SCC pumped on site.
- The hangers between the top and bottom chords were made of high strength threaded rods covered with PVC pipes. Connections of the hangers to the top chord by spherical nuts will allow for tension adjustments in the hangers after construction is completed and, if needed, during the life of the bridge.
- The tie-beams are of a unique composite design consisting of a hollow rectangular high strength steel outer casing that is filled with SCC and post-tensioned. The post-tensioning is to such an extent as to induce permanent compression in what is normally a tension, as well as a fracture critical, member.
- No lateral sway bracing was required in this system, thus removing vertical height restrictions and common maintenance concerns due to vehicle collision.
- An extremely high span to depth ratio was able to be achieved that allowed for the required vertical clearance while eliminating the need for intermediate piers, as was required for this railroad overpass.
- Aesthetically pleasing
- Less fabrication labor than would be required for a truss
- Implementation of new theories that recognize a significant increase in capacity of concrete that is confined
- Prefabricating the arch accelerated construction time

Negative Results:

- Currently uneconomical
- Difficulty of analysis for overweight permits
- Floor beam spacing's in excess of 12' would make them fracture critical

Lessons Learned:

- Precise tolerances, especially in connection components, are required
- Use of a precast floor system would be more cost effective

Internal or External Reports:

"Concrete Filled Steel Tube Arch" Final Report

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Not currently planned, but possible

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

None

State DOT Contact: Fouad Jaber

E-mail: fouad.jaber@nebraska.gov

Phone: 402-479-3967

HDR Contact Name: Duncan Paterson

FHWA IBRC/IBRD Project Summary Report Form

Project Name: Omaha Dodge St. over I480
State: NE **Federal-Aid Project #:** 480-9 (703) **Fiscal Year:** 1999 **Funds Awarded:** Unknown
Fund Status: Unknown **Project Status:** Complete

Associated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance SteelTechnology Description: High Performance Steel girder system used to reduce material costProject InformationPositive Results:

- Hybrid girder sections utilizing both 50 ksi and 70 ksi grade steel
- Welding procedures (PQR) and guide lines for consumables for girder fabrication were developed as part of this project which were later adopted by the AWS
- LRFD Code equations for the design of High Performance Steel were developed and implemented as a result of this project

Negative Results:

None

Lessons Learned:

- Increased dead load deflections due to the high span to depth ratio introduces some difficulty in phased construction applications

Internal or External Reports:

"Flexural Capacity of HPS-70W Bridge Girders"

Publications, Presentations, or, Construction Studies:

"High Performance Steel: Research Front—Historical Account of Research Activities"



"Improved Moment Strength Prediction of Composite Steel Plate Girders in Positive Bending"



"Flexural Capacity Of Compact And Noncompact High-Performance Steel Plate Girders"



"High-Performance Steel: New Horizon In Steel Bridge Construction"

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Yes

Applicability to other States: Not Reported

Additional Project Notes:

None

State DOT Contact: Fouad Jaber

Phone: 402-479-3967

E-mail: fouad.jaber@nebraska.gov

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Pacific Bridge over I-680**State:** NE **Federal-Aid Project #:** NHI-680-9(877) **Fiscal Year:** 2004 **Funds Awarded:** \$300,000.00**Fund Status:** \$300,000.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Concrete in I-GirdersTechnology Description: High Performance Concrete used in I-girders to reduce material cost**Project Information****Positive Results:**

- Introduction of phasing and retrofitting schemes that allow for the retrofitting of existing columns and any incidental new substructure work that can primarily be done prior to closure of all or part of the existing bridge to traffic (i.e. incorporating as much of the existing substructure into the new design so that new work can be done under the bridge while maintaining full service to the superstructure above).
- Use of substructure geometry conducive to rapid construction (i.e. wall type integral abutments that reduce forming time, allow for girders to be placed earlier on in the construction sequence, and removes the need for time consuming MSE wall construction)
- Use of the innovative product "Expanded Polystyrene Geofoam" to reduce lateral earth pressures to make feature number 2 possible
- Limiting of the MSE wall construction that is incorporated into the new design to be outside the limits of the structural components of the bridge so that the time consuming construction of the MSE wall itself is not along the critical path of the construction activities
- Implementation of threaded rod technology with new details from the most current research work done on the topic
- Use of precast prestressed deck panels as an alternate design
- Use of 1 3/8" dia. Grade 150 Threaded Rods with Jam Nuts at 2'-0" Ctrs. for composite action in conjunction with feature number 7
- Use of 0.7" nominal dia. uncoated, seven-wire, low-relaxation steel prestressing strands in the precast prestressed concrete NU I girders

Negative Results:

- NDOR conducted several meetings with prospective suppliers, fabricators, contractors, and local government representatives prior to bid letting to ensure selection of the most economical solution and to make all parties involved aware of the various innovative aspects of this project. Upon review of these findings, the Roadway Design Division together with Bridge Division deemed the following course of action to be the most economically viable: Eliminate the necessity of SPMT's, rollers, or sliders by implementing innovative construction features that are accelerated and/or off of the critical path.

Lessons Learned:

- Eliminate the necessity of SPMT's, rollers, or sliders by implementing innovative construction features that are accelerated and/or off of the critical path. Additionally, simplification of the details associated with the threaded rod concept is desirable.

Internal or External Reports:

None available at time of report

Publications, Presentations, or, Construction Studies:

None available at time of report

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

None

State DOT Contact: Fouad Jaber
E-mail: fouad.jaber@nebraska.gov

Phone: 402-479-3967

HDR Contact Name: Duncan Paterson

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Skyline Dr. over Hwy. 6 (Dodge Street)**State:** NE **Federal-Aid Project #:** 0067(114) **Fiscal Year:** 2001 **Funds Awarded:** \$150,000.00**Fund Status:** \$150,000.00 Expended**Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: HPC Bridge Deck

Technology Description: High Performance Concrete precast prestressed bridge deck system used to reduce material cost and construction time

Project Information**Positive Results:**

- This full depth precast prestressed bridge deck panel system is compressed in two directions resulting in increased durability of the overall structure.
- A continuous channel or trough over the beam eliminates any potential problems related to quality of tendon grouting.
- Type K expansive cement was used for grouting
- Individual post-tensioning of strands results in ease of operation for the contractors
- Full-width deck panels eliminate the need for forming of the overhangs
- Cast-in-place overlays allow for adjustments in the roadway profile and provides an excellent riding surface.
- Faster construction
- Delayed composite action to reduce negative moment cracking

Negative Results:

- Difficulty forming the crown in the panels
- Concerns regarding quality of shear key grouting
- Conflicts between panel and shear connectors
- Many construction steps
- Uneconomical unless life cycle costs are considered

Lessons Learned:

- Don't use random oriented fiber under the plastic rods for forming the crown. Use a more compressible material
- Widen the shear key to allow for more uniform grouting
- Use plastic shims over the steel angle for minor elevation adjustments
- Greater speed of delivery for the panels would have been desirable

Internal or External Reports:

"NU-DECK Precast Deck Panels & Innovative Bridge Research and Construction" Final Report

Publications, Presentations, or, Construction Studies:

"High Performance Precast Concrete Nudeck Panel System For Nebraska's Skyline Bridge"

<http://tris.trb.org/view.aspx?id=746725>

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

None

State DOT Contact: Fouad Jaber
E-mail: fouad.jaber@nebraska.gov

Phone: 402-479-3967

HDR Contact Name: Duncan Paterson

1.29. NEVADA

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** NDOT Contract #3319 On SR 170, Bunkerville Road over Virgin River Bridge B-85**State:** NV **Federal-Aid Project #:** BHF-0170(082) **Fiscal Year:** 2003 **Funds Awarded:** \$300,000.00**Fund Status:** \$300,000.00 Expended **Project Status:** completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Steel**Technology Description:** Using high performance steel, HPS 70W, instead of traditional structural steel for the construction of a steel plate girder bridge.**Project Information****Positive Results:**

The use of high performance steel had a number of benefits related to the design of the structure:

- The increased strength of the steel allowed the use of reduced structural sections.
- Minimizing the materials required and overall loading on the structure.

Negative Results:

Feedback from personnel inspecting the fabrication of the girders indicated the high performance steel was harder to work with and more prone to weld cracking than standard steel. This resulted in minor increases to the time required for fabrication.

Lessons Learned:**Barrier to implementation of Technology:**

It is critical to remove all the mill scale to achieve a uniform weathered finish on the HPS 70W steel. Feedback has indicated it is more difficult to remove the mill scale from the high performance steel and requires more intensive blasting.

Edge cracking occurring on the splice welds was corrected by utilizing longer run-off tabs. The 2" tabs were increased to between 4" and 6" to prevent cracking.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: High Performance Steel (HPS) was used on B-89 structure in Mesquite.

Plans on Reuse of Technology: Yes, the results were favorable.

Applicability to other States: Yes, this technology is applicable to all states and has been used in many other states.

Additional Project Notes:

10/30/08: Construction is complete and bridge is in operation. <http://www.fhwa.dot.gov/BRIDGE/ibrc/resources.cfm>

Bridge Replacement: 5-span welded steel plate girder bridge (880' long X 39' wide); AASHTO M270, Grade HPS 70W high performance steel in new superstructure.

At the time of fabrication in 2006 the 70W material was \$0.18 (approximately 35%) more expensive than 50W material.

Grade HPS 70W steel was used for the flanges of hybrid girders with all other components fabricated from Grade 50W steel. More recently, HPS 70W steel was also utilized in the flanges of the B-89 structure in Mesquite. It is anticipated that similar use will be considered in future projects.

State DOT Contact: Jessen Mortensen

Phone: 775-888-7543

E-mail: jmortensen @dot.state.nv.us

HDR Contact Name: Duncan Paterson

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1.30. NEW HAMPSHIRE

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I-293 WB over Frontage Road**State:** NH **Federal-Aid Project #:** I-293-1(270) **Fiscal Year:** 2002 **Funds Awarded:** \$131,630.00**Fund Status:** \$102,166.60 Expended**Project Status:** Complete**Associated Project Names**Mill Street Bridge over the
Lamprey in Epping NH

Project: Change / Associated

Reallocated from / ☐ to: \$29,436.40**Technology Implemented:** Galvanized Deck Reinforcing (clad Stainless not available)

Technology Description: Galvanized Deck Reinforcing designed to resist corrosion

Project InformationPositive Results:

- The deck is performing well – 2009 condition rating is 8 – without NH's traditional waterproofing membrane and pavement

Negative Results:

- Stainless clad reinforcing steel was not available, even though the manufacturer promised the contractor delivery on several occasions. To prevent delay to the project, it was decided to change to galvanized reinforcing steel.

Lessons Learned:

- The galvanized reinforcing steel had serrated drip lines and other characteristics that made it dangerous to handle. The workers had to wear double gloves to prevent cutting themselves.
- The FHWA has not supported the use of galvanized reinforcing steel as a long term corrosion protection technology, which may not agree with field experience, and has resulted in reluctance to use the material in NH, even in view of reported problems with epoxy coated reinforcing steel in Florida and Virginia.

Internal or External Reports:

No formal reports produced.

Publications, Presentations, or, Construction Studies:

No formal publications, presentations or studies produced.

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

Bridge Number 016101800008900

Bridge opened to traffic in 2004.

\$164,295 was transferred to Epping Rapid Bridge Project.

State DOT Contact: Mark Richardson

Phone: 603-271-2731

E-mail: Mrichardson@dot.state.nh.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I-293 WB over Brown Ave.**State:** NH **Federal-Aid Project #:** I-293-1(270) **Fiscal Year:** 2002 **Funds Awarded:** \$287,000.00**Fund Status:** \$152,168.49 Expended **Project Status:** Complete**Associated Project Names**Mill Street Bridge over the
Lamprey in Epping NH

Project: Change / Associated

Reallocated from / ☐ to: \$134,831.51**Technology Implemented:** Galvanized Deck Reinforcing Steel (price escalation of stainless; State changed to galvanized reinforcing steel)Technology Description: Galvanized Deck Reinforcing Steel designed to resist corrosion**Project Information****Positive Results:**

- The deck is performing well – 2009 condition rating is 8 – without NH's traditional waterproofing membrane and pavement.

Negative Results:

- Due to the escalation in prices for the stainless steel reinforcing between the time the project was bid and the contractor's purchase order for the stainless steel, the bridge was changed to galvanized deck reinforcing steel. Without Federal participation, the State was unable to absorb the additional \$53,000 for the stainless steel reinforcing.

Lessons Learned:

- This bridge was constructed during a steel shortage and a rapid escalation in steel prices. Since this time period, most contractors are purchasing and taking delivery of reinforcing steel immediately after being awarded a project.
- The galvanized reinforcing steel had serrated drip lines and other characteristics that made it dangerous to handle. The workers had to wear double gloves to prevent cutting themselves.
- The FHWA has not supported the use of galvanized reinforcing steel as a long term corrosion protection technology, which may not agree with field experience, and has resulted in reluctance to use the material in NH, even in view of reported problems with epoxy coated reinforcing steel in Florida and Virginia.

Internal or External Reports:

No formal reports produced

Publications, Presentations, or, Construction Studies:

No formal publications, presentations or studies produced

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

Bridge Number 016101850007700

Bridge was opened to traffic in 2004

\$164,295 was transferred to Epping Rapid Bridge Project

State DOT Contact: Mark Richardson

Phone: 603-271-2731

E-mail: Mrichardson@dot.state.nh.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Mill Street over the Lamprey River in Epping, NH

State: <u>NH</u>	Federal-Aid Project #: <u>A000(135)</u>	Fiscal Year: <u>2002/2003</u>	Funds Awarded: <u>\$690,000.00</u>

Fund Status: \$835,773.00 Expended
\$18,522 Reallocated

Project Status: Complete**Associated Project Names**

Newbury Road over Connecticut River

Project: Change / Associated

Reallocated from / ☐ to: \$18,522**Technology Implemented:** Accelerated Bridge Construction – Completely Precast Bridge

Technology Description: Accelerated Bridge Construction, bridge completed in 8 days and greatly reduced construction time and congestion

Project Information**Positive Results:**

- Bridge was completed in 8 days once the site was prepared. The project contributed to knowledge, added to later by other IBRC projects that used full depth precast bridge decks on steel girders, that gave NHDOT the confidence to provide both cast-in-place and precast construction options for piers, abutments, and decks in many of the projects they advertise.

Negative Results:

- The cost was quite high compared to cast-in-place construction with a normal construction time frame (about a 35% premium)

Lessons Learned:

- Precast substructure systems are feasible
- conventional design mimicking Cast-in-Place can be used
- provide fabrication and erection tolerances in the details.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

- Article In the May 2005 PCI Journal
- NHDOT presentation at the 2004 PCI Convention in Atlanta, GA
- 2005 PCI Award for Best All Precast Solution
- Presented at FHWA ABC Workshops, most recently at the 2009 Rhode Island Workshop

(Each not available to be attached)

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: not reported

Applicability to other States: lessons learned are good for other states, but cost is prohibitive

Additional Project Notes:

Bridge Number 007801120005500

Bridge was opened to traffic in 2004.

IBRC Funding Status:

1. FY 2002 Award - \$290,000
2. FY 2003 Award - \$400,000
3. Transferred from the Frontage Road/ Brown Ave 2002 IBRC Project - \$164,295
4. Transferred to the Newbury RD 2005/2006 IBRC Project - \$18,522

IBRC funds expended on project - \$835,773

State DOT Contact: David Scott

Phone: 603-271-2731

E-mail: dscott@dot.state.nh.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Mosquito Bridge US Rt. 3 & NH Route 11 over Lake Winnisquam**State:** NH **Federal-Aid Project #:** A000214 **Fiscal Year:** 2004 **Funds Awarded:** \$400,000.00**Fund Status:** \$400,000.00 Expended **Project Status:** CompleteAssociated Project Names

(none)

Project: Change / Associated

Reallocated from / to: {\$}

Technology Implemented: Full Depth Precast Deck Panels used for Rapid Bridge Deck ReplacementTechnology Description: Full Depth Precast Deck Panels used to greatly reduce construction time and congestionProject InformationPositive Results:

- Deck was successfully constructed using the precast deck slabs in two phases, ½ width at a time

Negative Results:

- Contract period was longer than planned, partially due to difficulty in placing post tensioned tendons in deck panels

Lessons Learned:

- It is important for deck panel fabricator to precisely locate tendon ducts; the duct size has to be large enough to easily accommodate the size of the post tensioned tendon

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

NHDOT presented paper at the 2007 PCI Conference in Phoenix, AZ (not available to be attached)

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

Bridge Number: 023102310007300

Bridge was opened to traffic in 2006

State DOT Contact: David Scott

Phone: 603-271-2731

E-mail: dscott@dot.state.nh.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Newbury Road over Connecticut River**State:** NH **Federal-Aid Project #:** A000(582) **Fiscal Year:** 2005/2006 **Funds Awarded:** \$600,000.00**Fund Status:** \$618,522.00 Expended **Project Status:** Complete**Associated Project Names**Mill Street Bridge over the
Lamprey in Epping NH

Project: Change / Associated

Reallocated from / to: \$18,522**Technology Implemented:** Full Depth Precast HPC Deck Panels used for Rapid Bridge Deck Replacement

Technology Description: Full Depth Precast HPC Deck Panels used for rapid bridge deck replacement to greatly reduce construction time and congestion

Project Information**Positive Results:**

- The bridge was successfully built within the allotted time. The same fabricator built the deck panels as built the panels for an earlier IBRC project (Mosquito Bridge) that had difficulty placing the tendons due to problems with the duct alignment and size. The fabricator was careful to align the ducts on this project and used larger ducts, resulting in no field problems when inserting the tendons. The information from this project and the earlier IBRC project has been used to develop standard plans for precast full depth deck panels that are allowed as a contractor option on many projects. The University of New Hampshire also evaluated the panel joint details on this project for further work on the details

Negative Results:

None – the deck is performing well and the project stayed on schedule; the cost was higher than a cast-in-place deck

Lessons Learned:

- The panel joint configuration may be refined in studies being performed by the University of New Hampshire for a proposed Highways for Life project, but NHDOT has implemented full depth precast HPC deck panels as a contractors option on many projects
- Contractor scheduling of the deck panel fabrication must consider the required 45 day waiting period between casting the slabs and post tensioning them

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

- NHDOT presented a paper on this project at the San Antonio PCI conference in 2009 (could not locate)

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

Bridge Number: 011700990014900

Bridge opened to traffic in July 2008

IBRC Funding Summary:

1. FY 2005 Award - \$400,000
2. FY 2006 Award - \$200,000
3. Transfer 2002/2003 IBRC project Mill Street over the Lamprey River in Epping - \$18,522

Funds used - \$618,522.

State DOT Contact: David Scott

Phone: 603-271-2731

E-mail: dscott@dot.state.nh.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** NH Rte. 111 By-Pass over Flatrock Brook and Harris Road**State:** NH **Federal-Aid Project #:** A000033 **Fiscal Year:** 2003 **Funds Awarded:** \$300,000.00**Fund Status:** \$300,000.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Steel in Girder Flanges over the PiersTechnology Description: High Performance Steel in Girder Flanges used to reduce material cost**Project Information****Positive Results:**

- HPS steel was successfully used in flanges of this curved steel girder bridge. After cost studies for this project that showed the economic benefit of using HPS, NHDOT issued a design letter relaxing the deflection criteria to 1/1000 for typical designs so that stress, not deflection controlled designs, allowing them to take advantage of the high strength steel for other bridges. The design memorandum instructed designers to consider HPS for designs.

Negative Results:

None

Lessons Learned:

- Design studies for using HPS on this project led to a change in deflection criteria for all steel designs, benefiting NHDOT in the more economical design, whether or not HPS is used.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

- NHDOT presented design studies at the AASHTO T14 Steel Design Technical Committee in 2003. (could not locate)

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

Bridge Number: 028001610011400

Bridge Opened to traffic in 2008.

State DOT Contact: Mark Richardson

Phone: 603-271-2731

E-mail: Mrichardson@dot.state.nh.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Rollins Road over Main Street and B&M Railroad**State:** NH **Federal-Aid Project #:** 5391002 **Fiscal Year:** 1999-2001 **Funds Awarded:** \$453,000.00**Fund Status:** \$453,000.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Rebars in Deck and High Performance Concrete in Deck Slab and I Beams**Technology Description:** FRP Rebars in Deck and High Performance Concrete in Deck Slab and I Beams used to provide better long term performance**Project Information****Positive Results:**

- Bridge is performing well – the exposed concrete bridge deck is still rated 9 after 9 years of service. NHDOT is routinely using HPC in decks and prestressed girders.

Negative Results:

None- Load test studies by UNH have shown good performance for the deck and the structure; the carbon fiber reinforced deck cost \$200,000 compared to the estimated cost of \$29,500 for a conventional deck.

Lessons Learned:

- Decks can be reinforced with carbon fiber reinforced plastic grids and provide excellent service
- Few decks show no signs of cracking after 9 years of service as this one does. New England bulb tee girders provide durable superstructures.

Internal or External Reports:

"In-Service Performance Monitoring of a CFRP Reinforced HPC Bridge Deck", Final Research Report

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Yes

Plans on Reuse of Technology: Likely, NHDOT is routinely using HPC in deck and prestressed girders

Applicability to other States: Not Reported

Additional Project Notes:

Bridge Number: 022300910008500

Completed and opened to traffic in December 2000.

Bridge also incorporated the following features:

1. The concrete bridge rails on the southerly approach wingwalls were reinforced with stainless steel reinforcement.
2. The concrete bridge rails on the northerly approach wingwalls were reinforced with epoxy coated reinforcement.
3. The concrete rails on the bridge were reinforced with carbon fiber reinforced plastic grids.

Fund Awards Summary:

1. FY 1999 - \$100,000
2. FY 2000 - \$300,000
3. FY 2001- \$53,000

State DOT Contact: David Scott

Phone: 603-271-2731

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1.31. NEW JERSEY

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Edison Bridge-Route U.S. 9 SB over Raritan River**State:** NJ **Federal-Aid Project #:** QX200001190 **Fiscal Year:** 2001 **Funds Awarded:** \$500,000.00**Fund Status:** \$500,000.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Concrete in Deck SlabTechnology Description: High Performance Concrete used in deck slab to reduce dead load acting on piers and construction time**Project Information****Positive Results:**

- The HPC deck slab of this 29 span 4,400 – foot long bridge was one of the Department's first major applications of HPC technology. The use of single course deck reduced the dead loads acting on tall piers, an important consideration in view of seismic demand for designing the substructures. The use of single course also resulted in accelerated deck construction. The HPC was also used in the construction of pier plinths in combination with form liners to substitute for granite stone protection, resulting in big construction cost savings.

Negative Results:

- Relative inexperience by the contractor with HPC and then existing NJDOT Specifications resulted in cracked slab in the first cast four spans that required extensive post – construction sealing of cracks. The contributing element to these defects was also the winter concreting during low ambient temperatures and lack of appropriate curing method.

Lessons Learned:

- The experience gained on this project assisted the Department in refining and improving the HPC Specifications for the subsequent projects, namely very successful HPC application on the adjacent project of Edison Bridge Reconstruction.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

Text that accompanied the winning entry to the ACEC 2004 Engineering Excellence Award.

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

10/30/08: Project has been completed

State DOT Contact: Dave Lambert, P.E.

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E-mail: Dave.lambert@dot.state.nj.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Route 23 over Peckman's Brook**State:** NJ Federal-Aid Project #: BR-7801(107) Fiscal Year: 2006 Funds Awarded: \$200,000.00**Fund Status:** \$200,000.00 Expended **Project Status:** CompleteAssociated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Hybrid (Hillman) Composite Beams (HCB)

Technology Description: The HCB is comprised of three main sub-components that are a shell, compression reinforcement and tension reinforcement. The shell is comprised of a fiber reinforced plastic (FRP) box beam. The compression reinforcement consists of concrete which is pumped into a profiled conduit within the beam shell. The tension reinforcement consists of carbon, glass or steel fibers anchored at the ends of the compression reinforcement. This technology is being used to reduce long-term costs associated with corrosion.

Project InformationPositive Results:

- Light weight which makes it easy to transport and erect beams

Negative Results:

- It appears that making field changes to attach utilities to the beams will be difficult.
- The designer of these proprietary beams is developing inspection procedure for these HCB. It is not clear at this time if beam gets collision damage, what procedure will be used to repair these beams.
- It is difficult to verify presence of any voids in the filled concrete.
- Adhesive and couple of bolts are used to tie adjacent beams together. This may not be as effective as attaching the beams with the diaphragms and tie rods. Long term structural integrity from differential deflection of the beams need to be observed.
- It appears that beam ends can not be fabricated at a skew angle. The use of these beams for skewed bridges needs to be verified with designer.

Lessons Learned:

- These beams consists of components such as fiberglass, concrete etc. which are non-corrosive in nature. Therefore, they may have advantage for use in corrosive environment
- Minimum of 7" thick deck with two layers of rebar mat is recommended to avoid any possible differential deflection, which could create cracks in the deck.
- Long term structural integrity from differential deflection of the beams need to be observed.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

The project is substantially complete at this time

State DOT Contact: Jayant Dalal

E-mail: Jayant.dalal@dot.state.nj.us

Phone: Unknown

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Route I-280/Garden State Parkway Interchange 145**State:** NJ **Federal-Aid Project #:** Not Reported **Fiscal Year:** 2005 **Funds Awarded:** \$400,000.00**Fund Status:** Unknown**Project Status:** Unknown**Associated Project Names**

Alexander Road over Amtrack

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Self Consolidated Concrete in Drilled ShaftsTechnology Description: Self Consolidated Concrete in drilled shafts used to reduce labor costs**Project Information****Positive Results:**

- Four 6' Diameter Drilled Shafts and one (1) Test shaft were constructed without the use of concrete consolidation equipment and Labor. No defects were noted during the crosshole sonic logging testing. Good and consistent cylinders breaks were achieved.

Negative Results:

- Added material cost

Lessons Learned:

- Use of SCC in drilled shaft construction is potentially noteworthy because assuring consolidation of the concrete is a key aspect in drilled shaft construction. The use of SCC for the project's demonstration shaft and four (6' diameter) production shafts was 100% successful. Furthermore, Pier Shaft # 3 had to be tremie poured, because of the substantial quantity of water infiltration into the shaft. Nevertheless, cross-hole Sonic Logging testing indicated no defects and very consistent and sound concrete throughout the entire length of the shafts thereby, eliminating the need for further testing, which saved the Department a substantial amount of money.
- Due to the success of the SCC use in drilled shaft application; SCC use should be considered in the other construction activities where access and consolidation of concrete are an issue.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Due to the success of the SCC use in drilled shaft application; SCC use should be considered in the other construction activities where access and consolidation of concrete are an issue.

Applicability to other States: Not Reported

Additional Project Notes:

10/30/08: Project nearing completion. Drilled shafts were successfully constructed.

State DOT Contact: Unknown

Phone: _____

E-mail: _____

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Scotch Road over I-95**State:** NJ **Federal-Aid Project #:** _____ **Fiscal Year:** 2001 **Funds Awarded:** \$500,000.00**Fund Status:** \$490,000.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Steel in Plate GirdersTechnology Description: High Performance Steel in Plate Girders to reduce material cost**Project Information****Positive Results:**

- During design a cost comparison was made by Arora and Associates, P.C. between using Grade 50W and HPS70W steel for the bridge girders. The results are summarized below:

Grade	\$/LB	# Girders	Spacing	Weight	Cost
50W	1.21	12	9'-0"	1,883 T	\$4,557,000
HPS70W	1.31	10	11'-0"	1,616 T	\$4,233,000
Savings				267 T	\$324,000

Notes:

- Costs are in YEAR 2000 dollars
 - HPS70W was used for primary members and 50W was used for secondary members.
 - The bridge is a two span continuous structure [149.11' (45.450 M) – 149.11' (45.450 M)] with a 15 degree skew. The out-to-out width is 104.33' (31.800 M). The bridge is supported on integral abutments behind MSE walls and a central multi-column pier.
- Another study was carried out by NJDOT in conjunction with Dr. Sophia Hassiotis, Associate Professor, Department of Civil, Environmental and Ocean Engineering, Stevens Institute of Technology, Hoboken, NJ (201-216-8231). The piles, abutments, MSE walls, and girders were instrumented and monitored for several years. The purpose of the study was to measure stresses and deflections in the girders and the integral abutments and to determine if the bridge members behaved differently that expected due to the implementation of the LRFD design code. This was the first bridge in NJ to use HPS70W steel and LRFD design. The following observations were made:
 - Strain data from the girders of the Scotch Road Bridge, built with high performance steel girders and integral abutments, indicate that the girder distribution factor (GDF) formula prescribed in the AASHTO LRFD 1998 Manual is very conservative, overestimating the GDF considerably, especially at the outer girders. Furthermore, it appears that the end conditions used at the abutments, either fix-fix or pin-pin, have little effect on the overall GDF.

Negative Results:

None

Lessons Learned:

- The project has validated the use of several important technologies.
- HPS70W steel proved to be a cost-effective material for the design of longer span bridge girders where clearance is an issue.
- The LRFD bridge design specifications were adopted by the State of NJ with no serious consequences. The LRFD design, with the exception of the pier spread footing, provided reasonable results when compared to designs performed using the AASHTO Standard Specifications. Subsequent to the design and construction of this project, AASHTO revised Section 10 – Foundations, which is now better calibrated with the Standard Specifications.
- Integral abutments behind MSE walls is an economical solution compared to high concrete abutments. The elimination of joints has made this a relatively maintenance free structure.
- During fabrication there was some “bleeding” or staining of the HPS70W girders. The stains are still visible on the fascia girders. NJDOT subsequently revised their policy on painting of the HPS70W and 50W steel girders. In addition to the girder ends being painted, the exterior surfaces of fascia girders are now routinely painted.

Note: The 3rd cycle inspection of the bridge was made in September 2008. The bridge inspector made the following comment, “The overall condition of the structure is excellent.” No defects were noted and no repairs were recommended.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

Arora and Associates, P.C. prepared two presentations on this project. The first is a general project overview and the second focuses on the use of HPS70W steel.

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

10/30/08: Project has been completed.

State DOT Contact: Unknown

Phone: _____

E-mail: _____

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** US 46/NJ 23/I-80 Interchange**State:** NJ **Federal-Aid Project #:** NHS-IBT-7802(148) **Fiscal Year:** 2003 **Funds Awarded:** \$400,000.00**Fund Status:** Not Reported**Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: **Glass Fiber Reinforced Polymer GFRP Reinforcement for Sign Structure Foundations**

Technology Description: Glass fiber-reinforced polymer composite material with a combination of a polymer matrix and a glass reinforcing agent used for sign structure foundations to provide substantial corrosion resistance

Project Information**Positive Results:**

- Reinforcement is light weight and easy to handle

Negative Results:

- Material is expensive not readily available. Long lead time for orders.
- Material not easy to cut. Shear cutting not permitted.
- Bending of bars not allowed in the field. Bent bars are not available(according to Contractor)

Lessons Learned:

- Material's non-corrosive quality is definitely a plus especially in adverse conditions usage. This factor will lead to substantial improvement in serviceability and life of the concrete.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

- The choice of sign structures foundation for testing the GFRP makes it difficult to monitor the performance of the concrete since it is buried.
- The economical life of the foundations in a sign support structure should be comparable to that of the other components forming the structure.

State DOT Contact: Francois Azar

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E-mail: Francois.azar@dot.state.nj.us

1.32. NEW MEXICO

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Dona Ana Interchange Bridge**State:** NM **Federal-Aid Project #:** Not Reported **Fiscal Year:** 2004 **Funds Awarded:** \$400,000.00**Fund Status:** Not Reported**Project Status:** CompleteAssociated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: **High Performance Concrete in P/S Bulb Tees (embedded MUST optical fiber sensor from Smartec Co. that will be used to monitor temperature, short and long term strain, prestressing forces and deflection in high performance concrete bridge girders.)**

Technology Description: Monitoring using optical fiber sensors from Smartec Co. in High Performance Concrete prestressed bulb-tees

Project InformationPositive Results:

- The project provided an excellent demonstration of the installation and performance of the optic fiber sensors in prestressed concrete girders.
- Information was gained on p/s losses in high performance concrete prestressed girders and actual distribution factors for shear and moment were determined.
- Future measuring using the sensors in this bridge is very likely.

Negative Results:

None

Lessons Learned:

- This project demonstrated the applicability of bridge monitoring sensors in an urban setting.

Internal or External Reports:Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

10/30/08: High Performance Concrete in Bulb Tees (Utilize embedded MUST optical fiber sensor from Smartec Co. that will be used to monitor temperature short and long term strain, prestressing forces and deflection in high performance concrete bridge girders.) The project is still ongoing last expenditures were June 2008.

State DOT Contact: Sherman Peterson
E-mail: sherman.peterson@state.nm.us

Phone: 505-827-3293

FHWA IBRC/IBRD Project Summary Report Form

Project Name: I-10 Bridges over University Ave./Main St./RR in Las Cruces NM
(Dona Ana County)

State: NM **Federal-Aid Project #:** Not Reported **Fiscal Year:** 2001 **Funds Awarded:** \$500,000.00
Fund Status: Not Reported **Project Status:** Complete

Associated Project Names

US 70 Roadrunner & Parkway
Bridge

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Concrete

Technology Description: High Performance Concrete used in prestressed concrete beams to reduce material costs

Project InformationPositive Results:

- This project demonstrated the value of instrumentation in obtaining critical data on high performance prestressed concrete beams and, more importantly, yielded invaluable data on the initiation and growth of camber in these members.
- Data was used to determine in place load distribution factors for both shear and moment.
- Information was gained on p/s losses from casting to in-service conditions.

Negative Results:

None

Lessons Learned:

- This project demonstrated the inadequacy of standard PCI factors for camber growth for estimating long-term camber in high-performance concrete beams.
- It greatly increased the Department's confidence level concerning the use of higher strength prestressed concrete beams.
- This has directly led to the routine use of 9,500 psi prestressed concrete beams in New Mexico.

Internal or External Reports:Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Yes

Plans on Reuse of Technology: Yes

Applicability to other States: Not Reported

Additional Project Notes:

10/30/08: IBRC funding moved to I-10 Bridges over University Ave. in Las Cruces NM (Dona Ana County). Scope of project was bridge replacement utilizing built-in strain gauges in the girders to measure strain levels. Bridges completed in 2003.

The US 70 bridges over Roadrunner and Parkway were delayed in construction, therefore another location was chosen to expend this IBRC funding. The original intent of this funding was transferred to this I-10 project also in Las Cruces, NM.

State DOT Contact: Sherman Peterson

Phone: 505-827-3293

E-mail: sherman.peterson@state.nm.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I-25 South Bound at Rowe Interchange**State:** NM **Federal-Aid Project #:** Not Reported **Fiscal Year:** 2005 **Funds Awarded:** \$190,000.00**Fund Status:** Not Reported**Project Status:** CompleteAssociated Project Names

NM 161 over Cebolla Creek

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Concrete in Superstructure

Technology Description: High Performance Concrete used in rapid bridge construction to reduce construction time and congestion

Project InformationPositive Results:

- The replacement bridge was completed in 58 days from time of traffic being moved to a detour to reopening. This was under the contract allotted time of 60 day specified in the contract. Precast superstructure and substructure units were used to greatly speed up the construction schedule.

Negative Results:

- Repaved approach roadway and bridge exhibit minor ride issues.
- Contractor reported a bit more effort in tolerance control was required to assure success.

Lessons Learned:

- In order to accomplish this rapid bridge project, it was imperative that the bridge design engineer stay involved in the project during construction.
- It was a requirement in the contract that all bridge submittals had to receive approval before any traffic could be detoured for demolition. This insured that the contractor fully understood the character of the work and was able to build the bridge in the rapid manner required.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Yes

Plans on Reuse of Technology: Yes

Applicability to other States: Not Reported

Additional Project Notes:

10/30/08: IBRD funding moved to I-25 Rowe Interchange project which is currently under construction. CN is D4017. Scope of project is replacement of I-25 SB Bridge at the Rowe I/C in Rowe NM in District 4. Precast pier caps and prestressed concrete slabs were utilized for rapid bridge construction.

The I-25 FR over Wolf Creek bridge replacement project and the NM 161 over Cebolla Creek bridge replacement project have yet to be funded for replacement, therefore the IBRD funding was combined and moved to the I-25 Rowe Interchange project. The intent to use rapid bridge construction techniques for this funding was incorporated into this project.

State DOT Contact: Ted Barber

Phone: 505-827-5449

E-mail: ted.barber@state.nm.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I-25 Frontage Road over Wolf Creek**State:** NM **Federal-Aid Project #:** Not Reported **Fiscal Year:** 2005 **Funds Awarded:** \$200,000.00**Fund Status:** Not Reported**Project Status:** Complete**Associated Project Names**I-25 South Bound at Rowe
InterchangeProject: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Concrete in Superstructure

Technology Description: High Performance Concrete used in rapid bridge construction to reduce construction time and congestion

Project InformationPositive Results:

- The replacement bridge was completed in 58 days from time of traffic being moved to a detour to reopening. This was under the contract allotted time of 60 day specified in the contract. Precast superstructure and substructure units were used to greatly speed up the construction schedule.

Negative Results:

- Repaved approach roadway and bridge exhibit minor ride issues.
- Contractor reported a bit more effort in tolerance control was required to assure success.

Lessons Learned:

- In order to accomplish this rapid bridge project, it was imperative that the bridge design engineer stay involved in the project during construction.
- It was a requirement in the contract that all bridge submittals had to receive approval before any traffic could be detoured for demolition. This insured that the contractor fully understood the character of the work and was able to build the bridge in the rapid manner required.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

10/30/08: IBRD funding moved to I-25 Rowe Interchange project which is currently under construction. CN is D4017. Scope of project is replacement of I-25 SB Bridge at the Rowe I/C in Rowe NM in District 4. Precast pier caps and prestressed concrete slabs were utilized for rapid bridge construction.

The I-25 FR over Wolf Creek bridge replacement project and the NM 161 over Cebolla Creek bridge replacement project have yet to be funded for replacement, therefore the IBRD funding was combined and moved to the I-25 Rowe Interchange project. The intent to use rapid bridge construction techniques for this funding was incorporated into this project.

State DOT Contact: Ted Barber

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I-40 Tucumcari/E. Interchange**State:** NM **Federal-Aid Project #:** Not Reported **Fiscal Year:** 2006 **Funds Awarded:** \$120,000.00**Fund Status:** \$120,000.00 Expended **Project Status:** Complete**Associated Project Names**I-40 Tucumcari/NM 209
InterchangeProject: Change / Associated

Reallocated from / to:

Technology Implemented: Fiber Reinforced Polymer Deck Strengthening / Remote Structural Health MonitoringTechnology Description: Analysis of state of the art in structural health monitoring (SHM) systems of bridges and on monitoring fiber reinforced polymers (FRP) strengthening system**Project Information****Positive Results:**

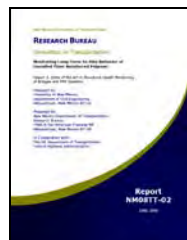
- There were positive results of using fiber reinforcing over a negative moment area to strengthen a bridge over one negative girder joint.
- Measurements did show some strengthening effects.
- Monitoring a bridge from a remote location was demonstrated.
- Much was learned about using strain gages, accelerometers, and thermocouples and remote collection of data using wireless communications and solar power.

Negative Results:

- There were a lot of issues getting communication and electricity supplied to power the measuring devices.
- The limited funding for this effort did not allow for full strengthening of the bridge, only a trial to verify that strengthening would work in one location.
- The project did not fund long term monitoring of the bridge.
- The effects of long term strengthening of fiber reinforcement was not determined.

Lessons Learned:

- Learned quite a bit about how to use solar power and cell phone technology to send data remotely.

Internal or External Reports:

"Monitoring Long-Term In-Situ Behavior of Installed Fiber Reinforced Polymer - Report I: State of the Art in Structural Health Monitoring of Bridges and FRP Systems"

http://nmshtd.state.nm.us/upload/images/Research/NM08TT02_FRP_FINAL_2009.pdf

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Not reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: see negative results and lessons learned

Additional Project Notes:

6/2009: Research Project completed by the University of New Mexico.

10/30/08: NMDOT could not report on the research end of the project. The construction funds were just authorized in 2008.

State DOT Contact: Jimmy CampPhone: 505-827-5532E-mail: jimmy.camp@state.nm.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Mountain Valley Road over I-40**State:** NM **Federal-Aid Project #:** Not Reported **Fiscal Year:** 2002 **Funds Awarded:** \$500,000.00**Fund Status:** \$470,151.22 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: HPC Prestressed Box Girders and Precast Pier Caps for Rapid Bridge Construction

Technology Description: High Performance Concrete and Precast Pier Caps for Rapid Bridge Construction

Project Information**Positive Results:**

- The use of precast prestressed box girders and a precast pier cap helped reduce construction time. The old bridge on NM 217 was closed to traffic, torn down and the new bridge built using precast elements and re-opened to traffic in 32 days.
- User-delay costs were saved versus the conventional 6 to 9 month construction period of building ½ a bridge at a time and detouring traffic. The prestressed box girders were cast using High Performance Concrete ($f'_c = 12,000$ psi compressive strength). The bridge is expected to have a design life of 100 years with little maintenance requirements.

Negative Results:

- The construction unit cost for this bridge was \$120.00 per square foot which was higher than the average bridge construction unit cost of \$98.00 per square foot in New Mexico in 2004.

Lessons Learned:

- IBRC Funding help pay for more than the additional cost of this bridge.
- The use of HPC will provide a long term bridge (100 years) with little maintenance requirements.
- As of 2010, the bridge is in good condition and the additional money spent for the HPC materials and Rapid Construction will turn out to be a good investment by NMDOT.
- More bridges should be built this way to reduce construction time, user delay costs and provide long term structures.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Yes

Plans on Reuse of Technology: Yes

Applicability to other States: Not Reported

Additional Project Notes:

10/30/08: Bridge replacement utilizing HPC prestressed box girders and precast pier caps for rapid bridge construction. New bridge is a 2-span bridge over Interstate 40 and built on the same alignment as the old bridge. Abutments and pier columns for the new bridge were built under the old Bridge prior to closing the old Bridge to traffic. Once new abutments and pier columns were built, the old Bridge was closed down to traffic, precast pier cap was placed on the pier columns and grouted, prestressed box girders were placed, a cast-in-place deck was poured along with approach slabs, and the new bridge was re-opened to traffic in 32 days. Permanent concrete bridge railing was added to the new bridge after it was opened to traffic. New Bridge was completed in 2004.

State DOT Contact: Ray M. Trujillo

Phone: 505-827-5448

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** NM 602 Bridge over Rio Nutria near Zuni NM**State:** NM **Federal-Aid Project #:** Not Reported **Fiscal Year:** 2003 **Funds Awarded:** \$400,000.00**Fund Status:** Not Reported**Project Status:** CompleteAssociated Project Names

I-40 over NM 371 @ Thoreau

Project: Change / Associated

Reallocated from / to: {\$}

Technology Implemented: Precast Superstructure and Substructure Components for Bridge Replacement

Technology Description: Precast superstructure and substructure components for bridge replacement used to reduce construction time

Project InformationPositive Results:

- The project demonstrated the utility of precast bridge elements in a rural setting
- The precast bridge elements were rapidly deployed

Negative Results:

- Project delays were encountered due to drilled shaft foundation issues. These issues were unrelated to the use of precast bridge components.
- Some components, namely pier and abutment caps, were manufactured at the site and lifted into position rather than manufactured at the precast yard and delivered to the site.

Lessons Learned:

- The remoteness of the location illustrated the limitations in the size of components that could be delivered to the site. Careful consideration should be given to this aspect of the work on future projects of this type.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

10/30/08: IBRC funding moved to NM 602 Bridge over Rio Nutria near Zuni NM (McKinleyCounty). Scope of project was bridge replacement utilizing precast superstructure and substructure components. Bridge completed in 2006

State DOT Contact: Sherman Peterson

Phone: 505-827-3293

E-mail: sherman.peterson@state.nm.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** US 64 over the Amargo River in Dulce, NM**State:** NM **Federal-Aid Project #:** Not Reported **Fiscal Year:** 2004 **Funds Awarded:** \$65,000.00**Fund Status:** \$65,000.00 Expended **Project Status:** Complete**Associated Project Names**

Gobernador Crossing

Project: Change / Associated

Reallocated from / to:

Technology Implemented: MMFX Reinforcing Bars in Bridge Deck

Technology Description: Micro-Composite, Multi-Structural Formable (MMFX) low-carbon, chromium bearing, reinforcing steel designed to have high corrosion resistance, strength and ductility

Project InformationPositive Results:

- NMDOT is looking at a long term material performance. The climate in Dulce, NM can range from -25°F in the winter months to 95° F in the summer months. Road salts are used during winter months and it is believed that the MMFX reinforcing bars in the deck will perform well under these conditions.
- Placement of the MMFX reinforcing bars were no different than epoxy coated reinforcing bars, which NMDOT typically uses.
- Although the rebar cost was higher, the overall cost per square foot for this bridge was \$123.00, which matched the average bridge cost in New Mexico that year. Therefore, no real added expense was seen on this bridge.

Negative Results:

- Cost for MMFX reinforcing bars was \$2.70 per pound which was more than the typical epoxy coated reinforcing bars NMDOT uses for bridge decks which averaged \$1.05 per pound.

Lessons Learned:

- NMDOT is now implementing MMFX reinforcing bars in bridges located in higher elevations and severe climate areas.
- NMDOT feels this strategy will provide long term bridge decks at reasonable cost for bridges in severe climate areas.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Yes

Plans on Reuse of Technology: Yes

Applicability to other States: Not Reported

Additional Project Notes:

10/30/08: IBRC funding moved to US 64 Bridge over Amargo River in Dulce NM (Rio Arriba County). CN is G2765. Scope of project was bridge replacement utilizing uncoated corrosion resistant reinforcing bars in the concrete deck (MMFX steel reinforcement). Bridge was completed in 2007.

The use of MMFX steel was demonstrated in the original proposed project which was located on US-64 over Gobernador Arroyo. However, in a slip up in the project funding request, the IBRC funding was not used to help fund the project at this location. Therefore, the funding was used on another project not too far from the original proposed location on another project.

State DOT Contact: Ray M. Trujillo

Phone: 505-827-5448

E-mail: raymond.trujillo@state.nm.us

1.33. NEW YORK

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Annandale Rd over Staten Island Rapid Transit**State:** NY **Federal-Aid Project #:** _____ **Fiscal Year:** 2003 **Funds Awarded:** \$360,000.00**Fund Status:** \$165,506.00 Expended **Project Status:** Initiated**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Stainless Clad Reinforcing Steel, with 4-yr Corrosion Monitoring Program

Technology Description: Stainless Clad Reinforcing Steel, with 4-yr Corrosion Monitoring Program

Project Information**Positive Results:**

- The bridge construction started in 2008. In October 2009 during Stage-I construction, we installed around 75 corrosion monitoring sensors in the first half of the bridge deck. All sensors are functioning well (except for two vibrating wire strain gauge) and giving intended data. The first half of the deck had epoxy coated rebars. We are planning to install sensors in the second half of the deck, Stage-II, containing stainless clad rebars.

Negative Results:

None

Lessons Learned:

- Field issues, such as power supply for data loggers and telephone lines to remotely collect data, seem to take lot more hours and efforts than actual technology on corrosion monitoring system.
- During first pour of concrete, we had total success in making sure that all sensors were operational. Two vibrating wire strain gauges stopped working later. We have many other vibrating wire strain gauges to supply data.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

Agrawal, A.K., Yi, Z., Alampalli, S., Ettouney, M., King, L., Hui, K. and Patel, M. (2009), "Remote Corrosion Monitoring Systems for Highway Bridges", Practice Periodical on Structural Design and Construction, Vol. 14, No. 4, November 2009, pp. 152-158, (doi 10.1061/(ASCE)1084-0680(2009)14:4(152)) (Not Available)

Additional Comments:

Technology used on Other Projects: Yes

Plans on Reuse of Technology: Yes

Applicability to other States: Not Reported

Additional Project Notes:

Bridge construction started in 2008. We have installed corrosion monitoring system in first half of the deck (Stage -I) containing epoxy-coated rebars.

We plan to install corrosion monitoring system in second half of the deck containing stainless steel clad rebars in June 2010. The construction of the bridge is expected to finish by the end of 2010.

We plan to monitor and collect corrosion data at least 4 years after the completion of construction. However, we plan to deploy an automated data collection system that will collect data indefinitely. A project report describing locations of sensors and all other details is expected to be submitted by the end of 2010.

This is a unique study which is expected to make significant contributions to the research on corrosion monitoring of bridges and corrosion resistance of stainless steel clad rebars.

State DOT Contact: Unknown

Phone: _____

E-mail: _____

FHWA IBRC/IBRD Project Summary Report Form

Project Name: I95 over Midland Ave
State: NY **Federal-Aid Project #:** _____ **Fiscal Year:** 1999 **Funds Awarded:** Unknown
Fund Status: \$600,000.00 Expended **Project Status:** Complete

Associated Project Names

TANE 98-87B

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Galvanized Reinforcing Steel, HPC, HPS

Technology Description: Testing of three different materials: Galvanized Reinforcing Steel, HPC, and HPS were used for different aspects of bridge construction

Project InformationPositive Results:

- All materials listed above were used successfully on this project.
- Materials were delivered on time, fabricated and installed without incident, and have been performing very well since installation.

Negative Results:

None

Lessons Learned:

- These technologies are now used as standard materials on Thruway Authority projects.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Yes

Plans on Reuse of Technology: Yes

Applicability to other States: Unknown

Additional Project Notes:

None

State DOT Contact: Paul E. Provost, P.E.

Phone: 518-436-3041

E-mail: paul_provost@ thruway.state.ny.us

FHWA IBRC/IBRD Project Summary Report Form

Project Name: NYS Thruway over Gravel Rd, Black Brook Rd, Birdsey Rd, Nine Foot Rd, & Grange Hall Rd
State: NY **Federal-Aid Project #:** _____ **Fiscal Year:** 1999 **Funds Awarded:** Unknown
Fund Status: \$93,000.00 Expended **Project Status:** Complete

Associated Project Names

TAS 98-8B

Project: Change / Associated

Reallocated from / to:

Technology Implemented: HPS, HPC, Galvanized Bar Reinforcement

Technology Description: Testing of three different materials: Galvanized Reinforcing Steel, HPC, and HPS on project implementation

Project InformationPositive Results:

- All materials listed above were used successfully on this project.
- Materials were delivered on time, fabricated and installed without incident, and have been performing very well since installation.

Negative Results:

None

Lessons Learned:

- These technologies are now used as standard materials on Thruway Authority projects.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Yes

Plans on Reuse of Technology: Yes

Applicability to other States: Not Reported

Additional Project Notes:

None

State DOT Contact: Paul E. Provost, P.E.Phone: 518-436-3041E-mail: paul_provost@ thruway.state.ny.us

1.34. NORTH CAROLINA

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Bridge 117 on SR 1118 over North Fork of New River (B-4012)**State:** NC **Federal-Aid Project #:** B-4280 **Fiscal Year:** 2006 **Funds Awarded:** \$150,000.00**Fund Status:** \$150,00 Expended**Project Status:** Initiated**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Micro-piles for lateral force resistance for shallow rock depths

Technology Description: Use of Micro-piles to support pier and abutment footings on shallow rock depth (17" below pier's footing) was investigated. Five lateral load tests were conducted on micro-piles to demonstrate the impact of casing joints and rock socket embedment on lateral behavior.

Project Information**Positive Results:**

- Rock embedment of 0.66m, 1.5m, and 3.0m carried lateral loads above 80kN, well above typical lateral design lateral loads.
-

Negative Results:

- none

Lessons Learned:**Barrier to implementation of Technology:** none

- 0.33m appears to be insufficient casing embedment to resist lateral loads on micro-piles. This may be as much for the reason that there is not enough rock penetration to guarantee a good rock socket as it was the behavior of the short piles
- Embedding vibrating wire rebar strain meters in the grout effectively captured the bending moment profile for the micro-piles when compared to the preliminary numerical models
- Strain gage measurements from Test I showed that the bending moment was attenuated at the rock socket

Internal or External Reports:**Publications, Presentations, or, Construction Studies:**

"Lateral Load Testing Micropiles to Evaluate the Impact of Threaded Joints and Casing Embedment on Short Micropiles in Shallow Rock" TRB, 2011

Additional Comments:

Technology used on Other Projects: FRP Beams not used on other Ohio projects; FRP Decks have been used

Plans on Reuse of Technology: yes, but pending final report of results

Applicability to other States: micro-piles are widely used across many states

10/30/08: Project B-4280 is to be advertized for construction on 7/15/2008.

\$3.3M Bridge replacement project. 2-span (50'-50'), 21" deep voided slab superstructure. Construction and initial performance of Micropile system will be documented.

State DOT Contact: Edward B. Moore
E-mail: Edward.moore@dot.state.oh.us

Phone: 513-933-6587

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Bridge 16 on State Route 1470 over Cartoogechaye Creek, TIP B-3485**State:** NC **Federal-Aid Project #:** 2005-22 FHWA/
NC/ 2006-35 **Fiscal Year:** 2003 **Funds Awarded:** \$230,000.00**Fund Status:** \$203,893.00 Expended**Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Bridge Deck reinforced with GFRP bars

Technology Description: Durability testing on a bridge deck reinforced with Glass Fiber-Reinforced Polymer composite material used to lower transportation costs and resist corrosion

Project InformationPositive Results:

- Densities ranging between 1/6th - 1/4th (i.e. 80 - 130 pcf) that of steel rebars, they offer a reduction in weight that leads to lowered transportation costs and easier handling on the project site.
- Resistance to corrosion
- Higher tensile strengths (30% - 50% higher than steel) FRP rebars are electrically and thermally nonconductive

Negative Results:

None

Lessons Learned:

- In future GFRP rebar applications the reinforcement ration could be further reduced, making composite reinforcements a more economical alternative from the structural/construction point of view.
- GFRP rebars offer a good alternative to steel or Epoxy Coated Rebars (ECR)
- From the findings of this research undertaking, it is recommended that the GFRP rebar provided by Pultrall and Hughes Bros. be used.

Internal or External Reports:

None

Publications, Presentations, or Construction Studies:

"Analysis and Testing of a Bridge Deck Reinforced With GFRP Rebars"



"ANALYSIS AND TESTING OF A BRIDGE DECK REINFORCED WITH GFRP REBARS"

Additional Comments:

Technology used on Other Projects: Used on various projects, see link below

Plans on Reuse of Technology: Unknown

Applicability to other States: Unknown

Additional Project Notes:

10/30/08: Project is completed. Report is printed and about to be released online.

NCDOT Project 2005-22 FHWA/NC/2006-35 April 2007 "Analysis and Testing of a Bridge Deck Reinforced with GFRP Rebars"

<https://apps.dot.state.nc.us/Projects/Research/SearchResult.aspx?Y=0&PID=0&CID=84&SCID=0&RID=0&K=&FHWA=>

State DOT Contact: Unknown

Phone: _____

E-mail: _____

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Bridge 80 on SR 1214 over Long Creek (TIP: B-3700)**State:** NC **Federal-Aid Project #:** 2006-16 FHWA/
NC/ 2006-18 **Fiscal Year:** 2004 **Funds Awarded:** \$400,000.00**Fund Status:** Not Reported**Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: HPC Deck Girder BridgeTechnology Description: High Performance Concrete deck girder system, comprising of a modified AASHTO Type III girder with an additional flange (deck) section used to reduce material cost**Project Information****Positive Results:**

- The construction of the bridge was completed without any major problems.
- The use of Larsa 2000™ as an analysis program proved to be very precise when considering the effects (prestress, dead, and live loading) on the deck girders and analyzing multiple moving loads with multiple lane paths at any point along the bridge length. The accuracy of the program, when compared to the NCDOT design calculations, was very comparable. The construction stage option allowed a timely and accurate assessment of deck girder camber and stress values at different construction steps.
- The ANSYS™ FE model resulted in plate stress values that were comparable to the actual load test results.

Negative Results:

- Limitations using Larsa 2000™ were encountered when the steel plate connectors were considered. The use of a more sophisticated FE program was required to analyze the smaller bridge components with more precision.

Lessons Learned:

- The diaphragm holes proved to be too large for the collapsible washers used for the connections. A decrease in hole diameter could be a solution to this problem. Another solution could be the use of concrete diaphragms.
- Although the deck girders were installed with an acceptable tolerance with respect to vertical tolerance, in order to eliminate the need for the asphalt topping in future projects, an extra inch of concrete could be added on the top of the deck girders during fabrication, which could be ground off prior to the opening of the bridge. This would cut down on construction time, which would in turn save money
- The flange connection analysis shows that the PCI handbook 6th Edition does not accurately assess all types of connections. Therefore, either different equations or analysis need to be derived, or additional experimental investigations performed.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

"Evaluation of Design and Construction of HPC Deck Girder Bridge in Stanly County, North Carolina"

Additional Comments:

Technology used on Other Projects: Unknown

Plans on Reuse of Technology: Unknown

Applicability to other States: Unknown

Additional Project Notes:

10/30/08: Project is completed and research report available online:

<https://apps.dot.state.nc.us/Projects/Research/ProjectInfo.aspx?ID=1582>

NCDOT Project 2006-16 FHWA/NC/2006-18 "Evaluation of Design and Construction of HPC Deck Girder Bridge in Stanly Co., NC.

State DOT Contact: Unknown

Phone: _____

E-mail: _____

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Fast Clad Urethane Paint System on Three Bridges over US 64**State:** NC **Federal-Aid Project #:** _____ **Fiscal Year:** 2003 **Funds Awarded:** \$400,000.00**Fund Status:** Not Reported**Project Status:** CompleteAssociated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Evaluation of Sherwin Williams Fast Clad Urethane Paint System on Three Bridges**Technology Description:** Sherwin-Williams two-coat paint system consisting of a Corothane I GalvaPac zinc primer and Fast Clad Urethane topcoat used to reduce labor costs by applying two-coats of paint compared to the traditional three-coat systemProject InformationPositive Results:

- Sherwin-Williams uses a two-coat Corothane 1/Fast Clad Urethane system which saves time and labor over NCDOT's standard three-coat inorganic zinc/waterborne acrylic system

Negative Results:

- By eliminating an intermediate coat that could otherwise provide a remedial safeguard against poor painting practices, the Sherwin-Williams Corothane 1/Fast Clad Urethane system is deprived of the redundancy safeguard
- A year after the Corothane1/Fast Clad Urethane system had been applied, all three bridges showed visible rust spots—particularly at edges, corners, bolts, and bottom faces of flanges—and varying degrees of paint delamination. Delamination was especially severe on the last bridge (Bridge 910190) on which the Corothane 1/Fast Clad Urethane system was applied. As evident on this project, this could be ascribed to the poor workmanship of the painting crew and the design attributes of the Corothane 1/Fast Clad Urethane system that are less tolerant of poor workmanship and painting mistakes
- The unsatisfactory outcome of the field application of the Corothane 1/Fast Clad Urethane system on North Carolina bridges stands in sharp contrast to the favorable laboratory test results of an FHWA study and the encouraging preliminary field experience of the Connecticut Department of Transportation

Lessons Learned:

- Since the application process is less forgiving when applying the Sherwin-Williams two-coat system, have more stringent contract requirements used on future work
- Ensure that the painting crew is properly trained and the products are properly applied

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

"Evaluation of Corothane 1/ Fast Clad Urethane Paint System Three Bridges Over US-64, Wake County, North Carolina" <https://apps.dot.state.nc.us/Projects/Research/ProjectInfo.aspx?ID=1805>

Additional Comments:

Technology used on Other Projects: Used only on the 3 bridges outlined in report

Plans on Reuse of Technology: Unknown

Applicability to other States: Texas, Massachusetts, Connecticut and Virginia have used the Sherwin-Williams two-coat system

Additional Project Notes:

10/30/08: Project is completed and research report 2006-20 is published.

Fast Clad Urethane Paint System for Three Bridges Over US-64 in Wake County, North Carolina "NBI and NCDOT Bridge Numbers:

000000000183190 (NCDOT Bridge No. 910190)

000000000183192 (NCDOT Bridge No. 910192)

000000000183202 (NCDOT Bridge No. 910202)

State DOT Contact: Unknown

Phone: _____

E-mail: _____

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Bridge 00890022 on New Salon Rd. over Mall Creek Rd.**State:** NC **Federal-Aid Project #:** _____ **Fiscal Year:** 2001 **Funds Awarded:** \$375,000.00**Fund Status:** Not Reported**Project Status:** Complete**Associated Project Names**

NBIS bridge 00630085, State

Route (SR) 1814 over Little Lick Project: Change / Associated

Reallocated from / to:

Creek

Technology Implemented: FRP Bridge Deck (Martin Marrietta's DuraSpan System)

Technology Description: Fiber-Reinforced Polymer composite material with a combination of a polymer matrix and a glass reinforcing agent used for deck design

Project Information**Positive Results:**

- The results confirmed full composite action between the steel girders and the GFRP deck
- Significant capacity reserves were found in every bridge, well beyond the analytical predictions
- The recorded strain levels on the GFRP deck were significantly lower than the allowable values recommended by the manufacturer

Negative Results:

None

Lessons Learned:

None

Internal or External Reports:

None

Publications, Presentations, or Construction Studies:

"Evaluation of Bridge Analysis Vis-à-vis Performance"

<https://apps.dot.state.nc.us/Projects/Research/ProjectInfo.aspx?ID=641>

Additional Comments:

Technology used on Other Projects: First time technology was used in North Carolina

Plans on Reuse of Technology: Unknown

Applicability to other States: Unknown

Additional Project Notes:

10/30/08: Project 2002-12 is completed; research report is filed and available in electronic format.

State DOT Contact: Unknown

Phone: _____

E-mail: _____

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** State Route 1178 over I-95, Town of Four Oaks, TIP: I-2704**State:** NC **Federal-Aid Project #:** 2004-27 FHWA/
NC/ 2006-31 **Fiscal Year:** 2002 **Funds Awarded:** \$385,000.00**Fund Status:** Not Reported**Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: MMFX reinforced concrete steel

Technology Description: Micro-Composite, Multi-Structural Formable (MMFX) low-carbon, chromium bearing, reinforcing steel designed to have high corrosion resistance, strength and ductility

Project Information**Positive Results:**

- The corrosion test results confirmed that that MMFX steel has a much lower corrosion rate compared to conventional Grade 60 steel. In light of this comparison, it is evident that MMFX can be used without any additional cost in comparison to conventional Grade 60 steel considering the advantage of enhanced corrosion resistance, which would result in longer service life of a bridge and lower repair costs
- Amount of MMFX steel can be reduced by 33% than that required for Grade 60 steel
- The ultimate load-carrying capacities of all three bridge decks investigated in this study were at least ten times the service load specified by the AASHTO Design Specifications (2004)
- The two bridge decks reinforced with MMFX steel exhibited the same deflections at service load as the deck reinforced with Grade 60 steel

Negative Results:

- The typical market cost of conventional Grade 60 steel is in the range of \$0.35-0.40/lb and the cost of MMFX steel is \$0.60/lb

Lessons Learned:

- Behavior of bonded bent MMFX bars is similar to straight bars including the linear and the non-linear behavior. Unbonded bent MMFX bars have similar behavior up to strain of 1.5 percent; however, the ultimate strength and strain at failure are reduced by 6 and 70, respectively. This finding is important for the use of MMFX steel as lifting hooks. The bonded bent MMFX bars developed the same strength and strain at ultimate to those of straight bars
- Substituting MMFX steel directly for Grade 60 steel in a design, the case for the Johnston County Bridge, is an overly-conservative approach
- MMFX steel can be used as the main flexural reinforcement for cast-in-place concrete bridge decks at a reinforcement ratio corresponding to 33% less than that required for Grade 60 steel. Therefore, a design of reinforced concrete bridge decks using MMFX steel may utilize an equivalent yield stress of 90 ksi for the MMFX steel bars
- MMFX steel has a much lower corrosion rate compared to conventional Grade 60 steel. Therefore, the use of MMFX steel could increase the service life of concrete bridges and lower repair costs.
- Since the proportional limit of MMFX steel is 100 ksi (689 MPa), the potential exists to further reduce reinforcement ratios by increasing allowable design stresses to 100 ksi (689 MPa) or more. Further studies would be necessary to investigate this possibility
- MMFX steel bars can be bent up to 90 degrees without reducing their ultimate strength

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

"EVALUATION OF MMFX STEEL FOR NCDOT CONCRETE BRIDGES"

<https://apps.dot.state.nc.us/Projects/Research/ProjectInfo.aspx?ID=1501>

Additional Comments:

Technology used on Other Projects: Unknown

Plans on Reuse of Technology: Future use being considered

Applicability to other States: Technology has been used in other states

Additional Project Notes:

10/30/08: Bridge project is completed and its research report is published.

NCDOT Project 2004-27 FHWA/NC/2006-31, December 2005. "Evaluation of MMFX Steel for NCDOT Concrete Bridges"

<https://apps.dot.state.nc.us/Projects/Research/ProjectInfo.aspx?ID=1501>

State DOT Contact: Unknown

Phone: _____

E-mail: _____

1.35. NORTH DAKOTA

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Cass County 4 locations 17th Ave. & 13th Ave.**State:** ND **Federal-Aid Project #:** _____ **Fiscal Year:** 2002 **Funds Awarded:** \$147,938.00**Fund Status:** \$147,938.00 Expended **Project Status:** Complete**Associated Project Names**

UND 0301

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance ConcreteTechnology Description: High Performance Concrete bridge deck system used to reduce material cost**Project Information****Positive Results:**

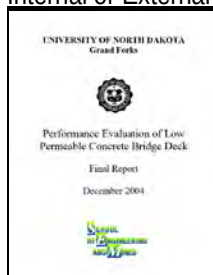
- The 38% fly ash replacement mix met the target design criteria for this project (i.e., slump, air content, and 28-day compressive strength). The two properties that had the greatest influence on the recommendation of optimal replacement percentage were freeze/thaw durability and rapid chloride ion permeability.
- The 35% GGBFS replacement mix also met the target design criteria for this project.

Negative Results:

- One problem was discovered. The C1 thermocouple on the 9th Avenue Bridge was apparently damaged during construction and did not record temperatures during the initial curing of the concrete. However since redundant thermocouples were installed at all data collection points, it was possible to activate the duplicate thermocouple for future data collection.

Lessons Learned:

- The two properties that had the greatest influence on the recommendation of optimal replacement percentage were freeze/thaw durability and rapid chloride ion permeability.

Internal or External Reports:

"Performance Evaluation of Low Permeable Concrete Bridge Deck"

http://www.dot.nd.gov/divisions/materials/research_project/uND0301final.pdf**Publications, Presentations, or, Construction Studies:**

None

Additional Comments:

Technology used on Other Projects: Unknown

Plans on Reuse of Technology: Unknown

Applicability to other States: Unknown

Additional Project Notes:

10/30/08: Complete. Project closed out.

Project records no longer at Division Office as sent to Records Center. Assumed that all of IBRC funds expended.

State DOT Contact: Unknown

Phone: _____

E-mail: _____

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I-29 over 17th Ave. S, Texas Turn & 9th Ave. S (3 Bridges)**State:** ND **Federal-Aid Project #:** _____ **Fiscal Year:** 2003 **Funds Awarded:** \$119,171.00**Fund Status:** \$119,171.00 Expended **Project Status:** Complete**Associated Project Names**

UND 0302

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Concrete

Technology Description: Monitoring of corrosion in High Performance Concrete bridge deck system

Project Information**Positive Results:**

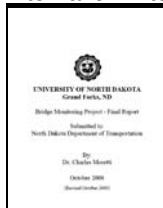
- Based on some of the results obtained, it appears that the concrete that contained the mineral admixtures (flyash, granulated blast furnace slag) did perform better than the plain concrete. The chloride data in particular indicates that after the first year of the project, the plain concrete consistently contained the highest chloride levels at 0.5, 3 and 5 inches of depth into the deck. The Icorr corrosion measurements indicated a similar trend, however the differences in the Icorr values were fairly small and the values clearly showed that all three decks were in a passive condition at all locations where the measurements were collected. The temperature data collected indicated that all the bridges experienced similar numbers of freeze/thaw cycles during the project, so it can be concluded that freeze/thaw effects were not a major variable in terms of the overall performance of the three bridge decks.

Negative Results:

None

Lessons Learned:

None

Internal or External Reports:

"Bridge Monitoring Project - Final Report"

http://www.dot.nd.gov/divisions/materials/research_project/uND0302final.pdf**Publications, Presentations, or, Construction Studies:**

None

Additional Comments:

Technology used on Other Projects: Unknown

Plans on Reuse of Technology: Unknown

Applicability to other States: Unknown

Additional Project Notes:

The Final Report is complete and in the process of being available on the NDDOT web page.

10/30/08: Complete. Project closed out.

Project records are no longer at Division Office as sent to Records Center. Assumed that all IBRC funds were expended.

State DOT Contact: Unknown

Phone: _____

E-mail: _____

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I-94 from Oakes INT E to E Valley City**State:** ND **Federal-Aid Project #:** _____ **Fiscal Year:** 2000 **Funds Awarded:** \$42,466.00**Fund Status:** \$42,466.00 Expended **Project Status:** Complete**Associated Project Names**

ND-01-01

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Stainless Steel Clad Reinforcing Bars**Technology Description:** The effects of using carbon steel rebar clad with stainless steel as a cost effective method for combating the effects of chloride intrusion**Project Information****Positive Results:**

None

Negative Results:

- Bent bars supplied are not fabricated to dimensions detailed in the project plans. The "k" bar legs are too long. This may require cutting of the bars and subsequent treatment such as capping or welding. Depending on the locations of the bars, this may result in an increase in contractor labor.
- Damage to seams produces an opening in the stainless steel cladding and entry point for moisture and corrosive materials to come into contact with the carbon steel bar.
- It was also noted that the stainless steel clad rebar was shipped on flat beds and was strapped on by chains. Stelax Limited had specified that chains were not to be used by the hauling companies. As a result of the chains, some rust residue had formed on the rebar.

Lessons Learned:

- Comments From Engineer in the Field: 1. If use of this material is continued, more knowledge should be obtained to accept the material in the field and look for irregularities in the coating. 2. The supplier should do a better job of bending the bars to the correct dimensions.

Internal or External Reports:

"Use of Stainless Steel Alternative for a Corrosion Resistance Structure"

http://www.dot.nd.gov/divisions/materials/research_project/nd0101abstract.pdf**Publications, Presentations, or, Construction Studies:**

None

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

10/30/08: Complete. Project closed out.

Project records no longer at Division Office as sent to Records Center. Assumed that all of IBRC funds expended.

State DOT Contact: Unknown

Phone: _____

E-mail: _____

1.36. OHIO

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Bridge No. SCI-23-0166, US Rte. No. 23, City of Portsmouth**State:** OH **Federal-Aid Project #:** (unknown) **Fiscal Year:** 1999 **Funds Awarded:** (unknown)**Fund Status:** Expended**Project Status:** Completed**Associated Project Names**

Route 79 – 0955

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Post-stressing Retrofit

Technology Description: Carbon fiber rods were affixed to a four span steel girder, concrete deck bridge as a retrofit in order to improved live load response of both stresses and displacements. Rods were affixed to the bridge and post tensioned to induce an axial compressive force, and a continuous negative moment due to the offset of the strands from the center of gravity.

Project Information**Positive Results:**

None.

Negative Results:

No actual improvement in bridge performance was detected after the carbon fiber rods were installed. The slight difference between the before and after deflections and strains was less than the variability that should be expected in the readings

Lessons Learned:

Barrier to implementation of Technology: Application of technology is ineffective.

The technology did not perform as intended. In some locations the maximum stresses increased although analysis indicated they would go down. It is possible that the gripping systems at the ends of the rods may not be able to withstand the required tensioning required to have the necessary effect. Future considerations include using more rods with higher tensioning to better distribute the force

Internal or External Reports:

" *Evaluation of Composite Post-Tensioning Systems on SCI-23-0096, Scioto County* "

<http://www.dot.state.oh.us/Divisions/TransSysDev/Research/reportsandplans/Reports/2003/Structures/14723-FR.pdf>

**Publications, Presentations, or, Construction Studies:**

None

Additional Comments:

Technology used on Other Projects: Yes, see associated Project Route 79 – 0955

Plans on Reuse of Technology: none – technology did not work.

Applicability to other States: Not Reported

State DOT Contact: Richard A Pratt, PE
E-mail: Richard.pratt@alaska.gov

Phone: (907) 465-8890

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Casebeer-Miller Rd over tributary of South Fork Gordon Creek**State:** OH **Federal-Aid Project #:** E070(331) **Fiscal Year:** 2005 **Funds Awarded:** \$100,000.00**Fund Status:** \$225,348.64 Expended **Project Status:** Completed**Associated Project Names**

Russell Road Bridge

Project: Change / AssociatedReallocated from / to: \$241,000

Walker Bridge, Irish Run

Project: Change / AssociatedReallocated from / to: \$74,500**Technology Implemented:** FRP Beam on Geosynthetic Reinforced Soil abutments

Technology Description: FRP Box sections were used and consisting of 25ft long by 4ft wide by 3/8" thick FRP plate epoxied to the bottom of 3 FRP I-beams (one on each edge of the plate and one in the middle) a deck was then cast on top of the I-beam sections and a foam-filler that was placed between the I-sections. Eight of the sections were assembled to create the 32ft wide deck. The deck is 10" CIP lightweight-concrete with FRP reinforcement. The design intended to place the FRP almost exclusively in tension and the concrete exclusively in compression.

Project Information**Positive Results:**

Project worked very well. Demonstrated good fit between FRP beams and GRS abutments. This type of bridge allows a bridge of up to 50' span to be built with equipment no larger than a small excavator in a very short time (30 days).

Long term monitoring showed that deflections were consistent from year to year, nor was there a discernable shift in the neutral axis over time.

Negative Results:

FRP Beam is not competitive with conventional construction.

Lessons Learned:

Barrier to implementation of Technology: This project competitively bid the "off the shelf" FRP components which were available from a number of sources. The project demonstrated that FRP cannot compete with reinforced or prestressed concrete, even when life cycle costs are considered.

The materials were easy to work with and the bridge was able to be built with small equipment.

The neutral axis of the system is higher than calculated by theory, likely a result of higher than specified concrete strengths. The eight beams acted monolithically as a result of the deck rather than as individual sections, and truck loads are more distributed over 4 beams rather than the 3 beams used for the design (leading to conservatism). Adjusting for 4-beam distribution lead to very good agreement between measured and predicted deflections.

Geosynthetic abutments is a good match for the FRP structure

Daily temperature fluctuations result in significantly larger (for warmer) strains, although the maximum strains and stresses are still small.

With no design parameters in the LRFD specification (1996) a DL factor of 2 and a LL factor of 5 were used. The deflection criteria, however, dictated a section very similar to the load criteria.

Internal or External Reports:

Design and Monitoring of Casebeer Miller Road Bridge

Fiber Reinforced Plastic Superstructure on Geosynthetic Reinforced Soil Abutments by Warren Schlatter, P.E., P.S.,
Defiance County Engineer

TRUCK LOAD TESTING AND LONG-TERM RESPONSE MONITORING OF CASEBEER MILLER BRIDGE by Bahram M.
Shahrooz, PhD, PE, FACI – Univ of Cincinnati

Publications, Presentations, or, Construction Studies:

<http://www.defiance-county.com/engineer/GRS.htm>

Additional Comments:

Technology used on Other Projects: Similar to other projects studying FRP for structural use in Ohio. Not yet implemented for statewide use.

Plans on Reuse of Technology: Yes, should the costs become competitive and long term performance is maintained.

Applicability to other States: Lessons learned are applicable to any state wishing to use FRP and Geosynthetic abutments.

It is recommended that during future inspections special attention be made to the bottom plates for signs of distress: bearing failure near the bolts; separation between modules; separation of plate from the beams. It is also suggested to map the cracking in the deck as an indirect means to monitor composite action.

State # PID 81740, E070(331). Funds transferred from Russell Rd. Bridge over Mill Creek (\$74,500). Funds transferred from Walker Bridge, Irish Run over Leith Run.

Warren Schlatter has been very active in GRS abutments and IBRC/IBRD.

He has additional information posted on the Defiance County Engineer's web site:

<http://www.defiance-county.com/engineer/GRS.htm>

State DOT Contact: Warren Schlatter
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Phone: 614-466-4050

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Eight Mile Road over Eight Mile Creek**State:** OH **Federal-Aid Project #:** E060(168) **Fiscal Year:** 2004 **Funds Awarded:** \$800,000.00**Fund Status:** \$695,602.16 Expended **Project Status:** Initiated**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Beams, FRP DeckTechnology Description: Fiber reinforced polymer beams were constructed with the fiber reinforced polymer deck.
All FRP was prefabricated and assembled in the field.**Project Information****Positive Results:**

- Prefabricated FRP panels were installed in one day.
- Testing of FRP panels confirms high strength (load test) and able to handle long-term loading (fatigue testing) Fatigue Testing at 2,000,000 cycles.
- Lightweight panels, 5500 pounds, easy to install and UV protection.
- Expected 100 year plus service life due to technology used.

Negative Results:

- High Cost: Cost higher than traditional until more widely used.
- Strap issues: time to drill holes and buckling of straps due to temperature change

Lessons Learned:

Barrier to implementation of Technology: Cost, wearing surface cracking along panel joints

- Laminate or plate longitudinal joints to prevent wearing surface cracking.
- Eliminate straps or slot holes to prevent strap buckling.
- Increase size of leveling screws to 7/8" diameter.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

OTEC 2008 Presentation - "Eight Mile Road Bridge Composite Superstructure" (unavailable)

Additional Comments:

Technology used on Other Projects: FRP Beams not used on other Ohio projects; FRP Decks have been used

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

At time of report project is still ongoing - \$104,397.84 left to use for the future in-place testing by University described above. Further reports will be made once the project and monitoring has been completed.

State DOT Contact: Edward B. Moore
E-mail: Edward.moore@dot.state.oh.us

Phone: 513-933-6587

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** FA-114-01.64 over stream**State:** OH **Federal-Aid Project #:** E060(865) **Fiscal Year:** 2005 **Funds Awarded:** \$155,500.00**Fund Status:** \$107,158.87 Expended**Project Status:** Initiated**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Deck

Technology Description: Fiber reinforced polymer deck panels are prefabricated for lightweight, accelerated deck construction.

Project Information**Positive Results:**

The FRP Panels were installed quickly. The polymer concrete wearing surface acted compositely with the deck panels, shifting the location of the neutral axes causing the deflection to be less than anticipated. The first year evaluation of the bridge revealed NO delamination of the wearing surface with the structure looking like the day it was opened to traffic. The bridge load rating calculated to be well over the required HS20 rating, since the design was based on deflection not strength.

Negative Results:

We selected to drill holes for the guardrail attachments in the field since we were using the existing abutments which were not parallel. The drilling procedure took longer than we had hoped it would. The fascia panels did not get painted, resulting in the side of fascia panels being discolored. Rain water was leaking through the deck at the lifting holes.

Lessons Learned:**Barrier to implementation of Technology:**

Holes for the guardrail attachments should be drilled the shop prior to shipping. This will allow the bridge to be open to traffic sooner taking advantage of the speed of installation. To eliminate the need for painting, the color pigment should be added to the resin. Until standard specifications have been written, a spot check of the fabrication process should be done to insure the quality of the panel construction.

Internal or External Reports:

None at this time.

Publications, Presentations, or, Construction Studies:

Masters thesis by Edward T. Baznik, University of Toledo, "Huron County Ohio Innovative Bridge Construction" (not available)

Additional Comments:

Technology used on Other Projects: FRP Decks have been used

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

The next major milestone is the two-year field evaluation the structure. During this field evaluation the bridge will be load tested again and strain and deflection data will be recorded for comparison with the initial load test.

If the results show no or only minimal changes over the two year evaluation period, we may request a time extension provided funds are available from the original grant. The time extension would be to complete another field evaluation at the end of a five-year period. We expect that no changes in the load capacity of the structure will have occurred in the two year post construction period.

State DOT Contact: Edward B. Moore
E-mail: Edward.moore@dot.state.oh.us

Phone: 513-933-6587

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** FAI-33-1309 Delmont Road over US33**State:** OH **Federal-Aid Project #:** G010(105) **Fiscal Year:** 2001 **Funds Awarded:** \$377,574.00**Fund Status:** Expended**Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Steel (HPS) in Plate Girders

Technology Description: Evaluation of HPS-70W thermo-mechanical-controlled process as compared to previous Q&T fabrication procedures. Evaluation of mechanical properties and performance via bridge load testing

Project Information**Positive Results:**

- Exceeds Q&T minimum material property requirements
- Exceeds toughness requirements
- Fatigue life criteria were met or exceeded
- AASHTO Live load distribution formulas are applicable for HPS design and give conservative results.

Negative Results:

- Thicker plates may not meet specified material properties

Lessons Learned:

Barrier to implementation of Technology: further study of thickness effects

"The results summarized ... support the continued use of HPS-70W in bridge construction within the state of Ohio. While there are still areas in need of further study, this project has demonstrated that the product can provide benefits not possible with conventional grades of steel"

Internal or External Reports:

Verification of Performance and Design Criteria for High Performance Steel Bridges

<http://www.dot.state.oh.us/Divisions/TransSysDev/Research/reportsandplans/Reports/2006/Structures/14789-FR.pdf>

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Yes, HPS is use where appropriate in the state of Ohio

Plans on Reuse of Technology: Yes

Applicability to other States: Study provided general information as to the performance of HPS and is applicable to all states.

State DOT Contact: Mike Loeffler
E-mail: Mike.Loeffler@dot.state.oh.us

Phone: 614-466-4050

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Route 49-0103, Dayton**State:** OH **Federal-Aid Project #:** 14715(0) **Fiscal Year:** 1999 **Funds Awarded:** (unknown)**Fund Status:** Expended**Project Status:** Completed**Associated Project Names**

Route 49-2002

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Deck Panel

Technology Description: Study the use of FRP composite structure as a bridge deck. Multiple fabricators were evaluated comparing existing installations. Each FRP deck system was scrutinized for positive and negative results. One system was then selected and installed in a side-by-side comparison with a standard deck.

Project Information**Positive Results:**

- Overall evaluation of FRP Deck systems
- Multiple fabricators available for comparison
- Impact and Distribution factors are consistent with concrete deck calculations

Negative Results:

- Layout of panels can lead to increased delaminations, particularly for large panels
- Direct sunlight can cause "bubble" delaminations in the panels, detaching the core from the face sheets

Lessons Learned:

Barrier to implementation of Technology: see below

Strong project management and clear and open communication are essential. A design/build approach could help facilitate collaboration among all the involved parties.

DESIGNER: The designer should deal with the following issues on future projects:

- Improve procedures for development and approval of shop drawings, as well as, better definition of construction procedures
- Collaborate with deck supplier to determine responsibility for deck-to-girder connection details
- Develop general interface control specifications which would include foreseeable loads and deflections between girders and decks from all loading sources including thermal effects.
- Consider composite action between the deck and girder
- Provide diaphragms for end support at non-structural joints
- Consider the elastic modulus of FRP bars when designing the reinforcement
- Provide sufficient concrete cover over FRP bars to ensure that radial thermal expansion does not cause cracking.

CONTRACTOR: The builder should be sure to cover open holes on the upper deck surface to prevent water intrusion. Haunches should not be formed until the deck panels are in place. The panels can be temporarily supported with either soft shims or by placing a leveling screw in the deck panel while forms are set up and grouted.

MANUFACTURER: The deck manufacturers need to have a representative on site throughout the placement of the deck, and they should supply the contractor with a written procedure for

installation of the deck panels. They should also design and be responsible for the connection of deck panels to supporting bridge girders. Drain holes should be placed in all panels that have voids.

Internal or External Reports:

9.0 CASE EXAMPLE – SALEM AVENUE BRIDGE INVESTIGATION

http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_564_app4.pdf

EVALUATION OF SALEM AVENUE BRIDGE DECK REPLACEMENT

Issues regarding the composite materials systems used Edited by Mark P. Henderson, P.E. LJB, Dayton, OH

Publications, Presentations, or, Construction Studies:

Performance Comparison of Four Fiber-Reinforced Polymer Deck Panels

Reiner M. W. Reising,¹ Bahram M. Shahrooz,² Victor J. Hunt,³ Andy R. Neumann,⁴ and Arthur J. Helmicki⁵

<http://scitation.aip.org/getabs/servlet/GetabsServlet?prog=normal&id=JCCOF2000008000003000265000001&idtype=cvips&gifs=yes&ref=no>

Additional Comments:

Technology used on Other Projects: Lessons learned applied will be applied to future FRP applications

Plans on Reuse of Technology: Not Reported

Applicability to other States: Lessons learned here are applicable to all bridge owners

The project named Route 49-2002 is a continuation of this project.

State DOT Contact: Tim Keller

Phone: 614-466-2463

E-mail: Tim.keller@dot.state.oh.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Route 79-0955**State:** OH **Federal-Aid Project #:** Not Reported **Fiscal Year:** 1999 **Funds Awarded:** Not Reported**Fund Status:** All funds Expended **Project Status:** Completed**Associated Project Names**Bridge No. SCI-23-0166, US
Rte. No. 23, City of PortsmouthProject: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Post-stressing Retrofit

Technology Description: Study focused on measuring the effects of applying fiber reinforced polymer reinforcing bars as a post-tensioning method to an existing bridge. The post tensioning strands were applied to the girders with external stiffened steel angle brackets

Project Information**Positive Results:**

- none

Negative Results:

- No decrease in deflection or strain measurements on bridge
- Does not appear to have affected the system in a measurable fashion

Lessons Learned:

Barrier to implementation of Technology: ineffective as applied

- Computer Modeling of the structure demonstrates that the project has potential but the actual implementation did not match the model.
- The effect of the post tensioning can be increased by adding more strands and/or increasing the pretension. Using the stronger carbon fibers rods as originally planned would allow increasing the pretension without increasing the amount of material.
- The 2-D model does not capture the overall behavior of the bridge and likely accounts for the discrepancy in the predicted behavior. Small changes in truck loading positions can affect the strain gage readings on the structures and might account for the increase in deflection readings after installation of the post tensioning.

Internal or External Reports:

This attached report details theory and application of the post tension repairs.

"Evaluation of Composite Post-Tensioning System on Bridge COS-79-0955, Coshocton County"

<http://www.dot.state.oh.us/Divisions/TransSysDev/Research/reportsandplans/Reports/2003/Structures/14722-FR.pdf>**Publications, Presentations, or, Construction Studies:**

None

Additional Comments:

Technology used on Other Projects: Yes, see associated project Bridge No. SCI-23-0166, US Rte. No. 23, City of Portsmouth

Plans on Reuse of Technology: No. Technology does not work.

Applicability to other States: None, technology does not work as implemented.

Additional Project Notes:

(none)

State DOT Contact: Mike Loeffler, Vicky Fout

Phone: 614-466-4050

E-mail: Mike.Loeffler@dot.state.oh.us, Vicky.Fout@dot.state.oh.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Stelzer Road, Columbus**State:** OH **Federal-Aid Project #:** 14721 **Fiscal Year:** 1999 **Funds Awarded:** Not Reported**Fund Status:** Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Concrete

Technology Description: Fiber reinforced composite tube deck with prestressed concrete filling each tube was used in place of a traditional concrete-poured deck.

Project InformationPositive Results:

- none

Negative Results:

- Material delivered not within contract specifications
- Increased deflections in deck
- Warm temperatures increased deflections and caused longitudinal gaps to form between the deck and haunch
- Substantially high initial cost, long term repairs likely
- Conventional deck for adjacent bridge replaced at the same time is clearly performing better

Lessons Learned:

Barrier to implementation of Technology: poor performance as intalled

- Composite deck greatly affected by temperature
- Anisotropic coefficient of thermal expansion created patterned cracking
- Improvements necessary to FRP quality control before application is appropriate

Internal or External Reports:**Performance Evaluation of Bridge with Fiber Reinforced Composite Decks****ODOT State Job Number:** 14721

Final Report, August, 2003:

<http://www.dot.state.oh.us/Divisions/TransSysDev/Research/reportsandplans/Reports/2003/Structures/14721-FR.pdf>Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: No

Plans on Reuse of Technology: No. Quality control issues must be addressed

Applicability to other States: Not Reported

Post-tensioning of deck tubes:



State DOT Contact: Mike Loeffler, Vicky Fout Phone: 614-466-4050
E-mail: Mike.Loeffler@dot.state.oh.us, Vicky.Fout@dot.state.oh.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Steever Road (CR153) over the Tiffin River**State:** OH **Federal-Aid Project #:** E080(262) **Fiscal Year:** 2006 **Funds Awarded:** \$250,000**Fund Status:** Expended **Project Status:** Completed – Monitoring on-going**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Steel Beam Superstructure with Geosynthetic Reinforced Soil Abutments

Technology Description: "The soil mass of GRS systems is reinforced in layers with a polymeric geosynthetic, and the layered reinforcement is attached to facing elements that constitute the outer wall. Various materials, including natural rock, concrete block, gabion, or timber, may be used for the flexible facing. GRS structures are more forgiving to differential foundation settlement thus minimizing the bump that commonly develops between the roadway and bridge. GRS structures can be put into service quickly, can be built by maintenance personnel, and are especially well suited to projects constructed in areas that are difficult to access with heavy equipment. GRS structures are good for demolition and the recyclable nature of their components."

Project Information**Positive Results:**

Construction and performance are both excellent. Both abutments were built and ready for loading in one week each. Settlement and expansion contraction data are as good as or better than expected.

Negative Results:

- None to date

Lessons Learned:

Barrier to implementation of Technology: none

This project, along with a number of other local projects, demonstrates the wide applicability and flexibility of GRS as an abutment material. Higher abutment structure allows for span shortening and possible pier elimination.

This system can be easily and quickly constructed with light equipment. They also have reduced lead time since the materials are readily available.

Internal or External Reports:**Publications, Presentations, or, Construction Studies:**

<http://www.defiance-county.com/engineer/GRS.htm>

Additional Comments:

Technology used on Other Projects: Yes, Multiple locations in Defiance County, alone.

Plans on Reuse of Technology: Yes, GRS has been a success for the county

Applicability to other States: County experience suggests that this type of abutment can be used in multiple capacities and for a variety of locations.

Monitoring is ongoing and no reports have been produced to date: The Stever bridge has ongoing monitoring being done under the direction of Mike Adams with FHWA's Turner Fairbanks research center.

Warren Schlatter has been very active in GRS abutments and IBRC/IBRD.

He has additional information posted on the Defiance County Engineer's web site:

<http://www.defiance-county.com/engineer/GRS.htm>

10/30/08: Funds Obligated 7/1/08. To be awarded in December 2008.

E080(262). PID 83268

State DOT Contact: Warren Schlatter

Phone: _____

E-mail: dce@defiance-county.com

HDR Contact Name: Duncan Paterson

FHWA IBRC/IBRD Project Summary Report Form

Project Name: An Over-Height Collision Protection System of Sandwich Polymer Composites Integrated with Remote Monitoring for Concrete Bridge Girders

State: OH **Federal-Aid Project #:** E036(641) **Fiscal Year:** 2002 **Funds Awarded:** \$220,000.00

Fund Status: Expended **Project Status:** Completed

Associated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Over-Height Collision Protection System of Sandwich Polymer Composites

Technology Description: A sacrificial collision device utilizing advanced impact laminate materials was applied to bottom portions of concrete girders. The devices contain a multi-layer aluminum honeycomb core. It has the possibility to have integrated sensors to record impacts.

Project InformationPositive Results:

- Numerical simulations demonstrate that the transferred contact force is reduced for beams with the protection
- Full -scale lab tests validate the proposed concept
- Potential benefits for collision protection and impact mitigation

Negative Results:

- No in-situ results, laboratory demonstrations only

Lessons Learned:

Barrier to implementation of Technology: Further research needed with actual impacts on structures

The laboratory and numerical analysis both demonstrate that this system has the potential to mitigate impact damage on concrete girders. Test can not conclusively state that the system will be effective without in field testing of actual structures.

Internal or External Reports:

FHWA/OH-2008/6 -- "An Overheight Collision Protection System of Sandwich Polymer Composites Integrated with Remote Monitoring for Concrete Bridge Girders."

<https://spinternet.dot.state.oh.us/Divisions/TransSysDev/Research/reportsandplans/Reports/2008/Structures/134142FR.pdf>

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: No

Plans on Reuse of Technology: N/A

Applicability to other States: Should field impact test show that impact damage is mitigated through the device and is shown to be cost-effective, the technology will be applicable to all states.

State DOT Contact: Vicky Fout
E-mail: vicky.fout@dot.state.oh.us

Phone: 614-387-2710

1.37. OKLAHOMA

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I-35 over Chickaskia River**State:** OK **Federal-Aid Project #:** IBR-136N(057)RS **Fiscal Year:** 2001 **Funds Awarded:** \$300,000.00**Fund Status:** Not Reported Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: MMFX and Ipanex

Technology Description: MMFX , a corrosion resistant reinforcing steel and Ipanex, an admixture used as a corrosion inhibitor were used in the construction of the NB I-35 bridge over the Chickaskia River in Kay Co

Project InformationPositive Results:

Installs the same as normal reinforcement.

Negative Results:

None

Lessons Learned:

Barrier to implementation of Technology: Long term monitoring required to determine effectiveness

No work plan exists that would document any negative aspects associated with this technology other than the anticipated delays as a resulted of not being able to secure the stainless steel clad reinforcement that was in the original proposed research.

Internal or External Reports:

No report at this time. ODOT Bridge Division had worked with a Dr. Russell at OSU to evaluate the performance of this technology.

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: MMFX was not used on other Oklahoma projects. Ipanex has been used.

Plans on Reuse of Technology: Unable to determine, Final Report was not submitted

Applicability to other States: Unable to determine, Final Report was not submitted

Additional Project Notes:

10/30/08: Construction complete research continuing.

The initial technology of Clad Stainless Steel Rebars changed to the MMFX and Ipanex

MMFX , a corrosion resistant reinforcing steel and Ipanex, an admixture used as a corrosion inhibitor were used in the construction of the NB I-35 bridge over the Chickaskia River in Kay Co. The SB bridge was constructed using conventional epoxy coated steel and CL AA concrete as specified in the design. The use of the MMFX reinforcing steel was allowed due to the unavailability to secure the Stelax Stainless Steel Clad reinforcement at the time this contract was let.

A review of the Final Report as it relates to the performance of the MMFX and Ipanex in the ability to inhibit corrosion will determine the effectiveness of this technology. All in-field data collection has been done with no further research scheduled in the future.

State DOT Contact: _____

Phone: _____

E-mail: _____

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I-35 over Hickory River**State:** OK **Federal-Aid Project #:** IBR-143N(024)RS **Fiscal Year:** 2001 **Funds Awarded:** \$70,000.00**Fund Status:** \$17,924.97 Expended **Project Status:** Initiated**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Ipanex , a corrosion inhibitor and

Technology Description: Ipanex, an inorganic corrosion inhibitor admixture was used in the construction of bridge deck and parapet walls.

Project InformationPositive Results:

None, unfortunately report was never published.

Negative Results:

None, unfortunately report was never published.

Lessons Learned:

Barrier to implementation of Technology: ODOT Bridge Division had worked with a Dr. Gary Spencer at OSU to evaluate the performance of this technology.

No Work Plan exists that would document any negative aspects associated with this technology other than the field notes showing some low air contents while pumping the concrete through the pump truck. It is not clear from these records that this was or was not attributed to the use of this technology. It may very well have been attributed to the configuration of the pumping boom (elevated) while placing the concrete.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Yes. The Ipanex was also used on the I-35 over Chickaskia River.

Plans on Reuse of Technology: Unable to determine, report to validate performance was never submitted.

Applicability to other States: Unable to determine, report to validate performance was never submitted.

Additional Project Notes:

10/30/08: Construction complete research continues.

Ipanex, an inorganic corrosion inhibitor admixture was used in the construction of the SB I-35 bridge deck and parapet walls over Hickory Creek bridge in Love Co. Conventional epoxy coated reinforcing steel was used. The NB bridge, with conventional epoxy coated reinforcing steel and same CL AA concrete would serve as the control to this study. In addition, Silane water repellent was applied to the NB bridge only.

A review of the final report as it relates to the performance of the Ipanex in the ability to inhibit corrosion will determine the effectiveness of this technology. All in-field data collection has been done with no further research scheduled in the future. From conversations with field personnel and review of records, MMFX was not part of this study.

State DOT Contact: _____

Phone: _____

E-mail: _____

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I-40 Bridge over Business I-40 in Sayre**State:** OK **Federal-Aid Project #:** _____ **Fiscal Year:** 2002 **Funds Awarded:** \$225,000.00**Fund Status:** \$229,079.64 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Concrete in Deck Slab

Technology Description: An investigation of four different high performance concrete (HPC) mixtures was performed to achieve a greater durability than normal concrete, with an emphasis on reducing shrinkage.

Project Information**Positive Results:**

- Obtained high compressive strength with little to no cracks.
- Reduction in shrinkage of the in place mixes.
- Less cracking than CL AA control slab.
- The HPC mix design containing flyash and fibers had the least cracks.

Negative Results:

- Complication with dealing with multiple variables associated with producing a HPC mix design.
- The Shilstone Coarseness Factor chart did not perform as designed; further studies are needed to better understand the blending of local aggregate used in Oklahoma.
- The fiber mixtures were found to be very dry, matted and sticky.
- During construction, the materials used were seen to react differently than in the laboratory. It was found that the mixtures were not only developing higher air contents, but they were also changing their behavior properties at about 30 minutes in an undesirable way. At thirty minutes the concrete would rapidly stiffen and start to dry, making unpumpable and in some cases unworkable.

Lessons Learned:

Barrier to implementation of Technology: the many uncertainties encountered in this project such as high air content, low slump and workability all presented concerns to the investigator. The interactions of the admixtures used are still unknown and warrant further research. As was found in the field, the anti-shrink additive Tetraguard was best suited when partial dosing at the plant was followed up with trickle dosing once arrival to the job site produced a mix complying with the air content of 6-8% mix design. Original batches prior to this method resulted a rather stiff and dry mix which was not pumpable, several of the first loads were rejected. The use of fibers likewise warrants further research as they were not able to pump this harsh and sticky mix. Possibly increasing the mid-range additive was thought to be a solution.

Internal or External Reports:

“USE OF HIGH PERFORMANCE CONCRETE IN OKLAHOMA BRIDGE DECKS” This Final Report details the design, testing, application and evaluation of four different HPC mixtures used in four separate spans during bridge construction.

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: No, the HPC application was not used on other Oklahoma projects.

Plans on Reuse of Technology: Unable to determine which mixture is the best option, additional testing is recommended to further understand their effects.

Applicability to other States: Yes, the HPC technology has been used by numerous states on bridge projects.

Additional Project Notes:

10/30/08: Construction complete research continues

The results of this study showed the complexity of dealing with multiple variables associated with producing a HPC mix design. The completion of the field work including work done in the lab on field mixes showed promising results in terms of gained strengths and a reduction in shrinkages of the in place mixes. The four slabs using the HPC mix designs overall had less cracking than did the CL AA control slabs. The HPC mix design containing flyash and fibers had the least cracks of all mixes in the study. Further studies on the use of the Shilstone chart are needed to better understand the blending of local aggregate sources typically used in Oklahoma.

The first problem the investigator encountered in the field was that the concrete producer failed to supply the air entrainment additive that the mix design was based on. This should have been resolved prior to the start of the field work. As a result, the delivered concrete is believed to have reacted with the additive Tetraguard, used for shrinkage control and resulted in a stiff and dry mix. Many of the initial loads were rejected due to high air contents or the inability to pump the mix. The coarse aggregate gradation likewise varied from that used in the lab work for the mix designs, a more gap graded aggregate was realized once lab analysis was performed following the construction efforts.

As could be expected, the many uncertainties encountered in this project such as high air content, low slump and workability all presented concerns to the investigator. The interactions of the admixtures used are still unknown and warrant further research. As was found in the field, the anti-shrink additive Tetraguard was best suited when partial dosing at the plant was followed up with trickle dosing once arrival to the job site produced a mix complying with the air content of 6-8% mix design. Original batches prior to this method resulted a rather stiff and dry mix which was not pumpable, several of the first loads were rejected. The use of fibers likewise warrants further research as they were not able to pump this harsh and sticky mix. Possibly increasing the mid-range additive was thought to be a solution.

More research is needed to validate the use of the Shilstone Chart with regards to the local aggregate sources commonly used in Oklahoma. In addition, there is much to be learned as to the interaction of various admixtures in terms of air content and workability. The long term performance of these slabs should be continued so as to evaluate the overall performance of the HPC mix designs used in this study.

State DOT Contact: _____

Phone: _____

E-mail: _____

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I-40 EB over I-44**State:** OK **Federal-Aid Project #:** IBR-155N(391)IR **Fiscal Year:** 2004 **Funds Awarded:** \$366,103.00**Fund Status:** \$10,002.67 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Thin Bonded overlay**Technology Description:** Applying Flexogrid, an epoxy polymer overlay system to seal the bridge deck. This overlay system's intent is to provide waterproofing to the deck, increase skid resistance and extend the life span of the structure.**Project Information****Positive Results:**

- Preliminary data have shown tremendous increase in the overall skid resistance of the concrete surface, from 25.4 to 61.9.
- Shorter construction time.
- Test results indicated significant improved skid resistance after completion.

Negative Results:

- The final surface treatment overlay resulted in a rough riding surface.
- Higher cost than other bridge deck overlays.

Lessons Learned:**Barrier to implementation of Technology:**

Experienced contractor with this material and proper equipment are essential to better application.

Internal or External Reports:

"Evaluation of Flexogrid Bridge Deck Overlay System" This Construction Report details the evaluation of the Flexogrid bridge deck overlay system.

Though the construction process was clearly documented, it appears that as a result of a change in personnel during the follow up to this study, no final report was produced. Initial skid data and final skid data following the completion of the overlay treatment was however collected though never incorporated into a final report.

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: No, the Flexogrid system was not used on any other Oklahoma projects

Plans on Reuse of Technology: Unable to determine, further inspection wasn't performed and final report was never published.

Applicability to other States: Unable to determine, final report was never published.

Additional Project Notes:

10/30/08: Construction complete research continues.

The proposed project was to study the performance of an epoxy polymer overlay system Flexogrid. The proposed study would monitor the ability of Flexogrid to seal the bridge deck from future intrusion of moisture and chloride, thus leading to a reduction in steel reinforcement corrosion and resulting in a longer life span of the structure. In addition to reducing the permeability of the concrete matrix, the Flexogrid reportedly would increase the overall skid resistance of the concrete surface. Preliminary data in fact showed a tremendous increase from a 25.4 prior to treatment to a 61.9 following the overlay.

As was noted in the construction records an insufficient depth of the Flexogrid product was placed following the final application. It could perhaps be attributed to the inexperience of the contractor and or the equipment he used. In addition, the final surface treatment overlay resulted in a rougher surface than prior to application though no smoothness testing was performed. It was simply noted in the construction records as being a somewhat rough ride following the overlay.

By all accounts, after reviewing construction records and conversations with current staff at ODOT, the current Construction Report Feb. 2004 should be viewed as a final report to this study. Due to personnel changes within ODOT, no one associated with this study is part of the current research staff. All research is complete with no further plans to collect additional data.

State DOT Contact: _____

Phone: _____

E-mail: _____

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** SH-150 over Lake Eufaula**State:** OK **Federal-Aid Project #:** IBRY-146C(055)IB **Fiscal Year:** 2003 **Funds Awarded:** \$150,000.00**Fund Status:** \$15,299.34 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Surtreat Chemical placed on concrete to abate corrosion**Technology Description:** Applying Surtreat TPS, a surface applied inorganic migratory, penetrating corrosion inhibitor on concrete bridge deck. The Surtreat TPS treatment claims to abate corrosion of reinforcing steel by creating an ionic film on the reinforcing steel.**Project Information****Positive Results:**

None

Negative Results:

- From various tests performed, it remains questionable whether or not the Surtreat TPS treatment penetrated sufficient depths to reach the intended reinforcing steel. Half Cell test results referenced in the discussion section of the report, lend themselves to inadequate penetration as did the Rainbow Dye test.
- Treatment was not as effective as expected.
- Delamination and spalling of deck surface.

Lessons Learned:

Barrier to implementation of Technology: Longer monitoring time is needed to see the improvements in the half cells numbers

Internal or External Reports:

FIELD PERFORMANCE OF SURTREAT TPS
A SURFACE APPLIED, PENETRATING
CORROSION INHIBITOR

Construction Report
March 2004

Donald B. Rossmore
District Project Manager
Steve Williams, P.E.
Engineering Manager

Planning & Research Division
Construction Division of Transportation
FHWA, 117 North Moore Street
Washington, D.C. 20590
202-366-0001
202-366-0002

"Field Performance of Surtreat TPS a surface applied, penetrating corrosion inhibitor" This Construction Report details the construction practices used to complete this project with limited long term data to support the overall performance of the Surtreat TPS treatment. This report will be served as the Final Report.

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: No, the Surtreat TPS application was not used on any other Oklahoma projects.

Plans on Reuse of Technology: No, this technology was not a success.

Applicability to other States: No, the Surtreat TPS treatment did not performed as predicted.

Additional Project Notes:

10/30/08: Construction complete research continues.

Due to personnel changes associated with this project it appears that the Construction Report will serve as the final report. No further testing or monitoring of this project is scheduled.

Surtreat TPS reportedly claims to abate corrosion of reinforcing steel by creating a passivating ionic film on the reinforcing steel. An experimental evaluation of this product was performed on a bridge selected by ODOT Bridge Division. The bridge selected, was on SH-150 over Lake Eufaula in McIntosh Co. Through the elimination of corrosion it is anticipated that less maintenance will be required in the future. ODOT Planning and Research Division coordinated the efforts of the research associated for this study. Traffic control was provided by ODOT maintenance personnel.

From various tests performed, it remains questionable whether or not the Surtreat TPS treatment penetrated sufficient depths to reach the intended reinforcing steel. Half Cell test results referenced in the discussion section of the report, lend themselves to inadequate penetration as did the Rainbow Dye test.

Due to the problems of delamination and spalling of the bridge deck surface, the findings of the Half Cell tests were in question. Long term monitoring and testing for this project was not performed as outlined in the work plan due to changes in personnel within the research scope of this project.

A brief report includes construction practices used to complete this project with limited long term data to support the overall performance of the Surtreat TPS treatment.

State DOT Contact: _____

Phone: _____

E-mail: _____

1.38. OREGON

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Blevins Bridge – Tangent Drive Calapooia River**State:** OR Federal-Aid Project #: C043(014) Fiscal Year: 2002 Funds Awarded: \$11,550.00**Fund Status:** \$11,500.00 Expended **Project Status:** CompletedAssociated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Debris Deflection Device

Technology Description: "Debris Shark" deflection device that diverts debris away from specified locations.

Project InformationPositive Results:

None

Negative Results:

The Debris Shark did not function effectively.

Lessons Learned:**Barrier to implementation of Technology:**

- Water flow toward the turbine must be in line with the bent, Double row of pile with fender system and a curve in the creek upstream severely hampered the Debris Shark function.
- Request for more involvement from the manufacturer or supplier.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: No, the Debris Deflection devise was not used on other Oklahoma projects

Plans on Reuse of Technology: No, the application was a success.

Applicability to other States: No, this technology wasn't successful.

Additional Project Notes:

10/30/08: completed and closed.

The Debris Shark was salvaged when the bridge was replaced and may be used again at another site.

State DOT Contact: Bruce Johnson
E-mail: Bruce.V.JOHNSON@odot.state.or.us

Phone: 503-986-3344

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** The Broadway Bridge, NW Broadway over Willamette River

State: OR	Federal-Aid Project #: X-BHF-HPP-OTIA-C051(50)	Fiscal Year: 2003	Funds Awarded: \$400,000.00

Fund Status: \$400,000.00 Expended**Project Status:** Complete**Associated Project Names**Broadway Bridge Rehabilitation,
Phases 4 – 7Project: Change / Associated

Reallocated from / to:

Technology Implemented: Fiber Deck Panels

Technology Description: Fiber Deck Panels consisting of DuraSpan 500 deck units produced by Martin Marietta Composites (MMC) with top and bottom bonded FRP face sheets. The plans required a 1/8-inch thick top face sheet and a 1/16-inch thick bottom face sheet. Both face sheets are high strength bonded quadraxial E-Glass material. The face sheets are expected to add stiffness to the deck, decrease deflections and increase load capacity.

Project Information**Positive Results:**

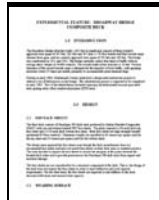
- The FRP deck panels allowed Multnomah County to replace the aging steel open-grid deck on the lift span sections with a solid deck surface while maintaining the total lift span weight within the allowable operating envelope of the bridge's machinery. The solid deck also allowed for the collection of stormwater runoff, future bike use on the roadway portion of the bridge, and protection of sub deck elements from the weather.
- There has been no significant degradation of the panels since they were installed.
- The epoxy grout used to attach the panels to the stringers has performed well without degradation.

Negative Results:

- The epoxy overlay material laid on the deck has had problems adhering to the surface of the panels. Some of this was a factor of how the epoxy was mixed and laid down. The thickness of the material may be a contributing cause. Another factor was the non-slip coating applied by the manufacturer to the upper surface of the panels prior to shipment. The manufacturer was concerned that the surface of the panels were too slick for construction workers to navigate once the panels were placed at the bridge site. The non-slip coating adhered well to the epoxy overlay, but broke free of the fiberglass surface once the deck was placed under traffic, causing delamination of the overlay. After several attempts to correct the deficiency, the County found that the best fixes involved removal of the non-slip coating and a light sand blasting of the fiberglass face sheet before reinstalling the epoxy overlay.
- Once cracks began forming in the overlay, water was able to penetrate down through the stud pockets and fill the voids in the panels, increasing the weight of the lift spans. Holes were drilled into the panels from below to allow the water to drain off.

Lessons Learned:

- The fiberglass panels are more flexible under load than a standard concrete deck; therefore an overlay material has to have the same flexibility as the panels. The County has been working with the ODOT to determine what materials are available for use in this type of application.

Internal or External Reports:

"EXPERIMENTAL FEATURE: BROADWAY BRIDGE COMPOSITE DECK"

The County Bridge Section has completed an extensive five-year inspection program of the FRP deck. This report, FRP DECK LOAD TESTING BASELINE AND FINAL TEST RESULTS GFRP COMPOSITE DECK, April 21, 2010, has been provided under separate cover, along with all related information regarding the panel design, testing, installation and monitoring.

Publications, Presentations, or, Construction Studies:

Chuck Maggio presented "Fiber-Reinforced Polymer Deck Installation, 2004" to the Portland Post, Society of American Engineers on October 6, 2004.



At the Western Bridge Engineers' Seminar in Portland, OR on Sep 26 – 28, 2005, three papers were presented on different aspects of the FRP deck.

- a) Steve Lovejoy from ODOT presented "Recent Experience with FRP Decks on Bascule Movable Bridges".
- b) Chuck Maggio, Multnomah County and John Ferguson, DEA presented "Fiber-Reinforced Polymer Deck Installation". (attached)
- c) Peter Dusicka, Portland State University, presented "FRP Composite Deck Panels for Broadway Drawbridge Deck Replacement".

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

10/30/08: completed and closed

State DOT Contact: Bert Hartman

Phone: 503-986-3395

E-mail: _____

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I-84 Irrigon Junction – Hilgard Interchange**State:** OR **Federal-Aid Project #:** S006(065) **Fiscal Year:** 2004 **Funds Awarded:** \$400,000.00**Fund Status:** \$350,560.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Steel in Plate GirdersTechnology Description: High performance steel (HPS) used bridge construction instead of traditional steel grade.**Project Information****Positive Results:**

- HPS is included in the ODOT design manual as acceptable steel.
- HPS continues to be used in Oregon.
- A new bridge is being design using HPS 70W steel for the flanges.

Negative Results:

- Higher unit cost of steel than anticipated
- Increased in fabrication cost due to sharp skew and variable superelevation.
- Cutting the parabolic webs also increased fabrication cost.

Lessons Learned:

Barrier to implementation of Technology: Using high performance steel (HPS) can result in savings when compared to traditional steel grades. The higher unit cost of the steel can be more than offset by the reduction in weight. Using HPS 70W in the girders of longer span bridges is the most cost effective.

Welding of HPS 70W steel is not a problem as long as appropriate materials and techniques are used.

AASHTO M270 Grade HPS 50W offers little to no advantage over Grade 50W and will increase cost. The use of HPS 50W steel should be confined to areas were additional notch toughness is required.

Availability of High performance steel can be problematic. Designers should check availability with the National Steel Bridge Alliance or with local fabricators before beginning design.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Yes, HPS beams are used on other Oregon projects.

Plans on Reuse of Technology: Yes, HPS continues to be used in Oregon and is included in the ODOT bridge design manual as acceptable steel.

Applicability to other States: Yes, this technology is applicable to all states and has been implemented in many states.

Additional Project Notes:

High performance steel continues to be used in Oregon. The Del Rio interchange bridge in Roseburg, Oregon that is currently being designed by ODOT Region 3 will use HPS 70W steel in the flanges. High performance steel is included in the ODOT bridge design manual as acceptable steel.

The low bidder's unit cost for the structural steel in place was \$3.92 per pound. This was higher than anticipated. The second and third bidder's unit prices were \$2.36 per pound and \$2.18 per pound respectively. Several factors may have contributed to the high unit prices. An extremely sharp skew and variable superelevation increased fabrication costs. For aesthetic reasons the depth of the exterior girders increased near the abutments. Cutting the parabolic webs increased fabrication cost and waste steel.

State DOT Contact: Bruce Johnson
E-mail: Bruce.V.JOHNSON@odot.state.or.us

Phone: 503-986-3344

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Sauvie Island Bridge**State:** OR **Federal-Aid Project #:** X-IBRC-C051(036) **Fiscal Year:** 2000 **Funds Awarded:** \$54,000.00**Fund Status:** \$54,000.00 Expended **Project Status:** Complete**Associated Project Names**Sauvie Island Bridge
Strengthening ProjectProject: Change / Associated

Reallocated from / to:

Technology Implemented: Fiber-Reinforced-Polymer Composite Strips

Technology Description: H-Lam Fiber Reinforced Polymer strips bonded to the bottom of steel beam flange to increase flexural capacity in member

Project Information**Positive Results:**

- Cyclic and quasi-static test results obtained from half-scale beams indicated that the use of polymer composite is capable of enhancing the structural behavior of steel beams.
- Based on the results obtained from both the quasi-static and cyclic loading tests, it is concluded that the use of composites succeeded in meeting the flexural demand.
- The predicted strength of the steel beam strengthened with H-Lam composites deviated only 6% from the experimental value.
- It should be noted that for concrete and masonry structures laminated with similar composite laminates, the minimum bondline strength requirements varies from 200 psi to 400 psi depending on the concrete compressive strength. From the results of the evaluation tests, the minimum strength was higher than 900 psi which more than two folds of that required for concrete.

Negative Results:

None

Lessons Learned:

- It is highly recommended for future applications, that a combined system (adhesively-bonded/mechanically fastened) system be used to increase the reliability of the system. This was the original design of the H-Lam system where small-diameter Nelson studs are provided to provide the additional mechanical fastening mechanism.

Internal or External Reports:

“A Pilot Project on Strengthening the Sauvie Island Bridge Steel Girders Using Advanced Composites Systems”
by Ayman Mosallam and Kenneth Huntley



“Time-Dependent Bondline Strength Evaluation Summary” by Ayman Mosallam, April 2005

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

After the installation of the fiber-reinforced-polymer composites, field measurements were taken on a regular basis of the stresses in the girders. It was shortly after the completion of this project that cracks were discovered in the concrete approaches to the Sauvie Island Bridge, which eventually led to the replacement of the bridge and its approaches with a new span. Therefore, the County was unable to obtain long-term in-place measurements of the stresses in the beams to ascertain the effects of repeated loadings, time, temperature and exposure to the weather on the composites.

10/30/08: Closed and competed

State DOT Contact: Bert Hartman

Phone: 503-986-3395

E-mail: _____

FHWA IBRC/IBRD Project Summary Report Form

Project Name: State Hwy #105 MP 4.748 & MP 6.89 - U.S. Bus. Route 101 Bascule Bridge over Old Youngs Bay., Astoria

State: OR **Federal-Aid Project #:** S105(002) **Fiscal Year:** 2000 **Funds Awarded:** \$330,000.00

Fund Status: \$330,000.00 Expended **Project Status:** Completed

Associated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Deck Panel

Technology Description: Fiber reinforced polymer (FRP) composite deck used to replace a timber deck with AC overlay.

Project InformationPositive Results:

- Highly resistant to corrosion.
- In service for 10 years
- No signs of degradation except in shop adhesive bonded joints and connection details.

Negative Results:

- Manufacturer's defect caused shop adhesive bonded joints to fail.
- Failed joints called for constant adjustment of bridge operational needs.
- Grouted pockets, connecting deck to stringers, failed.

Lessons Learned:**Barrier to implementation of Technology:**

- Adhesive bonded joints without mechanical fasteners have not proven effective.
- The constant impact loading from vehicular traffic and high humidity may be putting a great deal of demand on the connection detail that was not tested in a harsh environment prior to putting it into service.
- Also need to select the proper grout for heavy traffic use. We have another FRP deck that was installed with blind fasteners in the connected components and it has been performing satisfactorily.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Yes, The FRP deck panel was used on other Oregon projects.

Plans on Reuse of Technology: Yes, another FRP deck with blind fasteners was installed to replace the 10 year old FRP deck.

Applicability to other States: Yes this technology is applicable to all states, and has been used in numerous states.

Additional Project Notes:

10/30/08: completed and closed.

Replaced an old deteriorated timber deck and AC overlay with the Martin Marietta fiber reinforced polymer (FRP) composites deck. The FRP deck was highly resistance to corrosion and there were no signs of degradation due to corrosion or moisture except in the shop adhesive bonded joints and connection detail. The deck was in service for 10 years and had to be replaced due to the failures in the details and bonded joints.

The FRP composites material itself was performing satisfactorily but the deck had to be replaced under an emergency contract due to the manufacturer's defect causing the shop adhesive bonded joints in between the protruded sections to fail. The failed joints allow water to fill up the cells and causing weight changes to the draw bridge operations and the bridge crew constantly had to adjust the bridge operational needs. The grouted pockets connecting the deck to the stringers had also failed Eventually the deck had to be replaced under an emergency contract.

State DOT Contact: Benjamin Tang
E-mail: Benjamin.m.tang@odot.state.or.us

Phone: 503-986-3324

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Sylvan Bridge over Sunset Highway**State:** OR **Federal-Aid Project #:** S047 (039) **Fiscal Year:** 2002 **Funds Awarded:** \$80,000.00**Fund Status:** \$69,044.00 Expended **Project Status:** Complete**Associated Project Names**

None

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Steel

Technology Description: High performance steel (HPS) used bridge construction instead of traditional steel grade

Project Information**Positive Results:**

- The knowledge gained in the design, fabrication, and construction of the HPS 70W steel for the Sylvan Bridge will enable designers to more fully consider the steel bridge option when designing new bridges in Oregon.
- The (ductility factor) was not specified in the AASHTO LRFD Design Specification, but was left to the owner to determine the factor. The AASHTO LRFD Design Specification specified the same ductility factor used for design of bridges constructed with conventional steel.
- This bridge has been in service only for a few years and is expected to provide at least 75 years of service life.

Negative Results:

- Many of the steel plates that were manufactured and supplied using the Thermo Mechanical process (TMP) during rolling of the plate did not meet the strength or toughness requirements.

Lessons Learned:

- Construction Special Provisions required quench and tempered process for HPS 70W. The Material Lab agreed with Thermo Mechanical process instead. The Designer agreed to use the thermo mechanical process if the contractor provided samples from both ends of each rolled plate to verify that the required HPS 70W properties were achieved. The majority of thermo mechanical rolled plates did not pass the design requirements and were rejected. All quench and tempered plates did pass designed properties requirements. Rejection of plates caused delay of fabrication and construction of Sylvan Bridge.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

- Bruce Johnson and Hormoz Seradj, 2001 World Steel Bridge Symposium, Chicago, Illinois October 2-5, 2001 "DESIGN AND FABRICATION OF THE SYLVAN OVERCROSSING HPS 70W BOX GIRDER BRIDGE."
 - Hormoz Seradj and Bruce Johnson, 2002 FHWA Steel Bridge Conference for the Western United States, December 12-13, 2002, Salt Lake City, Utah, "DESIGN AND FABRICATION OF THE SYLVAN OVERCROSSING HPS 70W BOX GIRDER BRIDGE."
 - Hormoz Seradj, 2004 FHWA Steel Bridge Conference for, December 16-17, 2004, San Antonio, Texas, "DESIGN AND FABRICATION OF THE SYLVAN OVERCROSSING HPS 70W BOX GIRDER BRIDGE."
- (not available)

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

State DOT Contact: Bruce Johnson

Phone: 503-986-3344

E-mail: Bruce.V.Johnson@odot.state.or.us

1.39. PENNSYLVANIA

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Burd Run Road over Burd Run**State:** PA **Federal-Aid Project #:** X082(170) **Fiscal Year:** 2005 **Funds Awarded:** \$400,000.00**Fund Status:** \$400,000.00 Expended **Project Status:** Completed**Associated Project Names**SR307 Fogelsonger Rd over
Burd RunProject: Change / Associated

Reallocated from / to:

Technology Implemented: Glulam Deck on Steel Girders

Technology Description: Composite steel I-beams with glulam timber deck panels.

Project InformationPositive Results:

- Bridge closure reduced, hence preventing lengthy detours
- Simplified construction process.
- Live load capacity increased, as result of lighter deck.
- Bridge in service since September 2008. Timber Deck remains in "very good condition" per October 29, 2009 NBIS bridge safety inspection

Negative Results:

None.

Lessons Learned:

Barrier to implementation of Technology:

Internal or External Reports:

"2009 Bridge Inspection Report ST-2 Burd Run over Burd Run" This Inspection Report details the condition of the bridge during the 2009 inspection.

Publications, Presentations, or, Construction Studies:

None.

Additional Comments:

Technology used on Other Projects: No, this application was not used on other Pennsylvania projects

Plans on Reuse of Technology: Yes, this application has performed well.

Applicability to other States: Yes, This technology is applicable to all states.

Additional Project Notes:

3/17/10: Open

The original project name was SR 307 (Fogelsonger Road) over Burd Run.

State DOT Contact: Harivadan Parikh
E-mail: hparikh @ state.pa.us

Phone: 717-787-4774

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** SR 0885 Boulevard of the Allies over Forbes Ave**State:** PA **Federal-Aid Project #:** X111(489) **Fiscal Year:** 2004 **Funds Awarded:** \$332,000.00**Fund Status:** \$332,000.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Steel

Technology Description: High Performance steel (HPS) used in bridge construction instead of standard structural steel.

Project InformationPositive Results:

It contributes to the inventory of successful applications of HPS such as:

- Limiting the sectional properties
- Allowing the design to accommodate tight vertical clearances
- Using continuous minimally haunched girders.

Negative Results:

None

Lessons Learned:

Barrier to implementation of Technology: None

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Yes, HPS is used on other Pennsylvania projects

Plans on Reuse of Technology: Yes, this technology has positive results with an inventory of successful applications.

Applicability to other States: Yes, this technology is applicable to all states, and has been implemented in several states.

Additional Project Notes:

10/30/08: open

Last action : 6/5/09

State DOT Contact: Lou Ruzzi

Phone: 412-429-4893

E-mail: lruzzi@ state.pa.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** SR 1003 over Tionesta Creek**State:** PA **Federal-Aid Project #:** X013(117) **Fiscal Year:** 2006 **Funds Awarded:** \$200,000.00**Fund Status:** \$77,052.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Tubular Flange

Technology Description: Concrete-filled tubular flange girders (CFTFG) consist of a conventional web and bottom plates with the top flange fabricated from a rectangular tube filled with concrete. A demonstration bridge is designed using the CFTFG.

Project Information**Positive Results:**

Based on the results of the preliminary design and finite elements analyses the following conclusions are drawn:

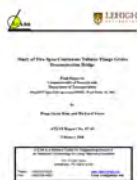
- The Continuous Tubular Flange Girders (CFTFGs) designed for the demonstration bridge have enough lateral torsional stability under the construction loadings that were considered, even with no interior bracing within the span, so that fabrication and erection effort can be reduced by eliminating the diaphragms.
- The field splice at the pier can simplify fabrication and erection and reduce the dead load effects at the pier section
- The precast concrete deck can reduce the time needed for construction, compared to a cast-in-place concrete deck, by reducing the time needed to place forms and reinforcing steel, and eliminating the time needed for the concrete to cure.

Negative Results:

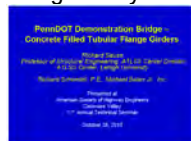
None at this time.

Lessons Learned:

Barrier to implementation of Technology: none.

Internal or External Reports:

“Study of Two-Span Continuous Tubular Flange Girder Demonstration Bridge” This Final Report details a design study of a two-span continuous tubular flange girder demonstration bridge.



“PennDOT Demonstration Bridge – Concrete Filled Tubular Flange Girders” This presentation is an update to the Final report above and includes results from the bridge construction (as well as other HPS technology projects).

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: No, CFTFG was not used on other Pennsylvania projects

Plans on Reuse of Technology: Yes, if the field observation substantiate the results of the preliminary designs.

Applicability to other States: Yes, this technology is applicable to all states.

Additional Project Notes:

10/30/08: under design

Research Study Complete

Companion: X-013(121) (Funding Code: L1CO)

State DOT Contact: William Koller

Phone: 814-678-7106

E-mail: wkoller@ state.pa.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** SR 1037 over Dubois Creek**State:** PA **Federal-Aid Project #:** X-045(125) **Fiscal Year:** 2001 **Funds Awarded:** \$500,000**Fund Status:** \$360,728.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Slab

Technology Description: To develop an effective means of connecting Fiber reinforced polymer (FRP) bridge deck to conventional reinforced concrete parapet. An instrumentation and testing program was implemented which consisted of performing controlled static and dynamic load tests, in addition to remote long-term monitoring.

Project Information**Positive Results:**

- Test truck load shows that vertical displacement of the bridge is very low and significantly less than the design specified maximum of L/800.
- Peak global stresses were on the order of 0.5ksi.
- The parapet behaves as a structural component of the bridge.
- The FRP slabs behaved elastically up to the ultimate load capacity.
- The use of epoxy overlay had negligible effect of the stiffness of the slab.

Negative Results:

- Out-of- plane of the parapet due to the test truck load was observed.
- Concentrated loads on the FRP slab cause bending in both directions in both the top plate and web plates.
- There was a dynamic amplification of local strains in the slab directly under the wheels of approximately 25%.
- The longitudinal joint in the FRP slab between the two panel sections doesn't appear to provide full continuity across the joint.

Lessons Learned:**Barrier to implementation of Technology:**

Fabrication techniques of the FRP play a vital role in the strength of the system. Poor fabrication led to brittle fracture of the slab at 20% of the expected capacity.

The ultimate failure of the parapet and the slab connection is due to brittle bond loss of the reinforcement embedded in the FRP slab.

Proper bearing of anchorages on the vertical webs are important for Honeycomb FRP slabs. Failure to do this will result in local flexural damage to compression flange.

Internal or External Reports:

Field Instrumentation and Long-term Monitoring of FRP Bridge over Dubois Creek in Great Bend, PA , December 2002
A hard copy is available upon request.

Publications, Presentations, or, Construction Studies:

"Anchorage of Reinforced Concrete Parapets on Glass Fiber Reinforced Polymer Bridge Decks" This publication details the investigation conducted to develop an effective means of connecting glass fiber reinforced polymer (FRP) bridge decks to conventional reinforced concrete parapets.

Additional Comments:

Technology used on Other Projects: FRP decks connected to reinforced concrete barriers not used on other Pennsylvania projects. FRP deck/slab has been used.

Plans on Reuse of Technology: Yes, Future construction recommendations should be implemented and dynamic testing under real time impact should be conducted to verify the FRP performance.

Applicability to other States: Yes, This technology is applicable to all states.

Additional Project Notes:

4/7/08: Closed

2002: Completed

Companion FPN : X-045(117) (Funding: Q120)

Believe remaining \$139,272 given back to HQ for redistribution

State DOT Contact: Harold Hill

E-mail: hhill@ state.pa.us

Phone: 570-963-4027

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** SR 15 over Johnson Creek and SR 2016**State:** PA **Federal-Aid Project #:** X037(199) **Fiscal Year:** 2005 **Funds Awarded:** \$150,000.00**Fund Status:** \$150,000.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Epoxy Overlay Deicing System

Technology Description: Epoxy overlay deicing system applied to bridge deck as additional protection.

Project InformationPositive Results:

Epoxy overlay deicing system provides secondary benefit of additional deck protection system in addition to providing de-icing qualities. County maintenance manager has been pleased with the benefits of the system. Reductions in winter maintenance and number of accidents have been noted.

Negative Results:

None.

Lessons Learned:

Barrier to implementation of Technology: Consider epoxy overlay deicing system on bridges having accident history or other contributing factors such as long span, high under-clears (which may contribute to deck freezing before road surface), and high super-elevation rates.

Internal or External Reports:

None.

Publications, Presentations, or, Construction Studies:

None. The district is monitoring epoxy overlay system effectiveness including performing annual visual inspections, anti-skid testing, and reviewing log books of winter maintenance personnel following snow removal operations to determine effectiveness of de-icing claim.

Additional Comments:

Technology used on Other Projects: No, this application was not used on other Pennsylvania projects

Plans on Reuse of Technology: Yes, this application is potentially a viable method to provide adequate protection to bridge decks.

Applicability to other States: Yes, This technology is applicable to all states.

Additional Project Notes:

- Closed on 9/12/08
- Companion to FPN# X037(198)

State DOT Contact: Gary Williams

Phone: 570-368-4262

E-mail: gwilliams@ state.pa.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** SR 2024 over Towanda Creek**State:** PA **Federal-Aid Project #:** X039(135) **Fiscal Year:** 2003 **Funds Awarded:** \$400,000.00**Fund Status:** \$400,000.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Corrugate Web

Technology Description: Demonstration project of a high performance steel (HPS) bridge, using I-Shaped girders with corrugated webs.

Project Information**Positive Results:**

- The preliminary designs study showed corrugated web girders can be lighter than conventional girders by approximately 10% when using the newly developed shear strength criteria.
- Corrugated web girder fabrication can be managed in a commercial steel bridge fabrication shop.
- Gas metal arc welding can be used effectively in the process of fabrication.
- Test results showed a web splice with a single row of bolts on each side of the splice can easily develop the shear capacity of a corrugated web.

Negative Results:

- Shear strength theory didn't safely estimate the shear strength of corrugated web girder.

Lessons Learned:

Barrier to implementation of Technology: Fabrication experience showed trapezoidal corrugations offer distinct advantages over sinusoidal corrugations.

Fatigue cracks generally initiated at the web-to-flange weld toe along the inclined web folds and the bend regions adjacent to the inclined folds.

Category B' design curve was found appropriate for finite fatigue design calculation, and 96.5 Mpa for the constant amplitude fatigue limit.

Bearing Stiffener strength can be calculated from modified AASHTO LRFD column formula.

Internal or External Reports:

"Corrugated Web Girder Shape and Strength Criteria"

"Corrugated Web Girder Fabrication"

"Fatigue Resistance of Corrugated Web Girders"

"Bearing Stiffeners and Field Splices for Corrugated Web Girders"

"I-Girders with Flange Rotational Restraint Braces"

These reports detail the design criteria development, fabrication and analysis of the corrugated I-girder bridge.

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: No, Corrugated web girder was not used on other Pennsylvania projects

Plans on Reuse of Technology: Yes, if the field testing can verify the laboratory results.

Applicability to other States: Yes, This technology is applicable to all states.

Additional Project Notes:

4/7/2008: Closed

State DOT Contact: Gary Williams

Phone: 570-368-4262

E-mail: gwilliams@ state.pa.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** SR 4012 over Shamokin Creek**State:** PA **Federal-Aid Project #:** X034(178) **Fiscal Year:** 2005 **Funds Awarded:** \$200,000.00**Fund Status:** \$187,513.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Bonded Reinforcement in Deck Panel**Technology Description:** Fiber reinforced polymer (FRP) reinforcement were externally bonded to concrete beams to evaluated the fiber-wrap technology for bridge repair.**Project Information****Positive Results:**

A proper strategy for implementation of this technology can result in considerable economic savings for PennDOT, as many concrete T-beam bridges are in need of repair.

Negative Results:

None.

Lessons Learned:**Barrier to implementation of Technology:** Through the repair contract, lab studies and post-construction load testing, it can be concluded that Externally Bonded FRP Composites are viable means to rehabilitate concrete T-beam bridges.

The stiffness of the repaired bridge did not change much.

Q/C is important during bridge repair.

Design parameters for repair shall be confirmed by quantitative testing.

Designed FRP should not encase bottom flange thereby trapping water and salts.

Extra FRP bottom layers preferred versus layers on side webs.

Internal or External Reports:

“DISTRICT 3-0 INVESTIGATION OF FIBER-WRAP TECHNOLOGY FOR BRIDGE REPAIR AND REHABILITATION (Phase III)” This Final Report details the findings of the investigation of the fiber-wrap technology for bridge repair and rehabilitation.

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: No, FRP bonded reinforcement was not used on other Pennsylvania projects

Plans on Reuse of Technology: Yes, this technology is potentially a viable means to rehab concrete T-beam bridges.

Applicability to other States: Yes, this FRP application is applicable to all states in need of similar types of repair or strengthening.

Additional Project Notes:

3/17/10

The Original Project name was SR 45 over Tributary to Buffalo Creek.

State DOT Contact: Gary Williams
E-mail: gwilliams@ state.pa.us

Phone: 570-368-4262

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** SR 4012 over Slippery Rock Creek**State:** PA **Federal-Aid Project #:** X102(143) **Fiscal Year:** 2003 **Funds Awarded:** \$120,000.00**Fund Status:** \$119,763.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Deck

Technology Description: The construction of a bridge consisting of galvanized steel beams acting compositely with fiber reinforced polymer (FRP) deck panels. Static load field testing was conducted to assess the composite response of the FRP decks system.

Project Information**Positive Results:**

- FRP deck acted compositely with steel stringers to some extent and hence assists the steel stringer in resisting applied moments.
- AASHTO LRFD formulas may be applicable for FRP decks on steel stringers in a short span simply supported bridge with small girder spacing.

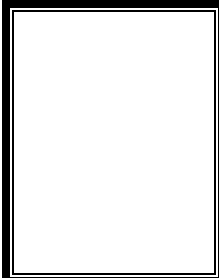
Negative Results:

None.

Lessons Learned:

Barrier to implementation of Technology: Some of the strain gages did not work efficiently when testing was conducted. Further research is required to verify the tested results through investigating the long-term performance of the steel-supported FRP deck bridges, both in the field and in the laboratory.

A three-dimensional finite element model is also a good way to validate the tested results.

Internal or External Reports:

“DISTRICT 3-0 INVESTIGATION OF FIBER-WRAP TECHNOLOGY FOR BRIDGE REPAIR AND REHABILITATION (Phase III)” This thesis details the composite response assessment of the steel beam-FRP deck system in the Boyer Bridge over slippery rock creek.

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Yes, FRP deck panel is used on other Pennsylvania projects.

Plans on Reuse of Technology: No, further research is recommended to verify the results.

Applicability to other States: Yes, This technology is applicable to all states.

Additional Project Notes:

3/17/10: Open

State DOT Contact: Jim Andrews
E-mail: jandrews@ state.pa.us

Phone: 724-357-2821

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** SR 4034 over Wintergreen Gorge**State:** PA Federal-Aid Project #: X012(196) Fiscal Year: 2002 Funds Awarded: \$500,000.00**Fund Status:** \$500,000.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Steel

Technology Description: High performance steel used in bridge construction instead of standard structural steel.

Project InformationPositive Results:

- Reduction in quantity of fabricated structural steel.
- Simplified erection.
- Number of field splices reduced

Negative Results:

- Material availability
- Welding requirements for welding grade 70 to grade 50 steel

Lessons Learned:

Barrier to implementation of Technology: Decision to use HPS should be made early in the design process to assure material acquisition. Fast track projects probably not well suited for use of this material

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Yes, HPS has been used on other Pennsylvania projects

Plans on Reuse of Technology: Unable to determine from this project, reports were not submitted.

Applicability to other States: Yes, This technology is applicable to all states, and has been implemented in several states.

Additional Project Notes:

3/17/10: Open

State DOT Contact: William Koller
E-mail: wkoller@ state.pa.us

Phone: 814-678-7106

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** SR 8043 (California Ave) over SR 65 (Ohio River Blvd)**State:** PA **Federal-Aid Project #:** X111(515) **Fiscal Year:** 2005 **Funds Awarded:** \$185,300.00**Fund Status:** \$185,284.00 Expended **Project Status:** CompletedAssociated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Coating/Paint

Technology Description: A two-coat paint system, Corothane I Galvapak One Pack Zinc Primer with Fast Clad Urethane topcoat was applied on a bridge superstructure. This new paint system was tested, evaluated and compared to the currently approved paint system.

Project InformationPositive Results:

None

Negative Results:

- The two-coat system developed pinpoint rusting after the first year of application, and the pinpoint rusting has continued to progress as observed in the second and third year review.
- The product did not perform at the same level as the currently approved three-coat paint system.
- There is no savings in material (paint) because the thickness (mills) still needs to be applied whether it is two coats or three coats.
- Material not atomizing properly and clogging the spray gun.

Lessons Learned:

Barrier to implementation of Technology: The accelerated curing properties of the two-coat system provided the quality control inspectors a shorter turnaround time to test the coating for proper coverage. However, problems with the package stability of the primer were noted in the course of application of the material, which effected application of the primer. If the two-coat paint system is tested again, the contractor should be made aware of the sensitivity of the package stability of the primer. Additional training of the selected contractor will be necessary for application of the Corothane I Galvapak Zinc Primer.

Internal or External Reports:

The letter from the Pennsylvania Department of Transportation to the paint manufacturer and the Final Report summarizing the lab testing results and the department decision on this paint system.

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: No, this Two-Coat paint system was not used on other Pennsylvania projects.

Plans on Reuse of Technology: No, the product did not perform well.

Applicability to other States: No, the product did not perform well.

Additional Project Notes:

The Corothane I Galvapak Zinc Primer is moisture-cured urethanes, which requires special processing during manufacturing to maintain the products integrity. Sherwin Williams needs to address the sensitivity of the primer, so we can have less construction issues with the material not atomizing properly and clogging the spray gun.

Additional discussions between the District Bridge Engineer and Structure Control Engineer, revealed the following:

- Sherwin Williams claims that this paint can be applied over a two night period (only 2 traffic control setups). However that did occur during the work in Pittsburgh. There are a number of factors contributing to this including weather and the need for touching up the paint.
- Evaluation of this product is closed and will not be approved for use on PennDOT projects.

State DOT Contact: Lou Ruzzi

Phone: 412-429-4893

E-mail: lruzzi@ state.pa.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** T-565 over Dunning Creek**State:** PA **Federal-Aid Project #:** X091(126) **Fiscal Year:** 2000 **Funds Awarded:** \$464,000.00**Fund Status:** \$464,000.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Deck Panel

Technology Description: Fiber reinforced polymer (FRP) deck used in bridge construction.

Project InformationPositive Results:

- Lightweight properties reduced erection time.
- Able to achieve a limited composite action.
- AASHTO LRFD could be applied for close beam spacing in short spans.

Negative Results:

- Difficulty attaching structure mounted guiderails to the FRP deck.

Lessons Learned:

Barrier to implementation of Technology:

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Yes, The FRP Deck have been used on other Pennsylvania projects

Plans on Reuse of Technology: Unable to determine from this project, reports were not submitted.

Applicability to other States: Yes, This technology is applicable to all states, and has been implemented in several states.

Additional Project Notes:

4/18/2006: Completed/Closed

State DOT Contact: Ralph DeStefano
E-mail: rdestefano@ state.pa.us

Phone: 814-696-7180

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** TR-776 Bridge over English Run**State:** PA Federal-Aid Project #: X032(218) Fiscal Year: 2004 Funds Awarded: \$134,000.00**Fund Status:** \$133,883.00 Expended **Project Status:** CompletedAssociated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Deck Panel

Technology Description: Fiber reinforced polymer (FRP) deck panels with polyester polymer concrete wearing surface used in bridge construction.

Project InformationPositive Results:

- Reduced construction time, the deck replacement project only requires the road and bridge to be closed for 14 calendar days.

Negative Results:

During the final inspection it was noted that there was some cracking evident in the PPC Wearing Surface. Subsequent to the final inspection, several more cracks appeared in the PPC Wearing Surface which prompted several discussions and meetings between all parties involved to come to a resolution on repairing the deck joints and cracks in the PPC wearing surface. Repairs were initiated to the field glued deck joints and cracks in the PPC on October 21, 2009. These repairs also included the re-tightening of the deck attachment bolts that held the deck to the existing steel I-beams, this may have also contributed to the cracks in the wearing surface.

Overall, in conclusion, there certainly are advantages with the time line for construction and installation for these types of decks. This was a benefit. The existing deck panels appear structurally sound; however, given the cracking that resulted in the field glued panel joints and the PPC Wearing Surface and the subsequent issues that has created, needless to say, it has resulted in a project that was not the most successful.

Lessons Learned:

Barrier to implementation of Technology: This project was initially Let with Bedford Plastics as the FRP Supplier in November 2005. Shortly thereafter, it was made known that Bedford Plastics was involved in a lawsuit and could not manufacture the FRP Panels. Therefore, a new FRP Supplier had to be obtained which resulted in Wagner's From Australia. This also resulted in a significant delays and re-organization in project funding.

Internal or External Reports:

None at this time. A "Construction Consultation Summary and Post Construction Evaluation Report" will be submitted to the District after LDG performs their last inspection as indicated in LDG's Scope of Work for Post Construction. This inspection is intended to take place one year after the initial inspection was performed on the deck on June 17, 2009.

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Yes, FRP deck panel is used on other Pennsylvania projects.

Plans on Reuse of Technology: No, this project was not a success.

Applicability to other States: Yes, This technology is applicable to all states, and has been implemented in several states.

Additional Project Notes:

The timeline for "Field Construction Operations" was as follows:

- May 26, 2009 – Road was Closed to Traffic and the existing bridge deck was removed.
- May 27, 2009 - 1st Dry Fit of FRP Panels
- May 28, 2009 – Additional Dry Fitting of FRP Panels
- June 2, 2009 – Additional Dry Fitting of FRP Panels and installation of Bearing Pad Material on top of existing beams
- June 3, 2009 - Installation of FRP Panels by field gluing deck panel joints
- June 4, 2009 – Installation of Polyester Polymer Concrete (PPC) Wearing Surface on FRP Deck
- June 8, 2009 - Approach roadway paving and guide rail. Open to Traffic
- October 21, 2009 – Re-tightening of deck bolts, repairing of cracks in PPC Wearing surface and attempts to properly adhere field glued deck joints.

The main advantage for this IBRC Deck Replacement Project was construction duration. The project only required the road and bridge to be closed for 14 calendar days. This was huge advantage compared to other deck replacement types (i.e., concrete deck). There is a large coal company located on the north approach to the project and the bridge is the only access in and out of the coal company. Approximately 50-100 coal trucks cross the bridge on a daily basis. Therefore, minimizing the amount of time the bridge was actually closed to traffic was a huge advantage for the coal company. If a concrete deck was utilized, construction duration would've been substantially longer, increasing the economic impact to the coal company.

A "Construction Consultation Summary and Post Construction Evaluation Report" will be submitted to the District after LDG performs their last inspection as indicated in LDG's Scope of Work for Post Construction.

The Summary Report will include a "Construction Consultation Summary" that took place over the Construction Duration, including but not limited to the following:

- 3-3-08 Formal Revised Contract Plans and Specifications
- Fiber Reinforced Polymer Bridge Deck Design Report – Shop Drawings
- Alternate End Support Shop Drawings
- Kwik Bond PPC 1121 Polyester Polymer Concrete & Healer/Sealer Product Data Sheets for Deck and Wearing Surface
- Tamms DURAL Fast Set Epoxy Gel Data Sheet for Deck Panel Joints (Glue between FRP Panels)
- Final Inspection Form & Construction Punch List
- Certificate of Manufacturers Warranty from Wagner's
- 6-17-09 Final Inspection / Cursory Initial NBIS Bridge Safety Inspection Report (of Items Related to Construction Contract Only)
- 8-11-09 Wagner's Investigation and Repair Recommendations Report
- 9-9-09 NBIS Bridge Safety Inspection Report

The Summary Report will also include a "Post Construction Evaluation Report". This will summarize the findings from the 2009 Inspection and compare those findings to the 2010 Inspection.

The Summary Report will also include photos documenting the construction processes.

This summary report will be submitted to the District and County.

State DOT Contact: Gary Williams
E-mail: gwilliams@ state.pa.us

Phone: 570-368-4262

1.40. PUERTO RICO

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Bridge# 281 at PR-139 (Km 2.5)**State:** PR **Federal-Aid Project #:** BHQ-139 (16) **Fiscal Year:** 2004 **Funds Awarded:** \$400,000.00**Fund Status:** \$400,000.00 Expended **Project Status:** Complete**Associated Project Names**

AC-013932

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Composite Deck

Technology Description: Fiber Reinforced Polymer used in deck design to significantly reduce construction time and maintenance costs

Project Information**Positive Results:**

- Impact to traffic was minor due to the rapid construction of the bridge; footings were pre cast also. It was possible to maintain existing roadway profile due to section reduced depth, avoiding flood level increase. Area is very sensitive to flooding.
- Bridge superstructure expected to be "maintenance free".

Negative Results:

None

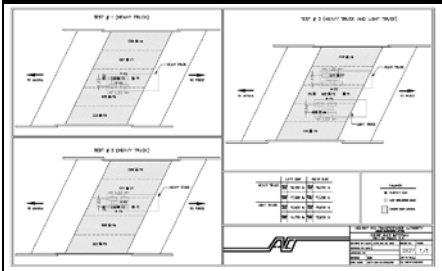
Lessons Learned:

- Technology implementation feasible for short span bridges where no alternate access roadway is available and rapid construction is needed.

Internal or External Reports:

None

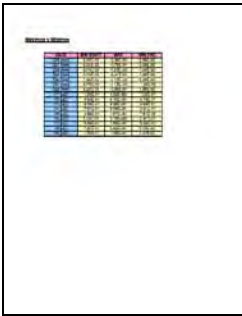
Publications, Presentations, or Construction Studies:



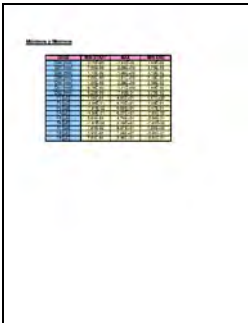
Load Test Drawings



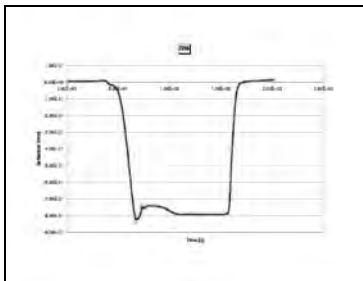
DOT Max and Min – Test 1



DOT Max and Min – Test 2



DOT Max and Min – Test 3



DOT Test 3 Graphs

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

Project Completed: August 2009

State DOT Contact: Héctor R. Laureano, P.E.

Phone: 787-365-4224

E-mail: hlaureano@act.dtop.gov.pr

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Bridges #2028 and #2029 on PR-52 over PR-1**State:** PR **Federal-Aid Project #:** IBRC-52 **Fiscal Year:** 2001 **Funds Awarded:** \$500,000.00
(15)**Fund Status:** \$500,000.00 Expended **Project Status:** Complete**Associated Project Names**

AC-520052

Project: Change / Associated

Reallocated from / to:

Technology Implemented: CFRP Bonded Reinforcement**Technology Description:** Carbon Fiber-Reinforce Polymer retrofit used to improve the performance and extend the life of two different deteriorated bridges**Project Information****Positive Results:**

- This was the first FRP project PRHTA performed. After its successful completion 2 additional bridges were retrofitted on PR-30 and another bridge will be rehabilitated soon in PR-26. The use of the technology has allowed the PRHTA to rehabilitate bridges with a minor impact to traffic in metropolitan areas. The material has performed well and delamination or other defects have not been observed.
- The retrofit increased the bending stiffness of the bridge by 15%, decreased the tensile strains in the bottom rebars of the concrete T-beams by 13%, and the maximum rebar strains under a heavy truck load case were only 10% or the yield strength
- All strains and deflections were reduced after the application of the CFRP

Negative Results:

- Only negative aspect was that CFRP application took more time than expected; but the reason was not related to the technology or application process but to a lack of personnel to perform the work. Work was performed by maintenance crews instead of a Contractor.

Lessons Learned:

- Technology is feasible for future implementation in bridges with high ADT in metropolitan areas.
- Personnel should not be removed from project or substituted after initial training of CFRP application.

Internal or External Reports:

Draft Report "Static Load Testing and Dynamic Testing of the Bridge 2028 near Cayey"

Publications, Presentations, or, Construction Studies:

"Static and Dynamic Testing of a Concrete T-Beam Bridge Before and After Carbon Fiber-Reinforced Polymer Retrofit"



"Monitoring the Performance of a R/C T Beam Bridge with Carbon Fiber-Reinforced Polymer Sheets"

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

Completion date was: November 2003

State DOT Contact: Héctor R. Laureano, P.E.
E-mail: hlaureano@act.dtop.gov.pr

Phone: 787-365-4224

1.41. RHODE ISLAND

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Eastbound I-95, Washington Bridge**State:** RI **Federal-Aid Project #:** 2001-CB-045 **Fiscal Year:** 2001 **Funds Awarded:** \$46,000.00**Fund Status:** \$46,000.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Galvanic Anodes in Bridge DeckTechnology Description: Galvanic Anodes installed in bridge deck to determine its resistance to rebar corrosion**Project Information****Positive Results:**

- The anodes were successfully installed during construction, and some were successfully retrieved during demolition. The rebar near the anodes did not appear to be deteriorating.

Negative Results:

- The length of time the anodes were in the deck was not sufficient (only approx. 2 years) to be able to determine if the anodes resisted deterioration of the steel rebar.

Lessons Learned:**Barrier to implementation of Technology:**

- To properly test these anodes, a study period of 20 years appears more appropriate to see if the anodes can truly resist rebar corrosion.

Internal or External Reports:

None.

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: This technology was not used on other Rhode Island projects.

Plans on Reuse of Technology: Unable to determine, a longer study period is recommended to determine the validity of the anodes resistance to rebar corrosion.

Applicability to other States: This technology is applicable and has been used by other sates.

Additional Project Notes:

10/30/08: project completed

State DOT Contact: Bob Pavia
E-mail: bpavia@dot.ri.gov

Phone: 401-222-2053 ext 4079

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Great Rd. Bridge 447**State:** RI **Federal-Aid Project #:** _____ **Fiscal Year:** 2005 **Funds Awarded:** \$390,000.00**Fund Status:** \$0.00 Expended **Project Status:** Initiated**Associated Project Names**

Garden street over I-95

Project: Change / AssociatedReallocated from / to: \$390,000.00**Technology Implemented:** Seismic Roller Isolation Bearings

Technology Description:

Project Information**Positive Results:**

- Results are inconclusive at this time. Project punch list completed in December 2010. Monitoring of bearings will take place for two years after final construction completion by MCEER. We anticipate MCEER to initiate monitoring in spring 2011.

Negative Results:

- So far, material/fabrication issues have caused problems in construction. The bearings required specialty welding and a PQR performed in accordance with AWS because of AISI-1045 and ANSI-4140 dissimilar metals. The bottom plate/masonry plate and the upper plate/sole plates were the issue. RIDOT waited significant time for the welding procedure from MCEER to correct this issue

Lessons Learned:**Barrier to implementation of Technology:**

- So far, we would strongly recommend making sure the steel components of the bearings are similar metals which can be welded in accordance with AWS procedures to avoid unforeseen construction delays.

Internal or External Reports:

None.

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: This technology was not used on other Rhode Island projects.

Plans on Reuse of Technology: Unable to determine, monitoring is ongoing.

Applicability to other States: Unable to determine, monitoring is ongoing.

Additional Project Notes:

10/30/08: In construction. 50% complete.

3/9/10: Project in construction. 2nd phase almost complete.

12/15/10: Final Inspection

Funding for this project was split between design/monitoring and construction. Total payment for the design/monitoring portion is \$135,000. The remaining balance of the \$390,000 being paid in construction upon completion.

State DOT Contact: Robert F Fura, P.E.
E-mail: rfura@dot.ri.gov

Phone: 401-222-2053 ext 4068

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Iway Contract 7, Arch Span**State:** RI **Federal-Aid Project #:** _____ **Fiscal Year:** 2004 **Funds Awarded:** \$320,000.00**Fund Status:** \$320,000.00 Expended **Project Status:** CompletedAssociated Project Names

Providence River Bridge

Project: Change / AssociatedReallocated from / to: \$320,000.00**Technology Implemented:** Strain Gauges & Load Cell InstrumentationTechnology Description: Strain gauges and load cell instrument used to verify load carried by concrete deck.Project InformationPositive Results:

- The information gained from the strain gages and load cell verified the analytical model used for design and enhanced the understanding of the load carried by the concrete deck. The load cell enabled direct correlation between the natural frequency of the cable and the load in the cable. The natural frequency of the cable was being used to determine cable loads during the final tensioning of the cables and was yielding incorrect results due to the stiffness of the connections. The load cell enabled the determination of a correction factor.

Negative Results:

- The strain gages were installed after some initial load was in the steel. It would have been ideal if the strain gages were applied in the fabrication shop so that strains due to self weight could have been determined. The gage results exhibited some 'noise' due to minor thermal, wind, or construction loads that had to be averaged out. Some gages did not work and had to be ignored in the analysis of the data.

Lessons Learned:**Barrier to implementation of Technology:**

- The strains for the concrete dead loads that were measured were relatively small and were influenced by the 'noise' of other minor loads. If the strain gages are installed earlier, they would measure the entire dead load with higher strains, and the other minor loads would be relatively less significant.

Internal or External Reports:

A final report was prepared by Maguire Group Inc. and submitted to the Rhode Island Department of Transportation entitled 'Iway Contract 7 Arch Span Superstructure Instrumentation'. The report describes the instrumentation program, the bridge, the assumptions and the results. (Not available)

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Strain Gauges and load cell instruments were not used on other Rhode Island projects.

Plans on Reuse of Technology: This technology may be reuse if installation occurs in the fabrication shop.

Applicability to other States: Yes, this technology is applicable to all states.

Additional Project Notes:

Project completed in 2007

State DOT Contact: Michael Savella
E-mail: msavella@dot.ri.gov

Phone: 401-222-2053 ext 4080

1.42. SOUTH CAROLINA

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** SC RTE 73 Myrtle Beach**State:** SC Federal-Aid Project #: BRZ-BR26(002) Fiscal Year: 2000 Funds Awarded: \$184,500.00**Fund Status:** \$112,500 Expended **Project Status:** CompletedAssociated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Stainless steel Rebar

Technology Description: Investigations into the performance of various corrosion resistant reinforcement steel in highway bridges used to increase long term performance of bridge. Three different types of reinforcement were tested: SS clad by SMI, stainless steel by Talley, and black steel with and without zinc anode.

Project InformationPositive Results:

- SCDOT gained valuable experience concerning corrosion in bridge decks by utilizing solid stainless steel rebar
- At pH 9.5 the carbon steel with Galvashield CC anode showed potential of -0.40 V in the absence of chlorides and -0.6 V vs SCE in the presence of chloride ions. The sacrificial protection was observed after 60 days of wet-dry exposure of the sample. The corrosion rate was less than 0.1 mpy and 8 mpy in the absence and presence of Cl⁻ ions.
- At pH 12.5, the carbon steel connected with Galvashield CC sacrificial anode showed a stable potential of -0.20 V vs SCE through out the testing period. In the presence of chlorides, the initial potential (-0.5 V vs. SCE) started to shift towards more negative potentials (-0.95 V vs. SCE) after 83 days. The corrosion rates calculated was 0.1 mpy and 9 mpy in the absence and presence of Cl⁻ ions.
- The corrosion rates of cylinders immersed in DI water with 3.5 wt.% NaCl suggests that the chloride ions have already reached the steel surface in the case of carbon steel, MMFX 2 and carbon steel with zinc anode. As expected, SS clad and stainless steel rebar samples showed lower corrosion rates of 0.017 and 0.022 mpy respectively.

Negative Results:

- Corrosion resistant steel reinforcement has a higher material cost when compared to traditional steel, a determination must be made if the lower life cycle costs outweigh the initial costs

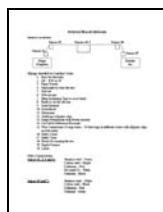
Lessons Learned:

Barrier to implementation of Technology: none

- Solid stainless steel rebar works well for resisting corrosion in bridge decks.

Internal or External Reports:

Myrtle Beach Proposal "Evaluation of Economical and Efficient Method For Corrosion Protection of Structural Concrete: Experimental Studies and Mathematical Modeling"



"Myrtle Beach Sensors"



Proposals (SCDOT2002) "Investigations into the Performance of Various Corrosion Resistant Reinforcement Steel in Highway Bridges"



Proposals_SCDOT2003 "Investigations into the Performance of Various Corrosion Resistant Reinforcement Steel in Highway Bridges"



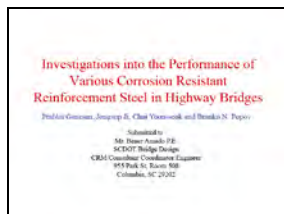
SCDOT_Abstract_2006 "INVESTIGATIONS INTO THE PERFORMANCE OF VARIOUS CORROSION RESISTANT REINFORCEMENT STEEL IN HIGHWAY BRIDGES"



SCDOT_Report_Sep2006 "Investigations into the Performance of Various Corrosion Resistant Reinforcement Steel in Highway Bridges"

Publications, Presentations, or, Construction Studies:

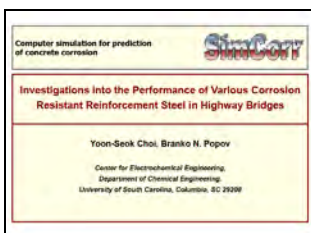
All titled: "Investigations into the Performance of Various Corrosion Resistant Reinforcement Steel in Highway Bridges"



"SCDOT_Jan252077"



"SCDOT_Jan252007-DrP"



"Simulation Part"

Additional Comments:

Technology used on Other Projects: not reported

Plans on Reuse of Technology: not reported.

Applicability to other States: Wide applicability, virtually every state has a need for steel with better resistance to corrosion

10/30/08: Project is complete

State DOT Contact:

Steven Schumacher, District 8 Area
Engineer

Phone: (304) 637-0220 ext 14

E-mail: steven.g.schumacher@wv.gov

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** S-42-655 over Norfolk/Southern Railroad**State:** SC **Federal-Aid Project #:** BRZ-
BR42(006) **Fiscal Year:** 2001 **Funds Awarded:** \$369,000.00**Fund Status:** \$360,000.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to: {\$}

Technology Implemented: FRP Deck PanelTechnology Description: Fiber Reinforced Polymer deck panels used to reduce deterioration caused by corrosion**Project Information****Positive Results:**

- SCDOT gained experience in working with fiber reinforced polymer (FRP) decks.

Negative Results:

- Obtaining composite action with the supporting girders was difficult. Shear studs were welded to the girders and the panels with corresponding pockets (through holes) were placed on the girders. The connection required grouting of the pockets to obtain the composite action. The contractor tried many different methods to place the grout, rather than mix it on site and place per the Manufacturer's recommendations.

Lessons Learned:

- Ensure that prospective contractors have experience in constructing Composite FRP deck bridges, especially in the placement of grout within the grout pockets.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

10/30/08: Complete

State DOT Contact: Terry Koon

Phone: 803-737-0028

E-mail: Koontb@scdot.org

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** SC Rte. S-54 over Tidal Creek**State:** SC **Federal-Aid Project #:** BRZ-BR10012 **Fiscal Year:** 2003 **Funds Awarded:** \$298,782.00**Fund Status:** \$285,083.91 Expended **Project Status:** Completed**Associated Project Names**

BR11(006)

Project: Change / AssociatedReallocated from / to: {\$13,698.09}**Technology Implemented:** Reinforcing bars: MMFX, Stainless steel, Stainless steel cladTechnology Description: Summarizes the corrosion performance of SS clad by SMI, stainless steel by Talley, black steel with and without Zn anode (*Galvashield CC*) and MMFX2 rebars embedded in concrete cylinders.**Project Information****Positive Results:**

SCDOT gained valuable experience concerning corrosion in bridge decks by utilizing several types of non conventional reinforcing steel.

Negative Results:

None

Lessons Learned:**Barrier to implementation of Technology:**

Solid stainless steel rebar is the most effective material for reducing corrosion in bridge decks, followed by MMFX. Stainless steel clad rebar did not perform well as the cladding tended to crack under stress, which caused significant localized corrosion.

Talley metals' stainless steel rebar provides longer life than MMFX and carbon steel rebars under corrosive conditions. The order of service life is Talley>MMFX>carbon steel under corrosive conditions. Hence, protection strategies for stainless steel rebars need to focus on this aspect of chloride attack and should passivate the surface for longer periods of time as compared to carbon steel

there is not much different in the cost for the installation of SB and MMFX (~\$15.00/ft2). The costs for the stainless steel rebars are nearly double that of SB or MMFX. Keeping in mind the service life which stainless steel rebars offer, it can be considered for bridge constructions where severe corrosion attack is possible

Internal or External Reports:

External Research Report by USC: "Investigations into the Performance of Various Corrosion Resistant Reinforcement Steel in Highway Bridges"

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: not reported

Plans on Reuse of Technology: if dolphins are shown to outlast timber and prove to be cost-effective, the technology will be reused.

Applicability to other States: pending long term durability.

10/30/08: Remaining funds of \$13,698.09 applied to BR11(006)

State DOT Contact: Bener Amado

Phone: 803-737-0181

E-mail: Amadob@scdot.org

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** SC 171 over Wappoo Creek**State:** SC **Federal-Aid Project #:** BR-IB 10001 **Fiscal Year:** 2002 **Funds Awarded:** \$205,000.00**Fund Status:** \$205,00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Pier Protection

Technology Description: FRP was used for channel dolphins in place of traditional timber.

Project InformationPositive Results:

SCDOT gained valuable experience associated with the use of fiber reinforced polymers (FRP) as channel dolphins

Negative Results:

Initial costs need to be justified with long term durability

Lessons Learned:**Barrier to implementation of Technology:** Long term effectiveness unproven, initial cost is high

The cost of FRP dolphins is initially much more expensive than timber. Long term durability has not been assessed, but it is assumed that FRP will far outlast timber. A cost benefit analysis should be done to determine the feasibility for future projects.

Internal or External Reports:

none

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: not reported

Plans on Reuse of Technology: if dolphins are shown to outlast timber and prove to be cost-effective, the technology will be reused.

Applicability to other States: pending long term durability.

10/30/08: Project is complete

State DOT Contact: Bener Amado

Phone: 803-737-0181

E-mail: Amadob@scdot.org

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** SC 377 Bridge over Black River**State:** SC **Federal-Aid Project #:** BR45002 **Fiscal Year:** 2004 **Funds Awarded:** \$390,933.00**Fund Status:** \$390,933.00 Expended **Project Status:** Not Reported**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Self Consolidated Concrete in I-Beams

Technology Description: Self Consolidated Concrete used in I-beams for easier placement and to reduce labor costs

Project InformationPositive Results:

- Gained experience in the use of self consolidating concrete (SCC) in prestressed concrete I beams.

Negative Results:

- The modulus of elasticity is lower for SCC versus normal weight concrete, resulting in more camber and/or deflections.

Lessons Learned:

- SCC is much easier to place and the beams require considerably less finishing work after the forms have been removed.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

None

State DOT Contact: Bener Amado

Phone: 803-737-0181

E-mail: Amadob@scdot.org

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** US 29 over Thicketty Creek**State:** SC Federal-Aid Project #: BRT-BR110006 Fiscal Year: 2002 Funds Awarded: \$405,000.00**Fund Status:** \$418,698.00 Expended **Project Status:** Completed**Associated Project Names**

SC Rte. S-54 over Tidal Creek

Project: Change / AssociatedReallocated from / to: \$13698.09**Technology Implemented:** HPS 70W Steel Girders

Technology Description: FRP was used for channel dolphins in place of traditional timber.

Project InformationPositive Results:

Gained experience with high strength steel (HSS) and hybrid girders. This was the first time this type of girder was used in South Carolina. SCDOT considers the use of HSS hybrid girders on mostly long span structures and utilizes this application if it is feasible.

Negative Results:

None

Lessons Learned:**Barrier to implementation of Technology:**

It was determined that hybrid girders are the most efficient. 70 ksi HSS steel was used in the flanges at negative moment regions and 50 ksi HSS was used for the remaining portions of the girders.

There is potential for minor weld cracking at stiffener locations due to fatigue loading conditions. Such cracks can potentially be eliminated by alternating transverse stiffeners on either side of the web instead of the traditional method of placing all transverse stiffeners on one side of the web for aesthetic purposes. Small internal cracks, however, may not be completely eliminated by this design alteration

Fabrication imperfections that greatly exceed standard tolerances lead to premature failure of HPS girders and can negate expected enhancements in capacity due to improved bracing scenarios.

Parametric studies involving computer simulations indicate that hybrid girder designs containing HPS 70W in both flanges and Grade 50W in the web provide performance that is comparable to that of homogeneous HPS 70W designs. Thus, hybrid girders containing HPS appear to be structurally adequate and economically feasible.

Laboratory testing confirms the conservative nature of flexural strength equations in the *AASHTO LRFD Bridge Design Specifications* (2004) despite the effects of fabrication imperfections.

AASHTO Standard Specifications Article 10.53 requires that in hybrid girders where the flange stress exceeds the yield strength of the web, the compression flange area needs to be greater than or equal to the tension flange area. The area of the tension flange is to include the area of reinforcing in the deck for composite sections. This requirement causes the compression flange to be made artificially large and reduces the economy of the hybrid section alternative.

Internal or External Reports:

IBRC contribution Report:  "Bridge Replacement Using High Performance Steel (HPS 70W) for US-29 Bridge Over Thicketty Creek, Cherokee County, SC",

USC Research Report:  "STRUCTURAL EVALUATION AND FATIGUE PERFORMANCE OF HPS70W BRIDGE GIRDERS"

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Yes, the state has three HPS bridges at the time of the report

Plans on Reuse of Technology: Yes, lesson learn and experience with the material show it a viable and potentially cost saving material. .

Applicability to other States: multiple states are already using HPS as a regular material

10/30/08: Project is complete

State DOT Contact: Bener Amado

Phone: 803-737-0181

E-mail: Amadob@scdot.org

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** US 378 over the Pee Dee River**State:** SC **Federal-Aid Project #:** BR-BR88041 **Fiscal Year:** 2006 **Funds Awarded:** \$250,000.00**Fund Status:** \$250,000.00 Expended**Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Prestressed Precast Cylinder Piles

Technology Description: Prestressed precise cylinder piles used to accelerate bridge construction

Project Information**Positive Results:**

- Validated that cylinder piles could be utilized in a high seismicity area even though the reinforcing was highly congested.
- The piles were easily installed by pre-drilling, followed by impact driving.
- Use of cylinder piles is compatible with accelerated construction since they are precast.
- The testing program demonstrated that cylinder piles are viable foundation options.

Negative Results:

- Some of the piles were slightly damaged (a layer of very stiff soils were encountered) by excess hammer energy.

Lessons Learned:

- Capacity is limited to spans shorter than those for drilled shafts, and more uniform soils. Installation of the piles creates a lot of vibration, which requires careful consideration of their use near existing structures.
- Many hammers have been used to drive large diameter cylinder piles but there are relatively few that are capable of driving them to a nominal resistance of 2400 kips. The APE 400u worked, but as the wave equation analysis presented in Section 6.5 indicates, it was near its theoretical limit for the given site conditions (see Fig. 23). If cylinder piles are used on the replacement bridge project, the use of a similar or larger hammer will be crucial to the success of the project.

Internal or External Reports:

"Foundation Testing Program Summary Report"

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

10/30/08: Complete

State DOT Contact: Bener Amado

Phone: 803-737-0181

E-mail: Amadob@scdot.org

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** US 76 over Lumber River and Swamp**State:** SC **Federal-Aid Project #:** BRT-BR88023 **Fiscal Year:** 2003 **Funds Awarded:** \$225,000.00**Fund Status:** Unknown**Project Status:** Unknown**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: SCC Drilled Shafts**Technology Description:** Self Consolidating Concrete used in drilled shafts to flow more easily through the rebar cages and reduce labor costs**Project Information****Positive Results:**

- SCDOT gained valuable experience using self consolidating concrete (SCC) in a drilled shaft. SCC worked well for this application due to increased flow ability of SCC.
- The use of set-retarding admixtures can significantly increase the time in which a concrete mixture will remain workable. This enhanced workability may be capable of overcoming placement difficulties associated with tremie placing concrete and congested rebar cages
- The Slump Flow, T50, and J-Ring tests were deemed acceptable quality control procedures for both laboratory and field conditions for drilled shaft applications.

Negative Results:

- The possibility of blockage and segregation may be increased at sand-to-aggregate ratios below 0.44.

Lessons Learned:

- SCC works well but contractors are reluctant to propose as an alternate to normal concrete and SCDOT does not want to specify it's use, due to increased costs and contractors lack of knowledge
- For drilled shaft applications, the dosage of set-retarding admixture should be adjusted to provide an extended initial set necessary to ensure that the workability of the concrete mixture is maintained for the duration of the pour and to allow for any construction delays in concreting and removal of the temporary casing after concreting is completed
- For a given dosage of set-retarding admixture, concrete mixtures can experience faster initial set times and increased slump loss when exposed to higher temperatures compared to the laboratory conditions.
- This research shows that merely estimating the additional amount of set-retarding admixture needed in hot weather conditions is not a sufficient measure to ensure that proper retained workability and set times are achieved. The amount of retarding admixture should be based on trial mixes under simulated conditions.
- It is a must that the static stability of the SCC mixture be part of the determination of the VSI rating. This should be done by observing the SCC mixture in the wheelbarrow or mixing drum directly after the completion of the slump flow test.
- The critical sand-to-aggregate ratio for these materials for passing ability and segregation resistance is 0.44 or higher.
- Due to the time-dependent effects of the HRWR admixture, it is recommended that laboratory mixing procedures account for transportation time and the HRWR admixture be adjusted to account for the transportation time so that SCC mixture will meet the specified quality control limits upon arrival to the job site.
- It is highly suggested that trial mixes be conducted under simulated conditions in order to determine the appropriate set-retarding admixture dosage and proper workability retention is achieved.

Internal or External Reports:

"Project Summary Report Self Consolidating Concrete (SCC) in Drilled Shafts Research Project"

Project Summary Report



"AN EVALUATION OF THE USE OF SELF-CONSOLIDATING CONCRETE (SCC) FOR DRILLED SHAFT APPLICATIONS" Final Project Report

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

10/30/08: Complete

State DOT Contact: Bener Amado

Phone: 803-737-0181

E-mail: Amadob@scdot.org

1.43. SOUTH DAKOTA

No Project Summary Reports were generated for this State.

1.44. TENNESSEE

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Massman Drive / I-40 in Davidson County**State:** TN **Federal-Aid Project #:** _____ **Fiscal Year:** 2003 **Funds Awarded:** \$114,443.00**Fund Status:** \$114,433.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Verify continuity assumptions

Technology Description: Instrumentation, testing and analysis of data to evaluated the effectiveness of the connection at the center pier in providing continuity under the deck's dead load.

Project Information**Positive Results:**

The study confirmed that full continuity over interior supports of steel beams made continuous for all dead and live loads placed subsequent to simple span beam erection conditions is viable, using flange slice plates and concrete support diaphragms

Negative Results:

Full continuity was not achieved in one outside girder.

Lessons Learned:

Barrier to implementation of Technology: More rapid and safe erection of steel beams over traffic is feasible with the proposed details.

More thorough quality inspection program be implemented to ensure that the desired connection at the kicker wedge plate location is achieved.

Internal or External Reports:

“EVALUATION OF EXPERIMENTAL BRIDGE: MASSMAN DRIVE BRIDGE, DAVIDSON COUNTY” This Final Report details the instrumentation, testing, and analysis of data for a two simple span bridge to act as a continuous bridge under the dead load of the deck.

Publications, Presentations, or, Construction Studies:

None.

Additional Comments:

Technology used on Other Projects: No, this study was not used on other Tennessee projects.

Plans on Reuse of Technology: Yes, it was proven that this method works and the bridge can designed as a continuous bridge under the dead load.

Applicability to other States: Yes, this application is applicable to all states; however it is recommended that quality inspection be implemented to ensure that the desired connection at the kicker wedge plates is achieved.

Additional Project Notes:

30/08: complete

used to fund studies to verify 'continuity' assumptions

State DOT Contact: Edward P. Wasserman

Phone: 615-741-3351

E-mail: _____

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** SR-53 over Martin Creek**State:** TN **Federal-Aid Project #:** _____ **Fiscal Year:** 2000 **Funds Awarded:** \$42,800.00**Fund Status:** \$42,800.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Steel in Plate Girders – Fabrication studiesTechnology Description: Testing of high performance steel to determine the diffusible hydrogen level in welds.**Project Information****Positive Results:**

- Improved hydrogen cracking control of welds for High Performance Steels (HPS). Verified the Charpy V-notch Toughness Values of ASTM A852 Steels.
- Diffusible hydrogen levels could be accurately measured using on-site testing and remote-rate hydrogen collection

Negative Results:

None

Lessons Learned:

Barrier to implementation of Technology: Low hydrogen weld consumables are needed for welding of HPS steels of Grade 70 and above. ASTM A852 has high impact properties.

Internal or External Reports:

These documents are test reports to determine diffusible hydrogen level in HPS welds.

Publications, Presentations, or, Construction Studies:

None.

Additional Comments:

Technology used on Other Projects: No, diffusible hydrogen testing was not used on other Tennessee projects

Plans on Reuse of Technology: Yes, it was determined that this form of testing accurately measured level of the diffusible hydrogen.

Applicability to other States: Yes, this technique is applicable to all states with HPS welds in need of similar testing.

Additional Project Notes:

10/30/08: Complete

Used to study fund fabrication studies

State DOT Contact: Edward P. Wasserman

Phone: 615-741-3351

E-mail: _____

1.45. TEXAS

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** All future precast segmental concrete bridge construction**State:** TX **Federal-Aid Project #:** IBR 2003(523) **Fiscal Year:** 2005 **Funds Awarded:** \$150,000.00**Fund Status:** \$150,000.00 Expended **Project Status:** Initiated**Associated Project Names**0-4562: Corrosion Resistance of
Grouted Post-Tensioning
SystemsProject: Change / Associated

Reallocated from / to:

Technology Implemented: Corrosion Resistance of Grouted Post-TensioningTechnology Description: Emulsifiable oils currently available on the market were used to reduce or prevent corrosion**Project Information****Positive Results:**

- Phase I of this project investigated oils uses for temporary corrosion protection measures and their effect on corrosion, bond and other factors.
- Two oils were found that did work to prevent corrosion.
- The oils had a negligible effect on bond strength so flushing is not required.
- HDPE duct could perform better than galvanized steel duct, and that the AASHTO friction factor for HDPE duct was overly conservative.
- Phase II has developed new long-term corrosion specimens and is also continuing to monitor the corrosion specimens from a previous project: 0-1405.

Negative Results:

- Phase II of this project was to investigate new materials or systems that could replace traditional steel strand and grout. They intended to procure strands made of stainless steel, MMFX steel, copper-clad steel but none of these are commercially available and could not be obtained even for testing.

Lessons Learned:

- There are several oils that can be used for temporary corrosion protection without negative effects on the long-term strength of performance of the tendons.

Internal or External Reports:

"Summary: Factors Affecting Bond and Friction Losses in Multi-Strand Post-Tensioning Tendons Including the Effect of Emulsifiable Oils" Phase I Summary Report.

Available at: <ftp://ftp.dot.state.tx.us/pub/txdot-info/rti/psr/0-4562-s.pdf>

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Not reported

Plans on Reuse of Technology: Yes

Applicability to other States: yes, the oils are off-the-shelf and available to all. Positive results when limiting corrosion

Additional Project Notes:

10/30/08: Active

State DOT Contact: Brian D. Merrill, PEPhone: 512-416-2232E-mail: bmerrill@dot.state.tx.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** EB Loop 340 – SH6 Overpass (Mainlanes and Frontage Road Over IH35)**State:** TX **Federal-Aid Project #:** 0015-01-163;
IBR 2003(719) **Fiscal Year:** 2003 **Funds Awarded:** \$400,000.00**Fund Status:** \$400,000.00 Expended **Project Status:** Unknown**Associated Project Names**Aa Amity West Overpass (CR
978 Over IH-35)Project: Change / Associated

Reallocated from / to:

Technology Implemented: Prefabricated Bridge Construction System

Technology Description: Prefabricated Bridge Construction System for piers and superstructure was employed to minimize disruption to IH 35 traffic:

Project Information**Positive Results:**

- The prefabricated piers required no construction of pier cap, however this was due to design and not prefab method
- Saved about 2/3 of the time on deck construction, deck required closure pour only
- Disruption to traffic was minimized

Negative Results:

- Visual inspections indicate good performance under service loads and laboratory studies have validated the design assumptions made and indicate sufficient capacity to resist the superimposed loads
- Footings took a little longer because of the need to accommodate PC Shells
- Columns took almost twice as long vs. conventional bridge construction, this was mainly due to getting column shells to line and grade on pedestals
- Did not see a considerable time savings in the superstructure construction

Lessons Learned:

- Prefabricated superstructure closure pour system execution is complex in the field, but exhibits sufficient structural capacity and good long-term durability performance
- Pre-Cast Column Shells did not perform as well as desired
- Pre-topped U-Beams performed well, but could be simplified

Internal or External Reports:

None

Publications, Presentations, or Construction Studies:

"Precast Bent and Deck Construction IH 35 Waco" Presentation



"Accelerated Bridge Design in Texas"

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

3/2010: Active

State DOT Contact: Lloyd M. Wolf, P.E.
E-mail: lwolf@dot.state.tx.us

Phone: 512-416-2279

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Farm to Market Road 1362 over Sue Creek**State:** TX **Federal-Aid Project #:** 0833-12-014; **Fiscal** 2001 **Funds Awarded:** \$95,000.00
IBRC2001(462) **Year:****Fund Status:** \$95,000.00 Expended**Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP laminate sheet strengthening of existing Pan Form bridgeTechnology Description: FRP laminate sheets used for strengthening of existing Pan Form bridge**Project Information****Positive Results:**

- We were able to strengthen an existing bridge and make it eligible to be widened using Federal Funds.
- The bridge remained open during construction and there was no need to purchase additional Right-of-Way (ROW).
- If we would have replaced the structure we would have had to close the road or use the existing structure to handle traffic during construction which would have required the additional ROW. Acquiring ROW would have lengthened the project development time and added to the total project cost.
- The application of CFRP was quick, and it took less than a week to complete each span.

Negative Results:

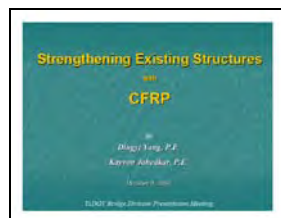
- We could have replaced the bridge for \$35 to \$45 per SF but instead we widened it at a cost of \$84.42 per SF. Considering the funding dilemma, however, this was the only way we could have used federal funds to retrofit this structure

Lessons Learned:

- It appears that using CFRP for strengthening existing structure is a viable option. However, each project should be evaluated on a case by case basis with regard to Hydraulic adequacy, Project location, ROW need and cost, Traffic handling, Overall Cost, and funding.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

"Strengthening Existing Structures with CFRP Presentation", TxDOT Bridge Division Presentation Meeting

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

10/30/08: Closed

State DOT Contact: Mark Steves
E-mail: msteves@dot.state.tx.us

Phone: 512-416-2265

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** FM 1684, Drainage Ditch Bridge**State:** TX **Federal-Aid Project #:** 2025-01-001;
IBR 2003(720) **Fiscal Year:** 2003 **Funds Awarded:** \$370,000.00**Fund Status:** \$370,000.00 Expended **Project Status:** Unknown**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Beams

Technology Description: Fiber Reinforced Polymer beams were implemented as a structural element to increase durability and reduce corrosion and construction time

Project InformationPositive Results:

- No delays in fabrication of beams and were easily implementable.
- Beams stiffness tested better than expected.
- Used with conventional concrete deck providing a high-performance composite action.
- Construction completed using conventional construction equipment. Heavy-Lifting equipment (cranes) not needed.

Negative Results:

- Compared to traditional methods FRP costs were 4 to 4.5 times higher, however long-term cost savings are expected to recoup costs

Lessons Learned:

- Very little built-in camber in FRP beams needed as they deflection is minimal when loaded with concrete deck and avoids excessively thickened ends on concrete bridge deck

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

"The Ongoing Evolution of FRP Bridges"



"Tivoli's Fiberglass Bridge" Article from Texas Contractor Magazine

Additional Comments:

Technology used on Other Projects: Yes

Plans on Reuse of Technology: Yes

Applicability to other States: Not Reported

Additional Project Notes:

10/30/08: Active

Final Voucher has been issued as of 6/24/08. Amount of final voucher is \$41856.16.

State DOT Contact: Armando Bosquez

Phone: 361-364-6405

E-mail: abosque@dot.state.tx.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** FM 1660 over Cottonwood Creek**State:** TX **Federal-Aid Project #:** 1566-02-016;
BR 2006(402) **Fiscal Year:** 2005 **Funds Awarded:** \$300,000.00**Fund Status:** \$300,000.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Replacement Bridge with Abutment Steel Sheet Piling, H-piling Bent Foundation, & Pretensioned Decked Slab Beams**Technology Description:** Replacement bridge with abutment steel sheet piling, H-piling bent foundation, & pretensioned decked slab beams used for rapid bridge replacement to reduce construction time**Project Information****Positive Results:**

- The new decked slab beam design and transverse connectors eliminated the need for cast-in place concrete in the bridge superstructure.
- Based on its success in this replacement project, TXDOT developed standard bridge details for the Decked Slab Beam for state wide use for rapid replacement requirements.
- The bridge was constructed in 33 days. We saved approximately 20 days in the construction sequence by eliminating slab forming and rebar placement, pouring and curing.
- Minimal disruption of traffic by using the decked slab beam super structure.

Negative Results:

None

Lessons Learned:

- The elimination of cast-in place concrete deck reduces the construction time.
- Minimal disruption of traffic by using the decked slab beam super structure.
- Suitable for off system rapid replacement bridges.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

"Accelerated Construction Techniques – Cottonwood Creek Bridge Replacement Project", presentation



"Rapid Short Span Bridge Replacement Innovations", presentation

Additional Comments:

Technology used on Other Projects: Yes

Plans on Reuse of Technology: Yes, the decked slab beams are considered a success and have been implemented as a statewide standard

Applicability to other States: Unknown

Additional Project Notes:

10/30/08: Closed

State DOT Contact: Lloyd M Wolf

Phone: 512-416-2279

E-mail: lwolf@dot.state.tx.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** IH35 NB & SB ML over Hill Road**State:** TX **Federal-Aid Project #:** 0015-07-063;
IBR 2005(912) **Fiscal Year:** 2004 **Funds Awarded:** \$400,000.00**Fund Status:** \$400,000.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Prefabricated Bridge Superstructure Assemblies Rolled into Place

Technology Description: Prefabricated bridge superstructure assemblies rolled into place used to reduce construction time

Project InformationPositive Results:

- Project was completed with conventional cast-in-place construction, within budget, traffic disruption and time constraints.
- TxDOT saved approximately \$2M by not implementing the "prefabricated bridge superstructure assemblies rolled into place" technology.

Negative Results:

- Project constraints and allocation of available resources precluded implementation of this innovative technology.
- The need to realign the roadway to a parallel alignment became apparent during project development and necessitated phased replacement on the alternate alignment. This removed the driver for the totally prefabricated and rolled-in superstructure.

Lessons Learned:

- Contracting community deemed rolled-in construction to have a lot of risks. Bringing in the specialty contractor to do just the roll-in alone was estimated at \$500,000 for this project.
- Recommended only when projects constraints necessitate this type of solution.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

3/2010 Project completed and closed.

State DOT Contact: Lloyd M. Wolf, P.E.

Phone: 512-416-2279

E-mail: lwolf@dot.state.tx.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** IH-35; SH 6 Interchange

State: TX	Federal-Aid Project #:	0015-01-217; IBR 2007(120 & 046)	Fiscal Year:	2005	Funds Awarded:	\$57,362.00 (120) \$400,000.00 (046)
Fund Status:	Unknown, presumed expended (120) \$326,895.46 (046)		Project Status:	Complete		

Associated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Prefabricated Concrete U-beams with Portion of Concrete Deck Cast onto Beam

Technology Description: Prefabricated concrete U-beams with portion of concrete deck cast onto the beam to reduce construction time and disruption of traffic

Project Information**Positive Results:**

- Eliminated deck forming, deck rebar placement and deck grading over traffic because all of these operations were moved off-site.
- Eliminated all but beam placement and closure pour casting over traffic.
- Interstate highway traffic was affected 2 nights / 4 span overcrossing bridge instead of 2 weeks for each bridge with usual CIP construction.
- Less work over traffic results in less disruption of traffic, increased worker and motorist safety.
- Bridge is performing well to date.

Negative Results:

- Pretopped U-beams are heavy compared to other precast and prestressed sections.
- More difficult to haul, overhangs subject to breakage during hauling, larger cranes needed to set beams.
- Grading and casting full depth deck off-site was complex, but contractor worked out a good system.
- Twice the cost of usual CIP construction per SF of deck area, because bridge superstructure was basically built twice with this system.

Lessons Learned:

- Accelerated CIP construction is usually a better choice in most cases. This solution is only suitable for special cases where project constraints warrant this type accelerated bridge construction and minimal traffic disruption.
- Contractor needs to be skilled to make this system work.

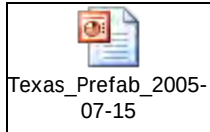
Internal or External Reports:

"Accelerated Bridge Construction in Texas", report

Publications, Presentations, or, Construction Studies:



"Precast Bent and Deck Construction IH35 Waco", presentation



"Texas' Totally Prefabricated Bridges Superstructures", presentation

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

Traffic Counts: IH 35 = 65-74k ADT; LP 340 = 23-49k ADT

Innovative: PTU's first time in nation, WAC only in state; PC Column Shells have been used elsewhere some, but not in TX??

Substantial Completion Bonus

\$6,800/day for every day under the bid days (520) with a max of 40 days (max bonus=40x6800=\$272,000)

(Also had lane rentals set up to encourage the contractor to only close IH 35 at night)

Current Contract Time = 520 + 63 = 583 days

As of Aug 30, 2006 Schedule Update: 583 days expires on April 26, 2006 (543 days expires on March 1, 2006)

Scheduled Completion = July 12, 2007 (636 days)

FR Bridges

4 – 115' spans, 1 - 460' unit

48'-3" Wide (46' roadway)

6 PTU's

~21,000 sf

ML Bridges

4-115' spans, 1- 460' unit

58'-3" Wide (56' roadway)

7 PTU's

~26,000 sf

PC Shell Notes (PC Columns)

Interior & Exterior Top View = ~4.5' x 3.0'

Exterior Bottom View (at bottom) = ~10' x 3.0' (varies w/ height)

Height = 22' to 26'

Interior Column Shell Weight = ~26,000 lbs = ~13 tons

Exterior Column Shell Weight = ~37,000 lbs = ~19 tons

PTU Notes (Prefab Superstructure used with IBR Funds)

Beam Length = 115'

Beam Width = 95.5" = ~8'

Beam Depth (excluding top 4" deck) = 34"

Interior Beam Weight (w/ final deck) = ~270,000 lbs = ~135 tons

Exterior Beam Weight (w/ final deck & T77 curb) = ~295 lbs = ~148 tons

Initially, 1 span per night; ultimately 2 spans per night (12-14 beams).

Closure Pour Width between beam ends = 2'-4"

Closure Pour Width between beam sides = 18 ½" FR, 22 ½" ML

Gap between flanges = ½" FR, 4 ½" ML

Cost (per Bridge Division): These bridges = \$85/sf; Conventional U-Beam bridge = \$45/sf

Time Saved (per bridge)Convention

-panels (5d)*
-overhangs (5d)*
-edge + other forms (4d)*
-rebar mat (5d)
-dry-run (1d)
-pour (1d)
-Disrupts Traffic (14d)

This Job

-closure pour (6d)
-No Disruption of Traffic

3/2010 Structures are complete and in service, and performing well. Periodic inspection of closure piers to evaluate performance to occur between 5 and 8/2010. See IBRC/IBRD Project Summary "EB Loop 340 – SH6 Overpass (Mainlanes and Frontage Road Over IH35)." (File: EBLoop340_IBR 2003(719).doc)

State DOT Contact: Lloyd M. Wolf, P.E.

Phone: 512-416-2279

E-mail: lwolf@dot.state.tx.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Live Oak Creek Bridge**State:** TX **Federal-Aid Project #:** IBR 2005(856) **Fiscal Year:** 2004 **Funds Awarded:** \$270,000.00**Fund Status:** \$269,939.60 Expended**Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Full Depth Precast Deck Panels and Precast Bent Caps

Technology Description: Full Depth Precast Deck Panels and Precast Bent Caps used to reduce construction time and congestion

Project Information**Positive Results:**

- Demonstrated technical feasibility of using precast full depth deck panels on a prestressed I-beam bridge (most national projects to date have involved structural steel girders).
- Avoided CIP deck construction in a region of Texas with difficult access to cast-in-place concrete and arid environmental conditions (can lead to shrinkage cracking).
- Accelerated deck construction versus the typical, especially in terms of erection.

Negative Results:

- High bid cost (only 2 contractors bid, partially due to remote location) of \$45.7/SF and \$36/SF for the deck compared to typical \$15/SF for CIP deck (with partial depth panels). This is consistent with national numbers for precast decks.
- Some difficulties in fabrication required extra quality control by the fabricator, including layout in the yard, and some specialized steel fabrication. Fabricator noted they likely "lost money on this job".
- Learning curve for contractor and fabricator. More cost effective connection details might save approximately \$5/SF.
- Connection grouting was somewhat time consuming.

Lessons Learned:

- Improve cost effectiveness of connection details.
- Minimize the amount of grouting.
- Recognize that a rapidly constructed bridge deck comes at a cost and this must be balanced with the savings in user costs. This project though was a "trial" in a low risk environment.
- Full-depth precast concrete panels can be effectively connected with conventional reinforcing bars.
- Bar splice length can be significantly reduced through use of HSS tubes

Internal or External Reports:

"NCHRP Report 584 "Full-Depth Precast Concrete Bridge Deck Panel Systems"

Publications, Presentations, or, Construction Studies:

"Precast Full Depth Bridge Decks", presentation

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

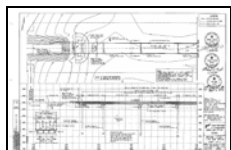
10/30/08: Active

Additional Documentation:

Erection Plan from 9/11/07



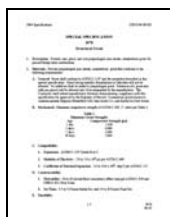
Erection Plan from 10/02/07



Stamped Bridge Plans

 A table titled "Tabulation of Bids" showing a list of bids with columns for item number, description, and amount. The table contains multiple rows of data.

Tabulation of Bids



Special Specification for Structural Grout

State DOT Contact: Michael D.Hyzak, P.E.

Phone: 512-416-2184

E-mail: mhyzak@dot.state.tx.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Martin Branch Bridge, Wise County, County Road 419

State:	<u>TX</u>	Federal-Aid Project #:	<u>0902-20-072, 0902-20-090; BR 2002(843)</u>	Fiscal Year:	<u>2004</u>	Funds Awarded:	<u>\$400,000.00</u>
		\$370,310.36 Expended					
Fund Status:	\$29,366.00 Dedicated to in-field instrumentation and evaluation, not yet spent			Project Status:	Complete		

Associated Project Names

Eighteen Mile Creek Bridge
Martin Branch Bridge, Wise
County, County Road 4191

Project: Change / Associated

Reallocated from / to:

Technology Implemented: SPS deck system

Technology Description: The Sandwich Plate System is a composite material technology, comprising two metal plates and an elastomer core. SPS offers an alternative to stiffened steel or reinforced concrete for engineered structures. SPS was used on this project to greatly reduce construction time.

Project InformationPositive Results:

- It took approximately 3 days to install the superstructure for three 50' spans, not including the overlay or railing.

Negative Results:

- Uneven deck surfaces, attributed to distortion from welding processes. Problem not directly attributable to the SPS technology.
- Excessive camber. Attributed to either weld distortion or incorrect beam camber. Problem not attributable to the SPS technology.
- Finding a thin polymer overlay system that met specification requirements. The specification requirements were written based on what overlay producers said they could provide. Used the overlay system that came closest to meeting specifications. Overlay is reportedly peeling up in service. Problem not attributable to the SPS technology.
- Lack of contact between superstructure and bearings, attributed to low dead load and stiffness of large prefabricated superstructure elements. Shims were fabricated to provide bearing contact. Bearing pad slippage is occurring.
- System is expensive when compared to other prefabricated superstructure systems capable of accelerated bridge construction.
- After superstructure installation was complete, a several month delay occurred prior to opening bridge due to determination of which overlay system to use and to correct lack of bearing. The project was intended to be an accelerated bridge construction project. Delay not attributable to SPS technology.

Lessons Learned:

- Prior to letting project, manufacturer of Sandwich Plate System (SPS) presented technology to numerous likely bidding contractors. This effort is deemed successful due to the closeness of all bids received.
- Size of prefabricated elements should have been smaller to lessen fit-up problems in the field and weld-induced distortion. These problems were not prevented even with the requirement to shop assemble elements prior to delivery.

Internal or External Reports:

Final Report – “Live Load Testing of Sandwich Plate System (SPS) Bridge in Wise County, Texas”

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

Texas Tech University has entered a second interagency contract (IAC) with TxDOT to instrument and evaluate in-service behavior of bridge. The amount of this contract is \$29,366, which comes from the \$400,000 IBRD allocation. An earlier IAC between TxDOT and Texas Tech for the same purposes ended due to the structure's completion not occurring until after the IAC's termination date.

10/30/08: Active

State DOT Contact: John M. Holt, P.E.

Phone: 512-416-2212

E-mail: jholt@dot.state.tx.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** On FM 3284 FR. 10M S. Drainage Ditch**State:** TX **Federal-Aid Project #:** 0738-03-024;
IBR 2000(985) **Fiscal Year:** 2000 **Funds Awarded:** \$150,000.00**Fund Status:** \$150,000.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Beams

Technology Description: Fiber Reinforced Polymer beams were implemented as a structural element to increase durability and reduce corrosion and construction time

Project InformationPositive Results:

- Loading tests performed showed minimal deflection of beams under loading.
- Used with conventional concrete deck providing a high-performance composite action.
- Construction completed using conventional construction equipment. Heavy-Lifting equipment (cranes) not needed.
- FRP beams have shown durability and proven to be easy implementable on other projects.
- East to install
- Minimal traffic disruption due to accelerated construction
- Improved work-zone safety
- Excellent corrosion resistance
- Should produce lower life-cycle costs
- Nearly full composite action was achieved between the FRP beams and reinforced concrete deck.
- The bridge rails contributed significantly to the stiffness of the system.
- A high degree of lateral load distribution was achieved among the beams.

Negative Results:

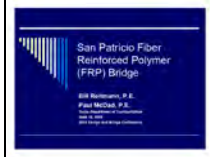
- Delay in fabrication of beams resulted as manufacturer attempted to fabricate "first of their kind" beams that complied with specifications and passed acoustic emission testing.
- Delayed overall construction.
- Added costs due to modifications to beams.

Lessons Learned:

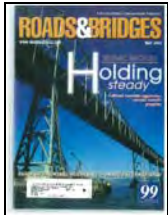
- FRP beams are feasible for construction and implementable.
- Make sure beams are fabricated and approved or close to being fabricated and approved before starting actual construction.
- The outer FRP beams are likely to be the most susceptible to degradation due to ultraviolet exposure. Therefore the outer beams should be inspected and if this becomes an issue a gel-coat can be applied. UV degradation most often affects only the outer layers and therefore is unlikely to affect the structural capacity of the system to a significant extent. It is noted that a pigmented outer layer was specified in addition to a c-veil to inhibit UV degradation.
- The resin type is very important to successful implementation. The resin type used for the bridge beams was a vinylester with a fairly high elongation to failure. Similar resin types with similar elongation to failure are recommended for future FRP bridge components.

Internal or External Reports:

"Field Monitoring of the San Patricio County FRP Bridge" San Patricio County FRP Bridge Draft Reports

Publications, Presentations, or, Construction Studies:

"San Patricio Fiber Reinforced Polymer (FRP) Bridge Presentation"



Article in "Roads & Bridges" magazine

Additional Comments:

Technology used on Other Projects: Yes

Plans on Reuse of Technology: Yes

Applicability to other States: Not Reported

Additional Project Notes:

10/30/08: Closed

State DOT Contact: Armando Bosquez

Phone: 361-364-6405

E-mail: abosque@dot.state.tx.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** RM 1061 at Draw Creek

State: TX	Federal-Aid Project #: 1245-02-029; BR0099(015); BR 99(999)	Fiscal Year: 1999	Funds Awarded: \$580,000.00

Fund Status: \$567,590.10 Expended**Project Status:** Complete**Associated Project Names**

Project: Change[]/ Associated

Reallocated from / to:

Technology Implemented: FRP Rebar

Technology Description: Fiber Reinforced Polymer Rebar used to eliminate electrochemical corrosion altogether by using non-metallic reinforcement

Project Information**Positive Results:**

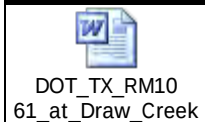
- Demonstrated that GFRP rebar, having superior corrosion resistance to that of epoxy coated steel reinforcement, could be safely and economically used to reinforce a bridge deck.
- Project Director has been active on American Concrete Institute Committee 440, FRP Reinforcement, in developing standard design, testing and construction standards for use of internal and external FRP reinforcement.
- Project Director served on review task group for the development of AASHTO Guide Specification, published in 2009.

Negative Results:

- Although GFRP bars do not produce an expansive corrosion product like steel, they have reduced mechanical properties after exposure to simulated and actual concrete environments and the reduction increases with time of exposure. Resulting long term behavior could not be assessed within the time frame of the IBRC Project.

Lessons Learned:

- The acceptance of new materials by structural engineers is a very slow process. In spite of 10 years of performance of the Amarillo bridge and the systematic development of ACI standards culminating in the 2009 AASHTO Guide Specifications, TxDOT engineers are only now considering GFRP rebar as a potential reinforcement option for bridge decks, and only as an alternative bid to epoxy coated steel with no consideration of long term cost savings resulting from the use of non-corroding reinforcement. Thus the GFRP bar must compete solely on the basis of first cost.
- The funding provided through the IBRC project was inadequate to do all the research planned while at the same time offsetting the additional cost of the project resulting from the use of the innovative material. Actually the funds encumbered to offset the cost were more than adequate while the funds tagged to cover the research effort were stretched so thin that the quality to the research was negatively impacted. This resulted from some antagonism which developed between two of the three universities performing the research tasks.
- GFRP reinforcement is a feasible alternative where either corrosion resistance or magnetic transparency is a design constraint.
- GFRP reinforcement cannot compete with epoxy coated steel for corrosion resistance unless the unique

Internal or External Reports:

"TX-1999-01 IBRC Content Contributions Previously provided"

Summary and Construction Photos



"Evaluation of Crack Widths in Concrete Flexural Members Reinforced with FRP Bars"

Internal or External Reports (continued)



"Feasibility of a Concrete Pavement Continuously Reinforced by Glass Fiber Reinforced Polymer Bars"

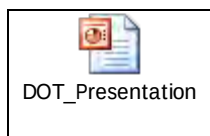
Additional Internal or External Report Resources:

From Research Funded by the IBRCP:

- Trejo, D., Aguíñiga, F., Buth, C. E., James, R. W., Yuan, R., and P. B. Keating. "FRP Reinforcing Bars in Bridge Decks: State of the Art Review," Research Report 1520-2, Texas Transportation Institute, Texas A&M University, College Station, TX, November 2000.
- Trejo, D., Aguíñiga, F., Buth, C. E., James, R. W., and P. B. Keating. "Pendulum Impact Tests on Bridge Deck Sections," Research Report 1520-1, Texas Transportation Institute, Texas A&M University, College Station, TX, July 2001.
- Phelan, R. S., Vann, W. P., and J. Bice. "FRP Reinforcing Bars in Bridge Decks – Field Instrumentation and Short-Term Monitoring," Research Report 9-1520-4, Multidisciplinary Research in Transportation, Texas Tech University, Lubbock, TX, August 2003.
- Trejo, D., Aguíñiga, F., Yuan, R. L., James, R. W., and P. B. Keating. "Characterization of Design Parameters for Fiber-Reinforced Polymer Composite Reinforced Concrete Systems", Technical Report 1520-3, Texas Transportation Institute, Texas A&M University, College Station, TX, June 2005.
- Trejo, D., Aguíñiga, F., Buth, C. E., James, R. W., Yuan, R., and P. B. Keating. "Fiber Reinforced Polymer Bars for Reinforcement in Bridge Decks," Project Summary Report 1520-S, Texas Transportation Institute, Texas A&M University, College Station, TX, September 2006.
- Trejo, D., Aguíñiga, F., Buth, C. E., James, R. W., Yuan, R., and P. B. Keating. "Preliminary Quality Control/Quality Assurance Standards (Criteria) for Inspection and Testing of FRP Bars," Product 9-1520-P1, Texas Transportation Institute, Texas A&M University, College Station, TX, January 2005.
- Trejo, D., Aguíñiga, F., Buth, C. E., James, R. W., Yuan, R., and P. B. Keating. "Design, Construction, and Maintenance of Bridge Decks Utilizing GFRP Reinforcement," Product 9-1520-P2, Texas Transportation Institute, Texas A&M University, College Station, TX, February 2005.

From Research and Testing Funded by TxDOT:

- Buth, C. E., Williams, W. F., Bligh, R. P., Menges, W. L., and R. R. Haug. "Performance of the TxDOT T202 (MOD) Bridge Rail Reinforced with Fiber Reinforced Polymer Bars," Research Report 0-4138-3, Texas Transportation Institute, Texas A&M University, College Station, TX, November 2003.
- Trejo, D., Gardoni, P., Kim, J. J., and J. Zidek. "Long Term Performance of GFRP Reinforcement: Technical Report," Technical Report 0-6069-1, Texas Transportation Institute, Texas A&M University, College Station, TX, February 2005.
- Okelo, R. and Yuan, R. L. "Bond Strength of FRP Reinforcement in Concrete." Texas results from Fiber Reinforced Polymer (FRP) reinforcing bar bond pullout and splitting strength "round robin tests" performed for Federation International du Béton (fib) Task Group 9.3, FRP Reinforcement for Concrete Structures and Intelligent Sensing for Innovative Structures (ISIS) Canada, coordinated by the European ConFibreCrete TMR Network. TxDOT IAC Performance of Fiber Reinforced Polymer (FRP) Re-Bar Pullout and Splitting Tests, Department of Civil & Environmental Engineering, The University of Texas at Arlington, Unpublished Report for TxDOT/ConFibreCrete TMR Network, November 15, 2001.

Publications, Presentations, or, Construction Studies:

"Fiber-Reinforced Polymer (FRP) Reinforcing Bars for Concrete Bridge Decks", presentation



"State-of-the-Art: Non-Traditional Reinforcing for Concrete Infrastructure", Concrete Construction Magazine



"The Texas GFRP-Bar Reinforced Concrete Bridge Deck", International Newsletter Article



"Stronger Longer", Civil Engineering Magazine



"FRP Composite Reinforced Concrete", paper



"Concrete Bridge Decks Reinforced with Fiber-Reinforced Polymer Bars" Transportation Research Record

Additional Publication, Presentation or Construction Study Resources:

Written by Others about TxDOT's FRP Rebars in Bridge Decks Project:

- Fiber Reinforced Polymer Composites Emerge as Useful Structural Material, Texas Construction Magazine October 2000, pp. 29 and 34.

Related Papers/Publications Written and Presented:

- Bradberry, T., Walton, S. and Yang, D. "Use of FRP Composites by The Texas Department of Transportation", CDCC 2007 Third International Conference on Durability & Field Applications of FRP Composites for Construction, Editors: B. Benmokrane and E. El-Salakawy, Department of Civil Engineering, Faculty of Engineering, University of Sherbrooke, Québec City (Québec), Canada, May 22-24, 2007, pp. 201-210. **Bradberry presented the paper.**
- Bakis, C. E., Ospina, C. E., Bradberry, T. E., Benmokrane, B., Gross, S. P., Newhouse, J. P., Thiagarajan, G. "Evaluation of Crack Widths in Concrete Flexural Members Reinforced with FRP Bars." Third International Conference on FRP Composites in Civil Engineering (CICE 2006), Miami, Florida, USA, December 13-15 2006. Bakis presented the paper.
- Walton, S. and T. Bradberry. "Feasibility of a Concrete Pavement Continuously Reinforced by Glass Fiber Reinforced Polymer Bars". Proceedings of 3rd International Conference on Construction Materials: Performance, Innovations and Structural Implications (ConMat'05), Vancouver, Canada, August 22-24, 2005, CD-ROM, 10 pp. Walton presented the paper.
- Aguíñiga, F., Bradberry, T. and D. Trejo. "Time-Dependent Mechanical Property Changes of Glass Fiber-Reinforced Polymers Exposed to High pH Environments." Proceedings of the American Society of Civil Engineering Conference, Earth & Space 2004: Engineering, Construction, and Operations in Challenging Environments, ASCE, Houston, Texas, March 7-10, 2004, pp. 585-592. Bradberry presented the paper.
- Bradberry, T. E. and S. Wallace. "FRP Reinforced Concrete in Texas Transportation—Past, Present, Future." Field Applications of FRP Reinforcement: Case Studies, Editors: S. H. Rizkalla and A. Nanni, American Concrete Institute International, SP-215, pp. 3-20 (2003). Bradberry presented the paper.
- Bradberry, T. E. "Concrete Bridge Decks Reinforced with Fiber-Reinforced Polymer Bars." Design of Structures 2001, Transportation Research Record 1770, Transportation Research Board, National Research Council, Washington D.C., December 2001, pp. 94-104. Bradberry presented the paper.
- Bradberry, T. E. "Stronger Longer." Civil Engineering Magazine, Focus: Structural Engineering, American Society of Civil Engineering, April 2001.
- Bradberry, T. E. "FRP Reinforced Bars for Concrete Bridge Decks." Proceedings of the Texas Section of the American Society of Civil Engineers, Texas Section—ASCE, Austin, April 5–8, 2000. Bradberry presented the paper.

Presentation Only:

- First Use of GFRP as Reinforcement for Continuously Reinforced Concrete Pavement: Application in Highway 40 East (Montreal, QC). Presentation for pre-conference short course: "Case Studies and Design of Composites for Bridges"; Prepared by B. Benmokrane, P. Eng., Ph.D and presented by Timothy E. Bradberry on behalf of B. Benmokrane, Session 2A: Composite Design, Processes, Monitoring and Failure Analysis, Polymer Composites Conference IV, Morgantown, WV, March 20-21, 2007.
- Barriers to the Use of FRP Composites in Texas Transportation Infrastructure. Prepared and presented by Timothy E. Bradberry, Session 1A: FRP Decks/Wearing Surfaces, Polymer Composites Conference IV, Morgantown, WV, March 21, 2007.
- Session 1B: Panel Discussion – Issues: Bidding Specifications, Constructability, Safety, Repair Procedures, Guide Rail Attachments and Connection. by Presenters of Session 1A, – Donald Williams, Raymond Bottenberg, James Nelson, Wally Mook, Riyadh Aboutaha, John Myers, Paul Ziehl and Tim Bradberry, Polymer Composites Conference IV, Morgantown, WV, March 20-21, 2007.
- Field Monitoring of GFRP Reinforced Concrete Bridge Decks in Canada. Prepared by B. Benmokrane, P. Eng., Ph.D; Presented by Timothy E. Bradberry on behalf of B. Benmokrane, Session 2A: Composite Design, Processes, Monitoring and Failure Analysis, Polymer Composites Conference IV, Morgantown, WV, March 20-21, 2007.
- Crash Test of a GFRP-bar Reinforced Texas Bridge Rail Following the Protocol of NCHRP 350, Test Level 3. March 12, 2002. Prepared and presented by Timothy E. Bradberry to ACI Committee 440, Detroit, MI, April 23, 2002.
- Fiber Reinforced Polymers (FRP) for Bridge Applications: Emerging Technology? Prepared and presented by Timothy E. Bradberry, 2002 TxDOT Bridge Engineers' Conference, May 12, 2002.
- Fiber-Reinforced Polymer (FRP) Reinforcing Bars for Concrete Bridge Decks. Prepared and presented by Timothy E. Bradberry at the request and sponsorship of The University of Minnesota Concrete Conference, 50th Anniversary, St. Paul, Minnesota, December 7, 2000.
- Fiber-Reinforced Polymer (FRP) Reinforcing Bars for Concrete Bridge Decks. Special presentation prepared and presented by Timothy E. Bradberry to and at the request of AASHTO T-21 Technical Committee for Fiber Reinforced Polymer Composites (FRPC) (now T-6 FRPC), under the sponsorship of Ohio Department of Transportation and AASHTO, Columbus, Ohio, November 16, 2000.

- Fiber-Reinforced Polymer (FRP) Reinforcing Bars for Concrete Bridge Decks - FRP Design Considerations, Prepared and presented by Timothy E. Bradberry, Amarillo FRP Bars in Bridge Decks Showcase, FHWA-TxDOT Co-Sponsors, TxDOT Amarillo District Office, Amarillo , TX, July 25, 2000.
- Texas FRP-Bar RC Deck Project, Prepared and presented by Timothy E. Bradberry, Western States Advanced Composite Workshop, FHWA-WASHTO Co-Sponsors, Portland, Oregon, May 23-24, 2000.
- Fiber-Reinforced Polymer (FRP) Reinforcing Bars for Concrete Bridge Decks. Special presentation made at the request of and exclusively for the audience of Paul Virmani, FHWA by Timothy E. Bradberry, Austin, TX, May 31, 2000.

Review Only:

As a result of his involvement as a voting member of ACI Committee 440, Fiber Reinforced Polymer Reinforcement, Bradberry has peer reviewed conference and journal papers related to FRP reinforcement, including one or multiple papers for the following journals and conferences:

- ACI Special Publications
- ASCE Journal of Bridge Engineering
- ASCE Journal of Composites for Construction
- CICE 2006-Third International Conference on FRP Composites in Civil Engineering
- CDCC 2007 Third International Conference on Durability & Field Applications of FRP Composites for Construction
- FRPRCS-7 (the 7th International Symposium on Fiber Reinforced Polymer Reinforcement for Reinforced Concrete Structures)
- Journal of Advanced Concrete Technology
- Transportation Research Board
- TxDOT

Related AASHTO Specifications Published:

- AASHTO LRFD Bridge Design Guide Specifications for GFRP-Reinforced Concrete Bridge Decks and Traffic Railings. Washington, DC: American Association of State Highway and Transportation Officials, ©2009. Bradberry served on the review task group for the contractor who developed the draft of this publication that was balloted by AASHTO SCOBS.

Additional Comments:

Technology used on Other Projects: Yes

Plans on Reuse of Technology: Yes

Applicability to other States: Yes

Additional Project Notes:

None

State DOT Contact: Timothy E. Bradberry
E-mail: tbradber@dot.state.tx.us

Phone: 512-416-2179

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Texas State Hwy SH 66 Over Lake Hubbard

State: TX	Federal-Aid Project #: 0009-04 254; IBRC 2001(339), 0451-01-032; HP 2006(694)	Fiscal Year: 2001	Funds Awarded: \$300,000.00 (\$190,929.35 & \$109,070.65)

Fund Status: \$300,000.00 Expended**Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Concrete – Utilize GGBFS in conjunction with Maturity Testing

Technology Description: Construction project consisted of two bridges measuring utilizing various innovated technologies including Ground Granulated Blast Furnace Slag in conjunction for increased concrete durability, Maturity Testing to counteract some of the slow strength development times of the GGBFS mixes, Deck Grooving used as an alternative to tining and Precast Caps to reduce construction time.

Project Information**Positive Results:**

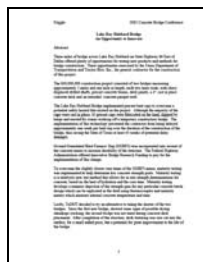
- Technology, materials accepted for statewide use.
- GGBFS and maturity testing aided in speedier completion of project.
- GGBFS aided in pumpability of concrete.
- Maturity testing aided in accurately estimating times for quick form removal, loading.
- An added advantage to the use of the GGBFS is the attractive finish the concrete gains. Although some GGBFS concrete is extremely white, with the aggregates available in the Dallas area, the finished produce has a slightly tan color. About \$60,000 was saved when the painting item was removed from the plans.
- Deck grooving provided increased durability of the deck
- There was concern that a smooth surface finish and saw cutting might have caused some spalling, if too much paste rose to the surface in finishing. No spalling has been observed.
- In using the precast caps, the contractor was able to prevent the accumulation of added overhead, and the State of Texas will be able to provide the promised end product to the taxpayers on time.
- Precast caps are inherently safer to construct. The form placement, steel tying concrete placement and form removal were all done on the ground rather than overwater

Negative Results:

- Some added cost for meters.
- Some skepticism of accuracy of meters compared to cylinder or beam breaks.
- To groove the 18,000 square yard deck took about 33 hours with a two man crew. The added cost for this work was about \$2.00 per square yard. TxDOT received \$0.06 credit for tining. Clearly, the saw cutting is a more expensive method to surface texture the bridge. However, the increased durability of the deck is certainly worth the comparatively small investment.
- Although a time savings had been anticipated when using the precast caps, the production rates for caps from start to finish was fairly close. The rate of cap production for the Westbound bridge, with cast in place caps was about 2.7 units per week with 4 sets of forms. The rate of cap production on the Eastbound bridge was about 2.0 caps per week. It should be noted that the manufacture of the caps was not the controlling cap operation. At any given point, Traylor Bros. had 4 to 10 caps stored in their casting yard.
- The addition of precast caps did not provide a cost savings to the State of Texas. In all, the cost to add the precast caps was about \$140,000. Had the precast caps been planned at the time of bidding, it is likely that the cost would not have been this significant, but the fact that two distinct systems with two different forming and placing systems were incorporated drove the price up somewhat. It is not unreasonable to believe that the schedule delay, had the precast caps not been incorporated would have cost significantly more than \$140,000 cap change order, thus justifying the changed design.

Lessons Learned:

- Technology is feasible and implementable
- It should be noted that the contractor was hesitant to use the 50% substitution due to the low early strengths. The low strengths appeared to be limited to the first three or so days. Seven day compressive strengths for the 50% mix exceeded 5000 psi. Although GGBFS does provide an excellent end product, on time critical work, the added delay for strength gain should be considered.

Internal or External Reports:

"Lake Ray Hubbard Bridge An Opportunity to Innovate"

CBC paper

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Technology approved for state wide use

Plans on Reuse of Technology: Technology approved for state wide use

Applicability to other States: Not Reported

Additional Project Notes:

10/30/08: Active

State DOT Contact: Tracey Friggle, P.E.

Phone: 214-320-6199

E-mail: tfriggl@dot.state.tx.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** US 40 (Old Route 66) West Bound Overpass in Gray County**State:** TX **Federal-Aid Project #:** _____ **Fiscal Year:** 2005 **Funds Awarded:** \$117,576.00**Fund Status:** \$117,362.24 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Anti-icing Pavement Overlay System

Technology Description: Anti-icing pavement overlay system used for increased traffic safety and accident reduction

Project Information**Positive Results:**

- The overlay system was installed in 2006 on a flexible bridge deck surface.. There has been a monitoring of the bridge for 5 winters. To-date, the TxDOT has been very satisfied with its performance.
- There has been a decrease in chemical use and accidents during winter storms.
- The friction values have remained good and there has not been any significant wearing or delamination to the surface.
- Continue use of this technology has been continued on 3 other bridges in Texas. Another in the Amarillo area and 2 in the DFW area.

Negative Results:

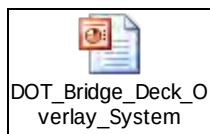
- The only negative regarding the use of this product is that the aggregate is proprietary and the cost is higher than other epoxy overlay systems the department uses. However, the deicing chemical absorption characteristic of the aggregate and its ability to reduce the amount of chemical used during winter storms, potentially out-weigh the increased cost.

Lessons Learned:

- Since the first pilot project was performed, there have been advancements in the equipment used to apply the overlay system. This decreases the labor cost for installation and the cost per square yard. The TxDOT is planning on using state maintenance forces to apply the overlay in the future to further reduce the costs.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

"Bridge Deck Overlay System" presentation

Additional Comments:

Technology used on Other Projects: Yes, 3 other bridges in Texas. Another in the Amarillo area and 2 in the DFW area.

Plans on Reuse of Technology: Yes

Applicability to other States: Not Reported

Additional Project Notes:

10/30/08: Active

Overlay system installed in 2006. Overlay has been monitored for the past 3 winters. To-date performance is satisfactory.

State DOT Contact: Tammy B. Sims, P. E.

Phone: 512-416-2476

E-mail: Unknown

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** US 82 WB at Park Rd. 18; Spur 327 Conn US 62

State: TX	Federal-Aid Project #: 0783-01-084; STP 9(9)HES, 0905-06-050; IM 27-7(082)	Fiscal Year: 2002	Funds Awarded: \$95,000.00
Fund Status: \$95,000.00 Expended		Project Status: Complete	

Associated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Embedded galvanic anode protection system

Technology Description: The use of the Embedded Galvanic Anodes as a corrosion mitigation option

Project Information**Positive Results:**

- The use of the anodes has raised the awareness of improved corrosion techniques for concrete structure repair.
- We have not experience a failure at the patch locations.

Negative Results:

- Though we have not had failure of the patch areas where the anodes were include in the repair, we are not certain we are improving the performance of the patch by using them. We have had some negative commentary provided by a competitors corrosion protection system representative that did cast some doubt on the usefulness of the anodes.

Lessons Learned:

- We need to approve the proposed concrete repair material to insure compatibility of the repair concrete with the anode.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Yes, to date the item has been included in fourteen bridge rehabilitation projects in six of our twenty-five districts

Plans on Reuse of Technology: Likely

Applicability to other States: Not Reported

Additional Project Notes:

10/30/08: Closed

State DOT Contact: Kevin Pruski

Phone: 512-416-2306

E-mail: kpruski@dot.state.tx.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** US 83 & SH 359 Interchange**State:** TX **Federal-Aid Project #:** 0038-01-056; **Fiscal** 2005 **Funds Awarded:** \$6,150.00
IBR2007(122) **Year:****Fund Status:** \$5,000.00 Expended**Project Status:** Complete**Associated Project Names**

Chacon Creek Bridge

Project: Change / Associated

Reallocated from / to:

Technology Implemented: **Graffiti Proofer and Concrete Curing Agent and Graffiti Remover Gel/SYS (SEI Chemical)****Technology Description:** The effectiveness of a graffiti proofer and concrete curing agent and graffiti remover, Gel/SYS (SEI Chemical) used to reduce labor time**Project Information****Positive Results:**

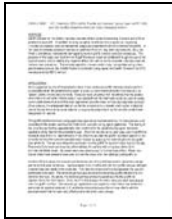
- Use of concrete graffiti removal products is definitely a topic of interest that the Department should pursue. The cleaning was achieved with minimal effort, minimal personnel, and conducted within a very short time.
- Current local practice of concrete graffiti removal efforts includes re-finishing the concrete surface with a sand/cement grout or painting over the graffiti surface.
- There may not be a significant cost savings with respect to material cost (cost comparison between methodologies was not addressed in this study), the real savings in implementing the use of these concrete graffiti removal products is anticipated in the reduction in labor time and effort intensity allocated to the cleaning efforts. The end result is that personnel can spend less time tackling unsightly visual pollution and focus its' labor efforts on roadway/structural maintenance needs.

Negative Results:

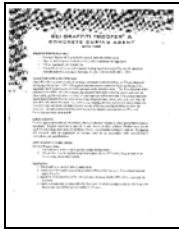
- Due to the inexperience in conducting research by the study contact person the anticipated results did not materialize quite as expected. 100% graffiti removal, without impacts to the concrete substrate, was not achieved. However, it is hypothesized that this is due to several factors and not to product deficiency.
- Removing efforts were more successful on red and black colors
- Some areas required removal by use of a brush and pressure washer. These areas appear to deteriorate the concrete substrate rather than the removal of the graffiti

Lessons Learned:

- Timing the use of the product so that the product expiration date does not play an influence on the results is essential.
- One major disappointment associated with the testing of this product was that it was taken for granted that several study areas (of different surface finishes) would be available to conduct the testing. The end result was that the study area was limited a specific area, of a single surface finish, and this area was not accessible until the project neared completion.
- 100% hands-on participation and close coordination with assisting personnel is essential to achieving uncompromised results. It can't be assumed that procedures will be executed as per discussions with personnel.
- Witnessing the application/testing operations first-hand is the only way to dismiss any second-guessing thoughts or doubts about the realized results.
- Planning for different testing scenarios is essential. For example, additional graffiti colors should have been tested and areas with different number of product coating applications would certainly confirm product success performance.
- Additional coats of the graffiti proofer/concrete curing agent may be needed. A minimum of two application coats of this substance is required per the manufacturer's instructions.

Internal or External Reports:

"FHWA/IBRC – SEI Chemical, SEI Graffiti Proofer & Concrete Curing Agent (GPC-100) and SEI Graffiti Remover Gel (GR-GEL) Summary Report"

Publications, Presentations, or, Construction Studies:

"SEI Graffiti Proofer & Concrete Curing Agent GPC-100" Graffiti Removal Product Information

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

State DOT Contact: Claudia González-Liendo, P.E.

Phone: (956)712-7459

E-mail: cgonzale@dot.state.tx.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Washington Street Under IH-40

State: TX **Federal-Aid Project #:** 0275-01-126;
 BR
 2002(412) **Fiscal Year:** 2002 **Funds Awarded:** \$85,071.00

Fund Status: \$85,071.00 Expended**Project Status:** Complete**Associated Project Names**Washington St. Underpass at IH
40Project: Change / Associated

Reallocated from / to: {\$}

Technology Implemented: MMFX Rebars

Technology Description: Micro-Composite, Multi-Structural Formable (MMFX) low-carbon, chromium bearing, reinforcing steel designed to have high corrosion resistance, strength and ductility

Project Information**Positive Results:**

- Concrete is performing the same as on other bridges; no steel is exposed to check for corrosion.

Negative Results:

None

Lessons Learned:

- Handles about the same as regular steel that is used.
- Long term performance will be monitored

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

The bridge was divided into quadrants and a wire attached to the reinforcing steel in that quadrant and run to a junction box in the concrete rail for a "meger" testing. Someone did a preliminary test before the bridge was opened, but don't believe a follow up has ever been done. See sheet 97 of the plans (bridge monitoring diagram). We were not involved with the testing program, only in construction of the bridge.

10/30/08: Closed

State DOT Contact: Joe Chappell, P.E.

Phone: 806-378-0071

E-mail: jchappe@dot.state.tx.us

1.46. UTAH

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** East Bound State Rte 79 Grade Separation/Reeves Rd.**State:** UT **Federal-Aid Project #:** _____ **Fiscal Year:** 2001 **Funds Awarded:** \$68,500.00**Fund Status:** \$78,320.77 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: MMFX Reinforcing

Technology Description: Micro-Composite, Multi-Structural Formable (MMFX) low-carbon, chromium bearing, reinforcing steel designed to have high corrosion resistance, strength and ductility

Project InformationPositive Results:

- Material in-place and functioning.

Negative Results:

- Originally, stainless clad rebar was going to be used in this project, however it was not obtainable. Therefore, MMFX rebar was used in its place. The structure is completed as scheduled with delays as a result of the MMFX.

Lessons Learned:

Works the same as normal rebar

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

10/30/08: Completed.

\$9,820.77 of QX20 added to project to complete.

State DOT Contact: _____

Phone: _____

E-mail: _____

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I-80 over Union Pacific RR near Lake Point**State:** UT Federal-Aid Project #: _____ Fiscal Year: 2002 Funds Awarded: \$459,000.00**Fund Status:** \$492,671.61 Expended **Project Status:** Complete**Associated Project Names**County Road over I-80 in Wanship, Project: Change / Associated Reallocated from / to:
UT**Technology Implemented:** Accelerated Bridge Construction – Precast deck panels

Technology Description: Accelerated bridge construction using precast deck panels to reduce construction time and traffic congestion

Project InformationPositive Results:

- This was Utah's first ABC project. It signified a change in bridge building in Utah for, at least, the next 3 years.

Negative Results:

None

Lessons Learned:

- The project itself provided valuable lessons learned with regard to connections, grout, and deck leveling which were all implemented statewide on future ABC projects.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Yes. ABC is ongoing in Utah

Plans on Reuse of Technology: Yes. ABC is ongoing in Utah

Applicability to other States: Not Reported

Additional Project Notes:

An additional \$33,000 QX20 was added to the original award.

10/30/08: Completed

\$33,671.61 in other QX20 funds added to cover additional costs.

State DOT Contact: Daniel Hsaio

Phone: 801-965-4638

E-mail: dhsiao@utah.gov

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I-215 NB over 3760 South Street at 3300 East Salt Lake City**State:** UT **Federal-Aid Project #:** _____ **Fiscal Year:** 2003 **Funds Awarded:** \$400,000.00**Fund Status:** \$382,394.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Accelerated Bridge Construction

Technology Description: Accelerated bridge construction to reduce construction time and traffic congestion

Project InformationPositive Results:

- This was Utah's second attempt at ABC construction techniques and the first in an urban interstate environment.
- A lot of positive press attention was given to this project.
- Several methods of ABC were utilized as shown in the project application.

Negative Results:

None

Lessons Learned:

- Several ABC methods were used on these two projects. Lessons learned related to PT deck, grout, leveling, Nelson studs, girder haunch.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Yes

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

I don't see that additional QX20 funds were added to this project.

10/30/08: Active.

Additional QX20 funds added to complete IBRC portion.

State DOT Contact: Daniel Hsaio

E-mail: dhsiao@utah.gov

Phone: Unknown

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** F-54, F-156 and C846**State:** UT Federal-Aid Project #: _____ **Fiscal Year:** 2005 **Funds Awarded:** \$250,000.00**Fund Status:** \$165,112.00 Expended **Project Status:** Unknown**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Instrumentation of deck to evaluate long term performance

Technology Description: Instrumentation of deck to evaluate long term performance

Project InformationPositive Results:

- The UDOT installed and utilized the instrumentation as proposed in their application. The results were monitored by Research staff and university personnel. The results are being used to make better decisions constructability and materials for bridges being planned.
- This project also includes installs permanent motion sensors to measure ground motion should an event occur.
- This project is considered a long term monitoring program which could explain the balance. The project is still active.

Negative Results:

None

Lessons Learned:

None

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

An additional \$63,255 (QX20) was added to this project. However, only \$165,112 was expended. According to my FMIS records, \$148,144 remains in this account. This project is considered long term monitoring which may explain the remaining funds. The project is still active.

10/30/08: Active.

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** I-84 Weber Canyon ABC**State:** UT **Federal-Aid Project #:** 0846(089) **Fiscal Year:** 2006 **Funds Awarded:** \$200,000.00**Fund Status:** \$200,000.00 Expended**Project Status:** Complete**Associated Project Names**

SR-105 Parrish Lane

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Accelerated Bridge Construction

Technology Description: Accelerated Bridge Construction used to slide in new deck overnight and minimize traffic impacts to I-84

Project InformationPositive Results:

- This was Utah's first attempt to build a deck and girder system adjacent to the existing deck and slide (on-rails) the new deck into place overnight.
- The project was a success in utilizing minimum impacts to I-84.
- The project also showed space requirements for offsite construction can be met within a narrow canyon with that included railroad, river and interstate.

Negative Results:

None

Lessons Learned:

- The project also showed space requirements for offsite construction can be met within a narrow canyon with that included railroad, river and interstate.
- The project was a success in utilizing minimum impacts to I-84.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

The project is completed.

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1.47. VIRGINIA

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Hawthorne Street over C&O (CSX) Railroad – 2003 IBRC #1**State:** VA **Federal-Aid Project #:** 000S (075) **Fiscal Year:** 2003 **Funds Awarded:** \$346,239.00**Fund Status:** \$345,499.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Deck Panels

Technology Description: A fiber-reinforced polymer (FRP) composite cellular deck system was used to rehabilitate a historical cast iron thru-truss structure (Hawthorne Street Bridge in Covington, Virginia). The most important characteristic of this application is reduction in self-weight, which raises the live load-carrying capacity of the bridge by replacing the existing concrete deck with an FRP deck.

Project Information**Positive Results:**

- Strongwell FRP bridge deck system is a lightweight and safe alternative to conventional reinforced concrete bridge decks.
- All the adhesive joints were able to resist the design service load without any indication of cracking.
- The strain and displacement showed linear elastic behavior up to design service load. The test results revealed an average deflection of span/664, which is slightly larger than the span/800 criteria in the AASHTO LRFD Bridge Design Specifications (2004). It should be noted that this limit is not intended for application to FRP composite bridge decks. However, no appropriate design limit is presently available.
- The proposed full-length, adhesively-bonded tongue and groove panel-to-panel joints can meet the necessary strength performance criteria. No failure was observed in the adhesive layer or in the joint interface, which indicates the adhesive layer and adhesive-substrate interface are stronger than the FRP components. Thus adhesive bonding will not control the design strength of this FRP deck system.
- No significant change in stiffness or strength of the deck after 3,000,000 cycles of a fatigue load at a minimum/maximum load ratio of R=0.1, with the maximum load of 22 kips and the minimum load of 2 kips. This demonstrated the durability of the adhesive joint under repetitive loading.
- The average first failure load was 100 kips in the strength tests on the adhesive joints, about five times the design service load of 22 kips. This value is close to the first failure load found in strength tests of as-received decks and indicates the adhesive joint will not influence the strength of the deck.
-

Negative Results:

- The cost per square foot of the Strongwell bridge deck system is significantly greater than a conventional reinforced concrete bridge deck of similar strength and stiffness. The best uses of the Strongwell bridge deck system are ones where the weight savings offset the higher initial material costs.

Lessons Learned:

- The failure in the top plate and the top flange of the tube was caused by weak-axis bending, with cracking parallel to the tube webs. This is also consistent with the failure mode in strength tests of as-received decks.
- The full scale model of two bays of the five-bay Hawthorne St Bridge provided valuable insights into the constructability of the adhesive panel-to-panel connections. The resulting field joint fabrication protocol was developed and used during fabrication of the deck joints in the field. The fabrication of the actual deck joints went smoothly and therefore validates the use of the developed protocol on other FRP deck installations.
- Based on the test results obtained during the laboratory testing of the two-bay model, it was concluded that this adhesive bonding technique has the necessary serviceability and strength characteristics to be used in other similar bridge deck replacements. The testing program addressed the performance of the proposed bridge deck system under repeated (cyclic) loads.

Internal or External Reports:

Final Contract Report – “Development and Evaluation of an Adhesively Bonded Panel-to-Panel Joint for a Fiber-Reinforced Polymer Bridge Deck System”

Publications, Presentations, or, Construction Studies:

Dissertation – “Strength and Life Prediction of FRP Composite Bridge Deck”



Dissertation – “Testing and Analysis of a Fiber-Reinforced Polymer (FRP) Deck”



Website Article – “VDOT Installing Innovative Bridge Deck on Historic Covington Bridge”

Additional Comments:

Technology used on Other Projects: This technology was used on the Tangier Island and Troutville Weight Station Ramp IBRC projects:



Final Contract Report – “Rapid Replacement of Tangier Island Bridges Including Lightweight and Durable Fiber-Reinforced Polymer Deck Systems”



Final Contract Report – “Plate and Tube Bridge Deck Evaluation in the Deck Test Bed of Troutville, Virginia, Weigh Station”

Plans on Reuse of Technology: Not Reported

Applicability to other States: Applicable to all states

Additional Project Notes:

None

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Relocated WBL Rt. 460 over Rt. 29 Bypass – 1999 IBRC #1**State:** VA **Federal-Aid Project #:** 000S (006) **Fiscal Year:** 1999 **Funds Awarded:** \$124,000.00**Fund Status:** \$118,795.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Stainless Steel Clad Reinforcement

Technology Description: The effects of using carbon steel rebar clad with stainless steel as a cost effective method for combating the effects of chloride intrusion (corrosion)

Project Information**Positive Results:**

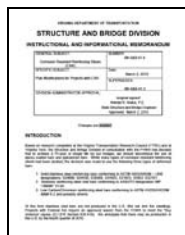
- Stainless steel-clad bars can be used as direct substitutes for either uncoated black steel or epoxy-coated bars for effective, corrosion-resistant reinforcement of concrete bridge decks that will be exposed to deicing salts.
- The long-term costs of such structures will be less than those built with either black steel or epoxy-coated bars, which have lower initial costs. This advantage of clad bars becomes more attractive as the expected service life of the structures is raised.
- VDOT has recently implemented the use of Corrosion Resistant Reinforcement in all new construction of bridges. See memo below under Internal or External Reports.

Negative Results:

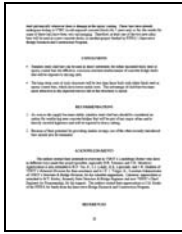
- Initial costs higher than traditional forms of reinforcing. The cost for the entire bridge increase by 4.2% due to the clad reinforcement.

Lessons Learned:

- As soon as the supply becomes stable, stainless steel-clad bars should be considered an option for reinforcing new concrete bridges that will be part of any major urban and/or heavily traveled highways and will be exposed to heavy salting.
- Because of their potential for providing similar savings, use of the other recently introduced bars should also be examined.

Internal or External Reports:

MEMO – "Corrosion Resistant Reinforcing steels"

Publications, Presentations, or, Construction Studies:

Final Report – “Trial use of a Stainless Steel-Clad Steel Bar in a New Concrete Bridge Deck in Virginia”

Additional Comments:

Technology used on Other Projects: Yes, technology was used on another IBRC project

Plans on Reuse of Technology: Yes, Virginia DOT has recently implemented the use of corrosion resistant clad reinforcement on all new construction of bridges

Applicability to other States: Technology applicable to all states

Additional Project Notes:

The project is complete

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Route 106 over Chickahominy River – IBRC #5**State:** VA **Federal-Aid Project #:** 000S (006) **Fiscal Year:** 1999 **Funds Awarded:** \$155,000.00**Fund Status:** \$155,000.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Lightweight HPC used on AASHTO Girders

Technology Description: This project involved the construction and early performance of the first bridge in Virginia constructed with lightweight high-performance concrete (LWHPC), which has a density of 120 lb/ft³. The elements which utilized this technology on this project were AASHTO girders and deck. LWHPC was primarily used to reduce the dead load on the bridge; however, the enhanced durability of LWHPC should lead to an extended service life with minimal maintenance costs.

Project Information**Positive Results:**

- The material performed well enough to recommend use of LWHPC in future use of beam and deck design.
- LWHPC can be produced such that the material is lightweight, workable, strong, volumetrically stable, and durable.
- In the test beams, the actual compressive strains measured at the level of the strands were less than those estimated by the ACI model and slightly more than those estimated by the PCI model.
- Structural tests for the trial beams indicated that the members had similar or higher actual flexural strength compared to the theoretical values.
- LWHPC and NWHPC beams had shorter transfer lengths than were predicted.
- Shrinkage in the LWHPC deck was satisfactory and within the limits recommended in the literature. Shrinkage of LWHPC was greater than shrinkage of NWHPC in the beams because lightweight aggregates offer less restraint and the LWHPC was suspected to have a high water content.
- Fibers provide residual strength that is expected to control cracking; however, the limited transverse cracking observed in the deck suggests that LWHPC does not require fibers in the initial years of exposure. Fibers appear to aid in controlling plastic shrinkage cracking since none was visible in the fiber section but a few were present in the control section.

Negative Results:

- The elastic modulus for lightweight concrete is lower than for normal weight concrete. The elastic modulus can be calculated theoretically using the appropriate constant. Currently, ACI 213 provides constants for strengths up to 6,000 psi. Extrapolating linearly to higher strengths appears to provide satisfactory results.
- In the test beams, specified strengths were not achieved. The LWHPC had much lower strength than did the NWHPC, which was attributed mainly to extra water in the LWHPC. Thus, better water control, including aggregate moisture, is needed in the production of LWHPC.
- The ratio of the flexural strength to the compressive strength was lower in LWHPC than in NWHPC.

Lessons Learned:

- VDOT inspectors should use density measurements to control the air content of the lightweight concrete after a relationship is established. The volumetric method for measuring air content is time-consuming and can cause adverse delays when a continuous deck is placed.
- In assessing the cost-effectiveness of LWHPC, the up-front material cost for lightweight concrete must be weighed against a variety of benefits, many of which accrue over the life cycle of the structure. The premium paid for lightweight concrete relative to normal weight concrete may range from 25 to 30 percent of the cost per cubic yard, which is expected to decrease with more use of this material. However, this increase is less than 10 percent considering the per cubic yard cost for in-place concrete. In the total cost of the bridge, the increase is much smaller, within a few percentage points.
- Several benefits of LWHPC are realized immediately and are expected to offset this cost largely. The reduced dead load of LWHPC translates directly into longer spans, reduced pier or smaller piers, and reduced substructure requirements, resulting in large cost savings. The cost of transporting and erecting LWHPC superstructure elements would be significantly reduced relative to those of normal weight concrete. In bridge decks, the internal curing and the lower modulus of lightweight concrete are expected to minimize cracking, as observed in this study. The enhanced durability of LWHPC is expected to lead to extended service life with minimal maintenance costs. The lower initial cost because of the lighter weight concrete elements and the increase in the service life of the bridge because of the enhanced durability should result in a reduction in life cycle costs of at least 10 percent. The savings for VDOT should be greater than \$20 million per year.

Internal or External Reports:

"First Bridge Structure with Lightweight High-Performance Concrete Beams and Deck in Virginia"

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Unknown

Plans on Reuse of Technology: Unknown, however the recommendation was made to use in future projects

Applicability to other States: Applicable in all states where bridges may benefit from reduced dead load

Additional Project Notes:

None

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Route 11 over Maury River – IBRC #6**State:** VA **Federal-Aid Project #:** 000S (006) & 5117 (105) **Fiscal Year:** 1999 **Funds Awarded:** \$85,000.00**Fund Status:** \$85,000.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Fibers used in HPC

Technology Description: The purpose of this research was to compare the performance of high-performance fiber-reinforced concrete (FRC) with that of conventional concrete in a bridge deck. FRC is expected to increase toughness, provide enhanced residual strength, and minimize the occurrence and width of cracking in bridge decks.

Project Information**Positive Results:**

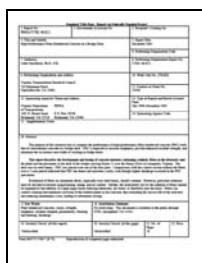
- Adding fibers provides residual strength and controls cracking. There were fewer and narrower cracks in the FRC even though the FRC had more shrinkage than the control. The residual strength is directly proportional to the fiber content.
- Controlling deflection through the actuator or the beam affects residual strength. The residual strengths were higher when the rate of deflection was controlled through the actuator.
- The permeability of FRC is comparable to that of conventional concrete. The addition of synthetic fibers together with a WRA can increase the cost of concrete from 25 percent to 40 percent per cubic yard. However, this increase is expected to be less than 10 percent, considering the per cubic yard cost for in-place concrete. In the total cost of the bridge, the increase is much smaller. These costs are expected to be offset by the benefits realized over the service life of the structure.
- Specifically, in this project, fibers were found to be effective in minimizing the severity and frequency of cracks over the piers. Fewer, narrower, and shorter cracks will minimize corrosion of the reinforcement within the concrete, thus extending the service life of the structure and reducing maintenance costs.

Negative Results:

- Adding fibers decreases workability.
- Pumping in a vertically downward direction reduces the air content and slump of freshly mixed concrete. However, concretes with reduced air content can provide satisfactory resistance to freezing and thawing if a satisfactory air void system is maintained.
- Differences in slump and air content were observed before and after pumping depending on the location of the sample.

Lessons Learned:

- Evaluation of fibers in continuous decks, especially over steel beams, should continue. However, particular attention must be devoted to mixture proportioning, slump, and air content. Further, the workability lost by the addition of fibers should be regained by the addition of a high-range water-reducing admixture, not water, or durability may decrease. Fibers can control cracking and minimize corrosion of the reinforcement in the concrete, thus extending the service life of the structure and reducing maintenance costs, leading to substantial savings.
- VDOT's Structure & Bridge Division should continue evaluating FRC with different residual strengths over the piers in continuous decks, especially on steel girders.
- VDOT inspectors should pay attention to mixture proportioning, slump, and air content.
- VDOT inspectors should ensure that HRWRA is used instead of water to regain the workability lost by adding fibers.
- VDOT inspectors should either test concrete at the point of placement or establish a relationship between the point of discharge from the mixer and the point of placement.
- The study showed that particular attention must be devoted to mixture proportioning, slump, and air content or durability may decrease. If as little as a 10 percent increase in the service life were achieved, the savings would be greater than \$20 million per year. Further work with fibers will allow for a refinement of the cost savings.

Internal or External Reports:

"High-Performance Fiber-Reinforced Concrete in Bridge Deck"

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Applicable in all states

Additional Project Notes:

This project and the corresponding research is complete.

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Route 123 at Occoquan River**State:** VA **Federal-Aid Project #:** 000S(008) **Fiscal Year:** 2001 **Funds Awarded:** \$228,580.00**Fund Status:** Unknown**Project Status:** Complete**Associated Project Names**East & West GW Memorial
Pkwy over I-495Project: Change / Associated

Reallocated from / to:

Technology Implemented: Clad Stainless Steel Rebars in Deck Slab

Technology Description: This project was an effort by the Virginia Transportation Research Council (VTRC) to identify cost effective, corrosion-resistant reinforcing bars that can be used in concrete bridges exposed to heavy salting. The bridge deck for this project was reinforced with Epoxy Coated Rebar (ECR) in the southbound lane and MMFX2 (Clad Stainless Steel Rebar) in the northbound lane. MMFX Steel is a Micro-Composite, Multi-Structural Formable low-carbon, chromium bearing, reinforcing steel designed to have high corrosion resistance, strength and ductility

Project Information**Positive Results:**

- The long-term costs of such structures will be less than those built with either black steel or epoxy-coated bars, which have lower initial costs. This advantage of clad bars becomes more attractive as the expected service life of the structures is raised.
- Stainless steel-clad bars can be used as direct substitutes for either uncoated black steel or epoxy-coated bars for effective, corrosion-resistant reinforcement of concrete bridge decks that will be exposed to deicing salts.
- The successful use of MMFX 2 in this study shows that VDOT's Structure & Bridge Division should continue to move forward with its implementation of clad stainless steel rebar.

Negative Results:

- Small supply and delay caused a change in the size of project scope from entire deck to a single span of deck.
- Construction and materials staff need to become familiar with surface markings and material characteristics of clad stainless steel rebar.

Lessons Learned:

- Although built separately, the two decks appear similar in condition and should allow a fair comparison between the southbound ECR deck and the northbound MMFX 2 deck.
- ECR appears to have been far less cost-effective per unit than MMFX 2 when both anticipated and unanticipated costs of ECR in this study are estimated. MMFX 2 showed both labor productivity and comprehensive in-place cost advantages over ECR in this application.
- The choice of deck reinforcing steel, the construction component that may determine the operational life of a structure, should reflect comprehensive initial and early preventive maintenance costs and should ideally include all potential indirect costs incidental to the use of specific reinforcing steel if cost-effectiveness is a design objective.
- VDOT's Structure & Bridge Division should commence working with the Knowledge Management Division to propagate the findings of this study and subsequent field experiences as "best practices" regarding the use of CRR.
- The Virginia Transportation Research Council (VTRC) should commence close evaluation of the crack patterns under Spans A, B, and C of the Route 123 Bridge to determine (1) the depth of salt penetration in these cracks, and (2) the location of the cracks relative to surface cracks.
- VTRC should continue to monitor the condition of the Route 123 Bridge and reevaluate the southbound and northbound decks in 5 years.

Internal or External Reports:

Research Report – "Field Comparison of the Installation and Cost of Placement of Epoxy-Coated and MMFX2 Steel Deck Reinforcement: Establishing a Baseline for Future Deck Monitoring"



Research Report – "Summary Report on the Performance of Epoxy-Coated Reinforcing Steel in Virginia"



Final Report – "Trial us of a Stainless Steel-Clad Steel Bar in a New Concrete Bridge Deck in Virginia"

Publications, Presentations, or, Construction Studies:

Dissertation – “Corrosion Protection Service Life of Epoxy Coated Reinforcing Steel in Virginia Bridge Decks”

Additional Comments:

Technology used on Other Projects: Yes, technology was used on another IBRC project

Plans on Reuse of Technology: Yes, Virginia DOT has recently implemented the use of corrosion resistant clad reinforcement on all new construction of bridges

Applicability to other States: Applicable to all states

Additional Project Notes:

None

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Route 250 over Tuckahoe Creek – 2000 IBRC #2**State:** VA **Federal-Aid Project #:** 000S (006) **Fiscal Year:** 2000 **Funds Awarded:** \$33,000.00**Fund Status:** \$32,997 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: GFRP Reinforcement

Technology Description: This project presented the tested tensile and bond properties of three commercially available Glass Fiber Reinforced Polymer (GFRP) reinforcing bars is use of top mat reinforcement. The properties investigated included the tensile strength, modulus of elasticity, peak bond stress, and general bond behavior of the bars. These bars are lightweight and have greatly increased corrosion resistance properties. GFRP were used to increase service life of the bridge and to provide a long-term cost effective design.

Project Information**Positive Results:**

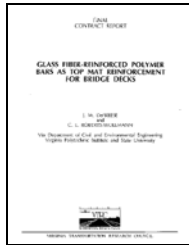
- The design modulus specified by ACI 440.1 (2001) was found to be acceptable for design.
- The design development length calculation given in ACI 440.1 (2001) was found to be conservative.
- After 1 year of service, no cracking was detected.
- The price of a concrete overlay, including milling, patching, and traffic control, for a deck that reaches rehabilitation prior to the 75-year design life averaged \$12.03 per square foot in 2004. The additional costs for alternative reinforcements, even for solid stainless steel reinforcement at \$7.90 per square foot and GFRP at \$5.07 per square foot more than bare steel, is less than the cost of one concrete overlay, including traffic control costs, before adjusting for inflation.
- More testing is needed, however initial results indicate that GFRP technology may be viable.

Negative Results:

- Slightly increased construction time for rebar placement due to increased number of bars, and an increase in initial cost of construction.

Lessons Learned:

- The design tensile stress specified by the ACI 440.1 (200 1) design guide is believed to be somewhat conservative, and alternative design approaches were proposed.
- It is difficult to provide recommendations for the bond coefficient for deflection calculations because not enough guidance is given in the ACI 440.1 (2001) guide. Design values were given for the k_b factor for crack width calculations for each of the tested manufacturers.
- The use of GFRP bars in concrete bridge decks is still a new concept. Before GFRP can be accepted as a reliable and cost effective material, more research is required.
- The monitoring of the bridge should be continued. Changes in strain and temperature over the years of service would indicate the performance of the GFRP bars. The performance of the bridge deck when cracking begins to occur should be examined. In addition, with continued monitoring, the durability of the testing instruments can be determined. In future projects, fiber optic sensors should be used to track the change in strain of the GFRP bars since they are more reliable than ER strain gauges. Similar spans reinforced with GFRP and steel should be monitored together to see how the two materials compare. Long-term monitoring of bridges in service is the best way to determine the durability of GFRP bars.
- In the design of bridge decks reinforced with GFRP as top mat reinforcement, the simplified strip method for deck design recommended by the AASHTO Standard Specifications and the AASHTO LRFD Bridge Design Specifications should be followed.
- The design of the GFRP reinforcement should conform to the recommendations of the ACI Guide for the Design and Construction of Concrete Reinforced with FRP Bars (2003).
- Electrical resistance strain gauges should not be used for long-term monitoring of embedded reinforcing bars.
- To ensure proper interpretation of data from embedded vibrating wire gages, samples of the concrete should be made to evaluate the coefficient of thermal expansion.
- Weigh-in-motion gauges should be calibrated prior to use in the field, as they typically measured smaller strains than the bonded electrical resistance gauges.

Internal or External Reports:

Final Contract Report – “Glass Fiber-Reinforcement Polymer Bars as Top Mat Reinforcement for Bridge Decks”



Report Submitted to FHWA – “Performance of a Bridge Deck with Glass Fiber Reinforced Polymer Bars as the Top Mat Reinforcement”



Final Contract Report – “Proof Testing a Bridge Deck Design with Glass Fiber Reinforced Polymer Bars as Top Mat of Reinforcement”

Publications, Presentations, or, Construction Studies:

Thesis – “Laboratory Tests of a Bridge Deck Prototype with Glass Fiber Reinforced Polymer Bars as the Top Mat of Reinforcement”



Thesis – “Field Test of a Bridge Deck with Glass Fiber Reinforced Polymer Bars as the Top Mat of Reinforcement”



Thesis – “Performance of a Bridge Deck with Glass Fiber Reinforced Polymer (GFRP) Bars as the Top mat of Reinforcement”



Thesis – “Shear Strength and Strength Degradation of Concrete Bridge Decks with GFRP Top Mat Reinforcement”

Additional Comments:

Technology used on Other Projects: Yes, other IBRC projects have used this technology

Plans on Reuse of Technology: Unknown

Applicability to other States: Applicable to all states

Additional Project Notes:

None

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Route 33 over Pamunkey River**State:** VA **Federal-Aid Project #:** 000S (006) **Fiscal Year:** 2002 **Funds Awarded:** \$300,000.00**Fund Status:** \$300,000.00 Expended **Project Status:** Complete**Associated Project Names**

NBL I-81 over Route 11

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Self Consolidating Concrete

Technology Description: Self Consolidating Concrete (SCC) is a type of concrete which is highly flowable and easily consolidates between congested reinforcing without the need for vibration. This project evaluated bulb-T beams made with SCC which were used in the Route 33 Bridge over the Pamunkey River in West Point, Virginia. The use of SCC in beams will have two major benefits: (1) expedited construction at the plant, a savings that is difficult to estimate at this time, and (2) improved quality.

Project Information**Positive Results:**

- SCC can be placed successfully, and beams with SCC behave successfully.
- SCC yielding adequate slump flow without segregation and with satisfactory strength and permeability can be prepared. However, proper attention must be devoted to mixture proportioning, workability, stability, and air content to ensure a quality product.
- Concrete with polycarboxylate-based HRWRA at the low air contents given in the specifications may not have the proper resistance to freezing and thawing when tested in accordance with ASTM C 666, Procedure A. Satisfactory freeze-thaw resistance is critical in elements that are critically saturated since the expansion of water during freezing generates high stresses. However, satisfactory field performance of the concrete investigated in this study is expected because of the lack of critical saturation.
Strand slip measured at the end of the beams was minimal, indicating satisfactory bond between the concrete and the strand.
- SCC members can be designed using the same methods, assumptions, and limiting values as used for normally consolidated concrete.
- The contractor (precast fabricator) for the project asked (and was given permission) to cast the remainder of the girders using SCC. VDOT now provides an option to use SCC at no additional cost to the department.

Negative Results:

- SCC is very sensitive to water content.
- A low slump flow does not lead to self-consolidation, and SCC with a low slump flow may require mechanical vibration. Slump loss with time and the short height of concrete discharge as in the top flange of the beam may necessitate minimal vibration for proper consolidation.
- A high slump flow may lead to segregation and loss of air voids.

Lessons Learned:

- The use of SCC in beams may have two cost benefits: expediting construction at the plant and improving quality.
- No estimate of the personnel-hours saved during fabrication at the plant was attempted in this study. Given the attention to mixture proportions, water content, and air content that SCC requires, the net cost savings during fabrication is difficult to predict.
- The cost savings from improved quality is more certain and more predictable. Consolidation problems in beams are common because of the geometry and the amount of reinforcement. Further, replacing and repairing beams are difficult and costly because of the deck structure above them. It is reasonable to expect that the better consolidation that results from the use of SCC will increase the service life of bridge beams by about 10 percent. If better consolidation results in a 10 percent increase in service life, a large savings would occur. In fiscal years 2003 through 2008, VDOT spent an average of \$10.68 million per year on prestressed concrete beams. Thus, VDOT could save close to \$1 million each year through the use of SCC in beams.
- VDOT's Materials Division and Structure & Bridge Division should permit the use of SCC in beams. However, the casting procedures should be closely monitored to ensure a quality product.
- The Virginia Transportation Research Council should work with VDOT's Materials Division and Structure & Bridge Division to develop a special provision for SCC to be used in future prestressed concrete girder projects. The goal is for the use of SCC to be standard practice for prestressed concrete girders and probably for most other precast elements.

Internal or External Reports:

Research Report – “Bulb-T Beams with Self Consolidating Concrete on Route 33 Bridge over the Pamunkey River in Virginia”

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Applicable to all states

Additional Project Notes:

None

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Route 601 over Dickey Creek, Sugar Grove – 2000 IBRC #1**State:** VA **Federal-Aid Project #:** 000S (006) **Fiscal Year:** 2000 **Funds Awarded:** \$558,150.00**Fund Status:** \$550,327.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Superstructure and Rapid Construction

Technology Description: This project is the first to use the Strongwell 36-in deep fiber-reinforced polymer (FRP) double-web beam (DWB) in a vehicular bridge superstructure. This technology was used to provide corrosion resistance in the beams and to gain a long-term cost savings by increasing the service life of the bridge.

Project Information**Positive Results:**

- The maximum measured deflection (L/996) of the Rt. 601 Bridge was significantly less than the design deflection of L/800. This can be attributed to bridge stiffening not included in the design of the Rt. 601 bridge. Sources of the additional bridge stiffness are unintended composite action between the girders and timber deck, restraint of girders at the bearings, and differences in the design truck and the test truck.
- Diaphragms were removed from between girders five through eight to investigate the need of intermediate diaphragms. Small changes were observed in the deflection and structural performance of the bridge. Girder distribution factors were increased a maximum of 12.3 % for interior girders and 7.8 % for exterior girders indicating that using the AASHTO specification girder distribution factors is still conservative. Additionally this indicates that the intermediate diaphragms are not necessary when the AASHTO girder distribution factors are used for bridge design. It is recommended that intermediate diaphragms not be used on glue-laminated timber deck-FRP girder bridges unless they are needed for bracing the girders during construction.
- Based on the assumption of compression failure, a fatigue life prediction was conducted using a remaining strength damage model. Stiffness reductions in the off-axis plies of the tensile flange and sub-flange were modeled using data extrapolated from coupon tests, but the resulting change in the stress level of the critical element was negligible. Therefore, the life at a given applied load level can be predicted simply by determining the stress level in the carbon plies and determining the corresponding cycles to failure 37 from the fatigue curve for the carbon/vinyl ester material. The validity of the prediction has not yet been verified due to limited fatigue test data.

Negative Results:

- The cost per foot of the Strongwell DWB is significantly greater than steel and reinforced concrete beams of similar strength and stiffness.
- Periodic inspections of the Rt. 601 Bridge have found deterioration or damage to the beams. The deterioration/damage was first noted during the Fall 2003 inspection and did not appear to have significantly worsened as of the inspection done during the Summer of 2004. The types of deterioration/damage can be placed in three categories: splinters, blisters, or cracks. The deterioration/damage found is deemed minor with no significant effect on the stiffness or strength of the bridge. Also, the deterioration/damage does not appear to be worsening. It is recommended that VDOT personnel continue performing routine bridge inspections of the Rt. 601 Bridge with any significant change in the condition of the beams (especially lengthening or worsening of the areas in question) communicated to VTRC.

Lessons Learned:

- The best uses of the Strongwell beam are ones where the weight savings and/or the improved durability properties will offset the higher initial material costs.
- The maximum girder distribution factors for the Rt. 601 Bridge were S/6.0 for interior girders and S/5.1 for exterior girders. These girder distribution factors are less than the girder distribution factors used for the design of the Rt. 601 Bridge. The use of the girder distribution factors in the AASHTO Standard Specification (which are S/4 for interior girders and the lever rule for exterior girders) and AASHTO LRFD Specification for glue-laminated timber decks on steel stringers (which are S/4.5 for interior girders and the lever rule for exterior girders) are recommended for use with glue-laminated timber- FRP girder bridges.
- The maximum measured dynamic load allowance for the Rt. 601 bridge was 36 %. Slightly larger than the dynamic load allowance used for the design of the Rt. 601 bridge (30 %). In previous research (Neely 2000) a dynamic load allowance of 90 % was measured for a similar bridge with a shorter span and shallower girders. Both of these values are larger than the dynamic load allowances specified in the AASHTO Standard Specification and AASHTO LRFD. It is recommended that further live load testing be conducted of glue-laminated timber deck-FRP girder bridges to further investigate the appropriate value of dynamic load allowance to use for these types of bridges. In the interim it is recommended to use a dynamic load allowance of 50% for glue-laminated timber deck-FRP girder bridges containing the 36 in double web beam. 36
- A strength based approach to predict delamination onset was followed in which average interlaminar stresses at the critical locations were compared to the interlaminar strengths using the Quadratic Strength Criterion. Detailed finite element analysis of the free edge, utilizing successive sub-models, did not indicate failure at that location. On the other hand, the predicted beam strengths assuming compression failure in the carbon plies of the top flange demonstrated excellent agreement with the experimental data. Therefore, despite the appearance of a delamination failure, the analyses suggest that the actual failure mode is compression. In addition, this analysis was able to capture the span dependence of the moment capacity which was observed experimentally. This span dependence is caused by the stress concentration at the load patch.
- Based on the assumption of compression failure, a fatigue life prediction was conducted using a remaining strength damage model. Stiffness reductions in the off-axis plies of the tensile flange and sub-flange were modeled using data extrapolated from coupon tests, but the resulting change in the stress level of the critical element was negligible. Therefore, the life at a given applied load level can be predicted simply by determining the stress level in the carbon plies and determining the corresponding cycles to failure from the fatigue curve for the carbon/vinyl ester material. The validity of the prediction has not yet been verified due to limited fatigue test data.
- The Route 601 Bridge in Sugar Grove, VA, spans 39 ft over Dickey Creek. The Bridge is the first to use the Strongwell 36 in deep fiber reinforced polymer (FRP) double web beam (DWB) in a vehicular bridge superstructure. The findings of this report show that the Strongwell 36 in deep FRP beam is a lightweight, durable alternative to conventional structural steel and reinforced concrete beams that can be designed using AASHTO specifications for bridge design. One disadvantage regarding the use of this beam is its cost. The cost per foot of the Strongwell DWB is significantly greater than steel and reinforced concrete beams of similar strength and stiffness. The best uses of the Strongwell beam are ones where the weight savings and/or the improved durability properties will offset the higher initial material costs.

Internal or External Reports:

"Construction of a Virginia Short-Span Bridge with the Strongwell 36-Inch Double –Web I-Beam"

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Unknown

Plans on Reuse of Technology: Unknown

Applicability to other States: Applicable to all states

Additional Project Notes:

10/30/08: The project is complete and a report can be found at http://www.virginiadot.org/vtrc/main/online_reports/pdf/06-cr5.pdf

The Route 601 Bridge in Sugar Grove, VA, spans 39 ft over Dickey Creek. The bridge is the first to use the Strongwell 36-in-deep fiber-reinforced polymer (FRP) double-web beam (DWB) in a vehicular bridge superstructure.

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Route 624 over Cat Point Creek – 2003 IBRC #2**State:** VA **Federal-Aid Project #:** 000S (0075) **Fiscal Year:** 2003 **Funds Awarded:** \$400,000.00**Fund Status:** Not Reported**Project Status:** Complete**Associated Project Names**VA Route 58 Business over
Route 58 Bypass – 2003 IBRC
#2Project: Change / Associated

Reallocated from / to:

Technology Implemented: Ultra-High Performance Concrete

Technology Description: A new ultra-high-performance fiber-reinforced concrete (UHPC) was introduced into construction for this project. The fibers in UHPC provide tensile capacity across cracks, resulting in high shear capacity in bending members. For this reason, additional reinforcement for shear capacity is not required.

Project Information**Positive Results:**

- UHPC has high strength and durability because of a low w/cm, low permeability, and a high resistance to cycles of freezing and thawing, and very tight cracks under load.
- UHPC beams with steel fibers do not need shear reinforcement.

Negative Results:

- The bid prices for first project selected for deployment of technology were extremely high. VDOT and FHWA decided to readvertise and use the technology on another bridge in the commonwealth.

Lessons Learned:

- UHPC can be satisfactorily produced at a precast prestressed concrete plant. Material is delivered in bags and should be kept dry to avoid prehydration. Mixing of UHPC requires more time than with the conventional mixtures. UHPC is self-consolidating. However, to eliminate surface blemishes, expedite the flow, and minimize delays, a limited amount of external vibration was applied, each time with a 1- or 2-sec duration. Vibration was limited because of concerns with fiber orientation and dispersion.
- Cracking in decks was influenced by the weather conditions at the time of placement. Decks placed in warm weather had more cracking.
- VDOT's Structure and Bridge Division should not use UHPC because of its high cost. More efficient shapes, design requirements, and material and construction specifications need to be developed to make the use of UHPC practical.
- VDOT's Structure and Bridge Division and Materials Division should support further research to evaluate the use of UHPC with fibers in closure pours because of the tight cracking pattern that would hinder the penetration of aggressive solutions.
- The use of UHPC beams can extend longevity. However, the casting of these beams requires extra attention in preparation and the materials used are proprietary and expensive, leading to a net cost increase in production. In this application, the contract unit price of the UHPC beams was more than 5 times the cost of the HPC beams. However, there were few UHPC beams, and this was the first application of these beams in Virginia. In certain applications, the higher cost may be justified because of the improved properties, extending service life with minimal or no maintenance. The cost savings from improved durability is certain and predictable. Replacing and repairing beams are difficult and costly because of the deck structure above them. Savings in cost are expected if shapes are optimized with minimal material, new design procedures are developed, and UHPC material with steel fiber is optimized for different applications. Work to optimize the shape is in progress at the Massachusetts Institute of Technology (Park et al., 2003). Other national organizations should also be encouraged to develop design procedures for UHPC beams.

Internal or External Reports:

Final Report – “Evaluation of Ultra-High-Performance Fiber-Reinforced Concrete”



FHWA Report – “Characterization of the Punching Shear Capacity of Thin Ultra-High Performance Concrete Slabs”

Publications, Presentations, or, Construction Studies:

Thesis – “Characterization of Punching Shear Capacity of Thin UHPC Plates”

Additional Comments:

Technology used on Other Projects: Yes, technology used in two other IBRC projects

Plans on Reuse of Technology: Unknown

Applicability to other States: Applicable to all states

Additional Project Notes:

10/30/08: Research and construction of bridge utilizing the UHPC girders is complete. Report scheduled to be completed in 2010.

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Route 668 over Gills Creek – 2002 IBRC #1**State:** VA **Federal-Aid Project #:** 00S (006) **Fiscal Year:** 2002 **Funds Awarded:** \$250,000.00**Fund Status:** \$237,736.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: GFRP Rebar

Technology Description: Glass fiber reinforced polymer (GFRP) bars are made of glass fibers pulled longitudinally that are held together by a resin. The purpose of this project was to investigate the performance of GFRP bars as reinforcement for concrete decks. The advantages of GFRP such as its high tensile strength, light weight, and resistance to corrosion make it an attractive alternative to steel. The deck of one end-span of the Gills Creek Bridge was constructed with GFRP bars as the top mat and epoxy-coated steel bars as the bottom mat.

Project Information**Positive Results:**

- Viable technology
- The price of a concrete overlay, including milling, patching, and traffic control, for a deck that reaches rehabilitation prior to the 75-year design life averaged \$12.03 per square foot in 2004. The additional costs for alternative reinforcements, even for solid stainless steel reinforcement at \$7.90 per square foot and GFRP at \$5.07 per square foot more than bare steel, is less than the cost of one concrete overlay, including traffic control costs, before adjusting for inflation.

Negative Results:

- Increased construction time for rebar placement due to increased number of bars, and an increase in initial cost of construction.

Lessons Learned:

- It is hoped that with future research, the dependability of GFRP bars as reinforcement in concrete bridge decks will be verified leading to an increase in the ease of construction, improvement of the durability of bridge decks, and a reduction in maintenance costs.
- In the design of bridge decks reinforced with GFRP as top mat reinforcement, the simplified strip method for deck design recommended by the AASHTO Standard Specifications and the AASHTO LRFD Bridge Design Specifications should be followed.
- The design of the GFRP reinforcement should conform to the recommendations of the ACI Guide for the Design and Construction of Concrete Reinforced with FRP Bars (2003).
- Electrical resistance strain gauges should not be used for long-term monitoring of embedded reinforcing bars.
- To ensure proper interpretation of data from embedded vibrating wire gages, samples of the concrete should be made to evaluate the coefficient of thermal expansion.
- Weigh-in-motion gauges should be calibrated prior to use in the field, as they typically measured smaller strains than the bonded electrical resistance gauges.

Internal or External Reports:

FHWA Report – Performance of a Bridge Deck with Glass Fiber Reinforced Polymer Bars as the Top Mat of Reinforcement



Final Contract Report – Proof Testing a Bridge Deck Design with Glass Fiber Reinforced Polymer Bars as Top Mat of Reinforcement



Final Contract Report – Glass Fiber-Reinforced Polymer Bars as Top Mat Reinforcement for Bridge Decks

Publications, Presentations, or, Construction Studies:

Thesis – Laboratory Tests of a Bridge Deck Prototype with Glass Fiber Reinforcement Polymer Bars as the Top Mat of Reinforcement



Thesis – Field Test of a Bridge Deck Prototype with Glass Fiber Reinforcement Polymer Bars as the Top Mat of Reinforcement



Thesis – Performance of a Bridge Deck with Glass Fiber Reinforced Polymer (GFRP) Bars as the Top Mat of Reinforcement



Thesis – Shear Strength and Strength Degradation of Concrete Bridge decks with GFRP Top Mat Reinforcement

Additional Comments:

Technology used on Other Projects: Yes, other IBRC projects have used this technology

Plans on Reuse of Technology: Unknown

Applicability to other States: Applicable to all states

Additional Project Notes:

None

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Route 33 over Pamunkey River – 2003 IBRC #3**State:** VA **Federal-Aid Project #:** 000S (075) **Fiscal Year:** 2003 **Funds Awarded:** \$308,000.00**Fund Status:** \$275,670.00 Expended **Project Status:** Complete**Associated Project Names**Route 33 over Mattaponi River –
2003 IBRC #3Project: Change / Associated

Reallocated from / to:

Technology Implemented: Self Consolidating Concrete (SCC) Lightweight High Performance ConcreteTechnology Description: Lightweight high performance concrete (LWHPC) is expected to provide high strength and high durability along with reduced weight. The purpose of this research was to evaluate and compare the prestressed LWHPC bulb-T beams and decks into two bridge structures.**Project Information****Positive Results:**

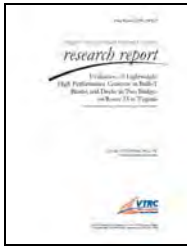
- SCC that flows into formwork and through reinforcement under the influence of its own weight can be made such that no external vibration is required. Although careful proportioning and batching are needed, SCC can be produced with locally available materials.
- SCC can have high compressive strength and low permeability for use in bridge structures.
- Several benefits of LWHPC are realized immediately and are expected to offset the increased lightweight material cost. The reduced dead load of LWHPC translates directly into longer spans, reduced number of piers or smaller piers, and reduced substructure requirements, resulting in a large cost savings, as was evidenced in the bridge structures described in this report. The costs of transporting and erecting LWHPC superstructure elements are significantly lower relative to those for NWC. In accelerated construction use of precast elements cast off site where more control in preparation is possible and less interruption to traffic occurs, LWC would be desirable for its reduced weight in handling and delivery to the jobsite. In bridge decks, the internal curing and the lower modulus of LWC are expected to minimize cracking. The enhanced durability of LWHPC is expected to lead to an extended service life with minimal maintenance costs.
- The premium paid for LWC relative to NWC may range from 25% to 30% of the cost per cubic yard, which is expected to decrease with more use of this material. However, this increase is less than 10%, considering the per cubic yard cost for in-place concrete. In the total cost of the bridge, the increase is much smaller, within a few percentage points.
- LWHPC with satisfactory strength and permeability can be achieved.
- The freeze-thaw resistance of beam concretes with LWHPC was marginal but was satisfactory for the deck concretes. The beam concrete has a lower air content requirement than the deck concrete since it is expected to be protected by the overlying deck; it also has a lower w/cm; both make it difficult to critically saturate. Therefore, the harsh test does not necessarily indicate poor field performance and the performance is expected to be satisfactory.
- Steam curing accelerates early strength development.
- Permeability values were all satisfactory, either low or very low, even when calcium nitrite was added.
- This project indicates that LWHPC can be successfully used in bridge beams and decks. If the improved quality results in a 10% increase in service life, large savings would occur. In Fiscal years 2003 through 2008, VDOT spent an average of \$10.68 million per year on prestressed concrete beams. Thus, VDOT could save close to \$1 million each year through the improvements expected with LWC.

Negative Results:

- LWHPC costs more than NWHPC because of the up-front material cost for lightweight aggregates.
- Steam curing results in lower ultimate strengths.
- The splitting tensile strength for the LWHPC was lower than for NWC, however this expected and can be addressed by adding sufficient reinforcement.
- The shrinkage values for the LWHPC were higher for the LWC compared to those for NWC; however, they were still in Grade 2 as defined by the FHWA.
- Concretes with a high slump flow are prone to segregation and bleeding. Tests should be conducted with the material used for a specific project to establish that the SCC flows sufficiently but will not segregate, bleed, or require additional consolidation. To minimize segregation, a large amount of fine material, a small NMA size, uniform grading, and low water-cementitious material ratios are needed or conventional mixtures with VMAs may be used.

Lessons Learned:

- Specimens steam cured initially and then kept in the moist room had similar strengths at 1 year as specimens kept outdoors or left in the laboratory air; however, the elastic modulus values were different. The moist-cured specimens had the highest elastic modulus, followed closely by those kept outdoors and then those kept in the laboratory air. Thus, moist curing for extended periods improves the elastic modulus for a given strength.
- The creep coefficient for the LWHPC over the early age time interval appears similar to that for NWC, but the elastic modulus for the concrete is reduced from that for NWC as expected because of the low stiffness of the lightweight aggregate. Relationships developed between strength and elastic modulus for different LWCs can be used to select the appropriate section modulus to overcome the reduced stiffness attributable to reduced elastic modulus.
- To mitigate high drying shrinkage, a large NMA size, a large amount of coarse aggregate, and a low water content are needed.
- To avoid an improper air-void system that would reduce freeze-thaw resistance, either a large air content or a conventional air content with the proper selection of admixtures that will lead to a reduced void size and spacing is needed.
- The use of SCC has the potential to provide initial savings because of the reduction in labor required to place the concrete. Further savings can be obtained because structures constructed with SCC should last longer.
- Specific test procedures should be followed to determine if concretes are self-consolidating or segregating. Specimens should be tested for strength and permeability made with and without consolidation to determine if they are self-consolidating. The slump flow test should be used to detect segregation based on aggregate distribution and a mortar halo around the spread. The U-tube or a similar test should be used to show that SCC can flow through the reinforcement and provide high workability without segregation.
- Rheometers should be used to provide data on yield stress and viscosity and to describe the flow characteristics while the mixtures are being developed. Low viscosity values indicate adequate flow characteristics. However, there is no correlation between the viscosity number and segregation or equilibrium height or spread in this limited study. Further work in this area is recommended.
- SCC is recommended for use in transportation structures that can benefit from concretes with high workability, particularly in thin sections and areas with dense reinforcement.

Internal or External Reports:

Final Report – Evaluation of Lightweight High Performance Concrete in Bulb-T Beams and Deck in Two Bridges on Route 33 in Virginia



Final Contract Report – Shear Strength of a PCBT-53 Girder Fabrication with Lightweight Self-Consolidating Concrete



Final Report – Laboratory Investigation of Lightweight Concrete Properties

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Yes, used on other IBRC projects

Plans on Reuse of Technology: Unknown

Applicability to other States: Applicable to all states

Additional Project Notes:

None

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Troutville Weight Station Ramp – 1999 IBRC #4 – FRP Panel**State:** VA **Federal-Aid Project #:** 000S (006) **Fiscal Year:** 1999 **Funds Awarded:** \$228,000.00**Fund Status:** \$228,045.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Composite Deck Panels

Technology Description: This project addressed the field performance of a multi-cellular fiber-reinforced polymer (FRP) composite bridge system. FRP technology used in deck panels typically far exceeds the costs of a reinforced concrete deck. This project examines the use of pultruded, off the shelf components as a lower alternative FRP deck system.

Project Information**Positive Results:**

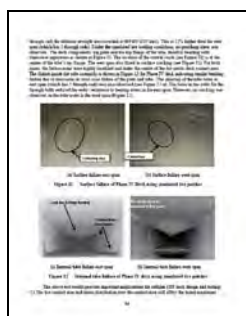
- The FRP bridge deck system performed well in the intense service load environment of the Troutville Weigh Station. For example, the Phase II deck survived 4,000,000 truck loadings with some loss in stiffness (12 to 25%) and minimal loss in strength.
- FRP decks made from adhesively bonded pultrusions are viable structures for highway bridge deck applications.
- A lower material cost relative to other FRP deck systems

Negative Results:

- In laboratory tests, two different schemes of loading patches were developed: a steel patch sized according to the AASHTO bridge design specifications; and a tire patch made from a truck tire reinforced with silicon rubber. It was seen that, due to the localization of load, effects of the stiffness and contact conditions of loading patches are significant in the stiffness and strength testing of FRP decks. Because of its highly localized behavior, a simulated tire patch yielded larger maximum deflection and strain than the steel plate under the same loading level. The tire patch produced significantly different failure modes compared to the steel plate: a local bending mode with less damage under the tire patch; and a local punching-shear mode under the steel plate. The results from both laboratory and field tests indicate that the unsupported edges should be avoided in practice.

- Due to the local effects of a real tire load, a simulated tire loading patch would be more appropriate in laboratory testing
- The unsupported edges are vulnerable to deterioration under repeated loads; therefore, in practice, design and construction with free edges should be avoided;
- The behavior comparisons of the west span and east span of Phase IV deck indicate that the number of through rods in this FRP deck system can be significantly reduced and only need to be included to allow for the hooked bolt connection of the deck to supporting stringers. Comparisons for experimental results of the same deck (Phase II deck) from field tests and laboratory tests showed no significant strength and load-carrying capacity loss after 4 million cycles fatigue loading. Field monitoring of the Phase III FRP deck did not show significant stiffness loss from about 0.7 million loading cycles to about 7 million cycles of truck loading.
- This project involved the development and implementation of a proposed FRP bridge deck system. The FRP deck developed was essentially a 5 foot by 15 foot panel. Four of these panels were either tested in the laboratory and/or placed in the Troutville Weigh Station. This research concentrated on specific aspects of FRP deck behavior but was not intended to develop a ready for market system. Further research is needed before this type of deck system is more than a special case option. The connection of adjacent panels was not investigated and this should be one focus of future research. Further investigation of environmental degradation is warranted. Also, design standards are not available and the FRP bridge deck industry has very few standards of performance or quality control developed.

Internal or External Reports:



Final Contract Report – Plate and Tube Bridge Deck Evaluation in the Deck Test Bed of the Troutville, Virginia, Weigh Station

Publications, Presentations, or Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Yes, research from this project was used in the deployment of two other FRP decks in Virginia:



Final Contract Report – Rapid Placement of Tangier Island Bridges Including Lightweight and Durable Fiber-Reinforced Polymer Deck Systems



Final Contract Report – Development and Evaluation of an Adhesive Bonded Panel-to-Panel joint for a Fiber-Reinforced Polymer Bridge Deck System

Plans on Reuse of Technology: Yes, as shown on the deployment of two other projects

Applicability to other States: Applicable to all states

Additional Project Notes:

The project and corresponding research is complete.

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1.48. VERMONT

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Bridge 2, Readsboro**State:** VT **Federal-Aid Project #:** STP ST CULV(4) **Fiscal Year:** 2005 **Funds Awarded:** \$200,000.00**Fund Status:** \$200,000.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Accelerated Bridge Construction with precast box culvert, wings, and headwall**Technology Description:** Using precast elements and accelerated bridge construction (ABC) techniques to reduce construction time.**Project Information****Positive Results:**

Using Accelerated Bridge Construction to combine innovative contracting language with pre-fabricated bridge components, we were able to construct the bridge using a 10 day road closure. This expedited the project development process by eliminating Right-of-Way and environmental impacts. The result was a project that could be designed and built in a very short time.

Negative Results:

None

Lessons Learned:**Barrier to implementation of Technology:**

- Much of the construction work is weather-dependent and we have no control over the weather so this type of project could present a risk to the contractor.
- The contractor used a small crew and had to work them long hours instead of hiring more workers. This can create stress and fatigue for field personnel.
- Sub-consultants can control the pace of work and may not be aware of incentive/disincentive on prime contractor

Internal or External Reports:

None.

Publications, Presentations, or, Construction Studies:

None.

Additional Comments:

Technology used on Other Projects: Accelerated Bridge Construction (ABC) technique was also used on the Woodstock Route 50 over Ottauquechee River project.

Plans on Reuse of Technology: Yes, the technology was a success.

Applicability to other States: Yes, this technology is applicable to all states and has been implemented in other states.

Additional Project Notes:

10/30/08: Innovation implemented and project open to traffic

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Bridge 213 carrying VT Rte 100 over Ryder Brook**State:** VT **Federal-Aid Project #:** BRF 029-(11) **Fiscal Year:** 2001 **Funds Awarded:** \$260,000.00**Fund Status:** \$259,999.97 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: **FRP Rebars and High Performance Concrete in Deck Slab; Fiber Optic Monitoring****Technology Description:** Glass fiber reinforced polymer (GFRP) bars used as reinforcement in high performance concrete bridge deck construction instead of traditional reinforcing steel bars.**Project Information****Positive Results:**

The GFRP Reinforced High Performance Concrete (HPC) Deck is performing well after 8 years. VTRANS collaborated successfully with the University of Sherbrooke to evaluate the performance of the Deck between 2002 and 2005. The evaluation included: Remote Monitoring of temperature and strain in the GFRP, HPC, and steel girders, and three Live Load Tests and Progress Reports, and a Durability Study. The tests also provided of Live Load Distributions from strain and deflection. The study reflected well upon everyone involved.

- Fiber Optics Sensors are performing well and yielding significant data about the performance of the bridge.
- No significant degradation in overall performance of the bridge.
- The deflection of bridge girders was well below the AASHTO allowable limits (Span/800).

Negative Results:

None

Lessons Learned:

Barrier to implementation of Technology: The study was more ambitious than we had anticipated. In hindsight, we should have known that it would be more work, time and expense than we expected to do it right. We were able to keep the study within the budget thanks to the generosity of the University and VTRANS Maintenance District. We should have allowed more time and money to do the study correctly and be fair to the University.

I think we could have a done a better job of protecting the sensors during construction when we lost some.

We have a remote sensing capability at the bridge that we are not using now.

Internal or External Reports:

“EVALUATION OF THE PERFORMANCE OF GLASS FIBER REINFORCED POLYMER (GFRP) REINFORCEMENT, AN INNOVATIVE MATERIAL, IN THE SUPERSTRUCTURE OF BR 213 OVER THE RYDER BROOK ON VT 100 IN MORRISTOWN, VERMONT”

These Progress and Final Reports detail the evaluation of the performance of glass fiber reinforced polymer (GFRP) reinforcement.

Publications, Presentations, or, Construction Studies:

"Designing and Testing of Concrete Bridge Decks Reinforced with Glass FRP Bars"

"DESIGN, CONSTRUCTION, AND TESTING OF THE HIGHWAY 55 NORTH (MAGOG, QUEBEC) CONCRETE BRIDGE DECK REINFORCED WITH FIBER-REINFORCED POLYMER (FRP) BARS"

These publications summarize the design, construction and testing of concrete decks reinforced with glass fiber reinforced polymer (GFRP) bars.

Additional Comments:

Technology used on Other Projects: FRP reinforcing bars were not used on other Vermont projects.

Plans on Reuse of Technology: Yes, the results were very positive. FRP performed well as an innovative structural material.

Applicability to other States: Yes, This technology is applicable to all states, and has been implemented in many states.

Additional Project Notes:

10/30/08: Innovation implemented and project open to traffic

The project was successful and demonstrated that GFRP Reinforced concrete Decks work well. Use of GFRP particularly in shallow reinforced concrete sections should increase as it becomes less expensive. AASHTO should include design procedures for GFRP in the AASHTO LRFD Bridge Design Specifications.

State DOT Contact: Thomas Lackey

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E-mail: Thomas.Lackey @state.vt.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Bridge #8 FAS 0166 over White River**State:** VT **Federal-Aid Project #:** BTN 2004(1) **Fiscal Year:** 2004 **Funds Awarded:** \$168,000.00**Fund Status:** \$106,519.05 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Steel in I-girders

Technology Description: High performance steel used in bridge construction in place of conventional structural steel.

Project InformationPositive Results:

- Learned design code requirements for hybrid girder design.
- Learned welding requirements for welding different grades of steel and applied these requirements to welding specifications.
- Superstructure depth minimized to meet hydraulic constraints; provided a solution for spanning the river that kept the structure out of the flood water elevation.

Negative Results:

Estimated the cost of the higher grade steel too high. Wasn't really sure how comfortable the industry was in fabricating these girders so had a fairly high cost estimate.

Lessons Learned:

Barrier to implementation of Technology: The steel industry is more advanced in new technology than I thought. Hybrids are the way to go when constraints are such that a low profile girder is necessary. Using the Hybrid steel girder gave us the strength needed to carry the loads and kept the structure out of the Q100 flow elevation.

Internal or External Reports:

None.

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: HPS was not used on other Vermont projects.

Plans on Reuse of Technology: Yes, the technology was a success.

Applicability to other States: Yes, this technology is applicable to all states and has been implemented in many other states.

Additional Project Notes:

This project was successful in that it paved the way for other engineers to design hybrids. If we had gone with grade 50 steel, we would have likely added another girder line. We were able to keep the beam spacing at 8'-10" and keep the superstructure depth low enough to meet hydraulic constraints. There were no problems relating to the different steel grades with the fabrication and the girders were delivered on time. As for construction, the contractor saw no difference in erecting these girders than if they had been conventional.

10/30/08: Innovation implemented and project open to traffic.

This is a case where the unit price of the steel (i.e. the innovative portion of the project) came in at a lower price than originally estimated; all expenditures applicable to the innovative portion of the project have been billed and accounted for.

State DOT Contact: Kristin Higgins

Phone: 802-828-0053

E-mail: Kristin.Higgins@state.vt.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Woodstock Route 50 over Ottauquechee River**State:** VT **Federal-Aid Project #:** BHF 020-2(32) **Fiscal Year:** 2005 **Funds Awarded:** \$200,000.00**Fund Status:** \$200,000.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Accelerated Bridge Construction with precast deck elements**Technology Description:** Using precast elements and accelerated bridge construction (ABC) techniques to reduce construction time.**Project Information****Positive Results:**

Using Accelerated Bridge Construction to combine innovative contracting language with pre-fabricated bridge components, we were able to construct the bridge using a 27 day bridge closure. The precast concrete box beams saved considerable time during construction compared to conventional cast-in-place methods. The community was very apprehensive about our proposed concept at first but was extremely happy with the results.

Negative Results:

None

Lessons Learned:**Barrier to implementation of Technology:**

- The Public Relations Officer included as a contract item and hired by the contractor during construction is a very important role and is key to how well these projects are tolerated by the public.
- The contractor worked 24/7 for 27 straight days to complete this project. This concentrated effort over this duration can create stress and fatigue for field personnel.
- Sub-consultants can control the pace of work and may not be aware of incentive/disincentive on prime contractor.
- Designers must be available to answers questions during the closure and empowered to make major decisions.

Internal or External Reports:

None.

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Accelerated Bridge Construction (ABC) technique was also used on the Bridge 2, Readsboro project.

Plans on Reuse of Technology: Yes, the technology was a success.

Applicability to other States: Yes, this technology is applicable to all states and has been implemented in other states.

Additional Project Notes:

State DOT Contact: Pam Thurber

Phone: 802-828-0041

E-mail: Pam.Thurber@state.vt.us

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** VT Bridge 64, VT 105 over Clyde River**State:** VT **Federal-Aid Project #:** BRF 034-3(14) **Fiscal Year:** 2002 **Funds Awarded:** \$153,000.00**Fund Status:** \$152,519.63 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: MMFX Rebars

Technology Description: MMFX corrosion resistant reinforcing steel was evaluated to determine if in fact, it provides superior corrosion resistance to conventional uncoated and epoxy-coated reinforcing steel.

Project Information**Positive Results:**

Had the opportunity to place this material and will be able to see in the future if it contributes to longer deck life.

Negative Results:

Minor issues with type of ties to use, epoxy coated wire was used.

Lessons Learned:**Barrier to implementation of Technology:** The materials and research lab tested specimens of MMFX2 rebar. Preliminary results indicate that the corrosion resistance is not significantly different than black reinforcing steel.

MMFX steel exhibit corrosion resistance less than epoxy-coated bars.

Internal or External Reports:**“EVALUATION OF MECHANICAL AND CORROSION PROPERTIES OF MMFX REINFORCING STEEL FOR CONCRETE”**

This Report, based on research, compares the mechanical and corrosion properties of MMFX to conventional reinforcing steel.

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: MMFX reinforcing bars were not used on other Vermont projects.

Plans on Reuse of Technology: No, the research results were not favorable and it was not recommended for future use.

Applicability to other States: This technology has been implemented in other states.

Additional Project Notes:

10/30/08: Innovation implemented and project open to traffic

State DOT Contact: Martha Evans-Mongeon

Phone: 802-828-0514

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1.49. WASHINGTON

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Chief Joseph Dam Bridge – Pearl Road over Foster Creek**State:** WA **Federal-Aid Project #:** T090 (001) **Fiscal Year:** 2001 **Funds Awarded:** \$500,000.00**Fund Status:** \$500,000.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to: {\$}

Technology Implemented: FRP Deck PanelsTechnology Description: Fiber Reinforced Polymer deck panels**Project Information****Positive Results:**

- FRP deck is performing as designed

Negative Results:

- Possible overload has damaged bridge superstructure

Lessons Learned:

FRP was relatively easy to work with and the design did not anticipate an overload which may have damaged the bridge.

Internal or External Reports:

Bridge Rating Summary – Report by Nicholls Engineering restricting bridge to one lane with load restrictions

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Unknown

Plans on Reuse of Technology: Not Reported

Applicability to other States: Applicable to all states

Additional Project Notes:

10/30/08: Project is closed and bridge is complete.

State DOT Contact: Aaron Butters
E-mail: buttera@wsdot.wa.gov

Phone: 360-705-7375

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Ever's Bridge – Shelton-Matlock Road over Decker Creek**State:** WA **Federal-Aid Project #:** A230 (005) **Fiscal Year:** 2001 **Funds Awarded:** \$425,000.00**Fund Status:** \$425,000.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Bonded Reinforcement

Technology Description: Fiber reinforced polymer (FRP) , is a composite material that use synthetic fibers to mechanically enhance the strength and stiffness of a polymer matrix. This project included the implementation of FRP repair alternatives to improve deck stiffness of an existing timber bridge. The FRP repairs were applied to the underside of the timber deck.

Project Information**Positive Results:**

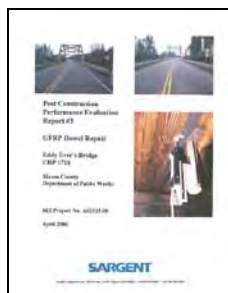
- Based on prior deflection data, it appears that the FRP/Timber composite repairs continue to improve the bridge deck stiffness. Significant improvements over measured deck deflections were shown for both the panel-to-support condition and the panel-to-panel condition for both the approach and main span.
- There have been no reflective cracking in pavement overlay on the deck surface

Negative Results:

- Some notable pavement damage has occurred on the deck surface since the installation of the FRP bonded reinforcement, however this does not appear to be related to these repairs.

Lessons Learned:

- It was suggested in the report that the repairs were effective to the point that the recommendation was made for use of this technology at other similar repair projects.
- It was recommended in the report that a more appropriate type of gage and monitoring system be used to quantify any changes in relative deflections. A scratch strain gage was given as appropriate alternative.

Internal or External Reports:

"Post Construction Performance Evaluation Report #3"

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Unknown

Plans on Reuse of Technology: Unknown, however recommendation was made for reuse on similar projects

Applicability to other States: Applicable to any state with glu-lam bridges

Additional Project Notes:

10/30/08: Project and work is complete.

State DOT Contact: Aaron Butters
E-mail: buttera@wsdot.wa.gov

Phone: 360-705-7375

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Monroe Street Bridge over Spokane River**State:** WA **Federal-Aid Project #:** 3891 (007) **Fiscal Year:** 2002 **Funds Awarded:** \$268,000.00**Fund Status:** \$268,000.00 Expended **Project Status:** CompleteAssociated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: HPC Deck Panels

Technology Description: A cast-in-place, high performance concrete (HPC) wearing surface overlaying precast, prestressed concrete deck panels was selected to replace the existing deck of the historic Monroe Street Bridge. HPC was chosen to increase the durability of the wearing surface, including controlling cracking.

Project InformationPositive Results:

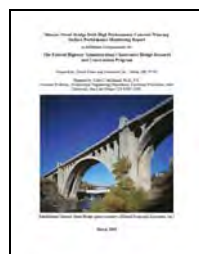
None

Negative Results:

- The HPC wearing surface is badly cracked. The cracks in the deck have been sealed twice, once by the contractor before the bridge was opened to traffic in 2005 and once by our crew in the fall of 2006. The cracks continue to propagate beyond the length that has been sealed, although the pace appears to be slowing. This will be a recurring expense for the life of the deck, and we don't expect the deck to achieve its design service life. The new cracks will have to be sealed as they emerge and the existing cracks will have to be re-sealed periodically to keep them from deteriorating and to try to keep water and de-icing materials from penetrating to the structural members below.

Lessons Learned:

- This project highlights the susceptibility of high-performance mix designs to any deviation from the required curing procedure. Curing procedures must be carefully and thoroughly detailed in the specifications and field personnel must adhere to the specification even if it means delaying the pour due to unfavorable weather conditions.

Internal or External Reports:

"Monroe Street Bridge Deck High Performance Concrete Wearing Surface Performance Monitoring Report"

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Applicable to all states

Additional Project Notes:

10/30/08: Project is closed and the bridge is complete.

State DOT Contact: Aaron Butters

E-mail: buttera@wsdot.wa.gov

Phone: 360-705-7375

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** SR 20, Fredonia Shaft Test**State:** WA **Federal-Aid Project #:** 0020 (153) **Fiscal Year:** 2005 **Funds Awarded:** \$400,000.00**Fund Status:** \$684,546.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Self-Consolidating Concrete

Technology Description: Self-Consolidated Concrete in Piles and effects of post-grouting shaft tips.

Project InformationPositive Results:

- Confirmed that self-consolidating concrete works well for drilled shafts.
- Compared capacity of shafts with post-grouted and non-post-grouted tips.

Negative Results:

None

Lessons Learned:

- This research has, in part, led to the use of shaft tip post-grouting on a current construction project (C8128 Snohomish River Bridge).

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Yes, technology used in at least one other project in WA, the Snohomish River Bridge project

Plans on Reuse of Technology: Used in one other project thus far

Applicability to other States: Applicable to all states

Additional Project Notes:

One of the other IBRD projects (Granite Falls Bridge, FY 2003) did not fully come to completion, so we moved the remaining amount from that project, \$284,546, to this project.

State DOT Contact: Mark Gains
E-mail: gainesm@wsdot.wa.gov

Phone: 360-705-7827

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** SR 20, Twisp River Bridge**State:** WA **Federal-Aid Project #:** 0020 (110) **Fiscal Year:** 1999 **Funds Awarded:** \$975,000.00**Fund Status:** \$975,000.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Concrete

Technology Description: High performance concrete in pre-tensioned and post-tensioned girders. The Twisp River Bridge is one of the first applications of the use of the WSDOT "super girders". Pre-tensioned and post-tensioned girders built in precast segments and combined by post-tensioning at the project site to make a 197 feet long single girder. High Performance Concrete was used in the Girders.

Project Information**Positive Results:**

- Advanced the state of the art for longer span precast girders. Nearly all WSDOT precast girders have been built in one piece since the Twisp bridge but there have been a few cases that a splice girder was needed and this project helped develop details.
- The bridge was constructed with minor environmental impact to the river.
- Post-tensioning after deck placement reduced the required girder closure concrete strength to 5.0 ksi, compared to 7.5 ksi.

Negative Results:

- Minor cracking occurred adjacent to the debonded strands in the thin portion of the girder bottom flange.
- Minor flexural cracking occurred in the end diaphragms after post-tensioning.

Lessons Learned:

- Learned more about long span concrete girders. WSDOT and the pre-casting plants and the trucking industry have worked together to allow construction and delivery of over 200' span lengths.
- Jacking corbels were omitted in lieu of simpler end diaphragms geometry, where steel reinforcing mats were designed by the strut-and-tie method and stresses were checked by the finite element model.
- Consideration should be given to placing intermediate diaphragms at girder closer instead of continuing only the girder section through the closure
- Cracking adjacent to the debonded strands can be mitigated by relegating the debonded strand locations to the thicker, more confined portion of the bottom flange.
- Flexural cracking can be mitigated by providing a gap at the bottom of the diaphragm, and by sequencing the tensioning from the center anchorages outward.

Internal or External Reports:

Cover Feature from PCI – "New Deep WSDOT Girders Used for the Twisp River Bridge"

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Applicable to all states

Additional Project Notes:

10/30/08: Project is complete with bridge constructed.

State DOT Contact: Bijan KhaleghiPhone: 360-705-7181E-mail: khalegb@wsdot.wa.gov

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** US 12 over Tieton River**State:** WA **Federal-Aid Project #:** 0012 (122) **Fiscal Year:** 2009 **Funds Awarded:** \$110,00.00**Fund Status:** \$23,660.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Self-Consolidating Concrete

Technology Description: Self-Consolidated Concrete in 5 pre-stress girders in the 80 foot span

Project Information**Positive Results:**

- The results were positive. Allowed the pre-casting industry to demonstrate the Use of SCC in precast girders. There benefits are reduced the need for very loud vibration (worker safety) and it reduced the need for additional finishing after the concrete has cured.

Negative Results:

None

Lessons Learned:

- SCC can be used in precast girders. Important to work with the precast plant to develop the proper SCC testing procedure.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Applicable in all states

Additional Project Notes:

9/2/11: Project is complete and bridge is constructed.

State DOT Contact: Bijan Khaleghi
E-mail: khalegb@wsdot.wa.gov

Phone: 360-705-7181

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** US Route 2 – Barclay Creek Bridge**State:** WA **Federal-Aid Project #:** 0002 (230) **Fiscal Year:** 2000 **Funds Awarded:** \$700,000.00**Fund Status:** \$700,000.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Steel in Plate Girders

Technology Description: Use of 70 ksi steel in bridge.

Project InformationPositive Results:

- Demonstrated use of 70ksi steel in bridges, successful project.

Negative Results:

- Supply of 70ksi is not readily available and is more expensive compared to 50ksi steel.

Lessons Learned:

- If there was a need in the future WSDOT would likely use 70ksi in the flange of steel girders with 50ksi in the webs (hybrid girders).

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Applicable to all states

Additional Project Notes:

10/30/08: Project is complete and bridge is constructed.

State DOT Contact: Bijan Khaleghi
E-mail: khalegb@wsdot.wa.gov

Phone: 360-705-7181

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** William Bugge Bridge, SR 104 over Hood Canal**State:** WA **Federal-Aid Project #:** 0104 (025) **Fiscal Year:** 2004 **Funds Awarded:** \$400,00.00**Fund Status:** \$400,00.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: ABC ConstructionTechnology Description: Rapid move of new 605-ft long precast concrete superstructure in high seismic region.**Project Information****Positive Results:**

- Results were positive. The project constructed pre-stress girders approach spans parallel to the existing spans and then removed the old steel spans and installed the new spans by sliding all the spans sideways

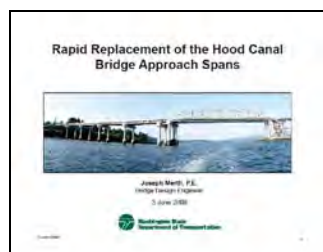
Negative Results:

None

Lessons Learned:

Rolling in spans was very effective. Must consider cost of additional false work.

Noted unequal bearing loads after placement as compared to design assumptions for pier cap. This required additional jacking and shimming to equal out loads and overstressing.

Internal or External Reports:

WSDOT Report – Rapid Replacement of the Hood Canal Bridge Approach Spans

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Project was a special circumstance, so applicability to other states may be limited

Additional Project Notes:

9/2/11: Project is complete and bridge is constructed.

State DOT Contact: Bijan Khaleghi
E-mail: khalegb@wsdot.wa.gov

Phone: 360-705-7181

1.50. WEST VIRGINIA

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Bigley Ave. Interchange Charleston, WV**State:** WV **Federal-Aid Project #:** Not reported **Fiscal Year:** 2002 **Funds Awarded:** \$357,000.00**Fund Status:** \$244,500.00 Expended **Project Status:** Completed**Associated Project Names**State Project #S320-77-
100.97.00Project: Change / Associated

Reallocated from / to:

Man Bridge D

Project: Change / AssociatedReallocated from / to: \$112,500**Technology Implemented:** HPC for patching**Technology Description:** Rapid set concrete was used for patching, greatly decreasing the set time for the repair patches, typically permitting overnight repairs.Project InformationPositive Results:

The use of rapid set concrete O/L has worked out well in D-1. The contractors have been able to mill the existing deck, hydro-blast the area to remove any unsound concrete, clean the area and place the rapid set overlay in quantities that make the use practical in areas that need to be opened to traffic in a limited time period, typically from late evening to early morning. D-1 has used this type of O/L on several projects after this one. Another project in the Bigley Ave I/C SB for approximately 0.45mile, Danner Road OP on I-64, East Point Drive Br on I-77 and the Hurricane RR O/P Br on WV 34.

Negative Results:

None reported.

Lessons Learned:**Barrier to implementation of Technology:**

Due to the rapid set nature of this material, this is pretty much a night time only operation especially in the summer months. The application of the wet burlap cure and keeping it wet is critical for this material.

Internal or External Reports:

none

Publications, Presentations, or, Construction Studies:

none

Additional Comments:

Technology used on Other Projects: not reported

Plans on Reuse of Technology: yes, as appropriate for other jobs need low traffic impact.

Applicability to other States: this is a good repair option provided the contractor is experienced with the material

10/30/08: Project complete in June 2006 however only \$244,500 was used for Bigley Ave. The remaining award amount of \$112,500 was de-allocated in FY 2003 and again reallocated in FY 2005. The remainder was authorized for use on a separate project, The Man Bridge D

State DOT Contact: Brian Kelley

Phone: 304-558-3171

E-mail: Bill.J.Kelley@wv.gov

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Culloden Railroad Overpass Bridge**State:** WV **Federal-Aid Project #:** BR0060(142)E **Fiscal Year:** 2003 **Funds Awarded:** \$400,000.00**Fund Status:** \$400,000.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: HPS GirdersTechnology Description: Hybrid HPS steel girders were used (100W, 70W, and 50W)**Project Information****Positive Results:**

All indications are that the material used is performing as anticipated

Negative Results:

The contractor initially sub-contracted the steel fabrication to a shop that was unprepared and ill-equipped to handle the type of fabrication necessary which resulted in a delay, however it had no effect on the overall project completion

Lessons Learned:

Barrier to implementation of Technology: none, project is a success.

Tighter control of the fabrication process with better language in the Special Provision would have been beneficial

Internal or External Reports:

none

Publications, Presentations, or, Construction Studies:

none

Additional Comments:

Technology used on Other Projects: not reported

Plans on Reuse of Technology: yes, as appropriate for other similar jobs.

Applicability to other States: access to material may be issue

State DOT Contact: Not reported

Phone: _____

E-mail: _____

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** East Street Viaduct carries CSX RR over WV Alt 14A**State:** WV **Federal-Aid Project #:** Not reported **Fiscal Year:** 1999 **Funds Awarded:** No record**Fund Status:** Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Bonded ReinforcementTechnology Description: Repair of multiple concrete girders with FRP sheets and as extra protection for the concrete surfaces.**Project Information****Positive Results:**

There have been no failures of the center span ceiling wrap in the 10 years since that project was completed. One portal was impacted by an over-height vehicle and the wrap prevented a small amount of busted concrete from falling onto traffic.

Negative Results:**Lessons Learned:**

Barrier to implementation of Technology: none, technology works and continues to perform well.

This structure is 3 spans. The outer spans carry North-bound and South-bound rail traffic, while the center is for the old trolley system of Parkersburg. This structure carries multipliable lines of CSX tracks. This project was to install FRP wrap on the viaducts interior concrete surfaces to protect them. It was decided to only wrap the underside of the unused interior span for fear of a failure of the wrap due to moisture and/or an over-height vehicle snagging the wrap and pulling it down on traffic. The contractor's conscientious work in installing the weep drains at all moisture locations has proved that wrapping the ceiling is a viable option for future similar projects. The outer spans also have the wrap going into the portal at the ceiling a short distance.

Internal or External Reports:

none

Publications, Presentations, or, Construction Studies:

none

Additional Comments:

Technology used on Other Projects: not reported

Plans on Reuse of Technology: yes, when applicable project is found.

Applicability to other States: this technology can be used by other states and should be considered for repair of concrete surfaces.

State DOT Contact: Michael Foley

Phone: 304-420-4687

E-mail: Michael.J.Foley@wv.gov

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Howells Mill Bridge CR 1 over Mud River**State:** WV **Federal-Aid Project #:** Not reported **Fiscal Year:** 2001 **Funds Awarded:** \$475,000.00**Fund Status:** \$475,000.00 Expended **Project Status:** CompletedAssociated Project Names

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Deck Panel

Technology Description: Repair of multiple concrete girders with FRP sheets and as extra protection for the concrete surfaces.

Project InformationPositive Results:

Allowed the rapid installation of a bridge deck.

Negative Results:

Rospalt 50 overlay was overpriced and did not perform as expected. Material "blistered" as soon as it was rolled into place. The deck surface draws moisture and freezes in the winter time, much faster than other roads and bridges in the area.

Lessons Learned:**Barrier to implementation of Technology:** product did not perform as planned. Overpriced. Not recommended for use

During installation of the shear studs, due to the shear stud pockets being pre cut, the locations interfered with the straps holding the stay in place forms. Grouting operations were difficult due to the grout constantly settling into the panels.

Internal or External Reports:

none

Publications, Presentations, or, Construction Studies:

none

Additional Comments:

Technology used on Other Projects: no

Plans on Reuse of Technology: no.

Applicability to other States: not recommended.

State DOT Contact: Michael Foley

Phone: 304-420-4687

E-mail: Michael.J.Foley@wv.gov

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Man Bridge in Logan Co.**State:** WV **Federal-Aid Project #:** IBRC-0010(162)E **Fiscal Year:** 2007 **Funds Awarded:** \$0.00**Fund Status:** \$112,500 Expended**Project Status:** Completed**Associated Project Names**

Bigley Ave Interchange

Project: Change / AssociatedReallocated from / to: \$112,500**Technology Implemented:** Use of a polymer deck sealant for penetrating cracked bridge decks and carbon stitching repair

Technology Description: Deck sealant to reduce cracks in bridge decks, new polymer sealant formulation

Project InformationPositive Results:

Materials found to perform as advertised when applied properly. Deck sealant penetrated cracks deeper than anticipated. Crack repaired with carbon stitching technique did not reflect through the overlay. Results indicate a state-wide initiative to seal existing bridge decks may be appropriate. Data from parapet sealing supports the elimination of the use of linseed oil. Very little investment necessary for specialized application equipment needed

Negative Results:

When not applied under proper supervision with material distributors technical support, a degree of wasted material occurs. Sections where the material was applied as per recommendations exhibited outstanding performance. Calculations for carbon stitching in regard to length and spacing appear to be conservative.

Lessons Learned:

Barrier to implementation of Technology: Application rates, temperatures, and surface preparation controls need to be developed, documented, and incorporated into a procedural training program for further use of these materials.

Training will necessary for State Forces to apply the products successfully. When applied to the correct situation and condition, the products perform well.

Internal or External Reports:

Internal report incomplete.

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: not reported

Plans on Reuse of Technology: yes, as appropriate for other similar jobs.

Applicability to other States: access to material may be issue

10/30/08: Project is ongoing. The structure is not currently in service; awaiting completion of the approach roadway segment. The LMC overlay has been placed. Additional application of the deck sealant product was incorporated into that operation due to the deck preparation method employed by the Contractor (hydro-demolition). Assessment of the cracks reflecting through the LMC overlay is currently being monitored periodically. The durability and longevity of the parapet sealant will continue to be monitored and evaluated. No additional funding will be required for this process.

05/03/10: Project is complete

State DOT Contact: Steven Schumacher, District 8 Area
Engineer

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Market Street Bridge**State:** WV **Federal-Aid Project #:** BRHI-0024(023)E **Fiscal Year:** 1999 **Funds Awarded:** \$3,531,889.00**Fund Status:** \$3,531,889 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Deck PanelTechnology Description: 1st generation FRP deck was set on steel welded girders. FRP panels are of alternating full-depth hexagons and double-half trapezoids. Panels are extruded to custom lengths.Project InformationPositive Results:

This FRP deck should be considered far quick replacement for decks on existing bridges where delay time should be kept to a minimum. The use of this material has reduced the maintenance cost of expensive overlays or replacements. This deck material is not prone to salt damage as found on concrete decks.

Negative Results:

There were some problems encountered during construction with temperature variations due to heat from the sun. There was some deflection in the panels, to correct the problem tie downs had to be placed on 2ft centers. This caused some coordination when grouting the panels. Another problem during construction was water being trapped in the panel voids. Additional drain holes had to be placed. Also due to the span length there were some problems associated with the expansion and contraction of the panels.

Lessons Learned:

Barrier to implementation of Technology: development of standard construction techniques.

This project was very unique and interesting. The problems encountered were minor considering this type of deck had not been used often. The possibilities for this material to become widely used are excellent. The use of this material will reduce future maintenance costs.

Reduced DL (22psf) of the deck saves in support system requirements.

Internal or External Reports:Publications, Presentations, or, Construction Studies:

Construction Report:

Additional Comments:

Technology used on Other Projects: no

Plans on Reuse of Technology: This FRP deck should be considered for quick replacement for decks on existing bridges where delay time should be kept to a minimum

Applicability to other States:

10/30/08: Project is complete and is closed. All expenditures have been finalized.

Project utilized high performance steel in the flanges of the girders.

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Stalnaker Run Bridge County Route 219/86 (MP 3.18) over Stalnaker Run**State:** WV **Federal-Aid Project #:** BR0219(128)D **Fiscal Year:** 2006 **Funds Awarded:** \$250,000.00**Fund Status:** \$250,000.00 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Self Consolidating ConcreteTechnology Description: Self consolidating concrete was used for abutment drilled shafts and 2 of 5 box beam girdersProject Information**Positive Results:**

The use of self consolidating concrete in abutment #1, three drilled caissons was a very good success. The concrete supplier had a mix design approved and all tests at the plant, field, and lab were very good. The project had no problems during placement. The project had a good working relationship with WVU. The students were able to work with the Contractor in coordination in getting their testing equipment placed inside the drilled caissons prior to placement of SC concrete. The District felt this was a very good product and is desirable to use again in drilled caissons.

Negative Results:

The outer 2 concrete beams for the bridge were also Self Consolidating Concrete from the beam manufacture, Eastern Vault. The Division had problems with the manufacture in producing all the required testing according to the project plans and proposal. The Division also received below plan average strength for the 28 day break on the concrete beams.

Lessons Learned:**Barrier to implementation of Technology:** none, project is a success.

The District feels the use of funding and new technology is a good resource tool and should be continued to be used on federal construction projects in the state when feasible.

Internal or External Reports:

Report to FHWA:  "TESTING OF SELF-CONSOLIDATING CONCRETE FOR DRILLED SHAFTS IN A RURAL BRIDGE REPLACEMENT IN WEST VIRGINIA"

Instrumentation plan (draft):  "Tentative Instrumentation and Data Collection Plan, Stalnaker Run Bridge Replacement"

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: not reported

Plans on Reuse of Technology: yes, as appropriate for other similar jobs.

Applicability to other States: access to material may be issue

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1.51. WISCONSIN

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Highway 151 over State Highway 26**State:** WI **Federal-Aid Project #:** _____ **Fiscal Year:** 2001 **Funds Awarded:** \$499,336.00**Fund Status:** \$499,336.00 Expended **Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: FRP Stay-in-Place Deck Forms and 2-D Prefab FRP Grid Deck Reinforcing

Technology Description: Fiber Reinforced Polymer design used a stay-in-place formwork system which provided a rapidly erected and safe working surface for contractor

Project Information**Positive Results:**

- The pultruded FRP stay-in-place formwork system provided a rapidly erected and safe working surface for contractor
- The separation of the deck from the diaphragm at the center pier was accomplished without problems and should be considered for all decks
- Longitudinal negative moment FRP reinforcing bars over the center pier were successfully used together with a FRP grid system for transverse moments in the deck
- The new system provided a 57% reduction in construction time, 30% reduction in crane time
- A rigorous QA/QC procedure was developed for WisDOT use of FRP reinforcing and forms
- Testing proved that the deck strength load capacity was 5-6 times the service design load
- A special modification for the ACI punching shear equation was developed to predict capacity
- Studies proved that freeze-thaw cycling would not affect the bond between FRP form and concrete

Negative Results:

- The initial overall cost of the new technology was 50% higher than for an identical steel reinforced bridge, part of the higher cost is due to contractor unfamiliarity with the new system
- Extensive instrumentation in the form of strain gages placed on the FRP bars and in the concrete provided only minimal useful data

Lessons Learned:

- The commercial off-the-shelf stay-in-place FRP formwork, which also served as bottom reinforcing, was overdesigned by the manufacturer and unacceptably expensive, composing 65% of the total FRP material cost. A more economical FRP stay-in-place form can be designed that may be more economical
- The flowable grout used to provide a bearing support for the FRP stay-in-place forms added unnecessary time and expense to the construction
- Life cycle cost analysis is needed to justify the use of FRP products used

Internal or External Reports:

Bank, Oliva, Russell, Dieter, Dietsche, Berg, Ehmke, Carter, Hill, Henke, Gallagher, "Bridge B-20-133 on US-151 With Fiber Reinforced Polymer Reinforced Concrete Deck," Final Report 1000-02-03 to Wis Dept of Transportation, Jan 2005, 89pp (see: https://www.engr.wisc.edu/cee/faculty/oliva_michael.html)

Publications, Presentations, or, Construction Studies:

"Reinforcing Concrete Bridge Deck with Prebaricated FRP Grids and Stay-in-place Forms", presentation

- D. Dieter, J. Dietsche, L. Bank, M. Oliva, J. Russell, "Concrete Bridge Decks Constructed with FRP Stay-in-Place Forms and FRP Grid Reinforcing", Transportation Research Record No. 1814, Journal of the Transportation Research Board, 2002, Washington D.C., pp219-226
- A.C. Berg, L.C. Bank, M.G. Oliva, J.S. Russell, "Construction and Cost Analysis of an FRP Reinforced Concrete Bridge Deck", Construction and Building Materials, 20(2006), Elsevier, March 2006, pp515-526
- L. Bank, M. Oliva, J. Russell, D. Dieter, "Concrete Bridge Decks with FRP Stay-in-Place Forms and FRP Mesh Reinforcing", 2001 Western Bridge Engineers Seminar, Sacramento, CA, Sept. 24-26, 2001
- L. Bank, M. Oliva, J. Russell, D. Dieter, J. Dietsche, "Concrete Bridge Decks with FRP Stay-in-Place Forms and FRP Mesh Reinforcing", Proceedings of the 5th NSF Workshop on Bridge Research in Progress, Univ. of Minnesota, Oct. 2001, pp85-90
- J.S. Dietsche, D.A. Dieter, L.C. Bank, M.G. Oliva, J.S. Russell, "Material Characterizations of a Glass Fiber FRP Composite Structural Element, Proceedings of the 2002 Society for Experimental Stress Analysis Conference, Paper #91, June 2002, 4pp.
- J. S. Dietsche, L. C. Bank, M. G. Oliva, D. A. Dieter, E. J. Helmueller, B. Sanders, "Material Characterization OF FRP Deck Material", Proceedings of CDCC 2002, 2nd International Conference on Durability of Fiber Reinforced Polymer Composites for Construction, Montreal, Canada, May 29-31, 2002
- E.J. Helmueller, L.C. Bank, D.A. Dieter, J.S. Dietsche, M.G. Oliva, J.S. Russell, "The Effect of Freeze-Thaw on Bond Between FRP Stay-in-Place Deck Forms and Concrete", Proceedings of CDCC 2002, 2nd International Conference on Durability of Fiber Reinforced Polymer (FRP) Composites for Construction, Montreal, Canada, May 29-31, 2002, pp. 141-151
- A. C. Berg, L. C. Bank, M. G. Oliva, J. S. Russell, "Construction of a FRP Reinforced Bridge Deck on US Highway 151 in Wisconsin", Proceedings 83rd Annual Transportation Research Board Meeting, Washington D.C., Jan 11-14, 2004, CD-ROM
- L. C. Bank, M. G. Oliva, J. S. Russell, D. A. Dieter, J. S. Dietsche, R. A. Hill and B. Gallagher, J.W. Carter, S. Woods, G.H. Anderson, "Details and Specifications for a Bridge Deck with FRP Formwork, Grid and Rebar", proceedings of FRPRCS-6, Ed. Kang Hwee Tan, Singapore, July 8-10, 2003, pp1301-1310

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

Awards Received:

1. "A Construction-Friendly and Durable Hybrid Bridge Deck System (HYDECK)", finalist for CERF 2004 Charles Pankow ASCE/CERF Award

10/30/08: Project constructed and closed.

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** IH 39/94 over Door Creek**State:** WI **Federal-Aid Project #:** 2004(276) **Fiscal Year:** 2003 **Funds Awarded:** \$400,000.00**Fund Status:** Unknown**Project Status:** Complete**Associated Project Names**

USH 151 over River Rd.

Project: Change / Associated

Reallocated from / to:

Technology Implemented: **Precast Full Depth Bridge Deck Panels with Transverse and Longitudinal Joints**Technology Description: Precast Full Depth Bridge Deck Panels with Transverse and Longitudinal Joints used to reduce construction time and keep I-90 open to traffic**Project Information****Positive Results:**

- The project provided a positive experience with the first SCC concrete deck in Wisconsin, performing well to date;
- Positive experience with first precast deck in Wisconsin, performing very well to date;
- Proved capability of precast decks to be used in future partial deck replacement work with night time closures;
- Proved that shear connectors for composite action are acceptable at 4ft spacing (vs. AASHTO 2ft max limit);
- Proved that it is not necessary to completely offset tension stresses in joints, due to service loads, when designing prestress for the deck joints

Negative Results:

- The lack of contractor familiarity with post-tensioning and precast decks partially resulted in a 170% increase in installed deck cost Compared to adjacent CIP bridge deck;
- Contractor inexperience with post-tensioning led to a delay of 2 weeks when grout entered PT ducts before the strand was prestressed.

Lessons Learned:

- The use of an epoxy overlay, with fine aggregate, provided superior resistance to winter icing compared to the adjacent CIP deck without an overlay;
- It is essential to enforce contract special provisions regarding submittal of a prestressing plan and a grouting plan for post-tensioned construction;
- A 30% cost premium should be expected for precast full depth decks with post-tensioned joints;
- staged construction, with a longitudinal deck joint, may increase construction time by 50% and should only be used when essential.

Internal or External Reports:

M.G. Oliva, L. Bank, J. Russell, "Full Depth Precast Concrete Highway Bridge Decks", Structures and Materials Test Lab Report, University of Wisconsin, Nov 2007, 120pp (research, design and construction study report)
(see: https://www.engr.wisc.edu/cee/faculty/oliva_michael.html)

Publications, Presentations, or, Construction Studies:

Precast/Prestressed Concrete Institute's 2006 "Harry H. Edwards Industry Advancement Award", Oct 2006

- J.W. Carter III, F. K. Hubbard, M. Oliva, T. Pilgrim, T. Poehnelt, "Wisconsin DOT's First Use of Innovative Full-Depth Precast Concrete Deck Panels Keeps U.S. I-90 Open to Traffic", PCI Journal, V. 52, N. 1, Jan-Feb 2007 (see: https://www.engr.wisc.edu/cee/faculty/oliva_michael.html)
- Scott Markowski, F. Ehmke, L.C. Bank, M.G. Oliva, J.S. Russell, J.W. Carter, S. Woods, "Full Depth, Precast, Prestressed Bridge Deck Panel System for Bridge Deck Construction in Wisconsin," 2005 PCI-FHWA National Bridge Conference, CD-ROM, Oct. 16-19, 2005
- F. Ehmke, S. Markowski, M. Oliva, J.W. Carter, L. Bank, J. Russell, S. Woods, R. Becker, "Rapid Staged Construction with Full Depth Precast Deck Panels", Ed. A. Azizinamini, 2005 FHWA Accelerated Bridge Construction Conference, San Diego, CA, Dec 15-16, 2005, pp105-110
- F. Ehmke, M. Oliva, L. Bank, J. Russell, "Rapid Staged Construction with Full Depth Precast Deck Panels," American Concrete Institute, Spring Convention, Atlanta, GA, April 22-26, 2007, (invited presentation)

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:Awards Received:

- "ACEC 2006 Wisconsin Engineering Excellence Award", with Alfred Benesch & Co.
- Precast/Prestressed Concrete Institute's 2006 "Harry H. Edwards Industry Advancement Award", Oct 2006
- Post Tensioning Institute 2006 Award of Merit (bridges), "Innovative P/T Bridge Work (Two Staged)", with Alfred Benesch & Co., Sept 2006.

10/30/08: project constructed and under evaluation.

Federal projects 2003 (680) and 2004 (726)

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** US Highway 151 over De Neveu Creek**State:** WI **Federal-Aid Project #:** _____ **Fiscal Year:** 2002 **Funds Awarded:** \$499,085.00**Fund Status:** Unknown**Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: 3-D Prefab 2 Layer FRP Grid Reinforced Concrete Deck

Technology Description: The use of 3-D prefab 2 layer Fiber Reinforced Polymer grid reinforced concrete deck on two different bridges along US Highway 151 to reduced construction time and provide increased durability

Project Information**Positive Results:**

- Very rapid construction was achieved using the prefabricated 2-layer FRP reinforcing grid with 93 man hours to place the reinforcing compared to 275 man hours for placing epoxy coated rebars on an identical adjacent structure,
- Laboratory testing proved that the FRP reinforced deck had a strength of 7.5 times the service wheel load,
- The prefabricated reinforcing grids could be manufactured and shipped to the bridge in lengths equal to the bridge width.

Negative Results:

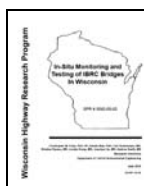
- The bridge cost was higher than the adjacent steel reinforced bridge due to a contractor bid price higher than expected and due to the FRP grid manufacturer's use of hand fabricated spacers between the two layers of grid, which increased material costs.

Lessons Learned:

- This type of reinforcing is very feasible for rapid and durable bridge deck construction,
- Construction speed for the deck can be nearly doubled,
- If the FRP grid manufacturing process could be further automated, the material costs would be considerably decreased,
- It would be very feasible to add a lightweight (1/8") FRP plate to the bottom of the grid – providing all the reinforcing and the deck forming in one prefabricated unit.

Internal or External Reports:

Bank, Oliva, Russell, Jacobson, Conachen, Ringelstetter, Spottiswoode, Carter, Henke, "Bridge B-20-148 on US-151 With Fiber Reinforced Polymer Reinforced Deck," Final Report No. 1009-03-10 to Wis Dept of Transportation, June 30, 2006, 64pp (available on web site: https://www.engr.wisc.edu/cee/faculty/oliva_michael.html)



Wisconsin Highway Research Program – In-Situ Monitoring and Testing of IBRC Bridges in Wisconsin

Publications, Presentations, or, Construction Studies:

"Reinforcing Concrete Bridge Deck with Prebaricated FRP Grids and Stay-in-place Forms", presentation

- L. Bank, M. Oliva, J. Russell, D. Jacobson, M. Conachen, B. Nelson, D. McMonigal, "Double Layer Prefabricated FRP Grids for Rapid Bridge Deck Construction: Case Study", ASCE J. of Composites in Construction, V10, N3, May-June 2006, pp204-212.
- D.A. Jacobson, L.C. Bank, M.G. Oliva, J.S. Russell, "Punching Shear Capacity of Double Layer FRP Grid Reinforced Slabs" Proceedings of the 7th International Symposium on Fiber Reinforced Polymer Reinforcement for Concrete Structures FRPRCS7, SP-230, American Concrete Institute, Farmington Hills, MI, 2005, pp.857-876
- L. Bank, M. Oliva, J. Russell, D. Jacobson, M. Conachen, B. Nelson, D. McMonigal, "Super-Sized Double-Layer Pultruded Gratings", Composites 2004 Convention and Trade Show, American Composites Manufacturers Association Convention, Tampa, FL, Oct. 6-8, 2004, CD-ROM
- D. A. Jacobson, L. C. Bank, M. G. Oliva, J. S. Russell, "Punching Shear in Fiber-Reinforced Polymer (FRP) Bi-layer Grid-Reinforced Concrete Bridge Decks", Proceedings 83rd Annual Transportation Research Board Meeting, Washington D.C., Jan 11-14, 2003, CD-ROM

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

Awards Received:

- ACEC Wisconsin "Grand Award for Best of State" in engineering 2005, American Council of Engineering Companies
- Popular Science "Best of What's New 2005", Dec 2005
- Best Applied Research Paper of 2006, ASCE Journal of Composites in Construction, "Double Layer Prefabricated FRP Grids for Rapid Bridge Deck Construction: Case Study," with L. C. Bank, J. S. Russell, D. A. Jacobson, M. Conachen, B. Nelson and D. McMonigal
- NOVA Awards 2006 – semi-finalist for development of a prefabricated modular FRP reinforcing and forming system for highway bridge decks

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** USH 63 over Rush River**State:** WI **Federal-Aid Project #:** 2007(463) **Fiscal Year:** 2005 **Funds Awarded:** \$400,000.00**Fund Status:** Unknown**Project Status:** Complete**Associated Project Names**

STH 35 over Tamarack Creek

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Accelerated Bridge Construction – Precast Substructure System

Technology Description: Accelerated bridge construction – precast substructure system used for rapid construction, each panel being set in place in 10-15 minutes and entire bridge set in place in one day

Project Information**Positive Results:**

- The project achieved very rapid construction of precast bridge abutment system with each 10ft. wide panel being set in place in 10-15 minutes, the entire abutment set in place in one day and joints grouted the second day with only 3-4 laborers.
- The rapid erection allowed start of construction of formwork for superstructure on the third day after start of abutment construction, compared to 1-2 weeks for cast-in-place concrete.

Negative Results:

- Abutment panels were overdesigned, resulting in very heavy components to be shipped from precast fabricator and lifted into place.
- The contractor was wary of safety in working with heavy abutment panels due to inexperience.
- The heavy abutment panels required a high capacity crane on site (compared to a normal size crane for Cast-in-Place construction) resulting in increased cost.

Lessons Learned:

- Abutment panels need to be designed more efficiently, reducing weight and cost of placement.
- Contractor familiarity with the process will result in even faster construction and we expect lower bids in the future.

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

Oliva, Bank, Okumus, Scullion, Unlu, Becker, "Precast Bridge Systems for Accelerated Construction", Proceedings FHWA Bridge Engineering Conference – Accelerated Bridge Construction, Orlando FL, April 8-9 2010

Additional Comments:

Technology used on Other Projects: Not Reported

Plans on Reuse of Technology: Not Reported

Applicability to other States: Not Reported

Additional Project Notes:

Project completion date: August 31, 2010

10/30/08: Under construction

federal project 2007(463)for PE. 2008(085) is the construction project, however no IBRC funds have been charged on this project to date. B-55-150

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** USH 12, Coffee Cr Crossing**State:** WI **Federal-Aid Project #:** 2006(565) **Fiscal Year:** 2004 **Funds Awarded:** \$400,000.00**Fund Status:** \$256,016.51 Expended**Project Status:** Complete**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: **Reinforcement Free Bridge Deck with Compressive Membrane Action, FRP Stay-In-Place Forms**

Technology Description: Reinforcement free bridge deck with compressive membrane action, FRP stay-in-place forms used to increase design life by reducing deterioration related to corrosion of reinforcing

Project Information**Positive Results:**

- A concrete deck was placed on the bridge without any reinforcement and is performing well after 2.5 years.
- Accelerated construction was achieved by use of FRP stay-in-place formwork, elimination of labor for reinforcement placement in the deck, using a sloped surface abutment rather than stepped for girder placement with crown, placement of girders at a 2% tilt from vertical, and elimination of a variable depth haunch above the girders.
- A new bridge deck design method was developed, based on punching shear rather than flexure, using a strut-and-tie method for analysis.
- The lightweight FRP stay-in-place forms also provided a crack control function for the reinforcement free deck.
- Elimination of deck formwork removal improved job site safety.
- The use of ties between girders and elimination of deck reinforcing resulted in reduced material costs.

Negative Results:

- Unfamiliarity with the FRP stay-in-place formwork led the contractor to bid the FRP forms at 3 times the material cost.
- Unnecessary additional grinding of the recesses in the girder flanges (to hold the forms) and use of a structural adhesive to keep the light weight forms in place were unexpected required due to producer's inexperience with the system. This should not happen in future applications of the system.
- The forming of the recesses (notches) in the flanges of the precast girders was poorly accomplished (roughness & uneven) and should be improved in the future.

Lessons Learned:

- Reinforcement free decks are a viable alternative for bridges with wide flange girders and short gaps between the girder flanges.
- FRP stay-in-place forms are easy to install and provide a good working surface.
- Steel tie rods between girder webs are installed prior to deck work and are preferable to flange level steel straps, often in contact with moist deck concrete, that have been suggested by others.

Internal or External Reports:

Reinforcement-Free Decks Using A Modified Strutand-Tie Model: Part 1 – Analysis, report



Reinforcement-Free Decks Using A Modified Strutand-Tie Model: Part 2 – Design, report

- Oliva, Bank, Russell, "Reinforcement Free Bridge Decks on Wide Flange Prestressed Precast Girders," Report to Wis Dept of Transportation, Nov 2008, 232pp (see: https://www.engr.wisc.edu/cee/faculty/oliva_michael.html)

Publications, Presentations, or, Construction Studies:

- H. Bae, M. Oliva, L. Bank, "Reinforcement-Free Bridge Decks Using a Modified Strut-and-Tie Model: Part 1 – Analysis," submitted to ACI Structures and Materials Journal, July 2009
- H. Bae, M. Oliva, L. Bank, "Reinforcement-Free Bridge Decks Using a Modified Strut-and-Tie Model: Part 2 - Design," submitted to ACI Structures and Materials Journal, July 2009
- H. Bae, M. Oliva, L. Bank, "Obtaining Optimal Performance with Reinforcement-Free Concrete Highway Bridge Decks," accepted for publ. Engineering Structures, July 2009
- L. Bank, M. Oliva, H. Bae, J. Barker, SW Yoo, "Pultruded FRP Plank as Formwork and Reinforcement for Concrete Members," Advances in Structural Engineering, V10, N5, 2007
- L. Bank, M. Oliva, H. Bae, J. Barker, SW Yoo, "Pultruded FRP Plank as Formwork and Reinforcement for Concrete Structures," Composites Research Journal, V.1, N.3, July 2007
- M. Oliva, H. Bae, L. Bank, J. Russell, S. Yoo, "FRP Stay-in-Place Formwork for Floor and Deck Construction", FRP Stay-in-Place Forms for Concrete Structures, American Concrete Institute, SP-257, 2008
- M. Oliva, H. Bae, L. Bank, J. Russell, J. Carter, S. Becker, "Design and Construction of a Reinforcement Free Concrete Bridge Deck on Precast Bulb Tee Girders," 2007 PCI/FHWA National Bridge Conference, Phoenix, AZ, October 21-24, 2007, CD-ROM
- M. Oliva, Bank, L., H. Bae, J. Barker, S. Yoo, "FRP Stay-in-place Formwork and Reinforcing for Concrete Highway Bridge Decks", FRPRCS-8, Patras, Greece, July 2007
- M. Oliva, L. Bank, H. Bae, "Development of a Design Method for Reinforcement-Free Decks Using a Modified Strut-and-Tie Model and Construction Case Study," accepted for presentation at 2010 FIP and PCI Annual Convention, Washington DC
- M. Oliva, L. Bank, H. Bae, C. Litow, "Aggregate-coated FRP Plank as Formwork and Crack Controlling Device for Reinforcement-free Bridge Decks" APFIS Convention, Second International Conference of International Institute for FRP in Construction for Asia-Pacific Region December 2009, Seoul, Korea
- M. Oliva, H. Bae, L. Bank, J. Russell, "Design and Construction of a Reinforcement-Free Concrete Bridge Deck on Precast Girders," 2007 Western Bridge Engineers' Seminar, Boise, Idaho, Sept 24-26, 2007, CD-ROM
- L. Bank, Oliva, M., Bae, H, Barker, J., Yoo, S. "Pultruded FRP Plank as Formwork and Reinforcement for Concrete Structures", COMPOSITES 2006, American Composites Manufacturers Association, St. Louis, MO, Oct 18-20, 2006, 8pp
- M. Oliva, Bae, H., Bank, L., Russell, J., "New Materials and Methods for Rapid Bridge Construction", Mid-Continent Transportation Research Forum 2006: Making Research Pay Off, MRUTC, Madison, WI, August 17-18, 2006

Additional Comments:

Technology used on Other Projects: Not reported

Plans on Reuse of Technology: the technology has potential but may not be able to overcome the expense

Applicability to other States: see lessons learned

Additional Project Notes:

Awards Received:

- ACEC Wisconsin 2007 Engineering Excellence Awards – Best of State, with Alfred Benesch & Co.
- American Composites Manufacturers Association “Best Construction and Infrastructure Technical Paper Award”, Oct. 2006, Bank, Oliva, Yoo, Bae and Barker.

10/30/08: project constructed.

IBRC work authorized under FA project 2005(224) for CTH BB. CTH BB was not constructed using any FA funds due to scope change. IBRC work was transferred to US 12 over Coffee Creek, which was constructed with FA project 2006 (565).

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1.52. WYOMING

FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Ranch Road Interchange over I-25**State:** WY **Federal-Aid Project #:** NHI-24-4(132)211 **Fiscal Year:** 2002 **Funds Awarded:** \$49,000.00**Fund Status:** \$49,000 Expended**Project Status:** Completed**Associated Project Names**

Project: Change / Associated

Reallocated from / to:

Technology Implemented: High Performance Steel (HPS)Technology Description: Project utilized high performance steel in the flanges of the girders.**Project Information****Positive Results:**

High Performance Steel has been incorporated on additional projects.

Negative Results:

None: Routine inspections verified the in field performance, there have been no issue with the structure since construction.

Lessons Learned:

Barrier to implementation of Technology: none.

Project help familiarize designers with the use of HPS and the welding procedures

Internal or External Reports:

None

Publications, Presentations, or, Construction Studies:

None

Additional Comments:

Technology used on Other Projects: it has been used on various other projects in the state

Plans on Reuse of Technology: yes, HPS is a good material and designers now have experience with it.

Applicability to other States:

10/30/08: Project is complete and is closed. All expenditures have been finalized.

Project utilized high performance steel in the flanges of the girders.

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FHWA IBRC/IBRD Project Summary Report Form**Project Name:** Statewide Sign Structures**State:** WY **Federal-Aid Project #:** 9943(000) **Fiscal Year:** 1999 **Funds Awarded:** \$42,000.00**Fund Status:** \$42,000 Expended **Project Status:** Completed**Associated Project Names**

(none)

Project: Change / Associated

Reallocated from / to:

Technology Implemented: Sign StructuresTechnology Description: Tuned mass dampener was patented for sign structures**Project Information****Positive Results:**

A tuned mass damper was developed. University of Wyoming applied for a patent and license it though Valmont. The tune mass device increased dampening of a structure to decrease both in and out of plane vibration. This results in increased fatigue life of the sign pole.

Negative Results:

Not being used by WYDOT. The device was noisy. The patent may have reduced implementation by other agencies

Lessons Learned:

Barrier to implementation of Technology: device is not being used due to noise.

The concept was viable and demonstrated a reduction in fatigue stresses but other problems, in particular the noise level from the device, proved to be too much to overcome.

Internal or External Reports:

Parts attached no electronic copy available:



"Traffic Signal Pole Research (Damping)"

Publications, Presentations, or, Construction Studies:

Additional Comments:

Technology used on Other Projects: no

Plans on Reuse of Technology: no

Applicability to other States: use not recommended

Project was closed out in August 2004. The funds lead to a larger research effort. A total of \$160,000 was spent researching this topic

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2. TECHNOLOGY DESCRIPTIONS

Eleven (11) general technology categories were determined for classifying all projects. These general categories include:

2.1. HIGH PERFORMANCE CONCRETE

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs
Program Years 1999-2009

Technology Summary

1. High Performance Concrete

Prepared For:
Federal Highway Administration



Prepared By:
HDR Engineering, Inc.
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Suite 200
Cincinnati, OH 45242

June 2011

1. High Performance Concrete (HPC)

General Description

High performance concrete (HPC) is a concrete mixture made with admixtures or materials, combined appropriately to create a specifically selected mix design with targeted properties. When properly mixed, transported, placed, consolidated and cured, the resulting concrete has been demonstrated to provide superior performance when compared to traditional concrete mixes. Enhanced qualities include placement techniques, environmental resistance, and load resistance.

Some of the more common ways to obtain high performance concrete include a lower water to cement ratio, admixtures, and a high volume of blended cementitious mixtures which can include silica fume, fly ash, and ground granulated blast-furnace slag.

Applications for high performance concrete found in the innovative technology projects include girders, decks and overlays. Information given below is based on the summary sheets compiled from State submitted information.

Demonstrated Advantages

1. Increased durability
2. Limited cracking
3. Increased freeze/thaw durability
4. Increase scaling resistance
5. Extended service life
6. High early strength
7. Impermeability
8. Low heat of hydration
9. Increased flowability

Demonstrated Disadvantages

1. Increased quality control is usually required
2. Higher up front costs
3. Workability - current HPC mixes typically have high slumps
4. Non-routine construction - an experienced concrete contractor is necessary

Methods of Implementation

Described herein are the various applications that HPC was used for in the IBRC and IBRD programs. Positive and Negative results that are reported represent a general assimilation of comments provided in the IBRC and IBRD Summary Sheets, as reported by the States. A representative project is described to provide an example of how this technology was implemented.

1.1 Girders

Description: HPC was used to increase the concrete short term set strength and long term final strength. This technology generally involved the use of admixtures, allowing an increase in span length, durability and strength of prestressed girders. One particular benefit of note was that increasing the span lengths eliminated the need for additional substructures, providing a greatly reduced substructure cost by removing piers. The majority of the projects using HPC were successful in application.

Positive results: States reported valuable experience gained working with fabricators and contractors when working with HPC. This included optimizing new girder shapes, working with longer spans that have different camber requirements, and developing techniques to manage the heavier girders that proved to be more difficult to set in place. The learning curve for working

with HPC was greatly reduced at each step. Successful reports commented that mix strengths were achieved without difficulty. Other reports indicated a cost savings by eliminating substructures with the longer spans.

Negative results: Excess cooling heat can have an effect on relaxation of the pre-stressing strands, causing loss of pre-stress. Additionally, short term creep and shrinkage were underestimated by current AASHTO and PCI equations; this lead to complications predicting pre-stress loss and long-term camber. However, in studies that funded research, an improved predictive model was developed that helped resolve this issue. Although not necessarily a negative result, another issue requiring extra effort was that the shape of HPC girders can be further optimized to reduce material and other construction costs.

Representative project: The State of Iowa used HPC for the project named “136th Avenue over Buffalo Creek.” Ultra High Performance Concrete (UHPC) was used for girder design in a bridge replacement project. The girders were an optimized test section developed by FHWA and MIT with the goal to optimize the shape of UHPC and test its performance in the field. Girders were used in a bridge as a demonstration project. The girder has shown much improved live load distribution capabilities. The bridge is currently performing well and the FHWA girders are reported as being an effective option. However, the report indicated that the girder would need further refinement before nationwide implementation to reduce the material and other associated costs. Cost of the UHPC was reported as the biggest negative for the project.

1.2 Decks

Description: HPC was used for to increase durability, increase compressive strength, decrease permeability, reduce shrinkage, and increase freeze/thaw resistance in bridge decks.

Positive results: Successful implementation was demonstrated on multiple projects. Positive results included bridge decks with reduced or no cracking due to shrinkage and thermal effects, and reduced permeability to mitigate seepage and leeching. Similar to the girder designs, Owners were able to familiarize themselves with HPC technology and gain valuable experience using the technology, such as refining mix optimization. Other items that were initially of concern became non-factors, such as having difficulty installing shear studs in precast panels.

Negative results: The sequential nature of construction operations limited the reduction in construction time in uses for accelerated bridge construction. Inexperienced contractors led to problems on a few projects such as improper mixes arriving dry or matted to the job site. One project specifically mentioned that lacking a defined material specification caused construction delays. Although long term resistance of the decks has not been established, they appear to be performing sufficiently. Unfortunately they cannot yet be said to exceed the benchmark of traditional construction. Long term studies are ongoing to determine if initial costs are worthwhile over the life of the bridge.

Representative project: The state of Oklahoma used an HPC deck for the project named “I-40 over Business I-40 in Sayre.” HPC was used in the deck slab to investigate four different mixture types with the purpose of increasing durability over traditional concrete mixtures with an emphasis on shrinkage reduction. The field investigation consisted of test slabs for the HPC mixtures and actual bridge construction where the University of Oklahoma investigators served as consultants and additional tests were taken to further characterize the mixtures. The project was unable to determine which mixture is the best option based on the combined positive and negative effects that each component of the admixture created. As a result, this study recommended additional testing to further understand their effects.

1.3 Overlays

Description: HPC was used in overlays for waterproofing to increase durability in bridge decks.

Positive results: Implementation was typically successful and worked as designed in the projects that reported results.

No negative results: No negative results reported, to date, but, long term performance is yet to be determined.

Representative project: The state of West Virginia used this technology for the project “Bigley Avenue Interchange in Charleston”. HPC was used as a rapid set mix to patch existing bridge deck to decrease the set time and minimize traffic closure. The use of the rapid set concrete performed as intended. That is, contractors were able to limit lane closures to overnight, reopening the bridge for early morning traffic. They additionally discovered that for the particular rapid set they were using, keeping the concrete moist until a full cure was achieved was critical.

IBRC and IBRD Projects with Data Sheets Reported by States for HPC Technology

	State	County	Project
1.1	AL	Marshall	County Rte. 409 over Short Creek
	DE	Kent	Bridge 2-008F in Frederica, DE
	GA	Coweta	I-85 at State Route 34, Ramp Reconstruction of the Southeast Quadrant
	IA	Wapello	100th Avenue over Little Soap Creek, Keokuk Township
	IA	Madison	Madison County Bridge (14B-551-100) 290th street over unnamed creek
	IA	Buchanan	136th Ave. over Buffalo Creek
	IA	Buena Vista	County Bridge ID 86 on local road between Sections 23/26 Providence Township (Sec. 23/26 T90N, R36W) over Outlet Creek
	IN	Marion	21st Street over I-465
	MO	Jackson	Route 291 over Route 150
	MO	Pemiscot	RT 412 FRM RT B/Z to 2.3 mi. West, Bridge A6130
	MO	St. Louis	Route 61/67 over Mattese Creek
	NC	Carteret	State Route 1124 over Branch of Band Creek (B-3625)
	NE	Douglas	Pacific Bridge over I-680
	NE	Cass	262nd Street Bridge over I-80
	NJ	Essex	Route 23 over Peckman's Brook
	NM	Bernalillo	Mountain Valley Road over I-40
	NM	Mora	I-25 Frontage Road over Wolf Creek
	NM	Bernalillo	I-25 South Bound at Rowe Interchange
1.2	AR	Miller	State Hwy. 245 Bridge over Interstate 30 (Texarkana)
	AZ	Coconino	I-40 Sunshine BNSFRR OP WB, MP 237.10
	IA	Boone	Boone County Bridge (ID 85-25-031) 120th street over Squaw Creek
	IA	Pottawattamie	24th Street over I-80/I-29, Council Bluffs
	IL	Madison	170 from 2.5 Mi. East 115/70 To Bond County Line
	IL	Macon	US-51 from 0.6 Mi. North of Macon to Shelby
	IL	Christian and Sangamon	IL 104 over Brush Creek, 3 Mi. East of Kincaid & East of I-55
	IL	Fayette	IL 54 Over Spring Creek 1.5 Mi. North, Thawville Bridge
	IL	Clark, Menard, Fayette and Christian	Corenzo Rd. over I55;I-80 Kean Ave.
	IL	Cook	Wacker Dr. Viaduct
	MN	Hennepin	Diamond Lake Road over I-35W
	MO	St. Louis City	Adelaid Ave over I70
	MO	Jackson	Route 150 over Rail Road & Big Creek
	NC	Stanley County	Bridge 80 on State Route 1214 over Long Creek (TIP: B-3700)
	NC	Martin	Bridge 36 (B-4188) on State Route 1523 over Smithwick Creek, South of Williamston

1.2	ND	Cass	Cass County Southbound I-29 at 17th Ave. & 13th Ave.
	NE	Douglas	Skyline Dr. over hwy. 6 (Dodge Street)
	NJ	Middlesex	Edison Bridge-Route U.S. 9 South Bound over Raritan River
	NM	Dona Ana	I-10 Bridges over University Ave. Main St. RR in Las Cruces NM (Dona Ana County)
	OK	Beckham	I-40 Bridge over Business I-40 In Sayre
1.3	IL	Stephenson	Adeline Road, Freeport Road, and Eagle Point Road Bridges
	WV	Kanawha	Bigley Ave. Interchange, Charleston, WV

2.2. FIBER REINFORCED POLYMERS

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs
Program Years 1999-2009

Technology Summary

2. Fiber Reinforced Polymer

Prepared For:
Federal Highway Administration



Prepared By:
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June 2011

2. Fiber Reinforced Polymer (FRP)

General Description

Fiber Reinforced Polymer (FRP) is a composite material usually consisting of two main constituents: a reinforcing agent, which is typically fiberglass or carbon, and a polymer matrix, usually a resin, epoxy, vinyl ester, or polyester thermosetting plastic. FRP technology combines the strength of the ceramic glass fibers or carbon fibers with the toughness and ductility of the polymer. This combination utilizes the dislocation motion in the polymer matrix and transfers the load to the high strength fibers.

In order for fiber reinforced polymer to be effective, the fibers need to be orientated properly in each plane to absorb strains. If the fibers are all pointed in the longitudinal direction, the strength of the composite will have very good mechanical properties in that (parallel) direction and very weak mechanical properties in the transverse (perpendicular) direction. To counteract this, however, FRP can be developed so the fibers are oriented in all three dimensions if needed.

Applications for fiber reinforced polymer found in the innovative technology projects include wraps, steel strengthening, concrete strengthening, timber strengthening, and FRP decks (FRP Reinforcing is covered in 6. *Reinforcing Bars*). Information given below is based on the summary sheets compiled from State submitted information.

Demonstrated Advantages

1. Corrosion resistance
2. Weather resistance
3. Low maintenance
4. Long term durability
5. Lightweight
6. High fatigue endurance limits
7. High tensile strength
8. Relatively easy to construct
9. Many uses

Demonstrated Disadvantages

1. The technology is expensive
2. Pre-forming can cause time delays
3. Limited number of fabricators available
4. The material can be fragile if not properly handled
5. The epoxy used in wraps has limited fire resistance
6. FRP adhesives can experience shrinkage during the curing process

Methods of Implementation

Described herein are the various applications that FRP was used for in the IBRC and IBRD programs. Positive and Negative results that are reported represent a general assimilation of comments provided in the IBRC and IBRD Summary Sheets, as reported by the States. A representative project is described to provide an example of how this technology was implemented.

2.1 Wraps

Description: Carbon fiber wraps were bonded with an adhesive to girders, pier columns and caps, and other structures to provide reinforcement for either flexural capacity, shear resistance, transverse confinement, or a combination thereof.

Positive results: Successful implementation was demonstrated on multiple projects. States reported good protection against aggressive environment conditions and benefits associated with strengthened existing structures. In one instance, tests showed that keeping bridge open to traffic during epoxy curing did not result in degradation in flexural strength. This allowed for development of adequate shear resistance with relatively a quick application that did not disturb traffic.

Negative results: Long-term results for all projects are generally considered unproven. Results show that it may be hard to quantify the strengthening without field test post application of the wrap. The material has a tendency to be expensive, which results in higher upfront costs. Additionally, the wraps are greatly dependant on proper bonding. For this reason, supervision during the application of the wraps is highly recommended. The adhesive used to bond the wraps can be messy and can result in extensive cleanup post application, adding considerable labor costs. In one instance, the wraps did not restore as much strength as anticipated; however, this was not a common occurrence on the vast majority of successful strengthening projects. .

Representative Project: The state of Colorado used this technology for the project named “Castlewood Canyon Bridge, SH 83 over Cherry Creek”. Carbon fiber wraps were used to reinforce an existing arch bridge as a repair and strengthening to meet increased traffic loads. The FRP scheme was used to provide longitudinal reinforcement for flexural enhancement and transverse reinforcement for confinement, shear enhancement, and protection from concrete deterioration and steel corrosion. The project was highly successful by demonstrating: (a) the first use of carbon wraps in Colorado for arch rehabilitation by CDOT; (b) the use of precast slabs, and column, caps by splice connections to accelerate construction. Carbon wraps have continued to be used on pier cap repairs since the Castlewood project. Additionally, the State will utilize accelerated slab construction on other projects.

2.2 Steel Strengthening

Description: FRP composites used to strengthen steel. Two methods were used, including post-tensioned bars installed on girder to strengthen a bridge, and carbon fiber reinforced laminates added to bottom flange of steel girders.

Positive results: Successful implementation of CFRP plates were installed on bottom of steel girder. In post-tensioned applications, the overall live load and dead load capacities were improved. This was verified on one project in the field via load test. Strains of the extreme fibers were accurately predicted with an analytical model.

The post tensioning systems showed that small, but measurable improvements to strength could be achieved.

Negative results: Despite the increase in strength that was demonstrated, additional studies are needed to understand failure mechanisms. The learning curve for installation process was also an issue as contractors found it time consuming to properly install. Additionally, one report indicated that care must be taken to not induce galvanic corrosion between the carbon fibers and the steel.

Post tensioning systems did not affect the stiffness of the beams nor significantly increase the load carrying capacity.

Representative project: The state of Iowa used this technology for the project named “I-A-92 over Walnut Creek”. Carbon Fiber Reinforced Polymer (CFRP) laminates were bonded to the bottom flange of steel girders to strengthen overstressed beams. The project demonstrated that

the beams could be adequately strengthened by the additional CFRP plates. One major lesson learned on the project is that it is critical to have proper bond strength for force transfer. Also of note is that CFRP plates have minimal impact on changing the member's stiffness but can have a relatively large impact on changing member strength, if properly designed.

2.3 Concrete Strengthening

Description: FRP composites were used to strengthen concrete in a variety of manners, similar to steel strengthening projects involved post-tensioning and laminate applications.

Positive results: Successful implementation occurred when the technology was used to strengthen concrete beams. FRP composites used to strengthen concrete can have cost savings benefits by repairing a beam that otherwise would be replaced. Several states reported successful strengthening projects with very little interruption to existing highway traffic in during retrofit. Successful studies have led to draft specifications for AASHTO.

Negative results: There are multiple comments in the reports that bond between the FRP and concrete can be difficult to create and maintain. When FRP post-stressing strands were used in one instance, no decrease in deflection or strain measurement was measured on the bridge. In the testing phase of FRP post-stressing stands, the results showed potential for positive benefits, but the actual implementation did not match these results. Some bridges exhibited a loss of stiffness over time. Additionally, due to unfamiliarity with fabricators, the production of the materials resulted in project delays.

Representative project: The state of Hawaii used this technology for the project named "Salt Lake Boulevard Bridge over Halawa Stream". This project was performed to evaluate CFRP L-shaped stirrups as a shear retrofit applied over existing shear cracks, particularly under cyclic loading conditions. The research was performed to provide guidance for the shear retrofit to be performed on cracked AASHTO girders in the Salt Lake Boulevard Bridge. The CFRP retrofit was determined to significantly control the width of the existing cracks and increased beam stiffness.

2.4 Decks

Description: Precast deck panels were fabricated from FRP or utilized FRP shear studs.

Positive results: Successful implementation was demonstrated on multiple projects. States reported valuable experience gained using this technology. When decks were fabricated entirely from FRP, the lighter weight of the material usually resulted in a more favorable bridge rating. Due to the corrosion resistance characteristics of FRP, reduced maintenance and service life costs has been shown. Laboratory testing demonstrated the deck's structural capacity was adequate and acted compositely with stringers which assisted in resisting the applied moments. FRP shear stud packets worked as intended. Additionally, relatively fast construction time was reported on multiple projects.

Negative results: As well documented in many projects, there is a relatively high cost associated with FRP technology. Additionally, inexperience from fabricators that leads to time loss and increased construction cost should be accounted for during the project. Degradation can also be an issue, even prior to installation. On one project, simple exposure to sunlight caused delaminations and deterioration of the polymer. Similarly, on another project, moisture infiltration caused delamination of deck panels. Fabrication of the material can also be an issue. One state reported prefabricated FRP panels not fitting together correctly in the field.

Representative project: The state of Oregon used this technology for the project named "Broadway Bridge over Willamette River". FRP deck panels consisting of a proprietary product

called DuraSpan were used to replace the aging steel open-grid deck with a solid deck surface on a movable lift span. Before the panels were installed, even though they were not considered a structural component, it was expected they would add stiffness to the deck, decrease deflections and increase load capacity. These expectations were confirmed from the testing done by Portland State University. In addition, to date there has been no degradation of the FRP and the epoxy grout used to attach the panels to the stringers has performed well.

Unfortunately, the epoxy overlay material laid on the deck has had problems adhering to the surface of the panels, and after several attempts to correct the deficiency, the County found that the best fixes involved removal of the non-slip coating and a light sand blasting of the fiberglass face sheet before reinstalling the epoxy overlay.

2.5 Timber Strengthening

Description: FRP composites were used to strengthen timber. FRP laminates are bonded to timber structural members to increase flexural capacity.

Positive results: Successful implementation demonstrated on multiple projects. The FRP laminates showed the capability of extending span length capabilities of timber while still meeting HS-20 design load. The laminates can also be handled on construction site in a manner and with equipment similar to what is used for conventional glue-laminate (glulam) and prestressed concrete plank bridges. States reported the technology being significantly lighter than an equivalent prestressed concrete bridge. Due to the corrosion resistance characteristics of FRP, reduced maintenance and service life costs is expected.

Negative results: Higher material costs than expected were reported. Due to this cost, it does not appear to be practical for routine applications, especially since long-term durability has not yet been determined. Due to contractor unfamiliarity, there were challenges during erection. On one project, shrinkage during curing increased the rate of deterioration and weakened FRP.

Representative project: The state of Iowa used this technology for the project named “215 Avenue Bridge over Lime Creek”. FRP plates were bonded to the tension laminates of the glulam timber girders to strengthen the bridge. The girders performed as intended and are within current specified limits. However, the initial test results do not indicate a significant increase in stiffness resulting from the presence of the FRP reinforcement on the girders. Delaminations occurred on one beam during construction, but were found to not significantly affect the bridge’s overall strength.

IBRC and IBRD Projects with Data Sheets Reported by States for FRP Technology

	State	County	Project
2.1	AL	Madison	Repair of Girder Ends on I-565 Str # 015821, Huntsville, AL
	AL	Montgomery	AL -97 Bridge over I-65 near City of Letohatchie
	CO	Douglas	Castlewood Canyon Bridge, SH 83 over Cherry Creek
	DE	New Castle	BR 26 on Faulk Rd Over Naaman's Creek
	GA	Walker	State Route 337/GA SW Rail Road
	KY	Clark	Kentucky Route 3297 over Little Sandy River
	KY	Jefferson	I-65 over Jacob, Broadway, and Gray Streets
	KY	Jefferson	I-65 Bridge over Main St. Louisville
	KY	Shelby	KY 714 over Jephtha Creek
	MI	Ingham	I-96 over Business Rout I-69 (Lansing Road)
	MI	Shiawassee	I-96 Ramp over Land 82123-S11-0
	OR	Multnomah	Savie Island Bridge
	PR		Bridges #2028 and #2029 on PR-52 over PR-1
	TX	Burleson	Farm to Market Road 1362 over Sue Creek
	WI	Fond du Lac	US Highway 151 over De Neveu Creek
2.2	IA		Route 141 over Willow Creek
	IA	Pottawattamie	I-A-92 over Walnut Creek
	KY	Jefferson	KY 32 over Lytles Creek
2.3	GA	Cherokee	State Route 92 over Noonday Creek Bridge Rehabilitation
	HI	Honolulu	Salt Lake Blvd. Bridge over Halawa Stream
	KY		Louisa- Fort Gay Bridge
	ME		Winterport & Beaver Cove - Winterport Rt. 139 Plumber Bridge #3634, Beaver Creek Bridge
	ME	Franklin	Neal Bridge, Pittsfield
	MO	Morgan, Dallas, Crawford, Pulaski & Iron	X0596 Rte. C over Creek, P0962 Rte. B over Creek, T0530 Rte. M over Crooked Creek, Y0298 Rte. U over Creek, and X0945 Rte. C over river
	OH		Route 79 - Bridge COS-79-0955
	OH	Scioto	Bridge No. SCI-23-0166, US Route No. 23, City of Portsmouth
	OH	Hamilton	Eight Mile Road over Eight Mile Creek
	PA	Union	SR 4012 over Shamokin Creek (same technology)
	SC	Charleston	SC 171 over Wappoo Creek
	TX	San Patricio	FRP Bridge FM 3284 FR. 10M South Drainage Ditch
	TX	Refugio	FM 1684, Drainage Ditch Bridge
2.4	CO	Aurora	I-225 & Parker Rd. Phase III
	CO	Jefferson	Denver Parks O'Fallon Park Bridge over Bear Creek
	CT	New Haven	US Route 1 over Housatonic River
	HI	Maui District	Honolua Stream Bridge
	IA	Scott	53rd Ave. over Crow Creek Bettendorf
	IA	Johnson	4th Ave. over Ralston Creek
2.4	IA	Tama	Hwy. E64 over Small Creek East of US 63

	IA	Winndshiek	Iowa 24 over Goddard Creek
	IL		Jacksonville, S Fayette Street over Town Brook
	IL	St. Clair	Pleasant Ridge Rd. over Little Canteen Creek
	IN	Tippecanoe	County Bridge #153
	LA	Franklin Parish	Louisiana Route 70, Bayou Pierre Part
	MA		Franklin I-495 over MBTA Bridge
	MD	Harford	Rehabilitation of Bridge No. 12016 on MD 24 over Deer Creek
	ME		Fairfield, Emery Brook Bridge
	ME		State-wide, IBRC Program (Ricker's Bridge)
	ME		Union-Washington Skidmore/Medomak Bridge
	MO	Boone-Callaway	Route Y, Boone-Callaway County, Deck Replacement, Bridge N0038
	MO	Greene	FR-148 Bridge over Pearson Creek
	NC	Durham	NBIS bridge 00630085, State Route 1814 over Little Lick Creek
	OH		Route 49-0103, Dayton
	OH	Defiance, Huron, Miami	Casebeer-Miller Road, TR-114, SR-185
	OH	Huron	FA-114-01.64 over stream
	OR	Clatsop	State Hwy #105 MP4.78 & MP 6.89
	OR	Multnomah	The Broadway Bridge, NW Broadway over Willamette River
	PA	Bedford	T-565 over Dunning Creek
	PA		T-391 over Sideling Hill Creek
	PA	Susquehanna	State Route 1037 over Dubois Creek
	PA	Butler	State Route 4012 over Slippery Rock Creek
	PA	Lycoming	TR -776 Bridge over English Run
	PR		Bridge 281 at PR -139 (Km 2.5)
	SC	Spartanburg	S-42-655 over Norfolk/Southern Rail Road
	TX	San Patricio	FM 3284 over Drainage Ditch Gregory Texas
	VT	Lamoille	Bridge 213 carrying VT Route 100 over Ryder Brook
	VT	Washington	Moretown Bridge, Lovers Lane over Mad River
	WI	Fond du Lac	Highway 151 over State High
	WI	Dane	USH 12, Coffee Creek Crossing
	WV		Market Street Bridge
	WV	Cabell	Howells Mill Bridge CR 1 over Mud River
2.5	AL	Crenshaw	Surles Road Bridge over Bedsole Creek
	IA	Delaware	215 Avenue Bridge over Lime Creek
	ME		Municipal Pier in Milbridge
	ME		Union-Washington Skidmore/Medomak Bridge

2.3. SELF CONSOLIDATING CONCRETE

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs
Program Years 1999-2009

Technology Summary
3. Self-Consolidating Concrete

Prepared For:
Federal Highway Administration



Prepared By:
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June 2011

3. Self-Consolidating Concrete (SCC)

General Description

Self-consolidating concrete (SCC), sometimes referred to as self-compacting concrete, can easily fill and consolidate in complex structural shapes and around congested steel reinforcing, eliminating the need for mechanical vibration.

SCC is typically produced by adjusting traditional mix designs with the use of superplasticizers and viscosity modifiers. These admixtures create a flowing concrete that also meets shrinkage and other standard performance requirements. Amounts of these admixtures can be balanced to control undesirable effects like bleeding and segregation based on project needs.

Applications for self-consolidating concrete found in the innovative technology projects include concrete mix design in girders, decks and overlays. Information given below is based on the summary sheets compiled from State submitted information.

Demonstrated Advantages

1. Flowability (no honey-combing)
2. Fills formwork and encapsulates congested reinforcement easily
3. Reduced labor costs since there is no need for mechanical vibration
4. Reduced construction time
5. Increased construction safety

Demonstrated Disadvantages

1. Increased mix design costs
2. Vibrations from heavy trucks up to 4 hours after pour can cause debonding issues
3. Unfamiliarity by contractors
4. Potential for bleeding and segregation of the flowable concrete

Methods of Implementation

Described herein are the applications that SCC was used for in the IBRC and IBRD programs. Positive and Negative results that are reported represent general assimilation of comments provided in the IBRC and IBRD Summary Sheets, as reported by the States. A representative project is described to provide an example of how this technology was implemented.

Description: SCC was used in various applications including beams, abutments, pier columns and drilled shafts.

Positive results: Successful implementation was demonstrated on multiple projects. Uniform levels of consolidation and concrete density around reinforcing cages was observed without vibration. And, since vibrating is not needed, labor costs were reduced. States reported valuable experience gained in SCC technology including how to work with the material and placing repair applications while the structure is still subjected to live loads. More than one report indicated results that the finished surface conditions were aesthetically pleasing when completed.

Negative results: The material is more expensive due to the admixtures. Additionally, SCC is a relatively new technology and unfamiliarity by contractor/manufacturer was also reported as an issue. In one project, random vibrations for heavy live loads resulted in debonding between the reinforcement and concrete. It was also noted that SCC, if too flowable, will bleed through formwork and has the potential to self segregate apart from the aggregate.

Representative project: The state of South Carolina used this technology for the project named “US 76 over Lumber River and Swamp”. SCC was used in drilled shafts to take advantage of its

flowability properties through tight rebar cages and reduce labor cost since vibration is not needed. SCC worked as intended, but the State indicated not wanting to specify its use in the future due to increase material costs and contractors general lack of knowledge when working with the material. This project produced many lesson learned from the experience of using SCC. These included evaluating an appropriate sand-to-aggregate ratios, appropriate set times, and using trial mixtures under similar conditions to determine the proper retarding dosage.

IBRC and IBRD Projects with Data Sheets Reported by States for SCC Technology

	State	County	Project
3.	AL	Jackson	B.B. Comer Southbound Bridge U.S. 431 over Tennessee River
	CO	Las Animas	I-25NB over Purgatoire River I-25; I-25 NB over Main Street;
	HI	Honolulu	North Kahana Stream Bridge
	IL	Will County	High Road Bridge carrying High Road over Long Run Creek in Lockport Township, Illinois
	MI	Jackson	M-50 Bridge over Grand River
	NE	Buffalo	Nebraska Highway 68 over the BNSF Railroad in Ravenna
	NJ	Mercer	Route I-280/Garden State Parkway Interchange 145
	SC	Marion, Horry	US 76 over Lumber River and Swamp
	SC	Williamsburg	SC 377 Bridge over Black River
	WV	Randolph	Stalnakar Run Bridge County Route 219/86 (MP 3.18) over Stalnakar Run

2.4. HIGH PERFORMANCE STEEL

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs
Program Years 1999-2009

Technology Summary

4. High Performance Steel

Prepared For:
Federal Highway Administration



Prepared By:
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June 2011

4. High Performance Steel (HPS)

General Description

High performance steel is higher in strength than conventional steel and can result in bridges which are lighter in weight. In addition, they generally have greater atmospheric resistance, improved fatigue resistance (toughness), and improved corrosion-resistance properties. The three most common types in used are: HPS100W, HPS70W and HPS50W.

Applications for high performance steel found in the innovative technology projects include folded plates, beams/girders, corrugated webs, and an investigation regarding bracing requirements for HPS girders. Information given below is based on the summary sheets compiled from State submitted information.

Demonstrated Advantages

1. Higher yield strength
2. Less material needed to provide required strength
3. Expected service life as high as 75 years
4. Ability to accommodate tight vertical clearances
5. Improved toughness

Demonstrated Disadvantages

1. Special welding procedures
2. Deflection can control design

Methods of Implementation

Described herein are the various applications that HPS was used for in the IBRC and IBRD programs. Positive and Negative results that are reported represent a general assimilation of comments provided in the IBRC and IBRD Summary Sheets, as reported by the States. A representative project is described to provide an example of how this technology was implemented.

4.1 Folded Plates

Description: Folded Plate Bridge Systems offer an economical solution for bridges with maximum span lengths up to 60 ft. The system consists of a series of standard shapes that are built by bending flat plates into inverted steel box shape. This has many advantages for both steel fabricators and bridge owners with respect to customization and elimination of fabrication details. This technology was used on one project to reduce labor costs.

Positive results: Almost eliminating the labor associated with girder fabrication. This concept uses very thin plates, which reduces material costs. Unrelated to the folding plate technology, but to avoid painting issues related to corrosion, A1010 was used as a stainless steel alternative on the one project. The geometry selected for the folded plate was referred to as an inverted steel box shape. It is more stable and easier to inspect compared to conventional steel box sections. The compression element of the girders is stiffened using a small bump which eliminates the need for using expensive stiffeners.

Negative results: No negative results were reported.

Representative project: The state of Nebraska used this technology for a research, design, construction and monitoring project named “Folded Steel Plate Bridge Technology”. The folded plate geometry was an inverted steel box shape and was used to reduce labor cost associated with girder fabrication. The state reported that the folded plate technology essentially eliminates the labor associated with girder fabrication.

4.2 Beams/Girders

Description: HPS was used as an alternative to traditional steel in beam/girders to increase overall strength.

Positive results: Successful implementation was demonstrated on multiple projects. There is a material savings due to the ability to design smaller girders. With smaller girder, the design can accommodate larger vertical clearance. HPS has an increased ability to handle higher dead loads due to their own decreased self weight. Most of the projects reported no issues with fabrication. Maintenance costs are similar to traditional steel. States reported valuable experience gained working with the material.

Negative results: On one Delaware project, initial assumptions led to an insufficient lateral force restraining system. The restraining system was found to be insufficient when deformations and rotations occurred in the girders upon the removal of temporary supports. The lateral forces were thought to be caused by the large skew of the bridge. A retrofit plan was developed which called for welding stiffener plates to all girder webs along their lengths. Other projects indicated that deflection limits tend to control for longer spans. In another instance, additional work was required to develop special welding procedures. Some projects had issues with fabricator familiarity with HPS, however, most did not report fabrication issues. Additional camber was needed due to smaller girders.

Representative project: The state of Missouri used this technology for the project named “Route 224 over Route 13”. HPS girders were used to decrease the costs of material. Girders performed as expected and the reduced amount of material led to a cost savings of 11% achieved over conventional 50 ksi steel bridge. The project was an overall success.

4.3 Bracing Requirements

Unfortunately, insufficient information was provided in any of the bracing requirement projects to present accurate results regarding implementation.

4.4 Corrugated Webs

Description: HPS was used as an alternative to traditional steel in a corrugated web girder to increase overall strength. This was done on only one project.

Positive results: Overall technology produced a superstructure approximately 10% lighter and eliminated the need for transverse stiffening. The webs can be manufactured in commercial steel bridge fabrication shops and gas metal arc welding (GMAC) can be used effectively to joint the web to the flanges. Fabrication showed trapezoidal corrugations offered distinct advantages over sinusoidal corrugations. The use of a web splice with a single row of bolts on each side of the splice easily develops shear capacity.

Negative results: The use of shear strength theory calculated in the initial development stages did not safely estimate shear strength. As a result, however, the funded research provided new equations.

Representative project: The state of Pennsylvania used this technology for the project named “SR 2024 over Towanda Creek”. A demonstration bridge was designed and constructed to test the performance of HPS in the corrugated webs. It was found that corrugated web technology has the potential to be economical for deeper webs that would otherwise require multiple stiffeners.

4.5 Advancing Fabrication of HPS

Description: HPS was tested during welding to determine the diffusible hydrogen level. This was done on only one project.

Positive results: Improved hydrogen cracking control of welds for High Performance Steels (HPS). Verified the Charpy V-notch Toughness Values of ASTM A852 Steels. Diffusible hydrogen levels could be accurately measured using on-site testing and remote-rate hydrogen collection

Negative results: No negative reports were reported from the study.

Representative project: The state of Tennessee used this technology for the project named “SR-53 over Martin Creek”.

IBRC and IBRD Projects with Data Sheets Reported by States for HPS Technology

	State	County	Project
4.1	NE		Wagon Tongue Creek on Highway N-79 - Folded Steel Plate Bridge Technology
4.2	AR	Monroe	State Hwy. 49 over I-40 (Brinkley)
	DE	New Castle	Churchman's Road over I-95
	GA	Cook	I-75 @ State Route 37/Adel (FM 1500 ft West to 650 ft East I-75), Rowa, Peng
	ID	Bonneville	Sunnyside Road (I-15B) Interchange over I-15
	IL		I-55/ I-70 Poplar Street Complex
	IL	Lake, Champaign, Vermillion	IL 83 and US 45 over the Wisconsin Central Rail Road in Lake Villa, IL; IL 49S over I-74; IL 49N over I-74
	MN	Washington	Glen Road over TH61, City of Newport
	MO	LaFayette	Route 224 over Route13
	MO		Bridge A6358, HPS, Route 54 over Osage River
	MT	Silver Bow	I-15/I-90 over BNSF Rail Road
	NE		Omaha Dodge Street over I-480
	NH	Rockingham	State Route 111 By-Pass over Flatrock Brook and Harris Road
	NJ	Mercer	Scotch Road over I-95
	NV	Clark	State Route 170, Bunkerville Road over Virgin River
	NY	Washington	East Street Bridge
	OH	Fairfield	FAI-33-1309 Delmont Road over US33
	OR	Washington	Sylvan Bridge over Sunset Highway
	OR	Baker	I-84 Irigon Junction - Hilgard Interchange
	PA	Erie	SR 4034 over Wintergreen Gorge
	PA	Allegheny	SR 0885 Boulevard of the Allies over Forbes Ave.
	SC	Cherokee	US 29 over Thicketty Creek
	VT	Windsor	Bridge #8 FAS 0166 over White River
	WV	Putnam	Culloden Railroad Overpass Bridge
	WY		Ranch Road Interchange over I-25
4.4	PA	Bradford	State Route 2024 over Towanda Creek
4.5	TN	Jackson	State Route 53 over Martin Creek

2.5. ACCELERATED BRIDGE CONSTRUCTION

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs
Program Years 1999-2009

Technology Summary

5. Accelerated Bridge Construction

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Federal Highway Administration



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5. Accelerated Bridge Construction (ABC)

General Description

Accelerated bridge construction is any method of constructing a bridge which utilizes a process to significantly reduce the time to completion as compared to traditional construction techniques. Typically, ABC uses components that are precast or prefabricated and can be placed in days rather than weeks or months.

Applications for accelerated bridge construction found in the innovative technology projects include bridge replacement and new bridge construction. Information given below is based on the summary sheets compiled from State submitted information.

Demonstrated Advantages

1. Reduced/rapid construction time
2. Reduced traffic congestion
3. Public Satisfaction with project

Demonstrated Disadvantages

1. Usually involves complete road closure
2. Increased coordination required
3. May not be appropriate for complicated geometry
4. Material costs may be more expensive
5. Delays due to weather
6. Delivery/assembly issues due to heavier/larger bridge elements

Methods of Implementation

Described herein are the various applications that ABC was used for in the IBRC and IBRD programs. Positive and Negative results that are reported represent general assimilation of comments provided in the IBRC and IBRD Summary Sheets, as reported by the States. A representative project is described to provide an example of how this technology was implemented.

5.1 Concrete Filled FRP Tubes

Description: This construction technique has gained national attention as the “Bridge in a Backpack” system. The light FRP tubes are set on site and do not require heavy machinery to set. The tubes are then filled with concrete, which forms the basis of the structural system. The system is then covered with retained earth. When completed, the technology resembles a small arch bridge.

Positive results: The concrete filled FRP tubes have been very successful at greatly reducing construction time with projects completed within two weeks. Reports and on-line articles indicate that the results are aesthetically pleasing as well.

Negative results: none reported

Representative project: The State of Maine used this technology for the project named “Neal Bridge in Pittsfield, ME”. As this is the only IBRD project of this type, please see the Results portion above for the results. This project has been very successful and five more similar projects have been completed in Maine, with at least two more planned for 2012. The technology has also been reported positively in various media outlets. Outcome of each project seems to depend on the perspective of the owner and the expectations.

5.2 Prefabricated and Precast Elements

Description: Prefabrication involves major structural components are fabricated and constructed adjacent to the project site and rolled or lifted into place, rather than being constructed in place. Precast elements, a form of prefabrication, are used for various structural components that are traditionally cast-in-place (CIP). For example, precast elements can include abutment pile caps, pier columns, pier caps, and deck panels. Using these prefabricated components can greatly accelerate construction by eliminating setup and curing time associated with CIP concrete or by reducing bridge closures by assembling components prior to placement. One project that used a completely precast system for both substructure and superstructure reported the whole project as highly successful with no negative results. Precast elements are generally broken into the subsets of *precast deck panels*, *deck-slab-beams*, and *precast substructure*.

Positive results: Project using *precast deck panels* reported fast construction was achieved during re-decking. For one project in particular, daylight hours of operation were critical for a tourist setting and the entire deck was replaced with night closures greatly reducing potential economic losses. The *deck-slab-beam* system effectively eliminated the need for cast in place concrete in the superstructure. One project reported being able to construct a bridge in 33 days. The use of *precast substructure* not only reduced construction time, but it was reported that worker safety improved as well. This is because no elevated CIP work (forming, pouring, vibrating) was required by construction workers. It was also mentioned that, with proper planning, setting of the precast cap was not difficult.

Negative results: Contractor inexperience and increased costs were the primary negative aspects of some projects. Contrarily, some of the lessons learned with the IBRD projects showed that the potential to overcome these limitations were achievable. There were repeated concerns of *precast deck panels* cracking during installation, but this was not the case for all projects. Cracks were found during placement of *deck-slab-beam* systems on some projects which were attributed to improper handling. On one *precast substructure* project the State reported that, due to contractor inexperience, any time that was gained by using precast was lost during construction. For this project, several issues were not realized until construction commenced, including the need for expensive pressurized grout. One of the more important lessons that came out of this work was the discovery of needing appropriate special provisions and scope(s) of work, and to have them correct prior to beginning work.

Representative project: The State of Texas used this technology on the project names “FM 1660 over Cottonwood Creek”. The project was a bridge replacement that utilized precast abutment caps and deck-slab-beams. The bridge was constructed in 33 days with an estimated 20 days saved by eliminating slab forming, rebar placement, pouring and curing. The project was successful enough that TXDOT developed standard bridge details for the Decked Slab Beam for state wide use for rapid replacement requirements.

Description: Major structural components are fabricated and constructed adjacent to the project site and rolled or lifted into place, rather than being constructed in place.

5.4 Self Propelled Modular Transport (SPMT)

Description: SPMT allows for an entire superstructure or superstructure unit to be constructed offsite, under controlled conditions and then delivered to the project site via automated transport. Thus replacing an entire span can become a matter of hours rather than months.

Positive results: Off site construction can allow for increased quality control. For the project constructed with this technology, the bridge was closed over a weekend, as opposed to six months, with an estimate user-cost savings of the traveling public of over \$4M.

Negative results: The additional cost of using the SPMT was nearly \$1M.

Representative project: The state of Utah used this technology on the project titled “I-215 NB over 3760 South Street at 3300 East Salt Lake City”. It has since been used on other projects in Utah as well. The State has had sufficient successful ABC projects to standardize a decision tree for the appropriate uses of ABC, including SPMT. Media and public response has been very positive with the reduced construction delays.

5.5 Geosynthetic Reinforced Soils

Description: Reinforced soils using a polymeric geosynthetic material were used on two projects. The soil mass of GRS systems is reinforced in layers with a polymeric geosynthetic, and the layered reinforcement is attached to facing elements that constitute the outer wall. Various materials, including natural rock, concrete block, gabion, or timber, may be used for the flexible facing. GRS structures are more forgiving to differential foundation settlement thus minimizing the bump that commonly develops between the roadway and bridge. GRS structures can be put into service quickly, can be built by maintenance personnel, and are especially well suited to projects constructed in areas that are difficult to access with heavy equipment. GRS structures are good for demolition and the recyclable nature of their components.

Positive results: Similar to geofoam, the two states that used this technology reported successful implementation, easy/fast construction, excellent performance, and settlement and expansion contraction data was as good as or better than expected.

Negative results: One report noted that the technology has a tendency to be more expensive than fill, which results in higher upfront costs.

Representative project: The state of Ohio used this technology for the project named “Casebeer-Miller Road/TR-114/SR-185”. In addition to the positive results listed above, this project, along with a number of other local projects, demonstrates the wide applicability and flexibility of GRS as an abutment material. A higher abutment structure allows for span shortening and possible pier elimination in certain situations. This system can be easily and quickly constructed with light equipment. They also have reduced lead time since the materials are readily available.

5.6 Aluminum Bridge Decks

Description: In two projects aluminum alloys were used for bridge deck construction. This type of deck was used to reduce self weight dead load and to increase the allowable live load.

Positive results: The aluminum structural components are lightweight, reducing dead load and thus increasing the allowable live load. The placement of the deck was completed in 2 hours and traffic was allowed on the deck while the underside of the deck was connected to the bridge. After 3 years of monitoring the deck is performing as expected with no signs of deterioration or damage.

Negative results: Aluminum is more expensive than steel, which results in higher upfront costs. This technology has so far been limited to use on steel girder bridges.

Representative project: The state of Kentucky used this technology for the project named “KY-92 over Howard Creek in Clark County, KY”. As this is the only project reporting results, please refer to the above Results section. Also noted in the report is that training of construction workers to lift and place Aluminum deck panels is important to complete before construction, and practice runs should be conducted before placement on the actual bridge .

IBRC and IBRD Projects with Data Sheets Reported by States for ABC Technology

	State	County	Project
5.1	ME	Franklin	Neal Bridge, Pittsfield
	ME		State-wide, IBRC program (Rolin's Road)
5.2	IN	Dearborn	US-50 Bridge over Tanners Creek and Service Road, Lawrenceburg
	MN	Washington	TH 610 from 0.6 Mi. West Fernbrook Lane to 0.1 Mi. West 93rd Ave. in Maple Grove
	MN	Chisago	TH 8 over Center Lake Channel, 0.8 Mi. East of Center City; TH 72 over Tamarac River near Waskish
	MO	Newton	Route 64 1.5 Mi SW of Pomme De Terre Lake
	NH	Rockingham	Mill Street over the Lamprey River in Epping, NH
	NH	Belknap	Mosquito Bridge US Rt.3 & NH Route 11 over Lake Winnisquam
	NH	Grafton	Newbury Road Project
	NM	McKinley	NM 602 Bridge over Rio Nutria near Zuni NM
	SC	Florence/Marion	US 378 over the Pee Dee River
	TX	Crockett	Live Oak Creek Bridge
	TX	Williamson	FM 1660 over Cottonwood Creek
	TX	McLennan	IH-35: State Highway 6 Interchange
	TX	McLennan	IH 35 at FM 2063 & at Crossover Rd.
	UT	Summit	County Road over I-80 in Wanship, UT
	UT	Davis	I-84 Weber Canyon ABC
	VT	Windsor	Route 50 over Ottauquechee River
	VT	Bennington	Bridge 2, City of Readsboro Vermont
	WI	Fond du Lac	IH 39/94 over Door Creek
	WI	Trempealeau	USH 063 USH 63 over Rush River
5.3	TX	McLennan	EB Loop 340 – State Highway 6 Overpass (Main lanes and Frontage Road over IH35)
	TX	Bell	IH35 NB & SB Main lanes over Hill Road
5.4	UT	Salt Lake	I-215 NB over 3760 South Street at 3300 East Salt Lake City
5.5	LA		I-49 over Dooley Bayou - Geosynthetic Reinf Soil at Abuts
	OH	Defiance	Casebeer-Miller Rd. over tributary of South Fork Gordon Creek
5.6	KY	Whitley	KY-92 over Jellico Creek
	KY	Webster	Webster County Bridge 50, Crab Orchard Creek

2.6. REINFORCING BARS

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Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs
Program Years 1999-2009

Technology Summary

6. Reinforcing Bars

Prepared For:
Federal Highway Administration



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June 2011

6. Reinforcing Bars

General Description

Conventional reinforcement is susceptible to corrosion and typically requires a large number of labor hours to construct assemblies. The reinforcing bar technologies in this section have been designed to resist corrosion and/or increase strength. Reducing corrosion in the rebar is intended to provide an overall longer service life. Increasing strength will potentially decrease the amount of steel needed.

New Technologies for reinforcing bars found in the innovative technology projects include MMFX, galvanized, fiber reinforced polymer, stainless steel, and glass type reinforcing bars. Information given below is based on the summary sheets compiled from State submitted information.

Demonstrated Advantages

1. Reduced material quantity
2. Reduced material costs due to higher yield strength
3. Reduced labor costs
4. Corrosion resistance
5. Lightweight
6. Longer service life

Demonstrated Disadvantages

1. Some products are proprietary and can be more expensive
2. Most of the technologies have a limited number of manufacturers
3. Production issues can cause substantial delays

Methods of Implementation

Described herein are the various applications that reinforcing bars were used for in the IBRC and IBRD programs. Positive and Negative results that are reported represent general assimilation of comments provided in the IBRC and IBRD Summary Sheets, as reported by the States. A representative project is described to provide an example of how this technology was implemented.

6.1 MMFX

Description: MMFX rebar is designed to reduce corrosion and increase strength and toughness. Typical carbon steels form a matrix of chemically dissimilar materials (carbide and ferrite). These carbides are strong, but brittle and immovable at the grain boundaries and lead to inter-granular corrosion. The MMFX proprietary steel technology forms a matrix that is nearly carbide free, leaving a different structure at the atomic scale. MMFX is advertised as producing rebar with high strength, ductility, toughness and corrosion resistance which has enabled the development of a cost-effective MMFX steels.

Positive results: MMFX was demonstrated as successful in certain corrosion research projects and was demonstrated to reach higher deformation states before failing. On several projects iron workers reported that it was much easier to place than epoxy coated rebar since they did not have to worry about damaging protective coating (similar to black steel reinforcing). Studies showed the amount of steel can be reduced by up to 33% and provide the same performance. Since it is easier to place, and typically requires less steel in the design labor costs is reduced. Due to the purported higher corrosion resistance and lower life cycle costs, overall maintenance costs are anticipated to be reduced over the life of the bridge.

Negative results: With this technology, a limited number of manufacturers can provide MMFX reinforcement which led to delays on several projects. Results from flexure testing implied that

lap lengths need further study and the recommendation was given for the designer to reduce or eliminate the number of lapped joints. The material cost for MMFX steel, since it is proprietary and not produced on the same scale, is more expensive than traditional epoxy reinforcement. Short-term behavior of corrosion appears to be the same as regular rebar on several projects. No long term in-situ study is available yet to verify its corrosion performance.

Representative project: The state of Iowa used this technology for the project named “US 20/South Beaver Creek”. MMFX reinforcing bars were used to increase strength and protect against corrosion in concrete bridge deck. While the yield strength of the reinforcing was increased, the in-situ corrosion resistance performed no better than traditional steel reinforcing.

6.2 Galvanized

Description: Galvanized reinforcing steel is bare reinforcing steel coated with a protective layer of zinc metal. The zinc coating serves as a barrier to corrosive elements that the rebar is exposed to when embedded in concrete. In addition to the barrier protection that the zinc creates, it also provides a level of cathodic protection where the zinc will preferentially corrode when in contact with bare steel.

Positive results: Successful implementation was demonstrated on all projects which reported results. The resistance to corrosion increased compared to traditional reinforcement. On several projects, fabrication was delivered on time and installed without incident.

Negative results: Test results showed that the zinc coated reinforcement was brittle but still acceptable for design. The technology has a tendency to be expensive, which results in higher upfront costs. On one project, rebar did not meet ASTM specifications for deformation. On a different project, numerous rebar had formed rust residue from chains which were used by the hauling company, and on several projects rebar had serrated drip lines that made it dangerous to handle. No in-situ study is available yet to verify its long term corrosion performance.

Representative project: The state of New Hampshire used this technology for the project named “I-293 over Frontage Road”. Galvanized reinforcing bars were used to protect against corrosion in concrete bridge deck. The use of galvanized reinforcing bars performed as intended. Five years after construction the deck is still rated as excellent by the state, despite a lack of the traditional New Hampshire waterproofing. As such, all results indicate that the galvanized reinforcing is exceeding the performance of standard reinforcing.

6.3 Fiber Reinforced Polymer

Description: Fiber reinforced polymer is a composite material usually consisting of two main constituents: a reinforcing agent, which is typically fiberglass or carbon fibers, and a polymer matrix, usually a resin, epoxy, vinyl ester or polyester thermosetting plastic. FRP technology combines the strength of the ceramic glass fibers or carbon, with the toughness and ductility of the polymer matrix. This combination utilizes the dislocation motion in the polymer matrix and transfers the load to the high strength fibers. The FRP bars have a surface treatment that facilitates a bond between the finished bar and the structural element into which they are placed.

Positive results: Successful implementation was demonstrated on multiple projects. Reduced labor costs were achieved since it is simple to layout the very lightweight reinforcement. Projects reported that deck cracking was below AASHTO limits. Short term results indicate deterioration due to corrosion has been virtually eliminated. The measured concrete strain, deflection and forces performing as expected.

Negative results: The material is expensive, which results in higher upfront costs. FRP reinforcement is not always readily available and can lead to long lead times when ordering the material. Other issues reported included a project where “Aramid” brand FRP material was used and turned out to be very sensitive to field handling. Additionally, the material is not easy to cut, and shear cutting is not permitted. Bars cannot be field bent. No long term in-situ study is yet available to verify its corrosion performance.

Representative project: The state of Texas used this technology for the project named “RM 1061 at Draw Creek”. FRP reinforcing bars were used to eliminate electrochemical corrosion in concrete bridge deck. FRP reinforcing demonstrated superior corrosion resistance, and performed as intended for this project. The work was sufficiently successful that FRP reinforcement is undergoing ACI procedures for standardization of design, testing and construction. The project has been performing satisfactorily in excess of 10 years and has been a source of multiple papers and reports.

6.4 Stainless

Description: Stainless steel reinforcing contains a higher level of chromium that significantly reduces corrosion and increases the service life of the bridge. There are many different grades of stainless steels, all of which act in similar fashion. With the higher level of chromium present, a passive film of chromium oxide is formed which prevents surface corrosion and blocks corrosion from spreading into metal's internal structure. Two types of stainless reinforcing were used, solid and stainless clad reinforcing.

Positive results: Projects reported that deck cracking was below AASHTO limits. The installation process of stainless clad reinforcing is similar to epoxy coated steel, with similar requirement for handling. Working with solid stainless is similar to working with normal black steel reinforcing. Due to its anti-corrosion properties and similar strength qualities as black steel, stainless steel is expected to provide 100 year service life.

Negative results: The material is more expensive than black reinforcing, which results in higher upfront costs. Several projects reported that there were issues with the manufacturer being unable to supply clad stainless steel reinforcement and several projects intended to be used with stainless chose alternate reinforcing instead (galvanized, stainless-clad, or MMFX).

Representative project: The state of Missouri used this technology for the project named “Route 6, 0.8 Miles to 0.2 Miles West of Sullivan City”. Stainless reinforcing bars were used to prevent corrosion in concrete bridge deck. The project also used plastic tie wires, similar to epoxy-coated construction to avoid corrosion initiation in the ties. This type of deck was compared to a conventionally constructed deck using precast post tensioned stay-in-place panels and a top mat of epoxy coated reinforcement. The biggest negative aspect of the stainless steel is the increased cost of the material. The report for this project discussed the interim testing of the bridges for the first five years of service life. Thus far, results are inconclusive. The performance of the stainless steel, at least for the first five years, has been similar to conventional design.

IBRC and IBRD Projects with Data Sheets Reported by States for Reinforcing Bars Technology

	State	County	Project
6.1	DE	New Castle	BR 119 on State Route 82 over Red Clay Creek
	DE	New Castle	BR 712B, Ramp J, I95 Service Area, Newark
	FL	Pinellas	Jensen Beach Causeway (MMFX)
	IA	Grundy	US 20/South Beaver Creek Proj. NHSX-520-5(78)
	ID	Boise	State Route 21 over Mores Creek at New York Gulch
	ID	Bonner	Westmond Bridge, US 95 over BSFRR
	MI	Wayne	I-94 over Shook Road and C&O RR
	MI		I-94EB & WB over Riverside Drive
	NC	Johnston	State Route 1178 over I-95, Town of Four Oaks, TIP: I-2704, 2-span continuous steel structure (6 beam)
	NM	Rio Arriba	US 64 over the Amargo River in Dulce, NM
	OK	Kay County	I-35 over Chickaskia River
	OK	Love	I-35 over Hickory River
	SC	Charleston	SC Route S-54 over Tidal Creek
	TX	Potter	Washington Street Under IH-40
	UT	Weber	East Bound State Route 79 Grade Separation/Reeves Rd.
	UT	Utah	US 6 Bridge over UPRR
	VT	Orleans	VT Bridge 64, VT 105 over Clyde River
6.2	IL		Quincy 18th Street over Ceda Creek
	NH	Hillsborough	I-293 over Frontage Rd.
	NH	Hillsborough	I-293 over Brown Rd.
	NY		I-95 over Midland Ave
	NY		NYS Thruway over Gravel Road
6.3	FL	Duval	University Blvd. Bridge over Arlington River
	GA	Walton	County Road 289-Bearden Rd @ Jacks Creek NW of Good Hope, Bridges
	IN	Fountain	Thayer Road over I-65
	KY		KY 595 over West Fork Silver Creek
	KY	Scott	KY 3302 over Sugar Tree Branch (FRP)
	LA	East Baton Rouge	Elm Grove Garden Road Bridge
	MI		City of Southfield Bridges
	MI	Tuscola	M-15 @ Over Gooding Creek
	MO	Phelps	Southview Drive over Carter Creek
	NC	Macon	Bridge 16 on State Route 1470 over Cartoogechaye Creek, TIP B-3485
	NH		Rollins Road over Main Street and BMRR
	NJ	Passaic	US Route 46, NJ Route 23 & Interstate 80
	TX		RM 1061 at Draw Creek
	WV		East Street Viaduct carries CSX RR over WV Alt 14A
6.4	FL	Monroe	Jensen Beach Causeway (stainless)
6.4	GA	Gilmer	State Route 282 Bridge Replacement over Tails Creek West of

			Ellijay
	KY	Scott	Scott County Road 5218 over North Elkhorn Creek
	KY	Scott	KY 3302 over Sugar Tree Branch (stainless)
	MI	Ingham	EB I-496 over CSX RR and Holmes SD Road R12-4
	MI	Eaton	M-43 Bridge over Sebewa Drain
	MO	Grundy	Route 6, from 0.8 Mi. to 0.2 Mi., West Sullivan City
	MT	Flathead	US 2 over Middle Fork Flathead River Essex
	ND	Barnes	I-94 from Oakes INT East to East Valley City
	NY	Richmond	Annandale Road over Staten Island Rapid Transit
	SC	Horry	SC Route 73, Myrtle Beach SC

2.7. MONITORING

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Technology Summary

7. Bridge Monitoring

Prepared For:
Federal Highway Administration



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7. Bridge Monitoring

General Description

Monitoring technologies are used to observe both short-term and long-term performance and safety of bridges. These monitoring systems can measure a wide variety of bridge performance criteria, including strain, temperature, inclination, acceleration, load measurements, ice detection, vehicle speed and weight, corrosion and cracking.

Applications for monitoring found in the innovative technology projects include scour monitors, smart sensors, fiber optic sensors, displacement monitoring, and smart aggregates. Information given below is based on the summary sheets compiled from State submitted information.

Demonstrated Advantages

1. High resolution capabilities for data collection
2. Systems can be integrated over long distances
3. Instruments can measure a wide variety of bridge performance properties
4. Added safety with the ability to detect failures
5. Wireless technology available for monitoring applications

Demonstrated Disadvantages

1. Added cost to bridge
2. Requires a system for monitoring results
3. Data reliability can be an issue

Methods of Implementation

Described herein are the various applications that monitoring was used for in the IBRC and IBRD programs. Positive and Negative results that are reported represent general assimilation of comments provided in the IBRC and IBRD Summary Sheets, as reported by the States. A representative project is described to provide an example of how this technology was implemented.

7.1 Scour

Description: Scour monitoring was performed with sonar. This technology uses a river channel-bed monitor composed of a single-beam transducer. One project used this technology to evaluate channel-bed changes, including scour and backfill, in response to the hydraulic conditions near the bridge.

Positive results: The collected data correlated well with the historical hydrographic record. The monitored channel bottom was typically within 0.5 feet of the physical measurement and never varied more than 1.0 foot during substantial hydrologic events.

Negative results: No negative results were reported. The project using this technology was considered a success.

Representative project: The state of Missouri used this technology for two bridges summarized in one project named “SB Interstate 255 over the Missouri River in St. Louis County and US 24 East over the Grand River in Carroll County”. Scour monitoring was used to evaluate channel-bed changes in response to hydrologic conditions. Throughout data collection periods, Chariton River locations near Prairie Hill and Novinger recorded bed changes as much as 13 feet and 5 feet, respectively. Nearly all of the bed changes correlated well with the hydrographic record at these locations. Based on manufacturing specifications and independent depth measurements, the monitored channel bottom was typically within 0.5 foot of the physical measurement and never varied more than 1 foot during substantial hydrologic events.

7.2 Smart Sensors

Description: Smart Sensors are monitoring devices, typically wireless, powered by a solar cell, and integrated with a miniature computer, so that they can both collect data and monitor the structure for signs of damage. The sensors send electrical signals into the structure. If there is a crack or other damage, it will disrupt the electrical signal, and the system will detect and analyze the disruption.

Positive results: The greatest potential advantage of this technology is being able to collect and analyze live monitoring data to evaluate structural health and reliability. States reported valuable experience gained using wireless communication to monitor bridge structural health.

Negative results: There was difficulty in the reliability of some of the data collection systems. Some states reported issues getting communication and electricity supplied to power the measuring devices. There was also some difficulty in applying results to conventional concrete bridges.

Representative project: The state of New Mexico used this technology for the project named “I-40 Tucumcari/East Interchange”. Smart Sensors were used to monitor the structure after fiber reinforcing was placed in the negative moment region to strengthen the bridge. Although no collected data definitively indicated the long term strength of the reinforcement, the state reported valuable experience gained using instrumentation on bridges, remote data collection, wireless communications, and solar power.

7.3 Fiber Optics

Description: Fiber optic technology is used to monitor strain. The optical fibers are typically cylindrical and fabricated from polymer, glass or ceramic materials. Light propagates in the fiber sensors and is refracted at a certain wavelength at predetermined points along the fiber. As the fiber deforms, the wavelength of the refraction modifies. These variations in light are calibrated and then interpreted as a strain measurement by instrumentation. One unique aspect of this monitoring system is that one fiber can become a nearly limitless array of sensors along its length.

Positive results: Successful implementation was demonstrated on multiple projects. The sensors performed excellent in prestressed concrete girders. Information was gained on prestressed losses in high performance concrete girders along with actual distribution factors for shear and moment. Future monitoring using fiber optic technology was reported as very likely based on the results.

Negative results: Some problems with the sensors included optical loss, interference between other sensors, large discrepancies in strain when measurements were compared to other measuring devices, large compressive drops, and measurement noise (backscatter).

Representative project: The state of Hawaii used this technology for the project named “Route 19/Kealakaha Stream Bridge”. Fiber Optic monitoring was used to measure strain in the bridge. The study is only 70% complete, but initial results were positive. Laboratory scaled results showed overall good agreement between the fiber optic system, the strain gages, and the analytical model. For field installation, the optical fiber instrumentation will occur in tandem with construction of the instrumented elements. The system will be commissioned and verified under ambient vehicle traffic. Additionally, in the event of an earthquake that exceeds the minimum trigger threshold set for the instrumentation, the data loggers will record the readings on all instruments at 0.01 second intervals, with a back memory of 10 seconds prior to the triggering event.

7.4 Displacement

Description: Displacement monitoring devices are any device which measures strain (other than fiber optics), deformation, or movement of structure. There are various devices used to measure displacement.

Positive results: The displacement measurement devices were used to document performance of seismic isolation bearings and to measure tension strains where values were significantly below the levels that would be expected to cause cracking in deck applications. The equipment also enhanced the understanding of the load carried by a concrete deck.

Negative results: Some monitoring devices were installed after some initial load was applied, giving skewed results. One report stated in hindsight that it would have been ideal to have gages applied in a fabrication shop to determine the effects of self-weight. The gage results exhibited some “noise” due to minor thermal, wind and construction loads that had to be averaged out. A few of the gages did not work and had to be ignored in the analysis of the data. Reports also stated that the long term reliability is unknown. Sensors have also drifted from ‘zero’ reference over time.

Representative project: The state of Alaska used this technology for the project named “Kodiak HRBR CHNNL#1189”. Displacement monitoring was used on friction pendulum bearings to monitor thermal performance and verify friction resistance. Survey points were used to monitor displacement after seismic events. Initial monitoring performed as intended. Six months after installation, rubbing marks were found where the pendulum slid over the stainless steel dish, thus showing signs of movement. These signs were consistent with the survey data showing the thermal expansion and contraction of the bridge. However, to date, there have been no seismic events with a large enough magnitude close enough to the bridge site to validate the seismic performance of the Friction Pendulum bearings with displacement data.

7.5 Smart Aggregates

Description: Smart aggregates are used for monitoring corrosion in steel reinforced concrete. This monitoring system was used on one bridge project.

Positive results: Successful implementation demonstrated on one project. The smart aggregate technology demonstrated the capability to measure chlorides. Field tests were performed on two bridges and the readings from the sensors were comparable to measured chlorides from destructive testing.

Negative results: The project took longer than originally anticipated and requires additional testing before stating conclusively that the sensors are effective.

Representative project: The state of Maryland used this technology for the project named “Innovative Bridge Research & Construction Program, Phase II PE/Construction”. Smart Aggregates were used to monitor corrosion in steel reinforced concrete. The funding was used to develop, test, and evaluate a prototype sensor. Readings from the sensors were comparable to measured chlorides from destructive testing. The IBRD funds only supported the initial portion of the project and due to the success, the next phase of research continues. A full scale test of the sensors in the lab environment will follow as well as field testing at multiple locations. The long term goal of the study is to produce a sensor which will be a viable tool for transportation organizations.

IBRC and IBRD Projects with Data Sheets Reported by States for Bridge Monitoring Technology

	State	County	Project
7.1	MO	St. Louis & Carroll	SB Interstate 255 over the Missouri River in St. Louis County and US 24 E over the Grand River in Carroll County
7.2	HI		Kahoma Stream Bridge on Lahaina ByPass
	MI		Parkview over US131
	NM	Quay	I-40 Tucumcari/E. Interchange
7.3	HI		Route 19 / Kealakaha Stream Bridge
	IA	Polk	East 12th Street over I-235
	NM	Dona Ana	Dona Ana Interchange Bridge
7.4	AK		Kodiak Harbor Channel Bridge No. 1189
	IL		I-39 over Kishwaukee River
	LA	Jefferson Par.	Caminada Bay, LA 1 near Grand Isle, LA
	LA	Iberia Par.	I-10 Twin Span Bridge - Structure Health Monitoring
	MT	Phillips	Three Structures on Secondary Route 243, one mile North of Saco, Montana.
	RI	Providence	Providence River Bridge
7.5	MD		Smart Aggregate evaluation - Phase II

2.8. COATINGS AND CORROSION

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs
Program Years 1999-2009

Technology Summary

8. Coatings & Corrosion

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June 2011

8. Coatings and Corrosion

General Description

Coatings and corrosion technologies are primarily used to protect bridges by providing a barrier preventing water and other substances from penetrating concrete and interacting with steel components. It accomplishes this by minimizing the effects of leakage, oxidation, and deterioration associated with the freeze/thaw cycle. In addition, several of the technologies prevent deterioration by using a current to drive the ion exchange to arrest the corrosion process.

Applications for coatings and corrosion found in the innovative technology projects include metalizing, overcoating, encapsulating, cathodic protection anodes, zinc based, paint systems, Xypex, inert gas, polymer seal, lithium alkali-silica reaction, galvanic protection and Surtreat TPS. Information given below is based on the summary sheets compiled from State submitted information.

Demonstrated Advantages

1. Corrosion resistance
2. Some methods are a permanent solution
3. Prevents water seepage
4. Increased service life of bridge
5. Reduced labor costs

Demonstrated Disadvantages

1. Some methods require coating to be applied in shop
2. Higher material costs
3. Some methods have produced questionable or unverifiable results

Methods of Implementation

Described herein are the various applications of coatings and corrosion that were used for in the IBRC and IBRD programs. The Positive and Negative results that are reported represent a general assimilation of comments provided in the IBRC and IBRD Summary Sheets, as reported by the States. A representative project is described to provide an example of how this technology was implemented.

8.1 Metalizing

Description: Metalizing was applied on one project by using a sprayed-on galvanic cathodic system as a means of extending the life of precast, prestressed concrete I-beams. The same project tested three different types of zinc-based metals as anodes for galvanic cathodic protection.

Positive results: No positive results were reported.

Negative results: The systems were not offering any improved amount of protection to the pre-stressing strands when compared to beams that were not treated. It appeared that the system was not protecting the steel and the anodes did not develop enough current necessary to drive the ion exchange to arrest the corrosion process.

Representative project: The state of Illinois used this technology for the project named "I-474 FR 174 to Illinois River". The project tested three different types of zinc-based metals as anodes to protect against corrosion. Results from the surveys indicated that the systems are not protecting the steel as intended.

8.2 Overcoating

Description: Overcoating is the process of increasing the epoxy coat on standard concrete reinforcing. This technology was used on one project which evaluated the performance of bonding to normal weight concrete. This was done by applying an extra thick coating of epoxy up to 21 mils on No. 5 and No. 9 reinforcing bars.

Positive results: Specimens containing bars with coatings thickness in the range of 18-21 mils did not show significantly different deflections at failure when compared to those of the companion specimens with bars having a coating thickness range of 12-15 mils. The increase in coating thickness resulted in a reduction in the average crack spacing in the concrete and average crack width with thicker coatings. No. 9 single bars increased in coating thickness resulted in a reduction in the average crack width in the concrete. The reduction was less significant than that observed in a No. 9 Bundled Bar specimens. Furthermore, the increase in coating thickness resulted in no change in the average concrete crack spacing. The increase in coating thickness resulted in an increase of average crack spacing and average crack width for thicker coating thicknesses, and as a result, the DOT increased the minimum epoxy coating thickness, although not to extent of 18 mils.

Negative results: No negative results were reported. Cost was increased with respect to the additional coating.

Representative project: The state of Indiana used this technology for the project named “US 30 over Jain Creek”. Overcoating was used by applying an extra thick coating of epoxy to evaluate the performance in bond to normal weight concrete. This application performed as intended. This project is highlighted in the Positive Results above. In addition, there is a third stage of the project ongoing to monitor the deck performance in-service conditions.

8.3 Encapsulating

Unfortunately, insufficient information was provided by the encapsulating projects to provide accurate results regarding implementation.

8.4 Cathodic Protection Anodes

Description: CP Anodes make use of electrochemical chloride extraction (ECE), where negatively charged chloride ions are driven away from negatively charged rebar and potentially out of the concrete to re-passivate the rebar and reduce the rate of corrosion.

Positive results: The system was successfully installed on several piers and then activated for several months. The data collected showed measureable results of chloride extraction.

Negative results: Several locations had chloride concentrations in excess of the established threshold, and resistivity probe failures that occurred at some of these locations indicated corrosion within the treated structures could still occur despite re-passivation of the reinforcing steel following ECE treatment.

Representative project: The state of Minnesota used this technology for the project named “I-94 and Glenwood Avenue I-35 at Maryland Avenue”. Cathodic protection anodes were used to protect against corrosion in concrete bridge piers. Collected data showed measureable results of chloride extraction. A research report documents the installation of the system and the results and conclusions. The study showed that it is possible to install such a system and operate it for an extended period of time with positive results. That is, the results demonstrated reduced chloride levels. Unfortunately the study also found several locations with corrosion.

8.5 Zinc Based

Unfortunately, insufficient information was provided by the zinc based projects to provide accurate results regarding implementation.

8.6 Paint Systems

Description: Paint systems are already used to primarily provide the first layer of protection against the environment on steel and concrete surfaces and have a secondary aesthetic purpose. Some paint systems also are a deterrent against graffiti. Various types of paint systems were used for the innovative bridge projects all with an aim to increase durability.

Positive results: Anti-graffiti coating was stated as providing a potential alternate to overcoating with a potential to reduce labor associated with graffiti removal in one report. However, for the most part corrosion protection systems did not have positive results. One state reported that two-coat system saved time and labor in application over the standard three-coat system, but fell short on performance.

Negative results: Results for the new paint systems were generally not good. Peeling occurred on some applications, pitting rust on others. Reports indicated short term failure of the non-standard coating systems. Whereas the graffiti proofer held promise, it also did not achieve full removal results without the assistance of brush and pressure washer. Using the pressure washer caused deterioration of the concrete substrate. Additionally, it did not have consistent effectiveness and was of a similar cost to traditional re-painting or over-painting of the graffiti.

Representative project: The state of Pennsylvania used this technology for the project named “SR 8043 (California Avenue) over SR 65 (Ohio River Boulevard)”. A two-coat paint system was used as an alternative to the three-coat system to reduce costs of labor for application. Paint system did not perform as intended. Several locations showed rusting after first year of application.

8.7 Xypex

Description: Xypex is a proprietary concrete waterproofing agent that can be used as a coating, dryshake, mixed in with concrete, or used for general concrete repairs. Xypex is advertised as preventing the penetration of water by causing a catalytic reaction that produces a non-soluble crystalline formation within the pores and capillary tracts of concrete and cement based materials. Product was used on one project as an admixture to act as a water sealant for a concrete culvert.

Positive results: No positive results were reported.

Negative results: The only application where Xypex was used was in a concrete culvert application. Cracks and leakage occurred on project and it was recommended not to use this product in future applications.

Representative project: The state of Colorado used this technology for the project named “Pedestrian Underpass on SH7”. Xypex is a proprietary material used to act as a water sealant for concrete culvert. As noted in the Negative Results, the material did not perform as intended; the concrete culvert is leaking.

8.8 Inert Gas

Description: Nitrogen gas, an inert gas, was used on one project as a corrosion inhibitor. This was done by using nitrogen charged stays which displaces all the oxygen from the system and, in theory, stops the corrosion process by eliminating the cathodic oxygen reaction.

Positive results: No positive results were reported.

Negative results: More than half of the stays did not hold pressure and had extensive leaking and potential repairs could not guarantee leaks would be fully eliminated. There were high costs for normal maintenance and high safety risk with leaking nitrogen displacing oxygen inside the segments.

Representative project: The state of Maine used this technology for the project named “Waldo-Hancock Bridge over Penobscot River”. Inert gas was used to create an oxygen free environment around steel cable stays to reduce corrosion. Application did not perform as intended, leakage was extensive.

8.9 Polymer Seal

Unfortunately, insufficient information was provided by the polymer seal projects to provide accurate results regarding implementation.

8.10 Lithium Alkali-Silica Reaction

Unfortunately, insufficient information was provided by the lithium alkali-silica reaction projects to provide accurate results regarding implementation.

8.11 Galvanic Protection

Description: Galvanic protection was used on three projects and in two different ways. One utilized a proprietary product called Galvashield. Galvashield is advertised as an embedded galvanic anode which utilizes an innovative zinc core design surrounded by a specially formulated cementitious mortar to provide high capacity, high current output performance. Galvashield is used in concrete rehabilitation to control active corrosion adjacent to completed patch repairs and to prevent the formation of new corrosion sites. The small puck shaped anode is fastened to the exposed reinforcing steel. Once installed, the zinc core corrodes preferentially to the surrounding rebar, thereby providing galvanic corrosion prevention to the adjacent reinforcing steel. The other technology was a proprietary product called CORRSPRAY. This is an aluminum-zinc-indium based arced sprayed galvanic anode which was applied over concrete repairs.

Positive results: The construction went smoothly for Galvashield.

Negative results: There was no proof that either system will work long-term. The CORRSPRAY protection system costs up to 3 times more than that of normal concrete repair techniques and also took more surface preparation than expected.

Representative project: The state of Missouri used this technology for the project named “Route I-44”. Galvashield XP anodes, a proprietary material, were installed on 26 bridges to prevent corrosion. As noted in the Negative Results, the project was unable to verify performance thus far and long range results are still needed.

8.12 Surtreat TPS

Description: Surtreat TPS surface treatment is a proprietary product which provides corrosion mitigation primarily by reacting at the anodic sites present in the reinforcing steel mesh. It also contributes to cathodic protection by reducing porosity. As advertised, Surtreat TPS migratory corrosion inhibitor formulations contain chemically active substances which migrate on the wall of the concrete's gel pores down to the surface of the rebar, where they react with the ferrous hydroxide/oxide passivating film to convert it into a more durable passive film. This film is significantly more resistant to chloride attack and breakdown and is no longer totally dependent on pH for its stability. Through this process, Surtreat TPS is able to take a corrosion-active reinforced concrete to a corrosion-passive state. This technology was used on one project to resist deterioration due to corrosion.

Positive results: No positive results were reported.

Negative results: Test results showed Surtreat TPS may not penetrate sufficient depths to reach the intended reinforcing steel. Delaminations and spalling were still present in deck surface. The treatment was not as effective as expected.

Representative project: The state of Oklahoma used this technology for the project named "SH-150 over Lake Eufaula". Surtreat TPS was used to abate corrosion of reinforcing steel. Treatment was not as effective as expected. The projects suggest that longer monitoring time is need to see if long term improvements occur.

8.13 Post Tensioning Coating

Description: Emulsifiable oils currently available on the market were used to reduce or prevent corrosion. The one reported project investigated the oils' uses for temporary corrosion protection measures and their effect on corrosion, bond and other factors.

Positive results: Two of the oils were found to prevent corrosion while not affecting the bond strength to the post tensioning grout.

Negative results: None reported.

Representative project: The state of Texas used this technology to the project named "All Future Precast Segmental Concrete Bridge Construction". It investigated the use of anti-corrosion oiled coatings in various post tension ducts. The benefits of oiling are listed in the Positive Results above. Additionally, the study indicated that the oils need not be washed off and that grouting when the oil was still fresh did not affect the results.

IBRC and IBRD Projects with Data Sheets Reported by States for Coating and Corrosion Technology

	State	County	Project
8.1	IL	Peoria	I474 FR 174 to Illinois River
8.2	IN	La Porte	US 30 over Jain Creek
8.4	MN		I94 and Glenwood Ave I35 at Maryland Ave
8.6	MD	Cecil	US 1 Bridge No.0700300 over Octoraro Creek Clean & Paint Bridge for Evaluation of Two Two-Coat Paint Systems
	NC	Wake	Fast Clad Urethane Paint System on Three Bridges over US 64
	PA	Allegheny	State Route 8043 (California Ave) over State Route 65 (Ohio River Blvd)
	TX	Webb	US 83 & SH 359 Interchange
8.7	CO	Boulder	Pedestrian Underpass on SH7 (Arapahoe Ave) @ Bear Canyon Creek. SH7 Mp 53.5 Just east of SH157 Interchange
8.8	ME	Waldo	Waldo-Hancock Bridge over Penobscot River
8.11	MO	St. Louis City	Route I-44
	MO	St. Louis	Big Bend NB over I-44
	RI	Providence	Eastbound I-95, Washington Bridge
	TX	Lubbock	US 82 West Bound at Park Road18 (Spur 327, Conn US 62)
8.12	OK	McIntosh	SH-150 over Lake Eufaula
8.13	TX	Statewide	All future precast segmental concrete bridge construction

2.9. FOUNDATIONS

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs
Program Years 1999-2009

Technology Summary

9. Foundations

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Federal Highway Administration



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9. Foundations

General Description

Applications for foundations found in the innovative technology projects include fender systems, micropiles and geofoam. Information given below is based on the summary sheets compiled from State submitted information.

Demonstrated Advantages

Each foundation project is unique in its implementation. In general, however, the following characteristics were noted in the projects but do not necessarily apply to each project.

1. Can be put into service quickly
2. More forgiving to differential foundation settlement
3. Can be built by maintenance personnel
4. Well suited to projects that are difficult to access with heavy equipment
5. Materials are good for demolition and for the recyclable nature of their components

Demonstrated Disadvantages

1. High material costs
2. Some foundation technologies may have limited use in colder climates

Methods of Implementation

Described herein are the various applications that foundation innovative technology was used for in the IBRC and IBRD programs. Positive and Negative results that are reported represent general assimilation of comments provided in the IBRC and IBRD Summary Sheets, as reported by the States. A representative project is described to provide an example of how this technology was implemented.

9.1 Fender Systems

Description: One project provided detailed results using a new fender system technology. Piles with highly reactive, supplementary cementitious materials (SCM) were driven for the Key Royale Bridge. Six different SCM were used to construct the bridge and fender piles. This allowed monitoring under realistic exposure conditions rather than accelerated corrosion testing. Corrosion sensors were embedded in the bridge piles for periodic future monitoring. Removable fender piles were also installed with the same mixtures and will be removed in 15-20 years to be examined for ingress of chlorides and corrosion damage. In addition, durability segments were constructed using the same concrete and prestressing strand as the fender piles. These segments were hung from the fender piles for consistent exposure conditions and instrumented with corrosion sensors and temperature sensors for long-term corrosion and temperature monitoring. These segments will also be cored for evaluating the chloride ion penetration and concrete hydration over time.

Positive results: Reduced strain and acceleration, pile driving stresses, and static pile capacities collected from Embedded Data Collectors(EDC) were compared to the data collected from the conventional monitoring system, Pile Driving Analyzer (PDA). CAsE Pile Wave Analysis Program (CAPWAP) analyses were performed on PDA data to separate the skin and tip resistances. The results of CAPWAP analyses were also compared to the EDC's results. It was found that the plastic properties, volume of voids, and absorption were not significantly affected by the implementation of any of the mineral admixtures. At 28 days, each mixture exhibited nearly equal compressive strength in which the silica fume mixtures showed the highest. However, at 365 days each mixture containing mineral admixtures were nearly equal. The use of mineral admixtures improved the resistance to shrinkage. The surface resistivity was greatly increased when compared to the control. The chloride ion penetrability was significantly improved. The metakaolin mixture showed the best results for modulus of elasticity (MOE), as

they were nearly equal to the control at all ages. The silica fume mixtures displayed the lowest MOE at 7 days, and the highest at 365 days. Based on the results from the decision matrix, the most efficient proportions of mineral admixtures to be used in conjunction with 18% fly ash were: 30% slag, 10% metakaolin, 12% ultrafine fly ash, and 9% silica fume.

Negative results: The Initial cost of concrete fender piles was higher than that of normal concrete. It was also found that ACI's equation overestimated the modulus of elasticity for nearly all mixtures, with the 7 day test showed the greatest amount of overestimation.

Representative project: The state of Florida used this technology for the project named "Key Royale Drive Bridge over Bimini Bay" and is the project highlighted above in the Results section.

9.2 Micropiles

Description: Micro piles are small diameter piles installed where small scale construction or clearance issues need to be addressed. They are typically fill grouted and may have additional reinforcing within the grout for strength. For the innovative bridge research project, use of Micro-piles to support pier and abutment footings on shallow rock depth was investigated. Five lateral load tests were conducted on micro-piles to demonstrate the impact of casing joints and rock socket embedment on lateral behavior.

Positive results: The micropiles were able to resist lateral loads exceeding expectations. Rock embedment of 0.66m, 1.5m, and 3.0m carried lateral loads well above typical lateral design lateral loads. Instrumentation was able to verify the pile behavior during testing.

Negative results: none were reported

Representative project: The state of North Carolina lead the investigation titled "Bridge 117 on SR 1118 over North Fork of New River (B-4012)". As this was the only project to report, the results are as stated in the Results section above. Additionally, it was found that 0.33m appears to be insufficient casing embedment to resist lateral loads on micro-piles. This may be as much for the reason that there is not enough rock penetration to guarantee a good rock socket as it was the behavior of the short piles. Instrumentation was used on the project to verify the analytical approach.

9.3 Geof foam

Description: The soil mass is replaced with layers with a polymeric geof foam, and then layered reinforcement is attached to facing elements that constitute the outer wall. The geof foam can be put into service quickly, can be built by maintenance personnel, and are especially well suited to projects constructed in areas that are difficult to access with heavy equipment.

Positive results: Construction and performance are both excellent. Both abutments in the project that reported were built and ready for loading in one week each. Settlement and expansion contraction data are as good as or better than expected

Negative results: none reported

Representative project: The State of Ohio used this technology for the project titled "Stever Road (CR153) over the Tiffin River". As this was the only project to report, the results are as stated in the Results section above.

IBRC and IBRD Projects with Data Sheets Reported by States for Foundations Technology

	State	County	Project
9.1	FL	Manatee	Key Royale Drive Bridge over Bimini Bay
	NC	Carteret	Bridge 60 on US 70 Business over Trent River
9.2	NC	Stokes	Bridge 117 on State Route 1118 over North Fork of New River (B-4012)
9.3	OH	Defiance	Stever Road (CR153) over the Tiffin River

2.10. DECK COATINGS

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs
Program Years 1999-2009

Technology Summary

10. Deck Coatings

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10. Deck Coatings

General Description

Deck coatings are typically used to provide a barrier against moisture and provide greater resistance to abrasion. This typically reduces overall maintenance costs and increases the service life of the bridge. In addition, a number of overlays also have the ability to work as a deicing agent, which can provide increased driver safety.

Applications for deck coatings found in the innovative technology projects include overlays (non-deicing), overlays (deicing) and polyester. Information given below is based on the summary sheets compiled from State submitted information.

Demonstrated Advantages

1. Longer deck service life
2. Polyester cures very quick, within 2 hours bridge can be reopened to traffic
3. Ice prevention on deicing overlays
4. Corrosion protection
5. Increased driver safety due to increased traction
6. Significant skid resistance
7. Reduction in winter maintenance in deicing overlay systems

Demonstrated Disadvantages

1. Significantly higher costs
2. Polyester overlay requires specialized tasks and an experienced contractor
3. Some overlays result in a rough riding surface

Methods of Implementation

Described herein are the various applications that deck coatings were used for in the IBRC and IBRD programs. Positive and Negative results that are reported represent general assimilation of comments provided in the IBRC and IBRD Summary Sheets, as reported by the States. A representative project is described to provide an example of how this technology was implemented.

10.1 Overlay (Non-deicing)

Description: Flexogrid was the only non-deicing technology used for the innovative research program was a proprietary. Applied as an overlay over existing deck surfaces, Flexogrid was used as a lightweight, flexible epoxy overlay system advertised as twice as strong as concrete with excellent skid resistance, and is flexible enough to withstand cracking in cold climates.

Positive results: Tremendous increase in overall skid resistance. The construction time was less than a traditional overlay.

Negative results: Rough riding surface was experienced after implementation. The costs associated with this technology were reported as higher than other bridge deck overlays. And, although not related to the innovative bridge research program, the State of Iowa reported severe deterioration from delaminations over a 3 year period using the product.

Representative project: The state of Oklahoma used Flexogrid for the project named "I-40 EB over I-44". This project used overlay (non-deicing) technology by applying the proprietary material over the bridge deck as a seal, to provide waterproofing, to increase skid resistance, and to extend the life of the bridge. Preliminary data have shown tremendous increase in the overall skid resistance of the concrete surface. The report also added that experienced

contractor with this material and proper equipment is essential to better application. Unfortunately, a long term final study was never conducted.

10.2 Overlay (Deicing)

Description: This is an overlay system which includes the advantage of having deicing capabilities. The technology used was called SafeLane, an epoxy-aggregate pavement applied over existing deck surfaces. It is advertised as providing a non-skid surface and an anti-icing capability through a release of a naturally reactive deicer. The anti-icing feature acts like a rigid sponge, storing anti-icing chemicals inside the aggregate, and then automatically releasing them as conditions develop from ice and snow.

Positive results: The technology was placed without any problems. In addition to a deicer, it provided a secondary benefit of an additional deck protection system. There was also a benefit in the reduction in winter maintenance. Travel safety over the bridge was increased as verified by the reduction of accidents on the bridge.

Negative results: The material is proprietary and is expensive. There were concerns with aggregate becoming polished reducing skid resistance over the long term.

Representative project: The state of Texas used this technology for the project named “IH 40 WB”. As this project provided the majority of the information used for the Positive and Negative results above, the information will not be repeated here. Regarding the cost, however, it was noted that the deicing chemical absorption characteristic of the aggregate and its ability to reduce the amount of chemical used during winter storms, potentially out-weigh the increased material cost. Based on the success of this project, Texas has used this on other bridges as well.

10.3 Polyester

Description: Polyester concrete overlays are similar to applications of traditional overlays with the exception that they only require 2 to 3 hours to cure before returning traffic to the roadway.

Positive results: Successful implementation was demonstrated on multiple projects. Quick curing times resulted in less impact to traveling public. The overlay has maintained its skid resistance since application. The polyester overall bonded well to the concrete deck.

Negative results: The material cost are significantly higher than traditional overlays. The costs of repairs are generally high, in addition. Specialized contractors were needed in both the preparation and application of overlay.

Representative project: The state of Alaska used this technology for the project named “Parks Highway Sustina River Bridge Repair”. This project used polyester technology by applying a polyester concrete overlay over the bridge deck to take advantage of the quick cure time to reduce traffic closure, and to increase service life of deck. The overlay has performed successfully. It was specifically noted in the report that application of the polyester concrete is very specialized, which requires both workers and inspectors who have had extensive experience working with these materials.

IBRC and IBRD Projects with Data Sheets Reported by States for Deck Coatings Technology

	State	County	Project
10.1	OK	Oklahoma	I - 40 EB over I-44
10.2	ID	Bonner	State Hwy. 200 over Mosquito Creek
	NC	Buncombe	US 19 NBL over SR1781, Buncombe Co.; And US 25 over Ivy River, Madison Co. (I-26 over SR 1839)
	PA	Tioga	SR 15 over Johnson Creek and SR 2016
	TX	Gray	US 40 (Old Rout 66), West Bound overpass bridge in Gray County
10.3	AK	Matanuska-Syustina Borough	Parks Highway at Sustina River, MP 69.3
	ID	Bannock	I-15 Bridge over Center Street IC
	WV	Logan	Man Bridge in Logan Co

2.11. OTHER TECHNOLOGIES (MISCELLANEOUS)

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs
Program Years 1999-2009

Technology Summary

11. Other Technologies

Prepared For:
Federal Highway Administration



Prepared By:
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June 2011

11. Other

General Description

Applications for other technologies found in the innovative bridge projects include laser welding, timber decks, sandwich plates, toll systems, bearings, over-height impact systems, construction techniques, advanced engineered lumber, debris deflection, and sign structures. See *Methods of Implementation* below for general information on each technology.

Demonstrated Advantages and Disadvantages

Since the technologies in this section are not related, see *Methods of Implementation* for general information regarding the positive and negative results of each. Information given below is based on the summary sheets compiled from State submitted information

Methods of Implementation

Described herein are the various applications that other innovative technologies were used for in the IBRC and IBRD programs. Positive and Negative results that are reported represent general assimilation of comments provided in the IBRC and IBRD Summary Sheets, as reported by the States. A representative project is described to provide an example of how this technology was implemented.

11.1 Laser Weld

Unfortunately, insufficient information was provided by the laser weld project to provide accurate results regarding implementation. Investigations are ongoing at Virginia Tech to evaluate the procedure.

11.2 Timber Deck

Description: The bridge superstructure was constructed with steel I-beams made composite with glue-laminated timber deck panels on one project.

Positive results: The duration of the bridge closure was reduced since no cast-in-place concrete was involved. Because of this, lengthy detours over a prolonged period were prevented. The construction process was more simplified than working with traditional formwork. And, the live load capacity of the steel beams increased as a result of the lighter deck. The deck remains in “very good” condition after one year of service according to the inspection report.

Negative results: No negative results reported.

Representative project: The state of Pennsylvania used this technology for the project named “Bird Run Road over Bird Run”. A glue laminated (glulam) timber deck was used to increase live load capacity of the steel superstructure by reducing deck self-weight. As this was the only project, results are as presented in the results section above.

11.3 Sandwich Plates

Description: Sandwich plates are a deck system which utilizes two steel plates and bonds them to an elastomer core. The flexural stiffness and strength of a sandwich plate are many times those of a single steel plate and can be modified to meet numerous structural requirements by selecting appropriate thicknesses for the sandwich elements. Shear is transferred from one steel plate to the other by the bonded elastomer without the need for welds. The elastomer also provides continuous support to the steel plates, preventing local buckling, and eliminating the need of stiffeners. This technology was used on one project for accelerated bridge construction.

Positive results: One project provided sufficient information in the summary report. The construction time for installing the superstructure was 3 days for three 50' spans (excluding installing the barrier and overlay). Bidding prices were all relatively close, indicating that contractors are comfortable with the technology.

Negative results: Excessive camber was also noticed but not attributed to the sandwich plate technology. There was difficulty in finding a thin polymer overlay system that met specification requirements. Insufficient dead load led to a lack of contact between superstructure and bearings. Additionally, compared to other accelerated bridge construction technologies that are currently available, the sandwich plate system is relatively expensive.

Representative project: The state of Texas used this technology for the project named "Eighteen Mile Creek Bridge Carrying FM 1961". As this is the only project reporting results, please refer to the above Results section. One additional comment that was reported is that the size of prefabricated elements should have been smaller to lessen fit-up problems in the field.

11.4 Toll Systems

Unfortunately, insufficient information was provided for the toll systems project to provide results regarding implementation.

11.5 Bearings

Description: Two different projects used different innovative technologies for bearings. The two types of bearing utilized were friction pendulum bearings and seismic roller isolation bearings, each of which attempt to isolate seismic affects. Friction pendulum bearings use the characteristics of a pendulum to lengthen the natural period of the isolated structure so as to avoid the strong earthquake forces. During an earthquake, the supported structure moves with small pendulum motions. Since earthquake induced displacements occur primarily in the bearings, lateral loads and shaking movements transmitted to the structure are greatly reduced. Seismic roller isolation bearings utilize cylindrical rollers on V-shaped sloping surfaces to achieve seismic isolation.

Positive results: Successful implementation demonstrated for 10 years for friction pendulum bearings.

Negative results: Material and fabrication have caused negative issues in construction. In particular, seismic roller isolation bearings require special welding which caused delays. No major earthquake has yet occurred that would test the bearings for their design.

Representative project: The state of Alaska used this technology for the project named "Statewide Seismic Retrofit". Friction pendulum isolation bearings were installed to replace seismically vulnerable tall rocker bearings. The retrofit of the bridge was successful and performed as intended. No major earthquake has yet occurred that would test the bearings for their design.

11.6 Over-height Systems

Description: An over-height collision protection system utilizing sandwich polymer composites was used on one innovative technology project. This is a sacrificial collision device utilizing advanced impact laminate materials and was applied to the bottom portions of concrete girders. The devices contain a multi-layer aluminum honeycomb core. The device also has the potential to have integrated sensors to record any impacts.

Positive results: Numerical simulations demonstrated that the transferred contact force is reduced for beams with this protection. Full-scale lab tests validated the proposed concept which showed potential benefits for collision protection and impact mitigation.

Negative results: No real world measurements were recorded. Results are from laboratory demonstrations only.

Representative project: The state of Ohio used this technology for the project named “Over-height Collision Protection System of Sandwich Polymer Composites”. The over-height system used advanced impact laminate materials applied to the bottom portion of the concrete girder to protect against collisions. Material performed as intended, laboratory testing and numerical analysis both demonstrate that this system has the potential to mitigate impact damage on concrete girders.

11.7 Construction Techniques

Description: This technology used innovative steel gantries for construction phasing and erection techniques. The erection time and cost for the two new steel plate girders was reduced by using field assembled, track-moving, steel gantries for girder pick-up and drop-off in a very confined work zone. Segments of the girder were picked up from truck bed at each abutment, and then delivered to designated locations by the rolling gantry system moving along channel-shaped tracks which were temporarily attached to the bridge deck on each side of the 10-ft wide construction opening.

Positive results: A single lane of traffic was maintained at all times during construction instead of closing the bridge entirely.

Negative results: No negative results reported.

Representative Project: The state of Arizona used this technology for the project named “Virgin River Gorge structure #7 I-15 at Mile Post 22.55 Crossing Virgin River”. As this is the only project reporting results, please refer to the above Results section. Additionally, in order to facilitate the erection of field splices, diaphragms and lateral bracings (and for the safety of construction crew working over deep canyon) a 14-ft wide temporary wooden walkway was constructed on bottom flanges of the deeper existing plate girders located at each side of the opening. This walkway provided adequate work spaces on both sides and below the new girders. Regarding costs, the report indicated that the initial cost may be higher, but the overall cost and impact on the traveling public is reduced.

11.8 Advanced Engineered Lumber

Description: Advanced engineered lumber (AEL) is a mixed hardwood glue-laminated. It was installed as ties on one span of a railroad bridge.

Positive results: No evidence of tie moment, plate cutting in the ties, or tie spike pull out.

Negative results: Half of the ties developed cracks parallel to the edge joint of the multiple width boards which coincides with the J-bolt screw location. Large delaminations both in length and depth were observed on the overhanging portions of the ties. It was recommended that advanced engineered lumber ties to be removed from service.

Representative project: The state of Maine used this technology for the project named “New Meadows Bridge, Sagadahoc, ME”. AEL used mixed hardwood glue-laminated ties for increased strength. Ties did not perform as intended as described in the Negative Results.

11.9 Debris Deflection

Unfortunately, insufficient information was provided for the debris deflection project to provide results regarding implementation.

11.10 Concrete-Filled Tubular Flange Girders

Description: Concrete-filled tubular flange girders (CFTFG) consist of a conventional web and bottom plates. The top flange, however, is fabricated from a concrete filled tube. A demonstration bridge was designed and constructed using the CFTFG technology.

Positive results: The girders have sufficient lateral-torsional stability under the construction loading even with no interior bracing so as to be placed individually. This makes fabrication and erection easier. Field splices at the pier can simplify fabrication and erection and reduce dead load effects at the pier.

Negative results: No negative results reported.

Representative project: The state of Pennsylvania used this technology for the project named “SR 1003 over Tionesta Creek”. CFTFG used in steel girder design to reduce steel material costs. A demonstration bridge was constructed using CFTFG to test performance of technology. Positive results have been reported all the way through the construction of the demonstration bridge. The demonstration bridge was able to be erected one beam at a time without additional lateral-torsional bracing, performing as predicted.

11.11 Sign Structures

Description: Vibration dampeners were attached to sign structures used to increase fatigue life of sign poles by reducing the amplitude of vibrations and dispersing the harmonic vibrations.

Positive results: Devices increased dampening of structure which decreased both in and out of plane vibration, thus increasing fatigue life of sign pole.

Negative results: There was some noise associated with devices. The patent may reduce implementation by other agencies. Other studies have demonstrated systems that perform equally as well but without the noise issue.

Representative project: The state of Wyoming used this technology for the project named “Statewide Sign Structure Vibration Dampener”. A dampener was attached to sign structures to increase fatigue life of sign poles. Results show increase in fatigue life, however universal application is not being widely used due to noise produced by device.

IBRC and IBRD Projects with Data Sheets Reported by States for Other Technologies

	State	County	Project
11.2	PA	Cumberland	Burd Run Road over Burd Run
11.3	OK	Okmulgee	SH-7 over Branch Creek
	TX	Goliad	Martin Branch Bridge, Wise County, County Road 419
11.5	AK	Statewide	Statewide Sesimic Retrofit
	RI	Providence	Great Rd. Bridge 446
11.6	OH	Statewide	Over-Height Collision Protection System of Sandwich Polymer Composites
11.7	AZ	Mohave	Virgin River Gorge Structure #7 Interstate 15, @ MP 22.55 Crossing Virgin River
11.8	ME	Sagadahoc	New Meadows Bridge, Sagadahoc, ME
11.9	OR	Linn	Blevins Bridge - Tangent Drive Calapooia River
11.10	PA	Forest	SR 1003 over Tionesta Creek
11.11	WY	Statewide	Statewide Sign Structure Vibration Dampener

3. CASE STUDY SELECTION

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs
Program Years 1999-2009

Recommended List of Projects for Developing Detailed Case Studies

**Prepared For:
Federal Highway Administration**



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September 2011

Description

A maximum of 50 projects are to be recommended for development of a detailed case study. Case study projects are recommended based on the data obtained from the States as submitted by the project report form, and by how projects are incorporated in each of the technology categories identified in the Technology Summaries. A minimum of three (3) and a maximum of five (5) from each technology are recommended, with two exceptions. A project is included from each subcategory that received at least one Summary Sheet from a State. Listed below are 50 recommended projects from which a maximum of 30 will be selected for development.

To assist with the selection process, a number of the ranked case studies (35) were selected based on the quality of information provided by the States. The 50 Summary Reports are identified under the 'ID #' column in the table below. If the following column is a ranking of 1-35, with 1 being the most complete project with a positive outcome. 15 projects were ruled out immediately due to lack of data. The ranking is based on a selection process defined as follows:

A mechanism was devised to determine which of the projects showed positive outcomes and a thorough collection of project information based on the State Reports. Projects were first rated on a scale of 1-5 based on the positive impact of the technology on the project. The second rating from 1-5 was based on having sufficient data to populate a technology case study. From these 35, receiving the two scores, an additional weight was given based on discussions with FHWA. Thus, the projects were assigned in order of quality of the Summary from 1 to 35 with 1 being the most successful project with ample supporting data, and 35 being the least level of success with a project or a project with little or no supporting data.

Prioritizing Spreadsheets

Three Color-Coded Spreadsheets are presented in the second part of this section. Project selection in each is sorted according to:

- 1) Project Number ID
- 2) Order of Ranking Results
- 3) Ranking Results within each Technology Category

List of Recommended Projects for Developing Detailed Case Studies

Technology	ID #	Order of Results	Sub-Category or Bridge Component	State	Project	Federal-Aid Project #
HPC	1	34	Decks	OK	I-40 Bridge over Business I-40 in Sayre	Not Reported
	2	1	Girders	IA	136 th Avenue over Buffalo Creek	IBRC-C010(58)
	3	4	Overlay	IL	Wacker Dr. Viaduct	Not Reported
FRP	4	26	Wraps	AL	AL-97 Bridge over I-65 over City of Letohatchie	-
	5	6	Wraps	CO	Castlewood Canyon Bridge, SH83 over Cherry Creek	BR 0831-085
	6	18	Concrete Strengthening	MO	X0596 Route C over Creek, P0962 Route B over Creek, T0530 Route M over Crooked Creek, Y0298 Route U over Creek, and X0945 Route C over river	9900(589)
	7	11	Decks	OR	Broadway Bridge over Willamette River	X-BHF-HPP-OTIA-C051(50)
	8	15	Decks	MD	Rehabilitation of Bridge No. 12016 on MD 24 over Deer Creek	BH-IBRC-1247(10)N
	9	30	Timber Strengthening	IA	215 Avenue Bridge over Lime Creek	IBRC-C028(041)
	10	<i>Not Recommended for Task 2C</i>	<i>Steel Strengthening</i>	-	-	-
SCC	11	19	Girder	MI	M-50 Bridge over Grand River	38071-57079A
	12	22	Concrete Arch	NE	Nebraska Highway 68 over the BNSF Railroad in Ravenna	68-2(102)
	13	8	Drilled Shaft	SC	US 76 over Lumber River and Swamp	BRT-BR88023

Technology	ID #	Priority #	Sub-Category or Bridge Component	State	Project	Federal-Aid Project #
HPS	14	3	Beams/Girders	MO	Route 224 over Route 13	0133(043)
	15	27	Corrugated Webs	PA	SR 2024 over Towanda Creek	X039(135)
	16	21	Folded Plates	NE	Folded Steel Plate Bridge Technology	STPD-BR-79-2(108)
ABC	17	25	Prefabricated or Precast Elements	TX	FM 1660 over Cottonwood Creek	1566-02-016; BR 2006(402)
	18	2	Concrete Filled FRP Tubes	ME	Neal Bridge in Pittsfield, ME	Not Reported
	19	35	SPMT	UT	I-215 NB over 3760 South Street at 3300 East Salt Lake City	Not Reported
	20	33	Aluminum Bridge Deck	KY	KY-92 over Jellico Creek	125
	21	9	Deck	WI	IH 39/94 over Door Creek (Fond du Lac)	2004(276)
Reinforcing Bars	22	12	FRP	NC	Bridge 16 on State Route 1470 over Cartoogechave Creek	2005-22 FHWA/ NC/ 2006-35
	23	20	FRP	WI	US Highway 151 over De Neveu Creek	Not Reported
	24	Not Recommended for Task 2C	Galvanized	-	-	-
	25	Not Recommended for Task 2C	MMFX	-	-	-
	26	24	Stainless	MO	Route 6.8 Miles to 0.2 Miles W Sullivan City	0062(035)
Bridge Monitoring	27	10	Displacement	NH	Rollins Road over Main Stret and B&M Railroad	5391002
	28	16	Fiber Optics	VT	Bridge 213 Carrying VT Route 100 over Ryder Brook	BRF 029-(11)
	29	5	Scour	MO	SB Interstate 255 over the Missouri River in St. Louis County and US 24 East over the Grand River in Carroll County	Not Reported
	30	Not Recommended for Task 2C	Smart Aggregates	-	-	-
	31	Not Recommended for Task 2C	Smart Sensors	-	-	-

Technology	ID #	Priority #	Sub-Category or Bridge Component	State	Project	Federal-Aid Project #
Coatings & Corrosion	32	29	CP Anodes	MN	I-94 and Glenwood Avenue I-35 at Maryland Ave.	Not Reported
	33	<i>Not Recommended for Task 2C</i>	<i>Galvanic Protection</i>	-	-	-
	34	<i>Not Recommended for Task 2C</i>	<i>Inert Gas</i>	-	-	-
	35	13	Overcoating	IN	US 30 over Jain Creek	Not Reported
	36	<i>Not Recommended for Task 2C</i>	<i>Surtreat TPS</i>	-	-	-
	37	<i>Not Recommended for Task 2C</i>	<i>Post Tension Coatings</i>	-	-	-
Foundations	38	31	Micropiles	NC	Bridge 117 on SR 1118 over North Fork of New River (B-4012)	B-4280
	39	23	Fender System	FL	Key Royale Drive Bridge over Bimini Bay	Not Reported
Deck Coatings	40	7	Overlay (Deicing)	TX	US 40 (Old Rout 66), West Bound overpass bridge in Gray County	Not Reported
	41	32	Overlay (Non-deicing)	OK	I-40 EB over I-44	IBR-155N(391)IR
	42	<i>Not Recommended for Task 2C</i>	<i>Polyester</i>	-	-	-
Other Technologies	43	<i>Not Recommended for Task 2C</i>	<i>Advanced Engineered Lumber</i>	-	-	-
	44	17	Bearings	AK	Statewide Seismic Retrofit	Not Reported
	45	14	Concrete-Filled Tubular Flange Girders	PA	SR 1003 over Tionesta Creek	X013(117)
	46	<i>Not Recommended for Task 2C</i>	<i>Construction Technique</i>	-	-	-
	47	<i>Not Recommended for Task 2C</i>	<i>Over-Height Systems</i>	-	-	-
	48	<i>Not Recommended for Task 2C</i>	<i>Sandwich Plates</i>	-	-	-
	49	<i>Not Recommended for Task 2C</i>	<i>Sign Structures</i>	-	-	-
	50	28	Timber Deck	PA	Burd Run Road over Burd Run	X082(170)

Prioritizing Spreadsheet Sorted by (1) Project ID Number

Technology	ID	Positive Results (Scale 1-5)	Sufficient Data (Scale 1-5)	Order of Completeness	Sub-Category or Bridge Component	State	Project	Reasoning
HPC	1	4	2	34	Decks	OK	I-40 Bridge over Business I-40 in Sayre	+/-: barriers to implementation Data: good summary, 1 good report
HPC	2	1	1	1	Girders	IA	136 th Avenue over Buffalo Creek (UHPC)	+/-: Cost only deterrent, very positive Data: excellent Summary, multiple reports
HPC	3	1	1	4	Overlay	IL	Wacker Dr. Viaduct	+/-: specifications were only problem, Chicago now uses for all projects Data: good summary, 8 reports
FRP	4	3	2	26	Wraps	AL	AL-97 Bridge over I-65 over City of Letohatchie	+/-: Listed as ongoing project, poor correlation between implantation and experimental tests Data: good summary, 1 good report
FRP	5	1	2	6	Wraps	CO	Castlewood Canyon Bridge, SH83 over Cherry Creek	+/-: 'highly successful project', good lessons learned Data: good summary, 1 good report
FRP	6	2	1	18	Concrete Strengthening	MO	X0596 Route C over Creek, P0962 Route B over Creek, T0530 Route M over Crooked Creek, Y0298 Route U	+/-: project used to draft AASHTO Specs., long term effects unclear Data: extensive 5 volume report
FRP	7	2	1	11	Decks	OR	Broadway Bridge over Willamette River	+/-: good and bad results, problems with overlay Data: excellent summary, 3 reports
FRP	8	2	1	15	Decks	MD	Rehabilitation of Bridge No. 12016 on MD 24 over Deer Creek	+/-: good results, concerns about cost and method of production Data: excellent summary, 2 reports
FRP	9	4	2	30	Timber Strengthening	IA	215 Avenue Bridge over Lime Creek	+/-: suggest use only where aesthetics are important, challenges in constructing, very high cost Data: good summary, 1 good report
FRP	10	Not Recommended	For Task 2C	N/A	Steel Strengthening	-	-	-
SCC	11	2	2	19	Girder	MI	M-50 Bridge over Grand River	+/-: very good results, but difficulty with implementing, no long term data Data: good summary, 1 good report
SCC	12	3	2	20	Concrete Arch	NE	Nebraska Highway 68 over the BNSF Railroad in Ravenna	+/-: many + results but it is not cost effective, precast floor system is more effective Data: good summary, 1 good report
SCC	13	2	1	8	Drilled Shaft	SC	US 76 over Lumber River and Swamp	+/-: lessons learned state more experience is needed with product and contractors Data: excellent summary, 2 reports
HPS	14	1	1	3	Beams/Girders	MO	Route 224 over Route 13	+/-: highly positive results Data: good summary, 6 good reports
HPS	15	3	2	27	Corrugated Webs	PA	SR 2024 over Towanda Creek	+/-: successful implementation, additional needs for shear prediction Data: good summary, 5 avg. reports
HPS	16	2	2	21	Folded Plates	NE	Folded Steel Plate Bridge Technology	+/-: + results, project listed as ongoing Data: 1 paper (will obtain final report)
ABC	17	1	3	25	Prefabricated or Precast Elements	TX	FM 1660 over Cottonwood Creek	+/-: good results, led to new State standards Data: OK summary, 2 presentations
ABC	18	1	1	2	Concrete Filled FRP Tubes	ME	Neal Bridge in Pittsfield, ME	+/-: excellent results, national press coverage Data: excellent summary, 4 reports
ABC	19	2	5	35	SPMT	UT	I-215 NB over 3760 South Street at 3300 East Salt Lake City	+/-: many types of ABC investigated, good results Data: poor summary, no reports from state
ABC	20	2	5	33	Aluminum Bridge Deck	KY	KY-92 over Jellico Creek	+/-: success in implementing but very high cost. Data: OK Summary, no report
ABC	21	2	1	9	Deck	WI	IH 39/94 over Door Creek (Fond du Lac)	+/-: good results, ACEC of WI award winner but difficulty implementing Data: good summary, 6 reports
Reinforcing Bars	22	1	2	12	FRP	NC	Bridge 16 on State Route 1470 over Cartoogechave Creek	+/-: no negative results Data: good summary, 2 good reports
Reinforcing Bars	23	Not Recommended	For Task 2C	N/A	Galvanized	-	-	-
Reinforcing Bars	24	Not Recommended	For Task 2C	N/A	MMFX	-	-	-
Reinforcing Bars	25	2	2	24	Stainless	MO	Route 6.8 Miles to 0.2 Miles W Sullivan City	+/-: no construction issues but higher cost and no long term results Data: good summary, 2 good reports

Prioritizing Spreadsheet Sorted by (1) Project ID Number

Technology	ID	Positive Results (Scale 1-5)	Sufficient Data (Scale 1-5)	Order of Completeness	Sub-Category or Bridge Component	State	Project	Reasoning
Bridge Monitoring	26	3	2	29	Displacement	WI	US Highway 151 over De Neveu Creek	<i>This should be another FRP - it may have monitoring in it but I would add it back to FRP as another very good</i>
Bridge Monitoring	27	1	2	10	Displacement	NH	Rollins Road over Main Street and B&M Railroad	+/-: Good load test results for FRP reinf. and HPC Project Data: OK summary, 1 good report
Bridge Monitoring	28	2	1	16	Fiber Optics	VT	Bridge 213 Carrying VT Route 100 over Ryder Brook	+/-: good project results, some issues with implementation Data: good summary, 6 good reports
Bridge Monitoring	29	1	1	5	Scour	MO	SB Interstate 255 over the Missouri River in St. Louis County and US 24 East over the Grand River in Carroll	+/-: no negative results Data: good summary, 2 good reports
Bridge Monitoring	30	Not Recommended	For Task 2C	N/A	Smart Aggregates	-	-	-
Bridge Monitoring	31	Not Recommended	For Task 2C	N/A	Smart Sensors	-	-	-
Coatings & Corrosion	32	3	1	22	CP Anodes	MN	I-94 and Glenwood Avenue I-35 at Maryland Ave.	+/-: effectiveness problems for project Data: good summary, 1 excellent report
Coatings & Corrosion	33	Not Recommended	For Task 2C	N/A	Galvanic Protection	-	-	-
Coatings & Corrosion	34	Not Recommended	For Task 2C	N/A	Inert Gas	-	-	-
Coatings & Corrosion	35	1	2	13	Overcoating	IN	US 30 over Jain Creek	+/-: excellent results reported Data: excellent summary, 3 reports
Coatings & Corrosion	36	Not Recommended	For Task 2C	N/A	Surtreat TPS	-	-	-
Coatings & Corrosion	37	Not Recommended	For Task 2C	N/A	Post Tension Coatings	-	-	-
Foundations	38	3	3	31	Micropiles	NC	Bridge 117 on SR 1118 over North Fork of New River (B-4012)	+/-: good results, limited applicability Data: OK summary, 1 report
Foundations	39	2	2	23	Fender System	FL	Key Royale Drive Bridge over Bimini Bay	+/-: good results, cost is high Data: very good summary, 1 report
Deck Coatings	40	1	2	7	Overlay (Deicing)	TX	US 40 (Old Rout 66), West Bound overpass bridge in Gray County	+/-: good results, plans for future use Data: good summary, 1 presentation
Deck Coatings	41	4	2	32	Overlay (Non-deicing)	OK	I-40 EB over I-44	+/-: as many - as + results Data: OK summary, 1 good report
Deck Coatings	42	Not Recommended	For Task 2C	N/A	Polyester	-	-	-
Other Technologies	43	Not Recommended	For Task 2C	N/A	Advanced Engineered Lumber	-	-	-
Other Technologies	44	2	2	17	Bearings	AK	Statewide Seismic Retrofit	+/-: performing as intended but no EQ load to demonstrate isolation Data: OK summary, 1 good report
Other Technologies	45	1	2	14	Concrete-Filled Tubular Flange Girders	PA	SR 1003 over Tionesta Creek	+/-: no negative results Data: OK summary, 1 good report
Other Technologies	46	Not Recommended	For Task 2C	N/A	Construction Technique	-	-	-
Other Technologies	47	Not Recommended	For Task 2C	N/A	Over-Height Systems	-	-	-
Other Technologies	48	Not Recommended	For Task 2C	N/A	Sandwich Plates	-	-	-
Other Technologies	49	Not Recommended	For Task 2C	N/A	Sign Structures	-	-	-
Other Technologies	50	2	3	28	Timber Deck	PA	Burd Run Road over Burd Run	+/-: no negative results reported Data: poor summary, 1 report

Prioritizing Spreadsheet Sorted by (2) Results

Technology	ID	Positive Results (Scale 1-5)	Sufficient Data (Scale 1-5)	Order of Completeness	Sub-Category or Bridge Component	State	Project	Reasoning
HPC	2	1	1	1	Girders	IA	136 th Avenue over Buffalo Creek (UHPC)	+/-: Cost only deterrent, very positive Data: excellent Summary, multiple reports
ABC	18	1	1	2	Concrete Filled FRP Tubes	ME	Neal Bridge in Pittsfield, ME	+/-: excellent results, national press coverage Data: excellent summary, 4 reports
HPS	14	1	1	3	Beams/Girders	MO	Route 224 over Route 13	+/-: highly positive results Data: good summary, 6 good reports
HPC	3	1	1	4	Overlay	IL	Wacker Dr. Viaduct	+/-: specifications were only problem, Chicago now uses for all projects Data: good summary, 8 reports
Bridge Monitoring	29	1	1	5	Scour	MO	SB Interstate 255 over the Missouri River in St. Louis County and US 24 East over the Grand River in Carroll	+/-: no negative results Data: good summary, 2 good reports
FRP	5	1	2	6	Wraps	CO	Castlewood Canyon Bridge, SH83 over Cherry Creek	+/-: 'highly successful project', good lessons learned Data: good summary, 1 good report
Deck Coatings	40	1	2	7	Overlay (Deicing)	TX	US 40 (Old Rout 66), West Bound overpass bridge in Gray County	+/-: good results, plans for future use Data: good summary, 1 presentation
SCC	13	2	1	8	Drilled Shaft	SC	US 76 over Lumber River and Swamp	+/-: lessons learned state more experience is needed with product and contractors
ABC	21	2	1	9	Deck	WI	IH 39/94 over Door Creek (Fond du Lac)	+/-: good results, ACEC of WI award winner but difficulty implementing Data: good summary, 6 reports
Bridge Monitoring	27	1	2	10	Displacement	NH	Rollins Road over Main Street and B&M Railroad	+/-: Good load test results for FRP reinf. and HPC Project Data: OK summary, 1 good report
FRP	7	2	1	11	Decks	OR	Broadway Bridge over Williamette River	+/-: good and bad results, problems with overlay Data: excellent summary, 3 reports
Reinforcing Bars	22	1	2	12	FRP	NC	Bridge 16 on State Route 1470 over Cartoogechave Creek	+/-: no negative results Data: good summary, 2 good reports
Coatings & Corrosion	35	1	2	13	Overcoating	IN	US 30 over Jain Creek	+/-: excellent results reported Data: excellent summary, 3 reports
Other Technologies	45	1	2	14	Concrete-Filled Tubular Flange Girders	PA	SR 1003 over Tionesta Creek	+/-: no negative results Data: OK summary, 1 good report
FRP	8	2	1	15	Decks	MD	Rehabilitation of Bridge No. 12016 on MD 24 over Deer Creek	+/-: good results, concerns about cost and method of production Data: excellent summary, 2 reports
Bridge Monitoring	28	2	1	16	Fiber Optics	VT	Bridge 213 Carrying VT Route 100 over Ryder Brook	+/-: good project results, some issues with implementation Data: good summary, 6 good reports
Other Technologies	44	2	2	17	Bearings	AK	Statewide Seismic Retrofit	+/-: performing as intended but no EQ load to demonstrate isolation Data: OK summary, 1 good report
FRP	6	2	1	18	Concrete Strengthening	MO	X0596 Route C over Creek, P0962 Route B over Creek, T0530 Route M over Crooked Creek, Y0298 Route U	+/-: project used to draft AASHTO Specs., long term effects unclear Data: extensive 5 volume report
SCC	11	2	2	19	Girder	MI	M-50 Bridge over Grand River	+/-: very good results, but difficulty with implementing, no long term data Data: good summary, 1 good report
SCC	12	3	2	20	Concrete Arch	NE	Nebraska Highway 68 over the BNSF Railroad in Ravenna	+/-: many + results but it is not cost effective, precast floor system is more effective
HPS	16	2	2	21	Folded Plates	NE	Folded Steel Plate Bridge Technology	+/-: + results, project listed as ongoing Data: 1 paper (will obtain final report)
Coatings & Corrosion	32	3	1	22	CP Anodes	MN	I-94 and Glenwood Avenue I-35 at Maryland Ave.	+/-: effectiveness problems for project Data: good summary, 1 excellent report
Foundations	39	2	2	23	Fender System	FL	Key Royale Drive Bridge over Bimini Bay	+/-: good results, cost is high Data: very good summary, 1 report
Reinforcing Bars	25	2	2	24	Stainless	MO	Route 6.8 Miles to 0.2 Miles W Sullivan City	+/-: no construction issues but higher cost and no long term results Data: good summary, 2 good reports

Prioritizing Spreadsheet Sorted by (2) Results

Technology	ID	Positive Results (Scale 1-5)	Sufficient Data (Scale 1-5)	Order of Completeness	Sub-Category or Bridge Component	State	Project	Reasoning
ABC	17	1	3	25	Prefabricated or Precast Elements	TX	FM 1660 over Cottonwood Creek	+/-: good results, led to new State standards Data: OK summary, 2 presentations
FRP	4	3	2	26	Wraps	AL	AL-97 Bridge over I-65 over City of Letohatchie	+/-: Listed as ongoing project, poor correlation between implantation and experimental tests
HPS	15	3	2	27	Corrugated Webs	PA	SR 2024 over Towanda Creek	+/-: successful implementation, additional needs for shear prediction Data: good summary, 5 avg. reports
Other Technologies	50	2	3	28	Timber Deck	PA	Burd Run Road over Burd Run	+/-: no negative results reported Data: poor summary, 1 report
Bridge Monitoring	26	3	2	29	Displacement	WI	US Highway 151 over De Neveu Creek	<i>This should be another FRP - it may have monitoring in it but I would add it back to FRP as another very good</i>
FRP	9	4	2	30	Timber Strengthening	IA	215 Avenue Bridge over Lime Creek	+/-: suggest use only where aesthetics are important, challenges in constructing, very high cost
Foundations	38	3	3	31	Micropiles	NC	Bridge 117 on SR 1118 over North Fork of New River (B-4012)	+/-: good results, limited applicability Data: OK summary, 1 report
Deck Coatings	41	4	2	32	Overlay (Non-deicing)	OK	I-40 EB over I-44	+/-: as many - as + results Data: OK summary, 1 good report
ABC	20	2	5	33	Aluminum Bridge Deck	KY	KY-92 over Jellico Creek	+/-: success in implementing but very high cost. Data: OK Summary, no report
HPC	1	4	2	34	Decks	OK	I-40 Bridge over Business I-40 in Sayre	+/-: barriers to implementation Data: good summary, 1 good report
ABC	19	2	5	35	SPMT	UT	I-215 NB over 3760 South Street at 3300 East Salt Lake City	+/-: many types of ABC investigated, good results Data: poor summary, no reports from
FRP	10	Not Recommended	For Task 2C	N/A	Steel Strengthening	-	-	-
Reinforcing Bars	23	Not Recommended	For Task 2C	N/A	Galvanized	-	-	-
Reinforcing Bars	24	Not Recommended	For Task 2C	N/A	MMFX	-	-	-
Bridge Monitoring	30	Not Recommended	For Task 2C	N/A	Smart Aggregates	-	-	-
Bridge Monitoring	31	Not Recommended	For Task 2C	N/A	Smart Sensors	-	-	-
Coatings & Corrosion	33	Not Recommended	For Task 2C	N/A	Galvanic Protection	-	-	-
Coatings & Corrosion	34	Not Recommended	For Task 2C	N/A	Inert Gas	-	-	-
Coatings & Corrosion	36	Not Recommended	For Task 2C	N/A	Surtreat TPS	-	-	-
Coatings & Corrosion	37	Not Recommended	For Task 2C	N/A	Post Tension Coatings	-	-	-
Deck Coatings	42	Not Recommended	For Task 2C	N/A	Polyester	-	-	-
Other Technologies	43	Not Recommended	For Task 2C	N/A	Advanced Engineered Lumber	-	-	-
Other Technologies	46	Not Recommended	For Task 2C	N/A	Construction Technique	-	-	-
Other Technologies	47	Not Recommended	For Task 2C	N/A	Over-Height Systems	-	-	-
Other Technologies	48	Not Recommended	For Task 2C	N/A	Sandwich Plates	-	-	-
Other Technologies	49	Not Recommended	For Task 2C	N/A	Sign Structures	-	-	-

Prioritizing Spreadsheet Sorted by (3) Results within Each Category

Technology	ID	Positive Results (Scale 1-5)	Sufficient Data (Scale 1-5)	Order of Completeness	Sub-Category or Bridge Component	State	Project	Reasoning
HPC	2	1	1	1	Girders	IA	136 th Avenue over Buffalo Creek (UHPC)	+/-: Cost only deterrent, very positive Data: excellent Summary, multiple reports
HPC	3	1	1	4	Overlay	IL	Wacker Dr. Viaduct	+/-: specifications were only problem, Chicago now uses for all projects Data: good summary, 8 reports
HPC	1	4	2	34	Decks	OK	I-40 Bridge over Business I-40 in Sayre	+/-: barriers to implementation Data: good summary, 1 good report
FRP	5	1	2	6	Wraps	CO	Castlewood Canyon Bridge, SH83 over Cherry Creek	+/-: 'highly successful project', good lessons learned Data: good summary, 1 good report
FRP	7	2	1	11	Decks	OR	Broadway Bridge over Willamette River	+/-: good and bad results, problems with overlay Data: excellent summary, 3 reports
FRP	8	2	1	15	Decks	MD	Rehabilitation of Bridge No. 12016 on MD 24 over Deer Creek	+/-: good results, concerns about cost and method of production Data: excellent summary, 2 reports
FRP	6	2	1	18	Concrete Strengthening	MO	X0596 Route C over Creek, P0962 Route B over Creek, T0530 Route M over Crooked Creek, Y0298 Route U	+/-: project used to draft AASHTO Specs., long term effects unclear Data: extensive 5 volume report
FRP	4	3	2	26	Wraps	AL	AL-97 Bridge over I-65 over City of Letohatchie	+/-: Listed as ongoing project, poor correlation between implementation and experimental tests
FRP	9	4	2	30	Timber Strengthening	IA	215 Avenue Bridge over Lime Creek	+/-: suggest use only where aesthetics are important, challenges in constructing, very high cost
FRP	10	Not Recommended	For Task 2C	N/A	Steel Strengthening	-	-	-
SCC	13	2	1	8	Drilled Shaft	SC	US 76 over Lumber River and Swamp	+/-: lessons learned state more experience is needed with product and contractors
SCC	11	2	2	19	Girder	MI	M-50 Bridge over Grand River	+/-: very good results, but difficulty with implementing, no long term data Data: good summary, 1 good report
SCC	12	3	2	20	Concrete Arch	NE	Nebraska Highway 68 over the BNSF Railroad in Ravenna	+/-: many + results but it is not cost effective, precast floor system is more effective
HPS	14	1	1	3	Beams/Girders	MO	Route 224 over Route 13	+/-: highly positive results Data: good summary, 6 good reports
HPS	16	2	2	21	Folded Plates	NE	Folded Steel Plate Bridge Technology	+/-: + results, project listed as ongoing Data: 1 paper (will obtain final report)
HPS	15	3	2	27	Corrugated Webs	PA	SR 2024 over Towanda Creek	+/-: successful implementation, additional needs for shear prediction Data: good summary, 5 avg. reports
ABC	18	1	1	2	Concrete Filled FRP Tubes	ME	Neal Bridge in Pittsfield, ME	+/-: excellent results, national press coverage Data: excellent summary, 4 reports
ABC	21	2	1	9	Deck	WI	IH 39/94 over Door Creek (Fond du Lac)	+/-: good results, ACEC of WI award winner but difficulty implementing Data: good summary, 6 reports
ABC	17	1	3	25	Prefabricated or Precast Elements	TX	FM 1660 over Cottonwood Creek	+/-: good results, led to new State standards Data: OK summary, 2 presentations
ABC	20	2	5	33	Aluminum Bridge Deck	KY	KY-92 over Jellico Creek	+/-: success in implementing but very high cost. Data: OK Summary, no report
ABC	19	2	5	35	SPMT	UT	I-215 NB over 3760 South Street at 3300 East Salt Lake City	+/-: many types of ABC investigated, good results Data: poor summary, no reports from
Reinforcing Bars	22	1	2	12	FRP	NC	Bridge 16 on State Route 1470 over Cartoogechave Creek	+/-: no negative results Data: good summary, 2 good reports
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Bridge Monitoring	28	2	1	16	Fiber Optics	VT	Bridge 213 Carrying VT Route 100 over Ryder Brook	+/-: good project results, some issues with implementation Data: good summary, 6 good reports
Bridge Monitoring	26	3	2	29	Displacement	WI	US Highway 151 over De Neveu Creek	<i>This should be another FRP - it may have monitoring in it but I would add it back to FRP as another very good</i>
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Bridge Monitoring	31	Not Recommended	For Task 2C	N/A	Smart Sensors	-	-	-
Coatings & Corrosion	35	1	2	13	Overcoating	IN	US 30 over Jain Creek	+/-: excellent results reported Data: excellent summary, 3 reports
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Coatings & Corrosion	34	Not Recommended	For Task 2C	N/A	Inert Gas	-	-	-
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Coatings & Corrosion	37	Not Recommended	For Task 2C	N/A	Post Tension Coatings	-	-	-
Foundations	39	2	2	23	Fender System	FL	Key Royale Drive Bridge over Bimini Bay	+/-: good results, cost is high Data: very good summary, 1 report
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Deck Coatings	40	1	2	7	Overlay (Deicing)	TX	US 40 (Old Rout 66), West Bound overpass bridge in Gray County	+/-: good results, plans for future use Data: good summary, 1 presentation
Deck Coatings	41	4	2	32	Overlay (Non-deicing)	OK	I-40 EB over I-44	+/-: as many - as + results Data: OK summary, 1 good report
Deck Coatings	42	Not Recommended	For Task 2C	N/A	Polyester	-	-	-
Other Technologies	45	1	2	14	Concrete-Filled Tubular Flange Girders	PA	SR 1003 over Tionesta Creek	+/-: no negative results Data: OK summary, 1 good report
Other Technologies	44	2	2	17	Bearings	AK	Statewide Seismic Retrofit	+/-: performing as intended but no EQ load to demonstrate isolation Data: OK summary, 1 good report
Other Technologies	50	2	3	28	Timber Deck	PA	Burd Run Road over Burd Run	+/-: no negative results reported Data: poor summary, 1 report
Other Technologies	43	Not Recommended	For Task 2C	N/A	Advanced Engineered Lumber	-	-	-
Other Technologies	46	Not Recommended	For Task 2C	N/A	Construction Technique	-	-	-
Other Technologies	47	Not Recommended	For Task 2C	N/A	Over-Height Systems	-	-	-
Other Technologies	48	Not Recommended	For Task 2C	N/A	Sandwich Plates	-	-	-
Other Technologies	49	Not Recommended	For Task 2C	N/A	Sign Structures	-	-	-

4. CASE STUDIES

Selected Case Studies:

4.1. HPC, DECKS: OKLAHOMA – I40 BRIDGE OVER BUSINESS I-40 IN SAYER

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

**High Performance Concrete
Case Study: Decks**

Project

I-40 Bridge over Business I-40 in Sayre

Project State
OKLAHOMA

Prepared For:
Federal Highway Administration



Prepared By:
HDR Engineering, Inc.
9987 Carver Road
Suite 200
Cincinnati, OH 45242-5552

October, 2011

1. Project Description

The purpose of this project was to investigate and develop four different high performance concrete (HPC) bridge deck mixtures for the Oklahoma Department of Transportation.

High performance concrete is specifically engineered to meet specific performance criteria that includes mixtures to achieve optimum compressive strength, low permeability, modulus of elasticity, durability, workability, volume stability, etc. This project had several criteria elements which were requested for the mixture with the main focus on shrinkage stability.

Volumetric changes in concrete are inevitable. Therefore, efficient concrete design requires understanding the causes and nature of the changes. In the presence of no restraints, concrete shrinkage would be of little consequence. However, these contractions are usually restrained by its supports, an adjacent structure, and bonded reinforcement. All of these produce a gradually increasing tensile force on the concrete as it shrinks, leading to cracks in the structure. The cracks occur when connections develop between isolated microcracks, visible cracks, and pores. These cracks then allow corrosion of reinforcing steel and sulfate attack to develop when water and chloride ions are able to propagate inside the concrete structure. These corrosive additions have their own negative effects such as additional cracking, spalling, and delamination of the concrete. Over time the overall structural integrity and serviceability of the structure is lowered, which can lead to a structurally deficient or functionally obsolete bridge.

The state of Oklahoma contains a disproportionate number of structurally deficient and functionally obsolete bridges when compared to the rest of the United States. For this reason, the ability to create a concrete mix or have construction practices which can withstand the shrinkage and cracking issues related with traditional concrete mixes is vitally important for the long term durability for both Oklahoma and the nation's infrastructure needs.

The investigation was performed by the University of Oklahoma, School of Civil Engineering and Environmental Science. The report detailing the findings of the investigation was authored by Assistant Professor Chris C. Rasmseyer and Research Assistant Jason D. Giebler.

The research consisted of two parts: a laboratory and a field investigation. The laboratory investigation consisted of an initial system of batching matrices and then studying these batch matrices to develop the four desired mixes. The field investigation consisted of test slabs for the HPC mixtures and actual bridge construction. The University of Oklahoma investigators served as consultants and performed additional tests to further characterize the mixtures.

The research was to provide four HPC mixtures to be used in the 2004 Oklahoma IBRC bridge construction project with two of the four HPC mixtures to include reinforcing fibers. This was done by investigating several different local materials and admixtures for possible use. In addition, one of the main focuses of this HPC study was to look at aggregate blends of the concrete mixtures. This study was done by testing the validity of the Shilstone method; a method which provides a quantitative optimization for the aggregate proportions and adjusting these proportions during the construction process.

At the conclusion of the laboratory studies, the bridge construction was performed with the four mixtures. During this time, testing and field observations were made which resulted in on field adaptations to the mixtures by the University of Oklahoma investigators when necessary.

The variables that were studied in this investigation included air-entrainment, cementitious materials content, aggregate blend, water to cementitious materials ratio, supplemental cementitious materials, fiber reinforcement, a shrinkage-reducing admixture, and concrete temperature. This research investigates the aggregate blending through the use of percent retained charts, dry-rodded unit weights (DRUWs), and the Shilstone Coarseness Factor Chart. Additionally, the shrinkage-reducer was tested to considerable extent for dosage rates and the timing of the additions.

To perform this research the fresh concrete properties of air content, slump, unit weight, DRUW, and concrete temperature as well as the ambient humidity and temperature were recorded. The hardened concrete properties of compressive strength, unrestrained length change, and modulus of elasticity were found for all of the batches. Additionally, during the field test slabs, the Air Void Analysis was used and at the bridge construction, splitting tensile and freeze-thaw tests were performed.

2. Implementation

A research program was developed and implemented at The University of Oklahoma in conjunction with the Oklahoma Department of Transportation to (1) identify local materials to western Oklahoma and neighboring states that are suitable for generating HPC, and; (2) create mixture proportions for four different HPC mixtures to be used in bridge decks.

The first step of the research began by determining the cementitious materials to be used. This part of the investigation focused on studying optimal amounts and combinations of the materials rather than the affects of different manufacturers.

This was due to the need for the selected mixes to be used in future construction which leads to availability and economic issues. These materials consisted of fly ash, slag, and Type II Portland cement. The evaluation and comparison of each mixture was based on a combination of workability, compressive strength, and unrestrained length change.

Two coarse aggregates, an intermediate aggregate, and a fine aggregate were used. These materials were obtained from different quarry locations in western Oklahoma. The coarse and intermediate aggregates all consist of limestone. The fine aggregate used was quartz sand. As was done with the cementitious materials, the aggregates were assessed in mixtures to determine their suitability for HPC production. As stated in the summary, to create the aggregate blends necessary for the HPC mixtures in this study, the aggregate blending method referred to as the Shilstone method was used.

Several different types of admixtures were also evaluated in this investigation. These include admixtures for air entrainment, mid-range water reduction, and shrinkage reduction. The air-entrainer and water-reducer were used in each batch due to existing concrete practices in the area. These practices serve to meet guidelines set by ODOT for minimum air contents and workability levels.

Once the different materials were determined, the next step was the mix design development. Two levels of testing were performed. The first consisted of initial matrices which were tested for primary objectives. Those mixtures that displayed the most desirable results moved on to the second level where they were adjusted for traits most suitable for construction.

The primary investigation matrices for each variable were performed in the following order: air-entrainment, cementitious materials content, aggregate blend, water to cementitious material ratio, supplemental cementitious materials content, fibers, and shrinkage-reducing admixture. These were followed in a progressive manner by proportioning each variable and holding it constant for the next matrix and so on.

After the primary investigation matrices were completed, additional batching was performed to create mixtures with the desired properties. The secondary development was controlled by an empirical process. The air-entrainer, mid-range water-reducer, and shrinkage-reducer were varied along with the amount of ice added to the mixing water. This allowed the researchers to adjust the slump, air content, temperature, and compressive strength to the desired ranges while acquiring a lower length change than obtained by conventional concretes. Careful attention was paid to the batching and curing procedures due to the sensitivity of HPC and the number of variables present.

Several tests were performed during the optimization process. The primary tests include compressive strength, unrestrained length change, dry-rodded unit weight, unit weight, slump, air content, and concrete temperature. Secondary tests include modulus of elasticity, rapid freeze-thaw, splitting tensile, and air void analysis.

The final batches which contain the four HPC mixtures that were developed for the product of the investigation are as followed: Batch 40 (cement + fly ash), Batch 41 (cement only), Batch 42 (cement + fly ash + fibers), and Batch 43 (cement + fibers). For each of the batches the w/cm was set at 0.38 and the total cementitious materials content at 573.2 lb/yd³. For Batches 40 and 42 the cementitious materials were divided into 80% cement and 20% fly ash where Batches 41 and 43 contained 100% cement. The fibers which were used in Batches 42 and 43 had a dosage rate of 5.1 lb/yd³. An additional fifth batch, Batch 44, was performed to consider travel time of the mixing trucks in the field only. This batch is a duplicate of Batch 40 with an additional mixing time of approximately forty minutes. The table below contains the mix proportions and design information as well as fresh and hardened concrete properties for the final batches:

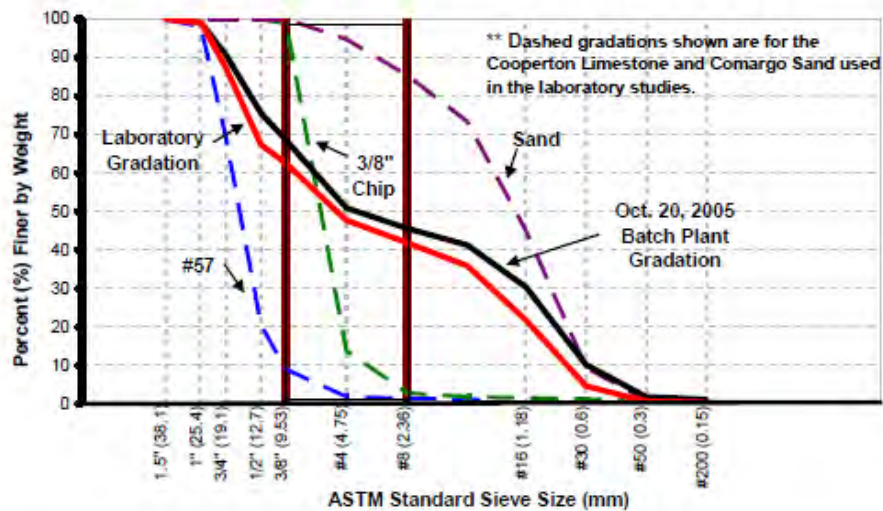
	Batch #	Air-Entrainment		Mid-Range Water Reducer		Shrinkage-Reducer	
		Designed Amount fl oz/cwt (mL/kg)	Actual Amount fl oz/cwt (mL/kg)	Designed Amount fl oz/cwt (mL/kg)	Actual Amount fl oz/cwt (mL/kg)	Designed Amount fl oz/yd ³ (L/m ³)	Actual Amount fl oz/yd ³ (L/m ³)
	40	6.9 (4.0)	5.0 (2.9)	10.3 (6.0)	10.3 (6.0)	12.9 (0.5)	38.8 (1.5)
	41	6.9 (4.0)	8.3 (4.8)	10.3 (6.0)	5.0 (2.9)	12.9 (0.5)	12.9 (0.5)
	42	6.9 (4.0)	6.9 (4.0)	10.3 (6.0)	19.1 (11.1)	12.9 (0.5)	12.9 (0.5)
	43	6.9 (4.0)	5.0 (2.9)	10.3 (6.0)	8.3 (4.8)	12.9 (0.5)	12.9 (0.5)
	44	6.9 (4.0)	5.0 (2.9)	10.3 (6.0)	10.3 (6.0)	12.9 (0.5)	12.9 (0.5)

Only three of the four HPC mixtures produced were cast as test slabs due to the contract between ODOT and the general contractor. It was decided through the investigation and meetings with those parties involved that the three mixtures would consist of Batch 40 (cement+fly ash), Batch 42 (cement+fly ash+fibers), and the Batch 43 (cement+fibers) mixtures.

The test slabs were designed to replicate the conditions of the bridge construction. This included the reinforcement design, the concrete placement and finishing methods, and the curing process to be used during construction. The method of finishing used for this project consisted of a hand vibrator followed by a mechanical finisher with auger that worked the top of the concrete as well as a roller and plate that followed behind to smooth and level. After this was finished, a moist curing of misters, wet burlap, and an experimental synthetic curing sheet were applied for the curing

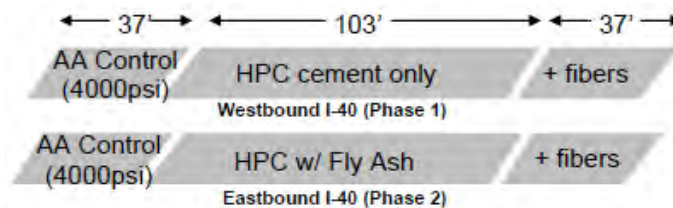
process. After curing, the concrete was applied with a diamond cut tined finish. The reason for all of the provisions at the slabs was to view the difficulties, if any, prior to construction.

One of the main focuses of this project is in the aggregate blend used in the mixtures. This entails a close consideration of the distribution of aggregate particles and their corresponding values to the Shilstone Coarseness Factor chart. To ensure this accuracy, sieving of the local aggregates supplied by the concrete batch plant for the research was performed. The table below shows the chosen blend gradations for the laboratory and batch plan stockpiles:



Concrete temperature, slump, air content, and unit weight properties were tested from specimens taken from the slab site. Air temperature and relative humidity were also noted. The specimens were then allowed to cure on-site for 1 day and brought to the laboratory where they finished their curing process exposed in an environmentally controlled chamber. Laboratory testing determined the shrinkage, modulus of elasticity, and compressive strengths on days 1, 3, 7, 28, and 56. In addition, and Air Void Analysis (AVA) test was taken on the test slabs. The AVA samples were taken by the investigators for each mixture at the site as the concrete left the truck, as it was placed, and from the finished slab.

The final part of the investigation involved the bridge construction. The first phase of the bridge deck replacement associated with this project was performed on I-40 westbound over I-40 business loop. The second phase was performed on I-40 eastbound over I-40 business loop. This deck pour consisted of three skewed slabs: two 37 feet long end slabs and one 103 feet long center slab. The figure below shows the batch mixture layout for the bridge deck construction:



Unlike the test slabs, all four design mixes were used during bridge construction. The first two spans, starting from the west end, were poured in one day and the last span in another. The first span was poured with the control mixture, ODOT AA (4000 psi) concrete. The remaining long center span was poured with the Batch 41 (cement) mix for the westbound bridge and Batch 40 (cement+fly ash) mix for the eastbound bridge. The final end span was poured with Batch 42 (cement+fly ash+fibers) mix for the westbound bridge and Batch 43 (cement+fibers) mix for the eastbound bridge.

Similar to the test slabs, concrete temperature, slump, air content, and unit weight properties were tested from specimens taken from the construction site along with air temperature and relative humidity. Also similar to the test slabs, the non-fibrous specimens taken from the construction site were allowed 1 day to cure. The fiber batches were allowed to cure at the site for 3 days. Laboratory testing determined the shrinkage and modulus of elasticity at day 28 and the compressive strengths on days 1, 3, and 28. Added to the construction testing was splitting tensile which was determined at 28 days.

3. Conclusions:

Definite conclusions could not be made for the test slabs and the first phase of the bridge deck based on the information provided. However, from the investigation, several observations were made:

- Medium to low range shrinkage and high compressive strengths with little to no shrinkage cracks can be achieved using high performance concrete.
- Air entrainment was one of the major variables in this investigation. Increased air content is linked to lower compressive strengths and increased shrinkage.
- In the laboratory, the required 4000 psi compressive strength was difficult to reach with air contents above 6%; however, in the field the strengths were higher for a given air content and the required 4000 psi compressive strength was achieved.
- Increasing the cementitious materials content while leaving the air entrainment ratio constant increases the air content of the batches. It is unclear whether the decrease in strength and increase in shrinkage is caused by the increased cementitious materials content, air content, or a combination of the two.
- In the laboratory, the air contents produced in the concretes while holding the air entrainment ratio constant were seen to increase with the w/cm.
- The aggregate blend was difficult to analyze in this investigation due to the multiple variables present, such as admixtures and air contents. Aggregates available for concrete production may not be able to be blended to the desired particle distribution due to gap gradations in the available aggregates.
- The Shilstone Coarseness Factor chart did not perform as designed. From the data obtained in this investigation, it is difficult to develop an adequate conclusion. This is due to multiple variables in the concretes, including air content, which created further changes in the mixtures. Additionally, it is unclear at this time how and to what extent the admixtures are actually affecting the mixtures.
- An increasing DRUW trend was found as the Shilstone Coarseness and Workability Factors increased.
- When blending the #57 coarse limestone and quartz sand, the 3/8 inch chip blend compared to the #2 coarse aggregate was found to have better workability and particle distribution.
- The chosen blend region of the Shilstone Coarseness Factor chart was located near the aggregate blend used currently in Oklahoma concrete practice today.
- The addition of fibers to concrete showed a tendency to lower the air content of the concrete in this research. The fiber mixes also reduced in shrinkage and increased in strength.
- The fiber mixtures were found to be very dry, “matted”, and “sticky”, which caused issues during construction. The mixture clogged the concrete pump during the test slab placement and adhered to the sides of the drop bucket during bridge construction.
- The shrinkage-reducer used in mix designs, Tetraguard®, was found to decrease the air content of the concrete drastically, reduced unrestrained-length change and increased compressive strengths. The initial shrinkage results were affected the most. In general very little shrinkage was found till approximately the 7 to 14 day curing period.
- No matter how much Tetraguard® was added as a single dose the concrete developed approximately a 3% air content. However, it was found that if the Tetraguard® was added in small repeated dosages, an increased air content could be achieved.
- There is no noticeable advantage for the maximum 75° F concrete temperature set for this project. The temperature is difficult to achieve and no beneficial results have been noted.
- During construction, the materials used were seen to react differently than in the laboratory. It was found that the mixtures were not only developing higher air contents, but they were also changing their behavior properties at about 30 minutes in an undesirable way. At 30 minutes the concrete would rapidly stiffen and start to dry, making it impossible to pump and in some cases unworkable.

4. Lesson Learned:

- ODOT has observed no significant problems with freeze-thaw in Oklahoma with concretes containing 6% air prior to this investigation. Since increased air content is linked to both increased shrinkage and lower compressive strengths, which has a direct correlation with tensile strength, it is recommended that air contents above 6% should not be used.
- It is difficult to produce any definite conclusions or comparisons on the cementitious materials study due to the variable contents. Additional studies should be conducted to further understand their affects.
- Additional research is needed on the blend of the aggregate used and not just the aggregate stockpiles available in Oklahoma. This means that an intermediate aggregate may be necessary. To do this some method of analyzing the concrete aggregate particle size distribution should be used to aid in the focus on the aggregate blends. A variety of methods are available for this including the modified 0.45 power chart, 8-18 rule, percent passing charts, and percent retained charts.
- To more adequately analyze the Shilstone Coarseness Factor chart, it is recommended to test with local materials to see the actual trend areas that are produced. This is due to the uncertainties remaining on what variables are contributing to the concrete characteristics as well as how the admixtures are actually affecting the mixtures.
- It is recommended to focus the aggregate blend choice at this time on the DRUW. The Shilstone Factor chart may be used as a good reference to what regions are desirable for this. This can be seen in the focused Shilstone area containing the highest DRUW. This area was also located near the currently used blend in construction. However, the blend chosen developed a DRUW higher than the one currently in use.
- Due to the difficulty of using the Shilstone method, caution should be taken until further research is done to simplify it. This additional research should start with the Shilstone and aggregate studies with similar admixtures and materials to those used in Shilstone's investigations. When a conclusion can be made, the additional matrix studies (air-entrainer, cementitious materials, w/cm, etc.) should then be tested. This will create more reliable data to compare directly to Shilstone's research. Additionally, it is recommended that the air-entrainment study should be performed last due to the many variables that affect the air-entrainer's performance.
- The use of the fiber entrained mixes in construction should include additional mid-range water-reducer to reduce the tendency for dry, "matted" or a "sticky" consistency. The mid-range water-reducer should be increased so that the w/cm is not altered unless further research on the w/cm is performed.
- Due to the fiber mixes having harsh workability and not displaying overwhelming improvements in the hardened concrete, it is believed that the other variables present overwhelm any benefits that the fibers have to offer. However, it is not known at this time if the fibers will add any long term durability and serviceability through characteristic plastic breaks, tensile stress relief during cracking, or any other properties that they have to contribute. Further research on the use of fibers with the different variables should be performed.
- The shrinkage from the time zero test developed at the University of Oklahoma should be used to better characterize the early shrinkage results displayed in the mixtures containing Tetraguard®.
- In the final mixtures developed in this research, it is recommended to use a multiple dosage rates of 155.1 fl oz/yd³ as needed. This "trickling" affect allows the Tetraguard® to be added while providing a method for controlling the air content. However, further research is needed to more fully understand the relationship between the Tetraguard® and the air-entrainer as well as how to accurately perform the "trickle" dosage of Tetraguard® in full scale batching.
- Additional research is recommended to see if the approximately 3% air content and reduced shrinkage that is found with the Tetraguard® can supply the needed durability for concretes with exposure to environmental affects. Currently, the concretes being used have a higher shrinkage level, but are required to have 6% air content to aid in durability.
- It is recommended that a low concrete temperature be achieved; although, further research is necessary to deem whether the 75° F maximum set for this project is reasonable.
- In future projects like this one, it is recommended for all of the parties involved to increase the communication level. This could potentially decrease the amount of concrete rejected, the amount of time to construct, increase the likelihood that the mix design meets all criteria such as pumpability and decrease the amount of last minute adjustments.

- The batch size of the trucks is recommended to be delivered in an experimental batching like this in 4 yd³ batches.
- Not only does additional research need to be conducted on the admixtures used in this investigation, but due to a different air-entrainer used in the field, additional research is necessary to develop conclusions on the differences.

5. Costs

In the 2004 fiscal year, the state of Oklahoma was granted \$225,000 in funding for this research into high performance concrete (HPC) bridge deck mixes through the FHWA Innovative Bridge Research and Construction program. The entire amount was expended.

4.2. HPC, GIRDERS: IOWA - 136TH AVENUE OVER BUFFALO CREEK

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

**High Performance Concrete
Case Study: Girders**

Project
136th Avenue Over Buffalo Creek, Buchanan County

Project State
IOWA

Prepared For:
Federal Highway Administration



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January, 2012

1. Project Description

The purpose of this project was to construct and analyze a highway bridge using an optimized, second generation pi-girder section fabricated out of Ultra High Performance Concrete (UHPC). The pi-girders get their name from the unique cross section resemblance to the Greek letter “ π ”. These girders were used to replace Jakway Park Bridge in Buchanan County, Iowa. The new bridge utilizes three 51 ft. long pi-girders for its middle span design. The construction was completed in fall of 2008, and has provided the first application of a second generation UHPC section for a highway bridge in the United States.



Figure 1: Completed Jakway Park Bridge, pi-girders used for middle span only

Developed in France during the 1990s, UHPC has seen limited use in North America. The mix consists of fine sand, cement and silica fume, and quartz flour in a dense, low water-cementitious materials ratio (0.15) mix. Compressive cylinder strengths of 18,000 psi to 30,000 psi can be achieved, depending on the mixing and curing regimen. The material has extremely low permeability and high durability. To improve ductility, steel or fiberglass fibers, approximately 2% by volume, are added, replacing mild reinforcing steel.



Figure 2: Second generation pi-girder

Recently, there has been increased interest in and research concerning the use of UHPC in bridges in North America. By using UHPC, departments of transportation hope to gain significant advantages in the mechanical properties and durability of concrete.

Although this is the first application for a second generation UHPC girder bridge in the United States, Iowa has used UHPC girders in one other bridge application. Iowa was first introduced to UHPC with a bridge project in Wapello County in 2006. UHPC was used in three 110 ft. long prestressed concrete bulb-tee girders. After the completion of this project and given the relatively high unit cost of UHPC, an effort was made by the FHWA to investigate a more cost-effective cross

section. Based on analytical evaluations conducted at the Massachusetts Institute of Technology, a first-generation pi-shaped girder with an integral deck was determined optimum. Specific dimensions were developed for the pi-shaped girder for bridge spans approximately 70 to 120 feet.

Testing of this first generation pi-section raised concerns over the transverse deck stiffness, lateral live load distribution and the possibility of crack formation in the thin deck under AASHTO service loads. As a result, a second cross section was developed, using 3-D finite element model analysis, and based on the same pi-girder section.

The analysis completed during this project was done to ensure that the second generation pi-girder section had adequate performance under live load testing, quantify conservatism in the design approach, and provide guidance to future bridge designs using UHPC pi-girders. To accomplish these objectives, laboratory testing on UHPC materials, construction monitoring during diaphragm installation, and two live load field tests were performed.

While still costly in comparison with more conventional bridge designs, the UHPC pi-girders will likely become more cost competitive as life-cycle cost data are accumulated and design processes become more streamlined. The tradeoffs for using UHPC include increased cost of materials, increased batch time for mixes, modification of forms due to increased shrinkage, and long setting and curing times that occupy precast beds.

The research completed on the pi-girders used at Jakway Park Bridge was performed by the Institute of Transportation at Iowa State University.

2. Project Implementation

The first step in implementing this technology was to develop the cross sectional shape of the second generation pi-girder. This was done by addressing the concerns identified during testing of the first generation section regarding transverse deck stiffness, lateral live load distribution and cracking in the deck. A 3-D finite element model was used for the analytical study of the second generation section.

To address the concerns with lateral live load distribution, larger radii were used at the web-deck interface and the deck thickness was increased from 3 to 4.125 inches. As an added benefit, the larger radii also decreased stress concentrations at the web-deck interface and improved material flow during the placement of the UHPC. The transverse strength and stiffness of the deck were enhanced by increasing the deck thickness and by also reducing the web spacing. Reducing this spacing also provided a more uniform spacing of the bulbs in a multi-girder bridge configuration. Finally, the thickness of the webs was also increased from 3 to 3.75 inches. This was to improve material flow during casting.

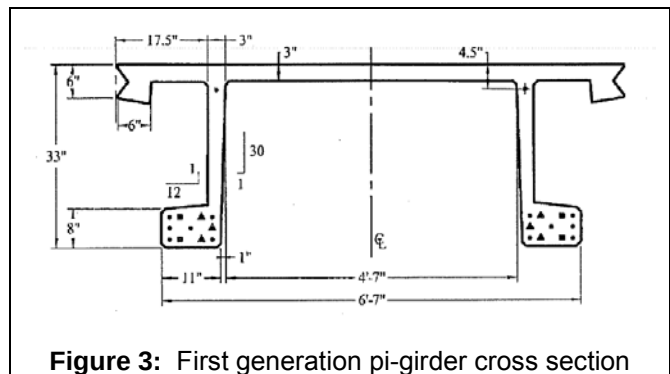


Figure 3: First generation pi-girder cross section

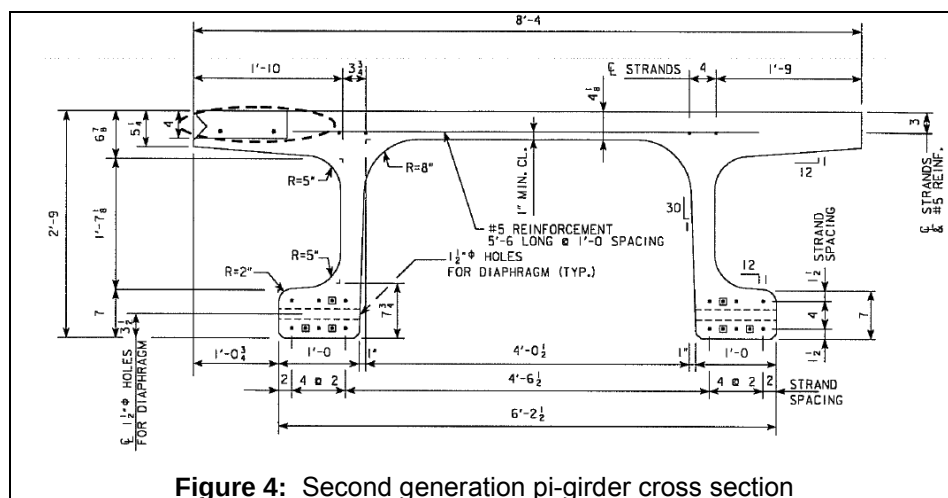


Figure 4: Second generation pi-girder cross section

Once the second generation pi-girder cross section was developed, the bridge design could be initiated. Similar to the determining the cross sectional properties, a finite element model of the three-girder center span was generated for the analysis. Looking at the type, size, and location requirements for the proposed bridge site, a total bridge length of approximately 120 ft. was required. From the test

results obtained during the creation of the first generation section, a maximum length of only 70 ft could be used, resulting in a 3-span layout of the bridge. Due to budget constraints, only the center span was constructed with the UHPC pi-section.

The cross sectional comparison between the first generation and second generation girders are as shown in Figure 3:

Section	Area (in ²)	MOI (in ⁴)	Self-Weight (lb/ft of section)
First Generation	609	89,060	657
Second Generation	861	105,730	932
Percent Increase (%)	41	19	42

Figure 5: Comparisons between first and second generation pi-girders

The pi-girders were fabricated in the fall of 2008 at the LaFarge plant in Winnipeg, Canada. Due to the large volume of UHPC required, a new method of batching and mixing the material in ready mix trucks was employed. Cementitious materials in premixed bags were first loaded into the trucks followed by water in the



Figure 6: Pi-girder fabrication process at plant

form of ice and then the water reducing admixture. Ice was used in place of liquid water to slow hydration and allow for several hours of mixing in the trucks. After the paste had become fluid, steel fibers were added through a screen to prevent clumping. Due to this unique method of mixing, a conservative value of 21.5 ksi was used for the compressive strength of the concrete.

The pi-girders contained no mild steel shear reinforcing. The steel fibers in the UHPC increased the tensile strength of the concrete, enhancing its ability to

resist inclined web shear cracking and flexure-shear cracking. The shear strength of the UHPC alone was estimated to be sufficient to avoid cracking.

A cast-in-place shear key was used to connect adjacent girders at the deck level. In addition, #8 bars were placed inside the grout pockets, on the top of the deck, which are spaced every 18 inches.

Twenty-two 0.6 inch diameter, low-relaxation prestressing strands provided the flexural reinforcement. Eighteen strands were placed in the bottom of the bulbs, nine in each bulb. Four strands were placed in the deck, two above each web. Transverse flexural reinforcement consisted of #5 bars placed in the bottom of the deck at 12 inches on center. The transverse flexural strength of the UHPC deck alone was estimated to be sufficient to avoid cracking, but the #5 bars were added to provide reinforcing to the section if the UHPC in the deck were to experience inelastic deformation.

The fluid UHPC material was placed into the forms with a crane-mounted hopper. Following placement into the forms, the top surface was immediately covered with plastic and then steam cured using thermal blankets for 48 hours at 195 degrees. Initial set to break forms was achieved in 25 to 30 hours after concrete placement, and prestressing strands were released at 40 hours after concrete placement.

Once the girder fabrication was complete, construction could be started. The pi-girders were the first component of the bridge superstructure to be erected. Upon arrival to the construction site, the pi-girders

were lifted into place using two cranes, one each on opposing ends of the span. Once positioned on the pier caps, the pi-girders were connected to one another at their top flanges by placing dowels in each grout pocket and then filling the pockets and shear keys with a non-shrink grout.

Following erection of the pi-girders, the end slabs and concrete diaphragms at the pier were cast. Finally, the steel tube diaphragms located between all adjacent webs for the pi-girders, were installed and bolted into place.

Construction of the Jakway Park Bridge was conducted throughout the fall of 2008. The total construction time was 52 days, and the bridge was opened to traffic on November 26, 2008.

Laboratory testing showed that the compression strength results from the UHPC concrete averaged 28.0 ksi after 250 days. This value was 30% larger than the value used for the design of 21.5 ksi. Compressive strengths during the design were limited to 21.5 ksi due to concerns about using ready-mix trucks for girder fabrication.



Figure 7: Grout pockets being filled

Field testing of the Jakway Park Bridge took place in both November 2008 and September 2009. The tests were conducted roughly a year apart to observe any possible changes in the behavior of the bridge throughout the first year of service. Through the use of field testing, this investigation was able to quantify the response of the bridge under service level loads and subsequently quantify the conservatism present in the design.

For the first test in 2008, thirty-two surface mounted strain transducers and six displacement transducers were attached to the bridge to quantify its response under a known static live load. The strain transducers were located at the pi-girder midspan, quarter-span, and near the eastern end support. The displacement transducers were installed at midspan to monitor maximum vertical deflections. The layout for the 2009 live load test a year later consisted of the same transducer layout.

3. Project Conclusions

The unique UHPC pi-girders used in the construction of the Jakway Park Bridge provide a new and effective option for bridge superstructures especially for projects with accelerated construction schedules. The project has so far been successful with tests revealing that through the first year of service the bridge experienced only minor changes in structural behavior, such as a 0.2 inch shift in the neutral axis location.

The design approach for the bridge was appropriately conservative in consideration of the relatively new geometry and materials. Future applications of this technology could employ less conservative design methods than those used for the Jakway Park Bridge. In particular, future designs could utilize longer spans, lower live load distribution factors, and most likely dispense with transverse mild steel reinforcement in the deck of the girders.

In addition to favorable results, other states have inquired about the possibility of using UHPC on similar projects. This project has also been positively reported on by at least two industry publications and by the Iowa Department of Transportation. Moreover, this project has received two awards. It was the co-winner of PCI's 2009 Design Award for Best Bridge Project (up to 75 ft span), and winner of the 2009 Quality Initiative

Structures Research Merit Award from the Associated General Contractors of Iowa and the Iowa Department of Transportation.

3.1 **Positive Results**

Listed are the specific comments provided by the Iowa Department of Transportation as positive results from the IBRD project:

- The use of ready-mix trucks in UHPC batching can provide compressive material strengths of 28 ksi.
- Based on the measured live load strains, allowing for a 2 in. asphalt overlay, and utilizing an impact factor of 1.33, the girder span length could be increased to approximately 65 ft without producing cracking when designed for live loads specified in the AASHTO LRFD 2008 Interims.
- The pi-girders have lateral distribution factors ranging from 0.62 for exterior girders and 0.75 for interior girders. Therefore the design value of 1.0 was conservative.
- The maximum measured dynamic amplification factor was 1.15 for speeds up to 25 mph. Since the design speed for this bridge is 25 mph, the AASHTO dynamic amplification factor of 1.33 used for the design of this bridge is conservative.
- The simplified, linear-elastic FEM provided accurate means of predicting values of live load strains and deflections, and thus distribution factors for this UHPC pi-girder bridge.
- The distribution factors predicted by the FEM model matched to within 8%, of the actual distribution factors measured in the field.
- The simplified method of modeling prestressing strands as pressures distributed over the bulbs of the pi-girder provided accurate estimates for both strain and deflection.
- The estimated total longitudinal strains for the bottom of the bulbs at midspan and quarter-span, the estimated total transverse strains on the bottom and top of the deck, and the estimated total vertical strains for the webs, were all below the cracking threshold, indicating that cracking is unlikely at service level loads.
- In general, the changes in strain observed for the comparison of the 2008 to 2009 static live load tests were minimal.
- No significant change in the neutral axis location was observed through field testing. The 2008 neutral axis was 11.6 in. and the 2009 the neutral axis was measured to be 11.8 in. from the top from the section.

3.2 **Lessons Learned**

Listed are the specific comments provided by the State as lessons learned from the IBRD project:

- If cracking of the UHPC is used as a criterion to limit stresses for durability considerations, relatively simple, linear-elastic finite element models can provide a highly useful tool in predicting behavior of the UHPC pi-girders. Such models can be developed cost-effectively and provide a useful tool for designers in predicting behavior, anticipating locations of concern, evaluating details, and identifying global changes in bridge performance through subsequent load tests. The verification of these models is of particular significance for future designs employing the UHPC pi-girder.
- The bridge did not behave as if perfectly simply supported as assumed in design. The concrete diaphragms at the piers appear to have provided some degree of continuity between the end spans

and pi-girder span. However, the 2009 test showed that the UHPC center span appeared to have lost some degree of rotational restraint.

- The AASHTO LRFD, 2008 Interim case (i) for Precast Double T Beam equations for distribution factors, predicted reasonable and somewhat conservative estimates of distribution factors for this UHPC pi-girder bridge.
- The steel diaphragms are not overly effective in improving the live load distribution between pi-girders for service level loads. However, when the midspan diaphragm was active the maximum live load strains on the bulbs were reduced by roughly 6%.
- Some improvement in predictions with relatively little additional cost might be achieved by employing elastic rather than coupled connections between individual girders.
- The largest increase in strain was observed on longitudinal gages, where a loss of rotational restraint at the pier appeared to have caused a slight increase in strain. Thus after a year of service the bridge was behaving more nearly as designed.
- Use of partial prestressing in UHPC pi-girder design (i.e. cracking of UHPC on the bottom of the bulbs is allowed under maximum service level loads) could yield cost savings. The unhydrated cement content of UHPC could provide for secondary hydration thus providing crack-sealing capabilities.

3.3 Negative Results

Listed are the specific comments provided by the State as negative results from the IBRD project:

- The steel diaphragms at midspan are not effective in decreasing the vertical web strain.
- High fabrication and material costs are associated with UHPC
- Limited availability of UHPC fabricators, at the time of the project the only fabricator was located in Winnipeg, Canada.

4. Costs

In the 2007 fiscal year, the state of Iowa was granted \$400,000 in funding for implementing UHPC technology through the FHWA Innovative Bridge Research and Construction program.

The cost for the entire project was approximately \$600,000.

From the recommendations provided in this report and the continued decrease in costs associated with UHPC and fiber reinforcement in North America (\$2000/sq. yd) as they become more widely used, UHPC pi-girder bridges are expected to become a more cost effective option as of 2007.

5. References

The majority of the information presented in this report, including pictures, are highlights from the Project Summary Report provided by the State and the following resources:

Keierleber, B., Bierwagon, D., Fanous, F., Phares, B., & Couture, I. (2007). "Design of Buchanan County, Iowa, Bridge Using Ultra High Performance Concrete and Pi Girders." August 2007.

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Keierleber, B., Sritharan, S., Bierwagon, D., Wipf, T., & Abu-Hawash, A. (2011). "Iowa's ultra-high performance concrete implementation". *Iowa Department of Transportation Research News, April 2011*. 1-12.

4.3. HPC, DECKS: ILLINOIS - WACKER DRIVE VIADUCT

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

High Performance Concrete Case Study: Decks

Project
Wacker Drive Viaduct, Chicago

Project State
ILLINOIS

Prepared For:
Federal Highway Administration



Prepared By:
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January, 2012

1. Project Description

The purpose of this project was to develop a High Performance Concrete (HPC) mix for the deck in combination with a latex-modified concrete (LMC) overlay for use on the bridge deck design of the Wacker Drive Viaduct reconstruction project in Chicago, IL.

Wacker Drive is a major artery in downtown Chicago running alongside the Chicago River. The project site was 4000 feet long with a typical width of approximately 114 feet. The viaduct is a double-deck section being reconstructed and carries approximately 60,000 vehicles each day. Eight bascule bridges and two elevated transit lines intersect the upper roadway and is also a heavily populated with pedestrian traffic, seeing approximately 60,000 pedestrians a day. With the popularity of this area, this project was a high profile project for the City of Chicago. This resulted in an ad campaign to help promote and educate the community who would be affected by the reconstruction. The city named the campaign, “Revive Wacker Drive”.



Figure 1: Wacker Drive project site

With the viaduct located in the heart of the city and sandwiched between the Chicago River and the city skyscrapers. The available construction space was limited and all utility relocations, foundation work and superstructure erection are confined within the narrow band of the viaduct and river. The two transit lines must also be modified and rehabilitated as part of the project and kept in operation. The upper level pedestrian traffic to buildings along the viaduct and the delivery truck traffic at the lower level must be maintained during construction. In addition, all of the fixed spans of the bascule bridges connecting to the viaduct and the historic architectural elements must be preserved or restored.

As a result of severe deicer-driven deterioration and weather damage, largely due to freeze-thaw cycles, during the 1970s a patch-up of the viaduct was attempted but the deck continued to show failures, forcing a 15-ton limit on the roadway.

Due to the high daily traffic rates and the difficulty of reconstructing in a downtown setting, a long-term replacement solution for the Wacker Drive Viaduct was vital for the project's success. A consulting firm was retained to carry out a detailed investigation of the viaduct structure. The purpose of the study was to assess current conditions and make recommendations for replacement. Based on their findings, the City of Chicago decided to reconstruct Wacker Drive using HPC.

There is no official definition for high performance concrete, but in recent years, the term HPC has been described as concrete with enhanced durability compared to concrete previously used in bridges. In the early demonstration projects, HPC was considered synonymous with high strength concrete. The high strengths were achieved through extremely low water/cementitious material ratios, high cement and silica fume contents, and high admixture contents. These new mix designs changed the workability of the concrete, often leading to problems for contractors in dealing with this new material. Currently, it is now better understood that to make durable concrete, high strengths are not necessarily required. Instead, the mix design can be optimized for ease of placement, consolidation, finishing, and curing in addition to minimizing permeability and shrinkage/thermal cracking. This will minimize the construction-related problems as well as maximize durability.

This project was the first time HPC was used in the state of Illinois; however, HPC has been used on numerous projects around the United States. To aid in their research, the Chicago Department of Transportation (CDOT) looked at over 40 projects around the United States to help develop the criteria for the mix. From these findings, and based off the demands for this project with the goal to achieve a long service life, the primary characteristics for the HPC mixes were defined as follows:

1. Early age strength, 2500-3000 psi at 18 hours
2. Tensioning strength at 4,200 psi
3. Ultimate 28-day strength at 6,000 psi
4. Good workability, placeability and uniformity
5. Durability, a service life of at least 75 years in an environment that includes wetting and drying, freezing and thawing, and salt exposure from deicing agents

The original design of the deck called for segmental construction using match-cast precast segments, each measuring roughly 8 feet by 50 feet. Cast-in-place fascia and sidewalk sections would then be constructed on each side of the viaduct. However, the low bidder on the project proposed an all cast-in-place HPC superstructure, and because this option left the structural system essentially unchanged, the cast-in-place option was accepted.

Since all concrete deterioration processes are driven in some manner by moisture, one way to minimize problems is to protect the concrete by making the concrete more impervious. Impermeability can either be achieved through changing the internal structure of the concrete or through exterior coatings. Internally, the concrete can be made more impermeable by lowering the water/cement ratio and adding ingredients such as silica fume, fly ash, or ground granulated blast furnace slag. Impermeability is defeated if the concrete cracks. To reduce the ingress of corrosion causing materials, part of the deck design for this reconstruction project incorporated a latex-modified concrete (LMC) overlay.

The overlay provided a durable wearing surface while providing protection to the underlying HPC from deicing salts. Since one function of the overlay is to protect the underlying HPC, the LMC must be well-bonded to the substrate and essentially crack-free. This is particularly important since the top surface of a bridge deck undergoes large thermal strains and experiences thermal shock, often due to cold rain or snow. The current design life for the LMC overlay is 20 years; for this project it is anticipated that the overlay will be removed and replaced when it becomes saturated with chloride from deicer salts.

LMC has been used since 1959 as a protective overlay for bridge and parking-garage decks. It is now considered a common overlay for providing resistance to the ingress of deicing salts while maintaining satisfactory adhesion or bond to the deck. Previous to LMC, bridge decks had to be designed with at least 4 inches of top cover to protect steel reinforcement from corrosive environments. That practice normally led to excessive stresses and deflections beyond permissible levels. The introduction of LMC as an option for overlays has the ability to decrease the dead weight on the deck with only a 2.5 inch required thickness.

2. Project Implementation

With the guidance from the engineering consulting firm retained by CDOT, a testing program was developed to determine which HPC mix to employ for the project. The same consulting firm was also responsible for developing suggested mix proportions for the HPC, observing batching procedures, cast test specimens at each plant, and transporting the specimens to their laboratories to conduct the required tests. On December 21, 1999 the Chicago Department of Transportation released a “Request for Letter of Interest and Qualification for Wacker Drive Reconstruction Project”, to solicit test samples from different suppliers.

Up to three different mixes could be submitted by the suppliers. Two of the mixes were suggested proportions from the consulting firm hired by CDOT, and the third optional mix could be developed by the supplier. Once the samples were obtained, testing went forward to evaluate the HPC mix performance, properties, and durability. The suggested proportions were as shown in Figure 2.

Concrete Component	Mix 1	Mix 2
Portland cement Type I or I/II	525-575 lb/yd ³	575-620 lb/yd ³
Fly ash Class C or F	10% addition (by weight of cement)	20% addition (by weight of cement)
Silica fume	5% addition (by weight of cement)	5% addition (by weight of cement)
Ground granulated blast furnace slag (GGBFS)	15 % addition (by weight of cement)	-
Coarse aggregate	¾ in. Maximum size (No. 67/CA11) crushed stone	¾ in. Maximum size (No. 67/CA11) crushed stone
Fine aggregate	Natural siliceous sand	Natural siliceous sand
Water/cementitious material ratio	0.36-0.38 (including water from HRWR)	0.36-0.38 (including water from HRWR)
Air entraining agent	1-2 oz/100 lb. Portland cement	1-2 oz/100 lb. Portland cement
HRWR, AASHTO M194 Type F	Approx. 100-128 oz/yd ³	Approx. 100-128 oz/yd ³

Figure 2: Suggested mix designs provided by consulting firm

A total of fourteen mixes were submitted by suppliers. Eight mixes were submitted by four ready mix designers, and six were submitted by the two pre-cast plants. These field-cast HPC specimens had moderate early strengths, with most achieving the 6000 psi requirement at 28 days, and continued to gain strength as more time progressed. The freeze-thaw results were excellent through 276 cycles. The charge passed in the rapid chloride permeability test continued to decrease over time. The 3-month chloride penetration results by ponding were borderline, however the 6-month results were below specifications. The scaling results were good except for popouts. Finally, shrinkage leveled off at less than 400 microstrain through 239 days, and is well below the 600 microstrain specification.

In addition to testing the HPC mix designs from different plants, the consulting firm made an extensive effort to test the bonding strength of the latex-modified concrete overlay. Since the original design called for segmental construction, the testing for the prototype used for the overlay analysis was performed on match-cast precise segments. In this prototype testing, several items needed to be evaluated:

1. Original overlay bond strength and interaction between overlay and segments
2. Overlay removal techniques
3. Surface preparation prior to casting the replacement overlay
4. Replacement overlay bond strength and interaction between overlay and segments

The prototype model simulated a portion of the proposed Wacker Drive Viaduct that includes an end span from an expansion joint to the first interior bearing supports. This model included the sidewalk and the outer

2-1/2 lanes of the span. The prototype was comprised of six precast segments and one transverse closure strip, and was topped with a LMC overlay.



Once the LMC overlay had cured for 10 days, bond tests were performed on each segment. This was done by drilling a 2.75 in. diameter core through the overlay and approximately 2 in. deep into the HPC substrate. Next, a 2.75 in. diameter steel disk was bonded to the core using the overlay material. Finally, a threaded rod and hydraulic ram were used to pull on the disk. The load was recorded using a load cell and strain indicator.

A 20 year design life is expected for the LMC overlay. Once the overlay is saturated with chloride from deicing salts, the material becomes

ineffective at protecting the HPC deck substrate. Therefore, at the end of the 20 year design life, the LMC overlay will need to be replaced. For this reason, removal and reapplication processes were tested.

Two methods of the removal process were tested. The first was called hydrodemolition. Hydrodemolition is a method of removing concrete using high-pressure water. Concrete is removed by computer controlled, self-propelled equipment utilizing a high-pressure water jet stream. The second is scarifying. Scarifying is the process of removing concrete using mechanical methods. In this case, concrete was removed using a drum with hardened steel bits that attach to a revolving grader. As an added advantage, both of these methods roughen the HPC substrate which allowed for increased bonding performance upon reapplication of the LMC overlay.

After the removal of the overlay, the exposed HPC surface was swept with a soft bristle broom and then power washed. Following that, the overlay was reapplied using the same bond tests described in the first application. Both the original LMC overlay and reapplication after removal produced good bonding results.

From these testing results, the consulting firm concluded, and later provided the recommendation to use design Mix 1 (see Figure 1) for the high performance concrete design mix and the latex-modified concrete for the overlay.

During construction the mix was pumped onto the deck and placed with a finishing machine. After hardening, the concrete was abrasively blasted. A 2.75 inch thick LMC layer was then placed on top of the concrete to act as the short-term sacrificial layer that soaks up winter road salts and chemicals. Approximately 25,000 cubic yards of concrete was used during the entire job, and was applied at a maximum rate of 220 cubic yards an hour. Pours reached up to 240 feet long and 110 feet wide.



Figure 4: Aerial photo of deck construction during rebar placement

The HPC pours and batching procedures needed to be monitored extensively to ensure that the proper mix was being used and weather conditions were adequate for placement. As a result of these quality control standards, the HPC mix was about twice as expensive as regular concrete. However, given the location of the project and the expected life of at least 70 years, the city anticipates that the overall life-cycle cost savings will more than make up for the higher initial construction costs.

3. Project Conclusions

The HPC deck design used in the construction of the Wacker Drive Viaduct project provided an excellent long-term solution for the City of Chicago. This high profile project in the heart of downtown Chicago was very successful and received positive media attention. In addition, several articles have been published detailing the use of the innovative deck design on this project.

As of 2011, ten years have gone by since the application of HPC for this project, and the Chicago Department of Transportation has been very pleased with results. In 2011, the second part of the “Revive Wacker Drive” project started construction, which is the reconstruction of an adjacent portion of Wacker Drive Viaduct. With the success of both the application and the performance of the HPC mix design on the first part, the new phases of the project will be utilizing the same concrete deck design. Furthermore, CDOT has been implementing HPC on several bridge decks since the success of the original Wacker Drive Viaduct reconstruction project.

3.1 Positive Results

Listed are the specific comments provided by the State as positive results from the IBRD project:

- The Chicago Department of Transportation has been very pleased with the results
- Testing procedures and results obtained by the consulting firm provided excellent guidance to develop the proper design of the HPC deck and LMC overlay
- Due to the success of the project, HPC have been used on numerous bridge applications inside the City of Chicago

- Design life of the bridge decks utilizing HPC concrete with LMC overlay are expected to have a design life of at least 70 years, with the LMC overlay replaced approximately every 20 years.

3.2 Lessons Learned

Listed are the specific comments provided by the State as lessons learned from the IBRD project:

- With these particular project specifications, it was very difficult for IDOT to issue a “Materials Certification” for the project. Therefore, there were delays in closing out the project.

3.3 Negative Results

Listed are the specific comments provided by the State as negative results from the IBRD project:

- High performance concrete, for this project, produced costs twice as high as normal concrete. This was largely in part due to the stringent quality control standards needed.

4. Costs

In the 1999 fiscal year, the state of Illinois was granted \$2,200,000 in funding for implementing HPC technology through the FHWA Innovative Bridge Research and Construction program. In addition, \$500,000 was reallocated from the City of Chicago Wacker Drive to Franklin Street project to this Wacker Drive Viaduct reconstruction project. \$2,700,000 has been expended.

The total cost for Part 1 of the Wacker Drive Viaduct project was approximately 200 million dollars. The HPC concrete cost approximately twice as much as normal concrete.

5. References

The majority of the information presented in this report, including pictures, are highlights from the Project Summary Report provided by the State and the following resources:

Wiss, Janney, Elstener Associates, Inc. (2001). “Wacker Drive Viaduct Reconstruction – Literature Review of High Performance Concrete.” October 21, 2001.

Wiss, Janney, Elstener Associates, Inc. (2002). “Wacker Drive Viaduct Reconstruction – Task 3: Latex-Modified Concrete Overlay.” February 27, 2002.

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Aillen Cho (2002). *Tight Focus, New Mix Puts Wacker Drive Back in the Loop*. Retrieved from: <http://enr.construction.com/projects/transportation/archives/020429.asp>

Chicago Department of Transportation (2011). *Project Overview of Wacker Drive, Part 2*. Retrieved from: <http://wackerdrive.net/Project-Overview/>

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<http://www.walshgroup.com/portfolio/heavy+civil/bridges/wacker-drive-reconstruction/gallery.html>

4.4. FRP, WRAPS: COLORADO - CASTLEWOOD CANYON BRIDGE OVER CHERRY CREEK

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

**Fiber Reinforced Polymer
Case Study: Wraps**

Project
Castlewood Canyon Bridge over Cherry Creek, Franktown

Project State
COLORADO

Prepared For:
Federal Highway Administration



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January, 2012

1. Project Description

The purpose of this project was to renovate an existing reinforced concrete arch bridge using a combination of carbon fiber reinforced polymer (CFRP) wraps and reinforcement. The subject bridge is located along State Highway 83 at the edge of Castlewood Canyon State Park in the Black Forest in Franktown, Colorado, carrying traffic between Franktown and Colorado Springs. The park is a historical area and the bridge is considered a historical landmark. The original two-lane reinforced concrete arch bridge was built in 1946. This report will primarily discuss the performance and implementation of the CFRP wraps on this renovation project.



Figure 1: Renovated Castlewood Canyon Bridge rib arches

During the summer of 2003, the bridge arches were repaired and strengthened using CFRP. The original arch was repaired, the spandrel columns were replaced, the bridge deck was replaced and widened from about 35' to 43'-0" including railings, and the overall deck length was increased from 373'-6" to 404'-5". An innovative FRP scheme provided the longitudinal reinforcement for flexural enhancement and transverse reinforcement for confinement, shear enhancement, and to protect against concrete deterioration and steel corrosion.

The original bridge was in poor condition and experienced severe cracking and other distress. The arch and column concrete had spalling due to extensive reinforcing steel corrosion, overstressing, and fatigue related cracking. The bridge was rated as structurally deficient and functionally obsolete.

New construction for replacing deficient structures may not be applicable or economically viable because of the high cost and substantial traffic disturbance. Because of these high costs, emphasis is being placed on the development of newer, more efficient, and more cost effective methods of repair and strengthening for bridges. The use of fiber-reinforced polymers in concrete bridge renovation projects has dramatically increased since the



Figure 2: Spalling concrete and exposed steel before renovation

early 1990's. As the bridge industry has become more familiar with these products, the installation of these light-weight materials has increased over time with reduced labor cost. In addition, the equipment needed for fiber reinforced polymers (FRP) repairs is typically less intensive, which has also resulted in increased cost effectiveness.

With the increased popularity, many innovative FRP applications have been developed and tested for use in new bridges and in existing bridge repair and strengthening. CFRP tendons and rods have been used in various prestressed concrete members. Additionally, externally bonded FRP plates and fabrics have been used to increase the flexural and shear strengths of beams. Externally bonded FRP shells and fabrics have been used to increase the strength and ductility of columns, especially in seismic regions. FRP rods have been used in a similar manner to conventional mild steel reinforcement in many bridge decks. Research regarding the use of various FRP applications in bridges is currently on-going all over the world.

FRPs are non-corrosive, lightweight, non-conductive, and very strong in tension. The corrosive resistance is important in bridges, where traditional steel reinforcement tend to deteriorate due to exposure to moisture and roadway deicing salts. Repair and strengthening of reinforced concrete structures using FRP composites is expected to significantly increase the lifespan of bridges, providing an attractive alternative to traditional rehabilitation techniques.

The research completed on the use of CFRP wraps at the Castlewood Canyon Bridge site was performed by Delchi Fafach, Beson Shing, Sunyoung Chang and Yunping Xi from the Colorado Department of Transportation.

2. Project Implementation

Before the renovation was implemented, four quarter-scale beams were tested with externally bonded CFRP fabric and CFRP rods. Two of the beams simulated the arch regions underneath the third spandrel columns in order to evaluate the behavior of an arch rib below the heavily loaded column. The remaining two beams simulated the arch-foundation moment connections.

Two of the beams were control beams and the other two were strengthened with FRP. Of the two beams that were strengthened with FRP, one was strengthened with a scheme similar to that used around the spandrel column-arch rib connections. This was accomplished using externally bonded CFRP fabric. The other was wrapped with the same CFRP fabric and reinforced with CFRP rods in a scheme similar to that used in the actual arch-foundation connections.



Figure 3: Epoxy overcoating in progress



Figure 4: Finished wrap application

The specimens were built in the structures lab at the University of Colorado at Boulder. The forms were constructed of wood, and steel reinforcement cages were placed inside the forms. Grade 40, non-epoxycoated deformed bars were used for all steel reinforcement.

Once cured, and the forms were removed, the specimens were placed outside to simulate real life environmental conditions. Following that, the specimens were then made ready for CFRP wrap placement.

Except for some grinding of rough corners, all surface preparation of the specimens, and cutting and placement of the wraps were performed by the same contractor who was scheduled to perform the same work on the actual bridge. The surfaces of the specimens were roughened by sandblasting. Epoxy was rolled onto the surface of the concrete

and the pieces of CFRP wraps were submerged in a pool of epoxy. The saturated CFRP wraps were laid on the epoxy-wetted concrete and pressed onto the surface with rollers. The specimens were left undisturbed and uncovered while the epoxy cured, which took approximately 24 hours. The application of the CFRP wraps required about 3 days, partly because the epoxy could not be applied to the specimens while they were heated from the sun.

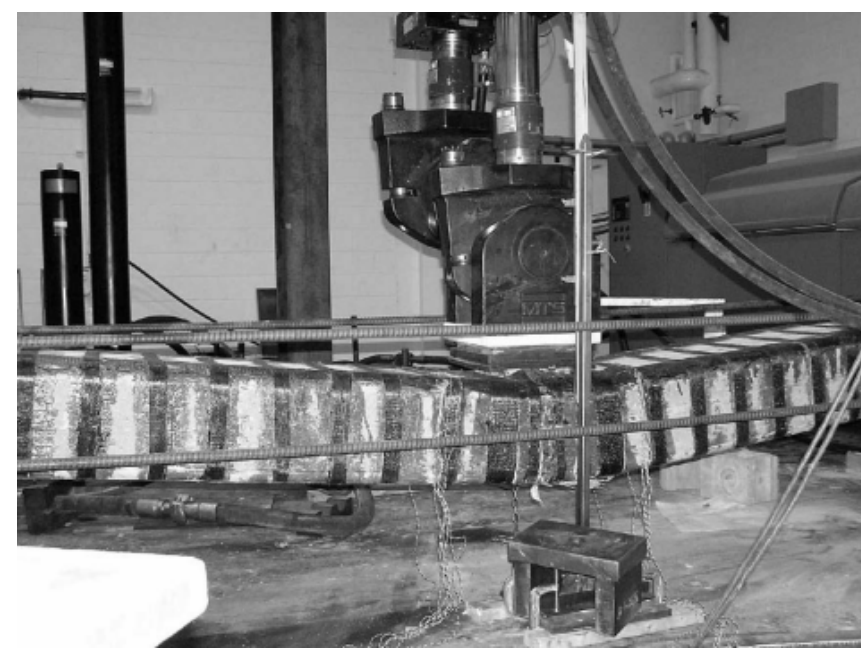


Figure 5: Piston applying the center load to the arch rib specimen

After the application of the CFRP wraps, testing started on the specimens. For the tests, the specimens were simply supported and tested to failure under a combination of axial load and bending moment. The axial load was applied using a manually operated 100-ton piston with a small reaction frame to apply axial loads between 30 to 75 kips. The primary bending load was applied with two 110-ton pistons with a center load reaction frame.

Stain gauges were attached to the specimens and linear variable differential transformers (LVDT) were used to measure displacement.

The tests results were used to calibrate analytical models which were used to evaluate the strength of the arch ribs in the actual bridge before and after construction.

Prior to renovation, bond strength tests for the CFRP wraps were also completed. The specimens used in these bond tests were pretreated with various environmental conditions expected at the Colorado site. These tests included the performance of the bond under freeze-thaw cycles, wetting in water, wetting and drying cycles in water, deicing chemicals, and alkaline attack.

The bond strength for each condition was tested using a direct pull-off test. Before the pull-off test was started, a loading fixture was attached to the CFRP wrap by an adhesive. The bond strength was then tested by a fixed alignment adhesion tool which was attached to the loading fixture and aligned to apply lift-off force perpendicular to the CFRP wrap surface. This lift-off force was then recorded.



Figure 6: Pull-off test being performed

Each environmental condition parameter reduced the average lift-off strength, however all specimens satisfied the 200 psi acceptance criteria for bond strength.

The final test of the CFRP wraps included a fire endurance test. The resin in FRP is a flammable element and it has potential risk under fire. To test the wrap, a thermogravimetry test was completed. The tested showed that the CFRP wraps have a maximum useable temperature of 446 degrees Fahrenheit.

Once all of the tests were completed, the renovation of the bridge followed. Before application during the renovation, the arch rib surface needed to be smooth and free from delaminations and spalls. Since the bridge had numerous areas which had deterioration, shotcrete was used to smooth the surface as required. After the shotcrete had cured, and surface preparations were completed, the CFRP wrap application process

followed. The procedure used for application during the renovation was the same procedure employed during the laboratory testing. The final step was to paint the arches to appear like concrete. This was an additional step that was not included in the testing phase.

In order to monitor the performance of the bridge, a wireless remote structural monitoring system was installed during renovation. This state-of-the-art monitoring technology has the ability to remotely access the data from a control office. The intent was to provide a cost effective system that reduced labor costs due to site visits. Eighteen strain gages were installed at the top, bottom and side surface of the arch along with two corrosion sensors to provide feedback on the CFRP rods. The sensors were tested after installation and baseline data was recorded. The results continue to be recorded by a solar powered datalogger.

3. Project Conclusions

The renovation at Castlewood Canyon Bridge was highly successful. This project was showcased at FHWA Bridge meetings in Colorado Springs during construction and demonstrated the first use of CFRP wraps in Colorado for arch rehabilitation by CDOT. Carbon wraps have continued to be used in Colorado for pier cap repairs based on the results from this project.

Additionally, the Castlewood Canyon Bridge renovation received an award from the 2004 Ninth Biennial Bridge Awards Competition sponsored by the Portland Cement Association. The award was given to this project because of the fine example of using an innovative approach to repairing an aging concrete structure while maintaining the historic features.

3.1 Positive Results

Listed are the specific comments provided by the State as positive results from the IBRD project:

- The test specimens retrofitted with CFRP wrap were between 22% and 30% stronger in bending than the control specimens.
- The stiffness of the specimens was also slightly increased by the FRP.
- The retrofitted specimens lost strength after the FRP rupture or bond failure. However, they still exhibited higher strengths than the control specimens throughout the tests.
- Structural analyses indicate that the bridge arches are much stronger than necessary to meet the required traffic loads. The retrofitting scheme increased the strength of the arches significantly. The strength of the arch to resist a concentrated load on the third spandrel column was increased by 30% compared to the original arch (prior to retrofit). These increased strengths were primarily due to the transverse FRP wraps which enhance the compressive behavior of the concrete.
- Pull-off test results of CFRP sheet-to-Concrete/Shotcrete under exposure to the influenced environmental parameters are satisfactory based on the recognized acceptance criterion (Minimum bond strength = 200psi). Good protection against aggressive environmental conditions is observed in CFRP composite material.
- The corrosion inhibitor which is applied on the substrates through a standard pump sprayer does not affect the pull-off bond strength.
- The data acquisition system, which uses wireless remote technology, performed well.

3.2 Lessons Learned

Listed are the specific comments provided by the State as lessons learned from the IBRD project:

- The retrofitted arch test specimen failed by rupture from the tension wrap. The average maximum FRP strain reached was 0.0077. This is only 63% of the ultimate strain specified by the manufacturer. In other beam tests, the rupture strain of the wrap was typically at least 0.01 (personal communication with the manufacturer). The cause of this premature rupture is unknown.
- For the case of concrete substrate, the most influential parameter on pull-off bond strength is "3% NaCl". The pull-off strength decreased significantly, up to 44%; however, the strength was still greater than the acceptable criteria.
- For the case of shotcrete substrate, the most influential parameters on bond strength was "Wet/Dry in Water". The pull-off strength decreased significantly, up to 40%; however, the strength was still greater than the acceptable criteria.
- Based on thermogravimetry analysis, the bond strength may significantly decrease because the epoxy starts decomposing at the temperature 446 degrees Fahrenheit. Thus, for the application of CFRP sheet to use strengthening concrete structures the maximum useable temperature is 446 degrees Fahrenheit.
- The bond between CFRP and substrate is critical in order to increase load carrying capacity of structures and effectiveness of strengthening systems. Construction processes such as handling, installation and curing of the material are also important parameters for strengthening/repairing concrete structures because ambient temperature, relative humidity, substrate moisture and substrate surface contamination can be affected by the adhesion. For use in civil infrastructure applications, a FRP sheet is required with a surface treatment or additive to enhance the fire endurance due to their potential as a fire hazard.
- More readings are needed in the future to evaluate the long-term performance of the arch of this bridge. The monitoring process of the arch of the bridge should be continued. The results obtained so far provide valuable information and can be used to compare with the strains and the corrosion data collected in the future for evaluating the long-term performance of the arch in the Castlewood Canyon Bridge.
- To evaluate long-term monitoring of corrosive conditions of reinforcement steel in concrete structures more accurately, several corrosion instruments should be installed at the overall locations of the arch.
- Both the corrosion sensors and wiring of the datalogger should be red-flagged during installation to alert construction workers to the presence of the device and wires to avoid damage to the device and the wires prior to pouring concrete or shotcreting.

3.3 Negative Results

Listed are the specific comments provided by the State as negative results from the IBRD project:

- The retrofitted arch test specimen failed by rupture from the tension wrap. The average maximum FRP strain reached was 0.0077. This is only 63% of the ultimate strain specified by the manufacturer. In other beam tests, the rupture strain of the wrap was typically at least 0.01 (personal communication with the manufacturer). The cause of this premature rupture is unknown.
- Resulting failure modes during pull-off tests while satisfactory based on the recognized acceptance criteria, are unsatisfactory based on the ACI criterion that the ideal failure mode is to have 100% failure in substrate.

4. Costs

In the 2003 fiscal year, the state of Colorado was granted \$400,000 in funding for implementing FRP technology through the FHWA Innovative Bridge Research and Construction program.

Repair and strengthening of reinforced concrete structures using advanced fiber-reinforced polymer composites have become very popular because the use of FRPs provides an attractive alternative to traditional rehabilitation techniques. The installation of these light-weight materials is less labor and equipment intensive. Due to the technological improvements of FRP since the 1990s, the costs associated with the use of FRP has started to decline.

5. References

The majority of the information presented in this report, including pictures, are highlights from the Project Summary Report provided by the State and the following resource(s):

Fafach, D., Shing B., Chang S., & Yunping X. (2004). "Final Report – Evaluation of the FRP-Retrofitted Arches in the Castlewood Canyon Bridge." December 2004.

**4.5. FRP, CONCRETE STRENGTHENING: MISSOURI - X0596 RTE. C OVER CREEK,
P0962 RTE. B OVER CREEK, T0530 RTE. M OVER CROOKED CREEK, Y0298
RTE. U OVER CREEK, AND X0945 RTE. C OVER RIVER**

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

Fiber Reinforced Polymer Case Study: Concrete Strengthening

Project

X0596 Rte. C over Creek, P0962 Rte. B over Creek, T0530 Rte. M over Crooked Creek, Y0298 Rte. U over Creek, and X0945 Rte. C over river

Project State **MISSOURI**

Prepared For:
Federal Highway Administration



Prepared By:
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January, 2012

1. Project Description

The purpose of this project was to validate the use of fiber-reinforced polymer (FRP) materials as a means to strengthen five existing concrete bridges that were considered structurally deficient. Five existing concrete bridges, geographically spread over three Missouri Department of Transportation districts, were strengthened using five different composite technologies in the summer of 2003. This project was given the name “Five Bridges Project”. Shown in Figure 1 are the technologies which were used at each of the five bridge locations.

Bridge	CFRP Sheets by Manual Lay-Up	Pre-Cured CFRP Laminates	CFRP NSM Bars	SRP by Manual Lay-Up	Mech. Fasten. FRP Laminates
Morgan County X-0596	X	X	-	-	-
Dallas County P-0962	X	-	X	-	-
Crawford County T-0530	X	-	X	-	-
Pulaski County Y-0298	X	X	X	X	-
Iron County X-0495	X	-	-	-	X

Figure 1: Composite technologies used at each bridge site

FRP has emerged as a means of repairing structurally deficient bridges. The advantages associated with such a system over conventional strengthening techniques are: expected long term durability, short construction times, and negligible traffic disturbances. In addition, the durability and lightweight attributes of FRP materials have led to their implementation in new bridge construction. Due to the relatively recent application of FRP to bridges, the long-term validation of FRP materials has yet to be fully realized. Load testing of bridges strengthened and constructed with FRP technologies serves as a means of validating the service performance of these materials over time.

The primary focus of this validation project was the load testing of all five of bridges. Load testing represented an imperative step in validating the effectiveness of FRP composites in the field. The first series of load tests began in July of 2003 and were conducted semi annually each spring and fall until the spring of 2008. This work was fundamental in verifying the long-term performance of FRP strengthening technologies.

In addition to load testing, several innovative means of monitoring were used to test the performance of the FRP repairs at bridge P-962 only. These included microwave nondestructive testing, fiber optics, laser profilometer, FRP alignment testing, impact echo testing, and pull-off testing. Bridge P-962 was also used to conduct life expectancy modeling to better understand the degradation mechanisms of FRP materials.

The FRP technologies utilized in the Five Bridges Project were manual lay-up carbon fiber reinforced polymer (CFRP) sheets, pre-cured CFRP laminates, CFRP near surface mounted (NSM) bars, steel reinforced polymer (SRP), and mechanical fastened FRP laminates. The subsequent pages provide a brief description of each of the FRP technologies. Figure 1 shows which technologies were used on each bridge.

Manual Lay-up Carbon Fiber Reinforced Polymer Sheets



Figure 2: Manual lay-up CFRP Sheets

Manual FRP lay-up is the process of adhering rolled sheets of FRP to concrete with a two-part resin. The types of FRP include glass, aramid, and the most common for structural applications, carbon. To ensure a good bond the existing concrete surface must be roughened with sandblasting and then smoothed and leveled with concrete or putty. Corners must be rounded in the case of shear strengthening with U-wraps to prevent localized stresses in the FRP.

Pre-cured Carbon Fiber Reinforced Polymer Laminates



Figure 3: Pre-cured FRP Laminate Plates

Pre-cured laminates are plates of the resin and fiber matrix that have been cured prior to application. These plates are applied to the prepared concrete surface with a two-part epoxy similarly to the FRP sheets. However, pre-cured laminates need to be properly supported to a soffit during installation to ensure there is a solid bond.

Carbon Fiber Reinforced Near Surface Mounted Bars



Figure 4: CFRP NSM mounted bars

Near surface mounted bars are rectangular or circular bars applied by cutting grooves into the existing concrete surface where an increase in moment capacity is required. The grooves are filled with epoxy and the bars are pushed into the grooves, causing excess epoxy to seep out. Additional epoxy is then applied over the bars where needed and the surface is finished.

Manual Lay-up Steel Reinforced Polymer



Figure 5: Manual lay-up SRP

Steel reinforced polymer (SRP) is very similar to FRP; the primary difference being that SRP contains high strength steel wires instead of carbon, glass or aramid fibers. SRP is applied in the same way as FRP sheets; it is impregnated with resin and applied to the prepared concrete surface.

Mechanically Fastened Fiber Reinforced Polymer Laminates



Figure 6: Mechanically fastened FRP laminates

Mechanically fastened FRP is comprised of pre-cured laminate plates with predrilled holes that are fastened to the concrete surface with mechanical bolts. No surface preparation is required, resulting in a faster installation process.

The research completed for the FRP repairs at these bridges was performed by the Center of Infrastructure Engineering Studies at Missouri University of Science and Technology, in cooperation with the National University Transportation Center.

2. Project Implementation

The load testing procedure for the Five Bridges Project involved the static placement of two loaded H20 dump trucks provided by MoDOT. Load tests utilizing loaded dump trucks have been conducted in the past and are an effective and simple means to evaluate bridge live load performance. The weight of the trucks was recorded to account for any large variances in weight between load tests and the potential for considerable differences in deflection. The weights of both the front and rear tandem axles were recorded. For modeling purposes and to assist in the normalization of the load test deflection data, the dimensions of the truck axles and distances to the centerline of each tire were recorded as well.

Testing utilized a Total Station and optical surveying prisms for targets located on the bridge and reference points.

Iron plates were epoxied to the undersides of the bridges at predetermined locations along the span and given time to cure prior to the load testing. The plates remained for future load tests. Magnetized target prisms were then attached to the plates using a range pole.

The three reference prisms were positioned at contrasting elevation points as far apart as possible and directed at the Total Station. The reference prisms served as guides in determining if the Total Station recorded any movement between readings.



Figure 7: Two loaded H20 design trucks used for load testing

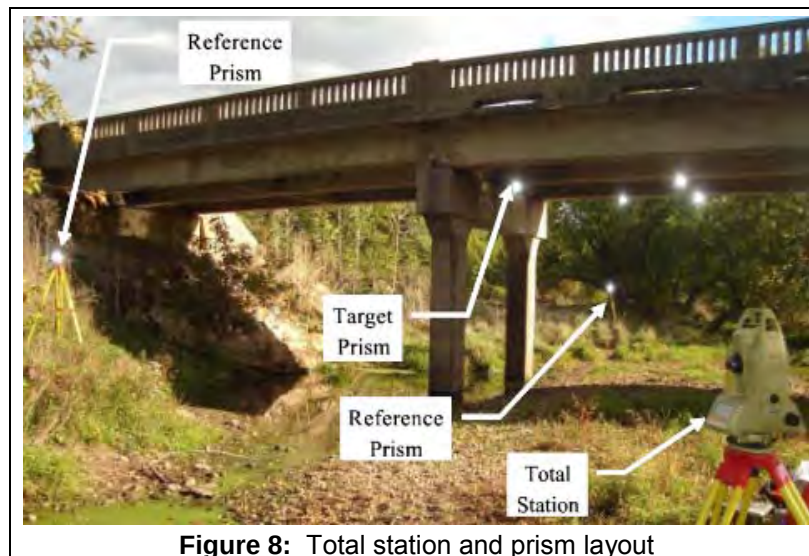


Figure 8: Total station and prism layout

The Total Station was set to record each data point three times. Bridge traffic was stopped and the elevation of each point before loading was determined to establish a baseline.

Next, the loaded dump trucks were placed on the bridge decks in configurations that would induce the largest stresses and deflections in the structure. The trucks stopped at five locations on bridges: X-596, T-530, X-495 and P-962 and stopped twice on bridge Y-298. (For bridge identification, see Figure 1.)

The first three stops were conducted with both trucks side-by-side driving down the length of the bridge. Stop 1

was conducted with both rear axles near the edge of the span to induce a maximum shear case. Stop 2 was conducted with both trucks side by side at midspan; this was a maximum moment configuration. Stop 3 was similar to stop 1 in that it produced a large shear case, only on the opposite side of the bridge. Stop 4 and 5 were overload conditions intended to produce the maximum moment and deflection on the exterior girder and interior girder.

Only two stops were conducted on bridge Y-298 due to the small size of the bridge. After the trucks had been placed, the bridge was given five minutes to settle under the load and the Total Station recorded the new elevations. The trucks were then moved off of the bridge and traffic was allowed to pass. After the final stop, the bridge was given five minutes to rebound and a final no-load run was conducted to determine if the bridge elevation had changed from the first reading.

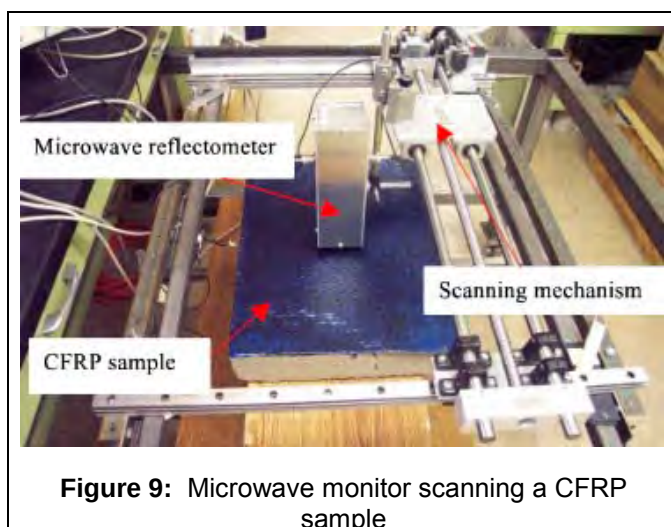
The deflection of the girders from each pass was determined by taking the difference between the baseline and the recorded stop elevations. The three readings taken at each point elevation were first analyzed. If any of the readings varied from the other two by more than 0.005 inches, it was removed from consideration. The remaining readings were then averaged to determine the point elevation. The baseline was subtracted from the calculated elevation to determine the deflection at the prism.

In order to appropriately account for the camber of the bridge due to thermal effects during testing, an appropriate baseline was established for each stop during testing. The thermal effects were accounted for by taking a weighted average of the first no-load stop and the final no-load stop based upon when the stop occurred.

This concluded the load test. Finally, the Total Station, reference prisms and target prisms were removed and the data processed.

As part of this project, nondestructive testing methods were also performed. Bridge P-962 was selected as a case study to test the performance and durability of the repairs. Built in 1956, Bridge P-962 carries County Route B across a medium sized creek. The bridge is 127.5 feet long and 23.75 feet wide. It has three spans, all consisting of three reinforced concrete girders, monolithically cast with a 6 inc thick deck slab. Below is a brief description and implementation of nondestructive testing methods:

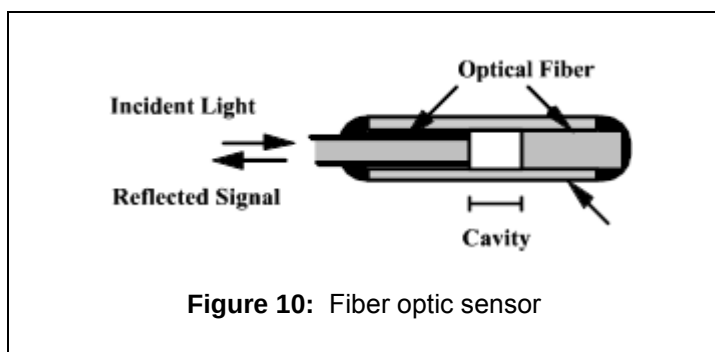
Near-Field Microwave Nondestructive Testing



The microwave inspection system employed a dual-polarized reflectometer for detecting defects such as disbond between CFRP laminates and strengthened structures. Microwave signals can penetrate inside dielectric materials and interact with their inner structure. These signals were interpreted by a laptop computer to identify delamination occurring between the laminate and the concrete. In order to attach the scanner to members of a bridge, the scanning platform was connected to a clamp and bracket and attached to the bridge member.

Several measurements using this system were conducted on Bridge P-962, whose members were strengthened with carbon fiber reinforced polymer laminates.

Fiber Optics



Fiber optic strain sensors offer benefits for permanent health monitoring applications. The sensors work by utilizing multiple-beam interference between two polished end-faces of a fiber. A capillary tube is bonded to the two fibers which maintains the alignment of their end faces. As the material and attached tube are strained, the reflected interference signal varies in response to changes in the cavity spacing. This variation can be interpreted to measure absolute strain.

A network of fiber optic strain sensors were embedded into bridge P-962. The sensing network monitored strain at the midspan in the center bay of the bridge. The sensor array was primarily intended to confirm the structural strengthening and to monitor performance over time.

Laser Profilometer



Figure 11: Laser profilometer being used under bridge

A laser profilometer is a newer technology that can be utilized for bridge monitoring. This portable device is used to test concrete surface roughness. The system uses a striping laser mounted at 45 degrees to the concrete surface and generates five profile lines. These lines follow the contour of the surface and get progressively more undulating as the roughness of the surface increases. In combination with the laser, the device also uses a video camera, mounted at 90 degrees to the surface, to image the profiles. The video signal is then transmitted wirelessly to a computer to be analyzed. It is important that concrete is smooth before the application of FRP panels.

Roughness measurements were taken under the deck at bridge P-962 where FRP panels were to be installed.

Alignment Testing

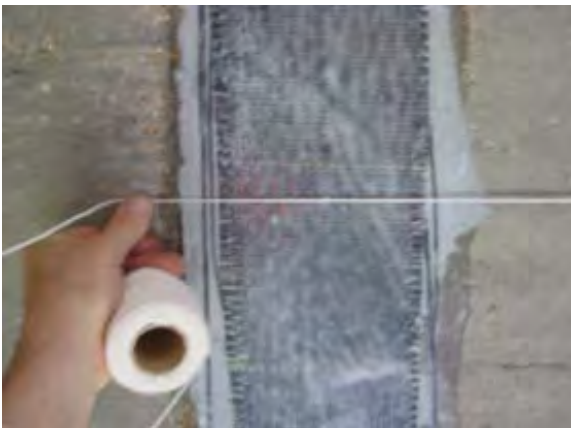


Figure 12: Alignment test being performed

The alignment of fibers has also been identified as an indicator of FRP performance. A misalignment of more than 5 degrees can significantly affect the performance of the repair. A method was developed to measure the alignment of the fibers. The FRP sheets were ordered with an embedded tracer woven into the fabric, and were installed using transparent epoxy. Then, a chord is simply stretched perpendicular to the edges of the fabric, photographed, and using imaging software, the angle between the tracer and the chord is measured.

Alignment measurements were taken for all of the FRP sheets at bridge P-962.

Impact Echo Testing



Figure 13: Impact echo measurements

Delaminations of only one square inch can be enough to affect the strength of the FRP materials and degrade the performance. To measure the delaminations, an impact echo tester was specially modified with an air coupled receiver to identify the delaminated areas of the test panels installed at bridge P-962. An impact echo tester works by sending out low-frequency sound waves that propagate into the structure and are reflected back to the surface. Areas with delaminations will reflect back a wavelength that weakly propagates through the material. The impact echo tester is connected to a device that measures these wavelengths, identifying delaminated areas.

Pull-off Testing



Figure 14: Pull-off test performed in field

The final test performed was the pull-off test. The load carrying ability of FRP is related to the bonding characteristic of the epoxy to the concrete substrate, and the bonding characteristic is a function of the surface roughness of the concrete. The pull-off test is used to measure the strength of the bond between the FRP material and the concrete substrate. To determine an appropriate test load rate about 20 plugs were laminated to FRP test sections at bridge P-962 in non-critical areas and were pull-tested to failure.

3. Project Conclusions

Where limited manpower exists for installation, the strengthening of reinforced concrete bridged with FRP using mechanically or adhesively fastened pre-cured plates is a promising technology. For short span structures as few as two individuals can install the strengthening system and this technique appears ideal for county level agency installation. Other techniques such as manual lay-up, NSM bars, and SRP are generally more field intensive installation techniques and therefore require greater manpower.

Based on the visual inspections to date, the SRP system exhibited signs of steel corrosion and was the worst observed strengthening deterioration for any system used. Corrosion of the high strength wire in the SRP system is particularly concerning due to its thin cross section. To increase the protection of the steel wire a more durable polymer system would be needed for this type system to hold promise in an aggressive external environment. This technique is not recommended for further field demonstration until a more durable protective polymer is used in combination with the steel wire.

The methods used for nondestructive testing at the P-962 bridge site produced generally positive results with two exceptions. Microwave nondestructive testing, fiber optics, laser profilometer, and impact echo testing each performed as intended, were successfully implemented, and showed the performance of the material matched expectations. The alignment test was successfully implemented, however approximately 25% of the measurements produced a misalignment greater than maximum allowable skew of 5 degrees. Similarly, with the pull-off test, the implementation was also successful, but it was found that nearly all plugs used in the test failed the second, third, or fourth time they were tested. The explanation provided in the research, suggests that repeated loading weakens the strength of the epoxy material over time and was not the result of inadequate bonding.

The life expectancy modeling for FRP strengthened concrete bridges produced encouraging results. A wide range of mechanisms for the potential degradation of CFRP composites are involved, including thermal degradation, weathering, chemical attack, ionizing radiation, creep, and fatigue. The modeling report concluded that the degradation of CFRP material is not a critical issue for the location of the P-962 bridge site.

3.1 Positive Results

Listed are the specific comments provided by the State as positive results from the IBRD project:

- Surveying equipment can compete with traditional systems when monitoring the serviceability of structures during static load testing.
- There was a decrease in deflection and a subsequent apparent increase in stiffness for bridges T-530 and P-962 due to strengthening.
- There was no dramatic increase in deflection for any of the tested bridges.

3.2 Lessons Learned

Listed are the specific comments provided by the State as lessons learned from the IBRD project:

- Where site problems make LVDT and dial gauge systems very difficult to set up and operate successfully, surveying equipment is an ideal alternative.
- Thermal effects were significant in the load testing results for the Five Bridges Project.
- The apparent increase in stiffness achieved by adding FRP strengthening is primarily attributed to the restraint of concrete cracks from opening.
- The visual inspections conducted during testing yielded some important information that will be helpful in tracking future degradations of bridge components for FRP strengthening.
- For Bridges X-495 and X-596, it was difficult to quantify the apparent increase in stiffness due to strengthening with load testing. This is due to a lack of flexural strengthening of the exterior girders.

3.3 Negative Results

Listed are the specific comments provided by the State as negative results from the IBRD project:

- Surveying equipment cannot be used to monitor serviceability of structures during dynamic load testing.
- The distribution fractions, or coefficients, for the western exterior girders of Bridge P-962 have increased over time.
- The apparent increase in stiffness for Bridges T-530 and P-962 due to strengthening decreased over time according to an average percent difference trend line.

4. Costs

In the 2003 fiscal year, the state of Missouri was granted \$250,000 in funding for researching the FRP technologies through the FHWA Innovative Bridge Research and Construction program.

5. References

The majority of the information presented in this report, including pictures, are highlights from the Project Summary Report provided by the State and the following resource(s):

- Missouri Department of Transportation (2005). *Preservation of Missouri Transportation Infrastructure – Validation of FRP Composite Technology Through Field Testing*. Research Development and Technology Brief. March, 2005.
- Missouri Department of Transportation (2006). *Missouri's FRP Composite Strengthening Field Test Enter Third Year*. Breakthrough Research Bulletin. May, 2006.
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**4.6. FRP, DECKS: MARYLAND - REHABILITATION OF BRIDGE NO. 12016 ON MD
24 OVER DEER CREEK – INCLUDING DECK REPLACEMENT UTILIZING
FIBER REINFORCED POLYMER DECK**

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

Fiber Reinforced Polymer Case Study: Decks

Project

**Rehabilitation of Bridge No. 12016 on MD 24 over Deer Creek – Including
Deck Replacement Utilizing Fiber Reinforced Polymer Deck, Harford
County**

**Project State
MARYLAND**

**Prepared For:
Federal Highway Administration**



**Prepared By:
HDR Engineering, Inc.
9987 Carver Road
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Cincinnati, OH 45242**

January, 2012

1. Project Description

The purpose of this project was to replace an existing bridge deck using precast fiber-reinforced polymer (FRP) deck panels. In addition, the bridge was instrumented with a wireless structural monitoring system to record load testing information and live load distribution data. The existing steel through truss bridge on MD 24 over Deer Creek is located in Harford County, Maryland. This bridge, known as the Rocks Steel Truss Bridge, was built in 1934 and is eligible for inclusion in the National Register of Historic Places. As shown in Figure 1, this highly skewed bridge is single span bridge, 122'-6" long and carries two lanes of traffic providing 30 feet of clear roadway.



Figure 1: Rocks Steel Truss Bridge over Deer Creek

A major problem with reinforced concrete decks is that cracking occurs over time allowing water and deicing chlorides to penetrate inside the concrete deck. This causes corrosion of the reinforcement which can eventually lead to deterioration of the concrete by creating delamination and spalls limiting the overall serviceability of the structure. In 2003, the deck at the Rocks Steel Truss Bridge site was replaced, due to its deteriorated condition. The remainder of the structure was in good condition with only minor concrete patching work to the bridge abutments, cleaning of the bridge bearings and painting of the truss needed.

FRP decks offer many advantages over conventional reinforced concrete decks, as they are lightweight, have reduced installation time, and offer better corrosion resistance. FRP decks used in bridge design have been tested in various corrosive environments and have performed very well. In many cases, precast FRP deck panels can be installed in one third the time of conventional cast-in-place concrete decks. Reduced installation time can be extremely advantageous when replacing structures in high traffic volume areas.

This was the first use of an FRP deck by the Maryland State Highway Administration (SHA). The FRP deck installed weighed 25 pounds per square foot. This included the deck, connections and grout. The asphalt overlay weighed 45 pounds per square foot to make the combined section weigh 70 pounds per square foot. When compared to traditional reinforced concrete deck, the FRP deck panels are approximately 40% lighter. This large difference in dead weight allows the bridge's live load capacity to be increased. Often weight restrictions on older bridges may be removed with the installation of an FRP deck.

One disadvantage with FRP is associated with exposure to ultraviolet radiation from sunlight. Overexposure to sunlight has been shown to have a harmful effect on the long-term strength in FRP materials. However, the Rocks Steel Truss Bridge deck is protected by the asphalt concrete overlay. In addition, a protective

additive has been incorporated into the design mix of the FRP deck panels, which protects against any degradation due to ultraviolet radiation. This FRP deck is expected to have a design life of at least 70 years.

The traffic volume at the Rock Steel Truss Bridge site was also a major concern. The bridge crossing was such that a complete detour of traffic during construction was only acceptable during the summer months. Since the bridge is on a school bus route, closure was unacceptable when school was in session. As a result, the bridge repairs had to be performed in a compressed ten-week period when schools were out of session.

The design of most bridges poses unique site and use related design challenges. Standard design details and practices must be modified to accommodate the parameters of a particular project. Working with a new design material dramatically increases the design challenges as very few standard details or practices exist to use as models.

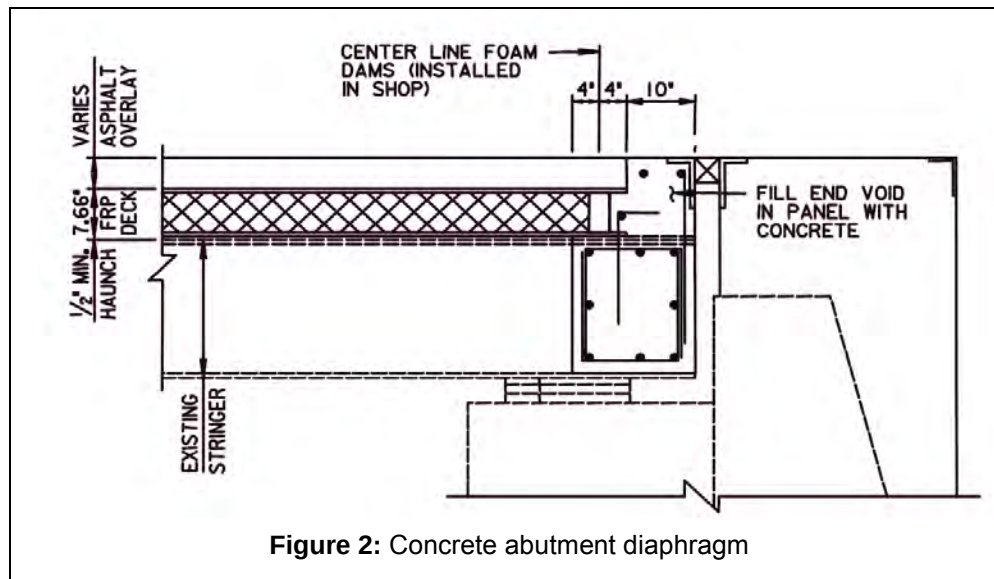


Figure 2: Concrete abutment diaphragm

One design challenge for this bridge was the 56 degree roadway skew. The FRP deck panels are placed perpendicular to the stringers and act as a continuous beam between the stringer supports. A problem arises at the ends of the bridge where the skew is encountered. At this location, the edges of the panels have no bearing support. To provide this necessary support, a concrete diaphragm was placed between the existing

stringers. The installation of the concrete diaphragm also solved several other concerns, including how to install the compression / expansion joints, how to protect the joint and the ends of the panels from damage due to live load impacts, and how to limit deck deflections at the ends of the bridge.

Creating the roadway crown was another design challenge. The selected deck was manufactured by the protrusion method. The fiberglass strands and fabric were pulled through a die at the same time coated with the polyester resin. The deck panels that were produced were perfectly flat. To create the crown, rather than modifying the deck panels, the thickness of the overlay across the deck was varied to achieve the necessary roadway cross slope. The advantage of this method was that the deck panels could be installed level without splicing the top chord of the panel, which was cheaper and quicker to install. The disadvantage of this method was that the overlay can become excessively thick which reduces vertical clearance. It also adds weight to the deck. Since the FRP deck panels are often used as a lightweight alternative this lessens one of the advantages when utilizing this type of deck system. However, regardless of the added thickness, this bridge still weighed less than the original design and overhead clearance could be maintained, therefore varying the thickness of the overlay was the best solution at this site.

The loads tests and structural monitoring were performed through the use of a wireless structural monitoring system installed during deck panel installation. For structures using relatively new materials, such as FRP, the use of load tests can prove the structure's capabilities. The monitoring system included a small data acquisition and communication node connected to seven different groups of strain transducers that acquired data in digital form, and relayed the data to a local base receiver attached to a personal computer.

The research completed on the use of FRP precast deck panels at this bridge site was performed by The Bridge Engineering Software and Technology (BEST) Center, Department of Civil Engineering, University of Maryland.

2. Project Implementation

Following removal of the existing deck, the first item to be completed was the construction of the abutment diaphragm. The diaphragm provided bearing support for the deck panels at the skewed end of the bridge.

Before the panels could be installed, steel angles were welded to the sides of the girders to develop a haunch. Bonding agent was applied to the top of the steel angles to adhere the FRP deck panels.

Although vertical clearance was not an issue for traffic going over the bridge, the 24.5 foot vertical clearance from the top of deck to the lowest steel member of the bridge restricted crane use. Because of this limited vertical clearance, a forklift was used to efficiently install the panels (see Figure 3). A forklift was used given the FRP's light weight properties.



Figure 3: Forklift lowering deck panel into place near the end of the bridge

The forklift placed the panels on the steel angles perpendicular to the girders to act as a continuous beam across the girder supports. Part of the advantage of this FRP deck system is that it was acceptable to place construction loads on the panels immediately after placement. This allowed the forklift operator to position the next panel into place by moving over the newly installed panels as it progressed from one end of the bridge to the other.

Before adjacent panels could be placed longitudinally next to each other, a bonding agent was placed on the transverse edge of the installed panel, so that the adjacent panels adhered to each other.



Figure 4: Bond between deck panel and top of girder

Shear studs pockets were formed into the panels. Once all of the deck panels had been placed, these pockets were filled with non-shrink grout.

At the skewed end of the bridge the rectangular panels were cut with a saw to fit the required dimensions of the bridge. A representative from the FRP manufacturer was on site and arranged for the proper cutting saw to be delivered to the project. After the placement of the skewed panels, the ends were properly sealed.

An asphalt overlay was then placed to provide the required skid resistance, to form the roadway crown, and to protect the FRP from ultraviolet radiation. While a polymer overlay is typically used in Maryland, the asphalt overlay was allowed because the FRP panels will not corrode.

The project was completed within the 10 week time line, and the installation of the FRP precast deck panels only required three days. Once the existing deck was removed and the existing girders cleaned, it took only 15 working days for the bridge to be opened to traffic. The rapid installation possible with these panels was vital in completing this bridge on time.

After construction was complete, the wireless monitoring system was installed. The strain transducers were installed at the following locations:

- Group 1 – strain transducers were placed at vertical and diagonal members of the steel truss. This was to measure the response of these members to live load.
- Group 2 – strain transducers were placed at three adjacent steel stringers. These gages were useful in studying the distribution of live load between stringers at different locations (exterior and interior stringers) and the effect of the FRP deck had on the live load distribution.
- Group 3 – strain transducers were placed at the bottom of the FRP deck in the mid-span of the panel in different directions. These gages showed the response of the FRP deck for live load.
- Group 4 – strain transducers were placed on bottom flange and top flange of the steel stringer, and bottom of the FRP deck, in the mid-span of the panel. Using these gages, the location of neutral axis for the mentioned stringer was found, which helped to study



Figure 5: Installation of strain transducer at the underside of deck near girder

the composite action and the contribution of the FRP in resisting compression stress. The effective width of the section could be studied as well.

- Group 5 – strain transducers were placed at first diagonal member, bottom chord member of the steel truss, and steel floor beam, respectively. This group showed the response of these members to live load.
- Group 6 – strain transducers were placed at the same locations as group 4 to verify the results in that group.
- Group 7 – strain transducers were placed at the same locations as group 3 to verify the results in that group.

3. Project Conclusions

The deck replacement at the Rocks Steel Truss Bridge site was very successful. The use of precast FRP deck panels on this historic bridge helped the State Highway Administration maintain the heritage of the region. A recent inspection in 2006 found that the deck still looked new, with no signs of problems. The Maryland SHA has planned rehabilitation projects with FRP deck panels for similar historic through-truss bridges in their State.

3.1 Positive Results

Listed are the specific comments provided by the State as positive results from the IBRD project:

- The FRP deck panel has no negative effect on steel truss, floor beams, or stringers.
- The FRP deck panel has not shown any excessive deformations or unexpected responses, which has increased the confidence in using such material for bridges.
- The distribution factor can be calculated using the AASHTO LRFD Specifications by taking the thickness of the deck slab as the total thickness of the FRP deck panel.
- Due to the light weight nature of the FRP deck panels, the inventory rating for the bridge was increased from 0.92 to 1.12.

3.2 Lessons Learned

Listed are the specific comments provided by the State as lessons learned from the IBRD project:

- Because differences in the as-built bridge versus original plans, any future designs must have some degree of tolerance for differences between planned dimensions and actual field dimensions. This was especially true when the deck was installed on the existing structure. It was rare to find an existing structure that has all member dimensions and spacing, matching the as-built plans. When placing a reinforced concrete deck, it is easier to adjust for changed conditions. With an FRP deck, however, it is not as easy since the deck panels are delivered to the site already fabricated. Therefore, it is important to design the deck system in a way that can easily accommodate small differences between planned and actual conditions.
- A representative from the FRP deck manufacturer was required on the project and was to be on site during installation. This representative was able to guide the contractor on how best to install the deck and offer valuable input into solving problems, specifically with the cutting of the end panels. This project's representative was able to arrange for the proper cutting saw to be delivered to the site immediately, in order to cut the necessary panels and properly seal the ends in a matter of hours, avoiding long construction delays.

- If shear studs are provided, the FRP deck panel and the steel stringer can be considered a composite section. Non-shrink grouting can be used and placed in the stud pocket after welding the shear studs, to produce the composite action.
- Effective width for the FRP deck panel and steel composite sections is governed by AASHTO LRFD criteria for computing the reinforced concrete section effective width based on the girder spacing. However, the test results only demonstrated the calculation of the effective deck width for small and medium spacing between stringers (spacing for this bridge is 49"). Further tests have to be performed for bridges with wider girder spacing to evaluate other criteria such as deck thickness or span length.
- Local action may have an effect on plate action especially for the cases of low driving speeds. The results show that the FRP deck panel functions as an orthotropic plate with higher strains in both the longitudinal and transverse directions between stringers.
- The response to loading for an FRP deck panel is not the same as the steel components. Furthermore, the FRP material is a composite and is not necessarily homogeneous as steel. Thus, the type of strain gage used for this project, which is appropriate for steel, may not be well suited for monitoring the behavior of the FRP panel, as the gages may not correctly measure the FRP response for loads moving across the bridges at higher speeds.

3.3 **Negative Results**

Listed are the specific comments provided by the State as negative results from the IBRD project:

- High fabrication and material costs for FRP deck panels. This FRP deck was approximately twice as expensive as a conventional reinforced concrete deck.

4. **Costs**

In the 2003 fiscal year, the state of Maryland was granted \$400,000 in funding for implementing FRP deck panel technology through the FHWA Innovative Bridge Research and Construction program.

The engineer's estimate for this project was \$924,400, and the low bid was \$911,100. Five contractors bid on the project and the 2nd lowest bid was slightly more than the winning low bid.

5. **References**

The majority of the information presented in this report, including pictures, are highlights from the Project Summary Report provided by the State and the following resource(s):

The Bridge Engineering Software and Technology (BEST) Center, Department of Civil Engineering, University of Maryland (2003). "Final Report – Bridge No. 12016 on MD-24 over Deer Creek (FRP Bridge Deck Replacement)." December 12, 2003.

Robert, J. (2010). "Deck Replacement for Skewed Truss Bridge on MD 24 over Deer Creek in Harford County, Maryland Utilizing a Fiber-Reinforced Polymer (FRP) Bridge Deck. April 13, 2010.

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4.7. SCC, GIRDERS: MICHIGAN - M50 OVER GRAND RIVER

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

**Self-Consolidating Concrete
Case Study: Girders**

Project
M-50 Bridge over Grand River, Jackson

Project State
MICHIGAN

Prepared For:
Federal Highway Administration



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January, 2012

1. Project Description

The purpose of this project was to develop three different types of self-consolidating concrete (SCC) mixes for a demonstration bridge utilizing SCC in its beam design. Then, using a monitoring system that was installed during bridge construction, the short-term and long-term performance of the beams were tested. The M-50/US-127 Bridge over the Grand River is located in Jackson, Michigan. This demonstration bridge consists of six simply supported 27 inch x 36 inch spread box beams with a span of 50 feet.



Figure 1: M-50/US-127 demonstration bridge using SCC beams

SCC was developed in Japan in the early 1980's in response to the decline in the skilled labor force in country. The inability to find adequate labor was leading to durability problems in concrete structures caused by either over or under consolidation. In developing SCC, the goal was to create a durable concrete mix which was easy to place and finish independent of the quality of the labor.

Worldwide, the use of SCC became more popular in the mid 1990's. By the year 2003 at least draft guidelines were in place in Austria, Finland, France, Germany, Italy, Netherlands, Norway, and Sweden.

SCC has developed slower in the United States. Beginning around the year 2000, US precast/prestressed product producers, as well as admixture companies, began to push for the ability to use SCC in their projects. Since then, research on SCC in the US has grown quickly. As a result of this rapid growth a FAST team was created by the Precast/Prestressed Concrete Institute (PCI) with the intention of developing guidelines for the use of SCC. Interim Guidelines for the use of SCC in precast/prestressed construction was published by PCI in 2003.

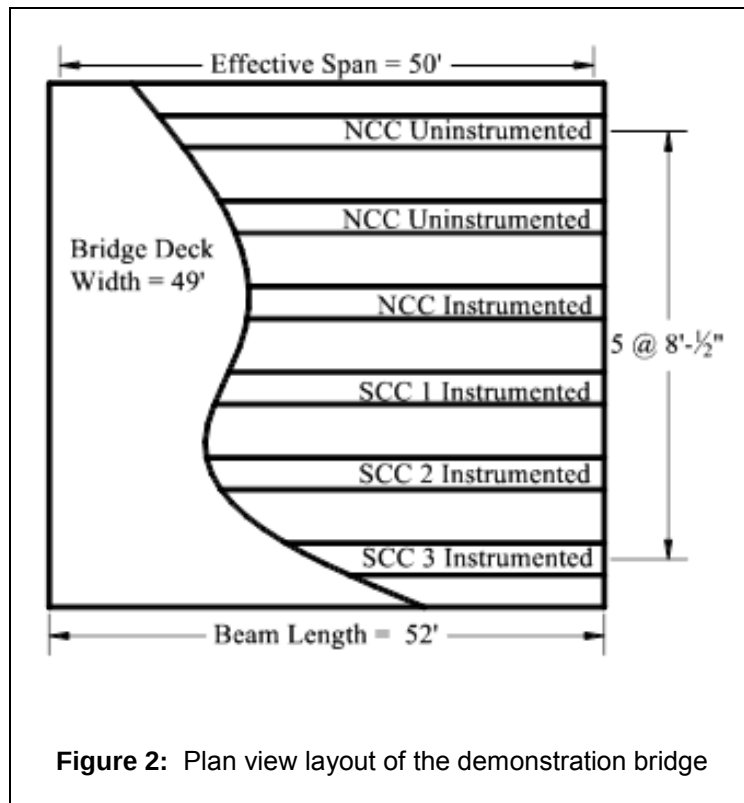
The use of SCC became popular because of three primary reasons: filling ability, passing ability, and segregation resistance. The filling ability of SCC is its ability to fully fill formwork without the use of vibration. This includes flowing around obstacles including dense steel reinforcing schemes and form block outs. The passing ability of SCC is its ability to flow around and through obstacles without segregating or experiencing aggregate blocking. The segregation resistance of SCC is defined as the ability to resist segregation of its coarse aggregate components through all phases of the construction process including transportation from the batching plant to casting site, placement in the formwork, and finishing of the product.

The successful development of these three factors has the ability to increase the productivity and product quality while reducing the cost of production. The high workability of SCC and removing the vibration requirement leads to a reduction in labor needed to produce concrete elements and faster production. Additionally, the self-consolidating nature of SCC has the ability to produce a higher quality finished product

than can be achieved with normally consolidating concrete (NCC). While SCC generally has higher material costs, these costs are usually offset by reductions in labor and increased productivity.

In the United States the precast industry and admixture companies continue to push for the widespread use of SCC in many areas of civil engineering construction. However, some agencies which make use of concrete technology including state departments of transportation have been slow to accept SCC as a viable alternative to NCC. These groups have expressed concerns with the long-term performance of SCC, and difficulties regarding quality control. These concerns have kept SCC as a popular research topic in the US, but has limited its implementation in construction projects.

Three SCC mix designs were developed for this M-50/US-127 bridge project. A fourth mix design, an NCC mix, was used as an experimental control. Three identical box beams were cast from each of the four mix designs. Of these three beams from each mix design, one was instrumented for long term monitoring of strain and temperature and was placed in the demonstration bridge. The remaining two beams from each mix design were instrumented for experimental evaluation. The experimental evaluation of the full-scale prestressed beams was done at Michigan State University's Civil Infrastructure Laboratory prior to the construction of the demonstration bridge. Two four-point bending tests were conducted in the laboratory for these evaluations. The two tests evaluated the flexural and shear performance of the beams. A fifth NCC beam was developed without any instrumentation. Two of these non-instrumented beams were used in the construction of the demonstration bridge. Finally, three NCC beams were cast to replace the SCC beams in the event that their laboratory performance was inadequate. A total of 17 beams, 8 NCC and 9 SCC, were cast for this project at the fabricator's precast plant in Michigan in the months of June and July of 2005. See Figure 2 for how the various beams were utilized in the demonstration bridge.



The short-term evaluation of SCC beams was accomplished through full-scale tests of replica bridge beams in the laboratory. This was done to ensure that the capacity demands in the bridge system were safely met by these members. Both the shear and flexural capacities were experimentally determined through structural testing to evaluate the short-term performance of the SCC beams with respect to the baseline NCC beams.

The long-term evaluation of the SCC beams included monitoring strain and temperature from the demonstration bridge. The collected data provided information about any prestressing force losses in the beams that could be attributed to the creep and shrinkage behavior of the SCC.

Finally, the production process evaluation included assessment of the mix design development, and quality monitoring of the concrete production and finished beams. This research effort also included an evaluation of the production process of SCC prestressed beams, in order to define any

necessary changes to better use SCC in future projects.

The research completed on the use of SCC at this bridge site was performed by Rigoberto Burgueno and David A. Bendert at the Department of Civil and Environmental Engineering, Michigan State University.

2. Project Implementation

The first part of the research project was to develop a mix design for the SCC. Many SCC mix designs have been proposed by researchers. Among all of the proposed SCC mix designs; there have been two methods which have performed the best. The first method achieves the fluidity requirements through the reduction of the coarse aggregate volume and the use of high range water reducer (HRWR). The stability comes from a low water to cement ratio with a high sand to paste ratio. The second method uses a high water to cement ratio with little to no HRWR to achieve the fluidity requirements, allowing for a moderate volume of coarse aggregate, while the stability is achieved through the use of a viscosity-modifying admixture (VMA) and moderate sand to paste ratios.



Figure 3: Inverted slump flow test

The performance of SCC is most often characterized by its properties to fill formwork, flow around obstacles, and resist segregation which determines the usefulness of the mix for a given application. The mix design properties used for the demonstration bridge were investigated using for selected tests: inverted slump flow test, visual stability index, J-Ring, and L-Box.

The inverted slump flow test uses a standard Abraham's cone which is inverted upside down. As the cone is lifted vertically, the SCC flows into a circular concrete patty. The average diameter of the patty is obtained from two orthogonal measurements. This average diameter represents the slump flow for the mix.

The visual stability index test is a qualitative measure of the concrete's ability to resist segregation. A rating system on a scale from 0 to 3 (with 0 showing no signs of segregation), has been developed to index the SCC

mix. This rating system is based on ASTM C 1611 and is shown in Figure 4.

Rating	Criteria
0	No evidence of segregation in the slump flow patty or sampling wheelbarrow
0.5	No mortar halo or aggregate pile in the slump flow patty, but very slight evidence of bleed or air popping on the surface of the SCC in the sampling wheelbarrow
1	No mortar halo or aggregate pile in the slump flow patty but some slight bleed or air popping on the surface of the concrete in the sampling wheelbarrow
1.5	Just noticeable mortar halo and/or a just noticeable aggregate pile in the slump flow patty and noticeable bleeding in the sampling wheelbarrow
2	A slight mortar halo and /or aggregate pile in the slump flow patty, and highly noticeable bleeding in the wheelbarrow
3	Clearly segregating by evidence of a large mortar halo and/or large aggregate pile in the center of the concrete patty and a thick layer of paste on the surface of the resting concrete in the wheelbarrow

Figure 4: Visual stability index criteria

The J-Ring test is similar to inverted slump test in that it uses an inverted Abraham's cone and the same type of procedure. In this test, the cone is placed inside of a ring of evenly spaced vertical bars which represents the reinforcing scheme of the beams which will be cast. Again, similar to the inverted slump

test, the cone is lifted vertically and the SCC flows into a circular concrete patty, as shown in Figure 5. As the mix flows through the vertical bars, the passing ability of the SCC is assessed. Based on changes in depth from the center of the patty to the inside of the ring and from the inside of the ring to the outside of the ring, an equation is used to calculate a "J-Ring value".

The L-Box test is another measurement of the passing ability of SCC. The test consists of two rectangular chambers arranged in the shape of an L, as shown in Figure 6. To obstruct the flow of the concrete, vertical bars are placed just outside a gate which is used to restrain the mix. The test is performed by filling the vertical chamber and allowing the



Figure 5: J-ring test patty

concrete to rest against the gate for one minute. After the concrete has rested, the gate is lifted up which allows the concrete to flow through the bars and into the horizontal chamber. Once the concrete comes to rest, the height of concrete in each chamber is measured. This measurement provides a ratio of the heights between the vertical and horizontal chambers. A higher value ratio represents the least resistance to passing ability.



Figure 6: L-Box test after release of concrete

Development of the final SCC mixes required numerous trial batches and adjustments to the mix designs. The performance of these mix designs were assessed through these testing methods. Adjustments were made to the mix designs based on the test results until satisfactory performance was consistently produced.

The final mix designs for each concrete type are given in Figure 7. The three SCC mix designs were the result of the mix development process that utilized the previously described four testing methods. The NCC mix design was the standard

fabricator mix used in Michigan for bridge beams. These mixes were chosen for their ability to perform adequately in both the plastic and hardened states.

	SCC 1	SCC 2	SCC 3	NCC
Constituents (lb/yd³)				
Cement	700	700	700	564
Fine Aggregate	1,591	1,513	1,320	1,354
Coarse Aggregate (17A)	1,350	1,350	1,450	1,883
Water	256	285	320	215
Air	6.00%	6.00%	6.00%	6.00%
W/c Ratio	0.37	0.41	0.46	0.38
Admixtures (oz/cwt)				
Air Entraining	1	1	1	1.9
HRWR	15	12	10.7	11.3
VMA	1	2	6	

Figure 7: Final SCC Mix Designs

Before the beams could be fabricated, a strand bond strength evaluation was required. This evaluation was needed to determine if the prestressing transfer length and development length required to develop full strand stress in the SCC mix design could be achieved. To evaluate the strand bond strength, a Large-Block Pull-out test was employed. This test was completed by casting 24 inch x 36 inch SCC test blocks with embedded strands, for each mix design. The strands were then pulled out of the block 48 hours after casting using a hydraulic ram. The performance of the mix designs from this test confirmed that the bond strength was acceptable for use in the prestressed beam design for the demonstration bridge.

Once the strand bond evaluation was completed, the production of both the NCC and SCC box beams could be started. The NCC beams were constructed first. Current precast/prestressed industry practice for producing box beams requires four stages, making it both time and labor intensive. This process included installing the prestressing strand, bottom stirrups, and metallic straps on the casting bed during the first stage. Next, the top reinforcing steel cage, including stirrups and longitudinal reinforcement, were assembled and set aside. In the second stage, the bottom flange of the beam was cast. As the concrete was poured into the form it was vibrated with mechanical vibrators. The level of the concrete in the bottom flange was checked to ensure that the proper thickness of the bottom flange was achieved. For the third stage, after the bottom flange was poured, consolidated, and leveled, a Styrofoam block that was temporarily installed. The Styrofoam block was used to fill the void inside the box and the pre-tied top-reinforcing cage. This step was done as fast as possible to ensure that the concrete in the bottom flange remained plastic since a homogeneous joint was desired after

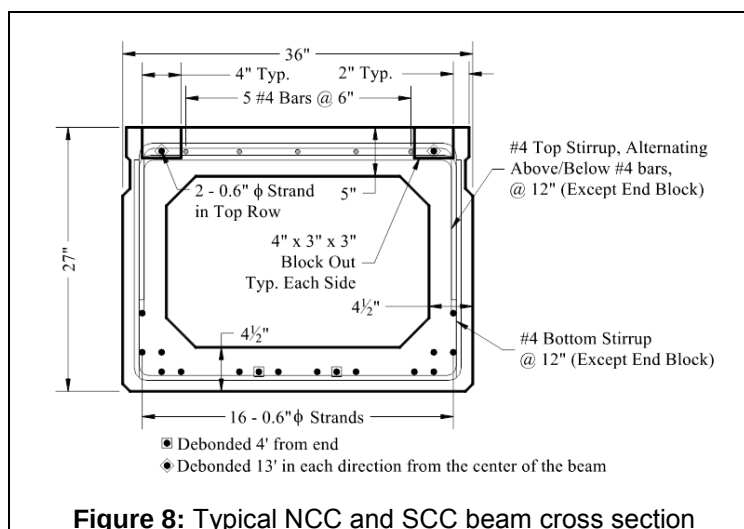


Figure 8: Typical NCC and SCC beam cross section

casting the webs of the box section. The fourth and final stage of the process involved casting the webs and top flange. During the fourth stage, the concrete was poured directly on top of the Styrofoam block and manually distributed throughout the formwork. Sufficient vibration was used in the sidewalls to ensure that a cold joint did not develop between the bottom flange and the sidewalls.



Figure 9: SCC beam with wooden void restraints installed and ready to be cast

Only two production stages were required for the SCC box beams. After failed attempts to hold down the Styrofoam block with spacers, special void restraints were created which were attached to the forms with a metal fastener. Once these were developed, the first step was to install the plastic spacers to ensure the correct vertical and horizontal location of the Styrofoam block. These were left inside the concrete. The void was then tied to the prestressing strands and attached to the restraints to ensure that it did not rise with the rising level of concrete. In the second stage of the production process, the concrete was placed in the forms. Due to the highly flowable properties of the mix, this was done in one step without any vibration.

Two test beams were produced for each concrete mix design. One of the beams was evaluated flexural capacity, and the other was evaluated for shear capacity. The beams were replicas of the beams to be used in the M-50/US-127 Bridge.

The flexural capacity of the box beams was assessed through four-point bending tests. The four-point bending setup was chosen to create a region of constant moment without shear to assess pure flexural response. The 52-ft beams were simply supported 1-ft from the ends on top of reinforced concrete support blocks. A 3-inch thick laminated elastomeric pad was used

between the beam and the reinforced concrete block to avoid stress concentrations and allow for beam end rotations. The beam was symmetrically loaded at midspan at two locations spaced 8 feet apart. Loading was applied by a pair of servo-controlled hydraulic actuators attached to a gravity reaction frame. To avoid local loading on top of the box beam upper flange, the load was distributed by means of a spreader steel beam that straddled the beam transversely. An elastomeric pad was used between the spreader steel beam and the top of the box beam to minimize stress concentrations. The flexural tests were conducted by monotonically loading the beam up to failure. Displacement and rotation transducers, along with strain gages were placed at several locations throughout the beam to monitor performance.

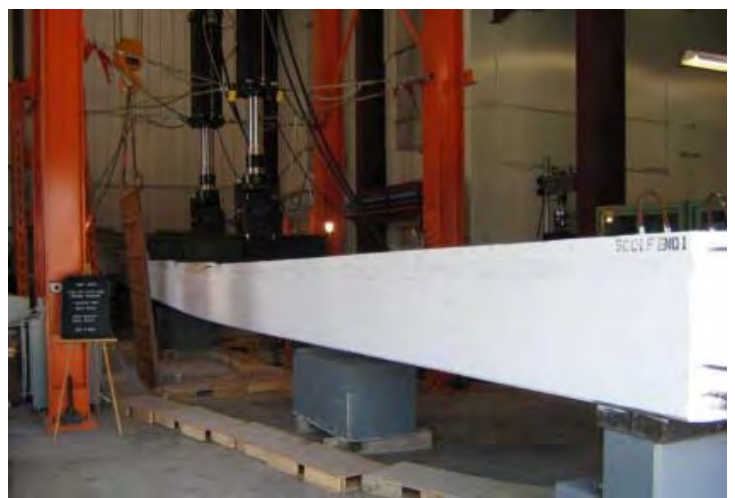


Figure 10: Hydraulic actuator used during testing

The shear tests were provided with a different instrumentation scheme than the flexural test beams. Again, instrumentation was placed to monitor performance and overall test setup control. In order to assess shear behavior, most of the hydraulic actuators were located in what was determined as the critical shear section. Similar to the flexure capacity, displacement and rotation transducers, along with strain gages were placed at several locations throughout the beam to monitor performance.

For the beams used in the construction of the demonstration bridge, a long-term field-monitoring program was established. The three SCC beams and one of the NCC beams were instrumented to monitor changes in

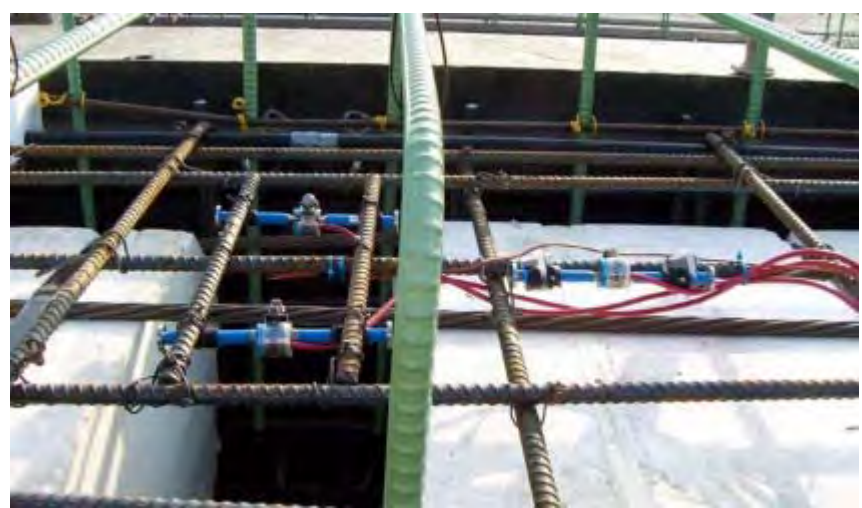


Figure 11: Vibrating wire gage paired with thermocouple

concrete strain and temperature during the service life of the bridge. Two types of instruments were installed in each beam to measure these parameters. Eight Type T thermocouples were installed to record temperature, and eight vibrating wire strain gages were installed to measure strain in the concrete in each of the four beams. The results obtained from the instruments are used to assess the performance of the SCC beams relative to the NCC beam.

3. Project Conclusions

The use of SCC to cast elements for highway bridges can lead to reductions in both the time labor required in production. For this project, the average time required to cast the SCC beams was 61 percent less than the time required to cast the NCC beams. Significant reductions in labor led were also realized. However, implementing SCC in a precast facility is not as simple as changing the concrete mix design. Extensive work is required to develop a mix design and certain modifications to typical casting operations are required to use SCC effectively. Further, time is necessary to gain the experience that will allow SCC to be used most efficiently.

Overall, the performance of the SCC prestressed box beams in flexure and shear was found to be essentially equal to that of the NCC beam and their behavior was well predicted by conventional prestressed concrete theory. While additional issues pertaining to long-term behavior of SCC in prestressed elements, namely creep effects, are still to be fully evaluated, the short-term flexural and shear response evaluated through this testing program indicates that the SCC prestressed beams safely satisfy their prescribed design requirements. The results of the laboratory testing program provided sufficient evidence to the fact that the SCC beams could be used in the demonstration bridge as planned.

As these mixes were developed, significant collaboration between the parties involved was necessary and extremely beneficial. The combined knowledge and experience of the admixture, precast, and research representatives was highly valuable in the development of mixes that satisfied both production and research objectives.

3.1 Positive Results

Listed are the specific comments provided by the State as positive results from the IBRD project:

- The ability to economically introduce SCC to local precast plants depends on the feasibility of using locally available materials and equipment commonly available to the plants. The mix design development process conducted for this research confirmed that materials and equipment commonly used in local precast plants is acceptable for use in the production of SCC. This includes many of the procedures common to local precast plants, such as methods of concrete mixing and transportation of the concrete from the mixing equipment to the casting area.
- The average time required to cast the SCC beams was 61 percent less than the time required to cast the NCC beams. Property tests also helped to assess and determine consistent quality control of the mixes from batch to batch.

- The Large Block Pull-out Test provided values that were useful in determining the bond strength between the prestressing strand and the different concrete types used in this project.
- The self-consolidating nature of SCC allows for a more complete compaction of the concrete. This, along with the superior flow behavior of SCC, led to beams being produced with higher surface quality on the SCC beams as compared to the NCC beams. Fewer and smaller surface imperfections were seen due to trapped air at the formwork concrete interface. This improved surface quality led to less patching of the beam surfaces.
- Results from laboratory testing indicated that the flexural and shear response of the SCC members is essentially equal to that of NCC members.
- The capacities of the SCC members exceeded the design capacity requirements for the demonstration bridge planned for this project.
- The decreased beam production time led to a nearly continuous batching operation. Greater amounts of concrete were produced in less time during the production of the SCC beams as compared to the NCC beams. This increased production rate leads to less down time for the labor during beam production.

3.2 Lessons Learned

Listed are the specific comments provided by the State as lessons learned from the IBRD project:

- The use of chemical admixtures in the SCC mix designs may affect the bond performance of the concrete. Specifically the use of VMA may lead to reduced bond strengths. While some reduction in bond strength over the NCC mix was seen, the size of the structural members used in this project was not bond critical. Slightly reduced bond strength, or an increased development length would not likely lead to a compromise in either flexural or shear strength for the bridge beams.
- The beneficial properties of SCC were realized in this project as the production of the box beams was reduced from four steps to two through the use of SCC. The most difficult part of the production process was restraining the Styrofoam block from the pressure generated by the flowing concrete as it filled the formwork. Wood restraints bolted to the top of the formwork were successful in restraining the Styrofoam block while not impairing the flow of concrete through the formwork.
- The constant quality control during the production of the SCC batches allowed for necessary adjustments to maintain consistent fresh property behavior throughout the beam production process. Small changes to the SCC mix design were required due to changing weather conditions and the conditions of the material constituents. Increased experience with SCC would lead to more accurate estimates of these necessary adjustments.
- Results from the long-term monitoring, to date, indicate that the SCC beams are performing similarly to the NCC beams. To date, the effects of temperature on the strain measurements are dominant. An attempt has been made to compare the measured strains to predicted values by estimating the strain variations due to prestress losses as well as temperature induced effects. Differences between the predicted and measured values exist. However, the applicability of time-dependent losses due to concrete shrinkage and creep to SCC is questionable. Little information on the applicability of current code prestress loss models to SCC exists. Thus, further work is required to obtain a better comparison between predicted and measured responses.
- The temperature analysis showed that, as expected, temperature does play a role in the discrepancies seen in the measured and predicted data. However, it can not be the temperature alone, as the temperature increase seen in the measured data should cause a tensile strain in the beam. The influence of the bearing system stiffness for the bridge could introduce a compressive strain increase on the order of what is seen in the measured data. However, the real behavior of this boundary condition is complicated and its complete analysis is beyond the scope of this report.

3.3 Negative Results

Listed are the specific comments provided by the State as negative results from the IBRD project:

- The original spacing blocks used to keep the Styrofoam void in place were ineffective
- Inconclusive results were shown in the long-term monitoring. The values of strain that were recorded were very different from the analytical values; however, the beams show similar behaviors for all of the concrete mix designs. Additional analysis trying to explain the differences that existed in the beam were conducted but proved to be inconclusive. Multiple factors were investigated without definitive results.
- More research is required regarding the development of SCC mix designs, as well investigating modifications to current casting operations that will allow SCC to be used more effectively.
- SCC generally has higher material costs, however, these costs are usually offset by reductions in labor and increased productivity.

4. Costs

In the 2004 fiscal year, the state of Michigan was granted \$200,000 in funding for development of SCC use in girder design through the FHWA Innovative Bridge Research and Construction program.

5. References

The majority of the information presented in this report, including pictures, are highlights from the Project Summary Report provided by the State and the following resource(s):

Burgueno, R. and David, B. A. (2007). "Experimental Evaluation and Field Monitoring of Prestressed Box Beams for SCC Demonstration Bridge". July, 2007.

**4.8. SCC, CONCRETE ARCH: NEBRASKA - NEBRASKA HIGHWAY 68 OVER THE
BNSF RAILROAD IN RAVENNA**

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

Self-Consolidating Concrete Case Study: Concrete Filled Steel Tube Arches

Project

Nebraska Highway 68 over the BNSF Railroad in Ravenna

Project State
NEBRASKA

Prepared For:
Federal Highway Administration



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HDR Engineering, Inc.
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January, 2012

1. Project Description

The purpose of this project was to present technical justification for the use of steel tube arches filled with Self-Consolidating Concrete (SCC). This technology was used to create a 174 foot single span tied arch bridge with a deck cross-sectional structural depth of 35 inches. The site for this bridge was the Ravenna Viaduct located in Ravenna, Nebraska.

Nebraska Highway 2 passes south of the city, and Route 68 cuts directly through town. Visitors to town pass over the Ravenna Viaduct as they approach town on Route 68 from the south. The viaduct passes directly over a major hub of the Burlington Northern Santa Fe (BNSF) Railroad. Because of this, there are very tight restrictions on the depth of the bridge members (due to railroad vertical clearance requirements), the type of work that can be done over the railway and the amount of time the railroad can be closed. Figure 1 shows the Ravenna Viaduct after construction.



Figure 1: Ravenna Viaduct tie arch bridge after construction

Several structure alternatives were discussed during the initial concept phase for the new Ravenna Viaduct. In the end, the drawbacks of each conventional system led to the arch bridge concept.

The first system discussed was the Inverted Tee (IT). One major drawback to this system was the method used to form the cast-in-place deck. Plywood is placed between the stems, the overhang is formed and the deck is placed. With this project, however, worker time spent over the railroad must be limited. This system would require extensive time spent over the railroad, imposing expensive railroad safety costs for the extended construction period.

Additionally, to obtain the necessary vertical clearance with the railroad the structural depth had to be limited to 35 inches. At this depth, the maximum distance a typical IT system can span is 100 feet. Therefore, a pier would be necessary. Due to the rail traffic, constructing this pier would be both difficult and expensive. Railway service would have to be suspended, and not resumed until after the construction was completed.

A plate girder system was the other alternative that was investigated. This system had similar drawbacks as the IT system. A structural depth of less than 35 inches is not possible without a pier and it requires workers spending significant time over the railroad to form the cast-in-place deck.

The steel tube arches filled with SCC, which were used in the final design; provided a unique solution for this location. This system has the ability to maintain the under-bridge structural depth requirements of less than 35 inches, and can provide spans long enough to eliminate the use of a pier, keeping worker time over the

railroad to a minimum. Additionally, a majority of the assembly and construction was done offsite before the bridge was placed over the railroad. This slender arch system was only possible because of new high performance steel and SCC, and new theories recognizing the increased strength of confined concrete.

There are three primary reasons for using SCC on projects: filling ability, passing ability, and segregation. The filling ability of SCC is its ability to fully fill formwork without voids and the use of vibration. This includes flowing around obstacles including dense steel reinforcing schemes and form block outs. The passing ability of SCC is its ability to flow around and through obstacles without segregating or experiencing aggregate blocking. The segregation resistance of SCC is defined as the ability to resist segregation of its coarse aggregate components through all phases of the construction process including transportation from the batching plant to casting site, placement in the formwork, and finishing of the product. Since the steel tube arches and chords are an inaccessible confined space, to ensure that they are completely filled, the highly flowable properties of this type of mix makes it ideal to use.

The main structural components of the arch system are:

1. Bottom chords
2. Top chords
3. Floor beams
4. Hangers
5. Deck

The system allows for a minimal structural depth by using the bottom chord as a tension tie and the top chord as a compression strut. Because of this, the resulting forces in the girder are reduced by this bottom chord/top chord interaction.

The bottom chords are 24 inch square by 0.5 inch thick steel tubes filled with SCC. Each tube is post tensioned with 38 fully tensioned 0.6 inch diameter strands. The post-tensioning ducts are grouted with non-shrink grout. The bottom chord is the most innovative feature of the system. The post-tensioning eliminates the concern over fatigue in the splice by keeping the section in net compression during loading. Filling the steel tubes with concrete makes the post tensioning more efficient by providing a larger effective area to sustain the post tensioning load. The concrete prevents the buckling of the steel, while the steel confines the concrete.

Each top chord consists of a pair of 12 inch diameter by 0.5 inch thick steel tubes filled with SCC. The arches are paired together to increase the moment of inertia in the lateral direction. However, enough room was given to provide space to connect the hangers. At their peak, the arches are 25 feet above the roadway grade. These arches are the primary compression member in the system. In this particular design horizontal bracing between the arch ribs was not required. The absence of horizontal braces provided unlimited overhead clearance, and created a more aesthetically pleasing structure.

The floor beams are W24x250 beams and are spaced at 8.75 feet on-center. 1.75 inch diameter high strength threaded rods serve as the hangers. The rods are connected between the top chord and the bottom chord also at 8.75 foot spacing.

Spanning under the roadway between the two bottom chords are the floor beams. Design of the floor beams offered several challenges. The floor beams needed to be an efficient, economic section spanning approximately 55 feet between the two bottom chords. The floor beams were limited to a depth equal to or less than the bottom chords, which was 30 inches. Since the work over the railway needed to be minimized, the system needed to provide an easy way to be constructed. Rapid construction was achieved, as the floor beams and the metal decking for the riding surface were attached to the girders before the bridge was assembled at the project site.

As part of the technical justification for this project a finite element model was developed to see how the dead, live, post-tensioning, and wind loads distributed throughout the system. Full scale specimens of the top and bottom chord elements were produced to monitor their performance under laboratory testing. Additionally, a full scale end section was produced in order to investigate fabrication issues.

The research completed on the use of SCC filled steel tube arches at the Ravenna Viaduct site was performed by the University of Nebraska-Lincoln.

2. Project Implementation

A finite element model was created to see how different loading conditions affected the bridge system. For the first analysis, six load stages were investigated. These included dead and post-tensioning loads, and are as follows:

- Stage 1: Effects of steel self-weight, floor beams, and metal decking only
- Stage 2: Stage 1 loading plus added concrete weight after the top and bottom chords had been filled
- Stage 3: Effects due to post-tensioning only
- Stage 4: Effects due to the placement of the deck
- Stage 5: Effects of barrier weight on composite cross section
- Stage 6: Effects of future wearing surface on composite cross section

The steel tube arch system performed adequately during all six stages of loading.

The second analysis investigated live loading. The required combinations included one-HS25 Truck, two-HS25 Trucks, and three-HS25 Trucks, with one, two, and three lanes loaded. The HS20 loading was converted through a load factor to obtain the required HS25 loading. The combination which included the three-HS25 trucks with three lanes loaded controls the design.

Finally, wind loading was analyzed using the finite element model. The lateral stability of the system was considered with a bi-axial stress analysis. The wind design loads were based on the AASHTO Standard Specifications. A 3D model was developed to determine the maximum bending moments and axial forces in the arch. The maximum fiber stresses accounted for the axial load and the bending moments in both directions. The maximum fiber stresses were found to be adequately less than the computed capacities.

After the computer models showed acceptable results, full scale laboratory testing followed. The elements which were used for full scale testing included one bottom chord member and one concrete filled steel tube arch.

The bottom chord was the first element tested. The bottom chord was fabricated to design specifications with one exception. Because of a steel shortage, it was not possible for researchers to purchase the needed 38 strands. Instead, only 20 strands (10 per duct), or just over half required by the design were used. Figure 2 shows the end of the bottom chord with the strand layout and grout access hole.



Figure 2: End of bottom chord



Figure 3: Bottom chord during loading

After the grout in the post-tensioning duct gained the required strength, the specimen could be tested. The specimen was tested as a 39.25 foot span. Two 300 kip hydraulic jacks were used to create point loads at 13.88 feet from each support. Figure 3 shows the bottom chord during loading.

The test specimen, with 20 fully tensioned strands, was expected to have a capacity of 230 kips per jack, and a deflection at ultimate load of 4.5 inches. This calculation makes an assumption for the ultimate strain in the concrete due to confinement.

The testing proceeded smoothly, and was continued until the output indicated the specimen was taking no additional load. The specimen stopped taking additional load at an ultimate force of 231 kips per jack, and a deflection at ultimate load of 4.52 inches

was recorded. Both were extremely close to the predicted values.

For the top chord, two 10inch diameter specimens were tested. One was filled with concrete and the other was left hollow. Both specimens were tested for flexural behavior. These specimens were fabricated early in the design process, and further revisions were made which increased their size to 12 inches.



Figure 4: Concrete filled steel tube under loading

For the top chord specimen, in order to make certain it was fully filled, it was filled while leaning at a steep angle as the concrete was pumped from the bottom to top. An air vent at the top ensured a complete fill.

The hollow specimen was tested as a 20 ft. simple span with a single point load at midspan. The load was applied using a 110 kip hydraulic jack. The specimen stopped taking load at an ultimate load of 39.8 kips, and reached a deflection of 10.7 in.

The concrete filled tube was tested in the same way as the hollow tube. The specimen was tested as a 20 ft. simple span, with a single point load. The loading stopped after it reached an ultimate load of 55.3 kips. The specimen was still taking force, however the jack ran out of stroke and the testing set-up appeared to be dangerous. The specimen was loaded to a deflection of 16.5 inches. For this test, the capacity of the tube increased by approximately 40 percent. Figure 4 shows the concrete tube testing in progress.

After the testing was completed, the tube was cut open to inspect the quality of the concrete fill. This was done 65 days after the concrete had been placed. Researchers discovered a 3 inch diameter circle at the very center of the tube that still retained visible moisture. The confining effect of the steel prevented excess moisture from escaping. This is not believed to affect the strength of the concrete. It is also interesting to note that visible moisture on the cut surface disappeared approximately four seconds after being cut, leaving a dry concrete surface.

In addition to the load testing, a full scale end specimen was created. This piece contains the bottom to top chord connection, as well as the first bottom to top chord hanger. Unlike the bottom



Figure 5: Full scale end specimen

chord specimen, this specimen was not load tested, and was only produced to discover any challenges or special considerations in fabrication. This specimen is shown in Figure 5.

After testing was complete, construction followed. The photographs below show the construction sequence:



Figure 6: Construction of substructure



Figure 7: Installation of arches



Figure 8: Arch bracing with temporary horizontal supports



Figure 9: Floor beam placement



Figure 10: Metal decking installation



Figure 11: Post-tensioning ties at beam



Figure 12: Ties being post-tensioned



Figure 13: Deck slab reinforcement installation



Figure 14: Deck slab post-tensioning



Figure 15: Railing construction

3. Project Conclusions

Utilizing SCC filled steel tube arches for the Ravenna Viaduct project was very successful. The results achieved on this project formed the basis for standardizing the system for future applications in Nebraska where vertical clearance issues are present.

3.1 Positive Results

Listed are the specific comments provided by the State as positive results from the IBRD project:

- The arch itself was constructed using high strength steel tubes filled with high strength shrink-compensating SCC pumped on site.
- The hangers between the top and bottom chords were made of high strength threaded rods covered with PVC pipes. Connections of the hangers to the top chord by spherical nuts will allow for tension adjustments in the hangers after construction is completed and, if needed, during the life of the bridge.
- The tie-beams are of a unique composite design consisting of a hollow rectangular high strength steel outer casing that is filled with SCC and post-tensioned. The post-tensioning is to such an extent as to induce permanent compression in what is normally a tension, as well as a fracture critical, member.

- No lateral sway bracing was required in this system, thus removing vertical height restrictions and common maintenance concerns due to vehicle collision.
- An extremely high span to depth ratio was able to be achieved that allowed for the required vertical clearance while eliminating the need for intermediate piers, as was required for this railroad overpass.
- The overall aesthetics of the bridge are pleasing.
- There was less fabrication labor than would have been required for a truss bridge.
- The design process implemented new theories which recognized a significant increase in capacity of concrete due to confinement.
- Prefabricating the arch accelerated construction time.

3.2 Lessons Learned

Listed are the specific comments provided by the State as lessons learned from the IBRD project:

- Precise tolerances especially in connection components are required.
- Use of a precast floor system would be more cost effective.
- The effects of confinement are greatest in pure axial members. It is partially for this reason that the arch bridge system is efficient; large bending moments are resolved through the use of axial forces in the top and bottom chords.
- Through the production of the test specimens, it was determined that fabrication of system components should be monitored closely to ensure proper dimensions. Accurate dimensions, especially in the connection components, are extremely important. Most notably, the spherical nut must be fabricated to precise tolerances outlined in the specifications.

3.3 Negative Results

Listed are the specific comments provided by the State as negative results from the IBRD project:

- Currently, use of the technology is expensive.
- Difficulty of analysis for overweight permit vehicles.

4. Costs

In the 2003 fiscal year, the State of Maryland was granted \$400,049 in funding for implementing SCC technology through the FHWA Innovative Bridge Research and Construction program.

5. References

The majority of the information presented in this report, including pictures, are highlights from the Project Summary Report provided by the State and the following resource(s):

Tadros, M.K., and Girgis (2006). Department of Civil Engineering, University of Nebraska-Lincoln. "Concrete Filled Steel Tube Arch." January 4, 2006.

4.9. SCC, DRILLED SHAFTS: SOUTH CAROLINA - US 76 OVER LUMBER RIVER

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

**Self-Consolidating Concrete
Case Study: Girders**

Project

US-76 over Lumber River Bridge Site, Horry and Marion County Line

Project State

SOUTH CAROLINA

**Prepared For:
Federal Highway Administration**



**Prepared By:
HDR Engineering, Inc.
9987 Carver Road
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Cincinnati, OH 45242**

January, 2012

1. Project Description

The purpose of this project was to evaluate the use of self-consolidating concrete (SCC) as a viable material in drilled shaft applications and compare it to conventional drilled shaft concrete. The replacement bridge site is located on US-76 over Lumber River along the Horry and Marion County line in South Carolina was chosen as the site to perform the work associated with this project.

Drilled shafts are deep, cylindrical, cast-in-place concrete foundations formed by drilled excavation. They can range from 2 to 30 feet in diameter and can be over 300 feet in length. Although once considered a specialty foundation, their use as a structural support has recently increased. They are particularly advantageous where increased lateral loads from extreme event limit states govern bridge foundation design. In many instances, a single drilled shaft can replace a cluster of piles eliminating the need for a pile cap.

Since drilled shafts typically have deep foundations, the tremie concrete method is used to place the concrete into the shaft. This is completed by pouring the concrete below the water line through a pipe; then, the lower end is kept immersed in fresh concrete so that the rising concrete from the bottom displaces the water.



Figure 1: Various defects in drilled shafts, throughout the United States, due to loss of workability

Recent results from integrity and load testing, throughout the United States, have shown that inadequate workability during the duration of concrete placement in drilled shafts can lead to defects that are unfavorable for drilled shaft foundations. Tremie placement of the concrete should readily flow through the rebar cage, and displace the drilling slurry upward in one uniform horizontal layer. However, if workability is not maintained for the duration of the pour there is a probability that debris can become entrapped causing

structural defects. Also, when concrete is placed into a cased hole, there is a need for the concrete to maintain its workability throughout the entire duration of the pour. This maintained workability is essential because when the casing is removed the concrete must be able to flow laterally to displace any water that is present outside the casing, and produce a high lateral stress on the soil or rock so that there is adequate bond between the concrete and surrounding bearing stratum.

SCC is relatively new in the United States, particularly in drilled shaft applications. The high workability of SCC and removing the vibration requirement leads to a reduction in labor needed to produce concrete elements and faster production. Additionally, the self-consolidating nature of SCC has the ability to produce a higher quality finished product than can be achieved with Ordinary Drilled Shaft Concrete (ODSC). While SCC generally has higher material costs, these costs are usually made up by reductions in labor and increased productivity.

A laboratory study was performed as part of this project to examine the difference between ODSC and SCC for both fresh and hardened properties. The fresh properties include filling ability, passing ability, segregation resistance, workability over time, bleeding characteristics, and controlled setting. The hardened properties included the comparison of the compressive strength, elastic modulus, drying shrinkage, and permeability.

Using the mix developed in the laboratory study, a total of four, 6 foot diameter drilled shafts were constructed using both ODSC and SCC. Two of these drilled shafts were used for experimental tests, one from each mix. These experimental drilled shafts were exhumed, sawed and cored at select locations. The remaining two drilled shafts, also one of each mix, were kept in-place and subjected to axial static load testing. Non-destructive testing, using cross-hole sonic logging (CSL), was performed on all of the shafts. Pulse velocity testing was performed on cores obtained from the exhumed shafts.

The report summarizing the findings for this project was prepared by a consulting firm with the assistance of Dr. Dan Brown and Dr. Anton Schindler of Auburn University, and the Association of Drilled Shaft Contractors (ADSC).

2. Project Implementation

A laboratory testing program was developed to investigate the use of self-consolidating concrete as a viable material to be used in drilled shaft construction. This research was separated into five separate phases to evaluate the concrete's performance. These phases included the effects of the type and dosage of high-range water reducing admixtures (HRWRA), effect of retarder dosage, appropriate SCC mixture procedures, selection of SCC properties, and method to modify the viscosity modifying admixtures (VMA) of SCC. Separate batches were produced and tested for each phase to evaluate the performance.

After this evaluation, additional laboratory tests were performed. These included slump flow test, J-ring test, L-block test, visual stability index (VSI), segregation column test, bleeding test, unit weight and air content, curing, and time of set for the fresh concrete. The hardened concrete tests consisted of compressive strength, modulus of elasticity, drying shrinkage, and permeability.

General conclusions involving all of the testing procedures can be found in the "Project Conclusions" section of this report.

After the testing was completed, the results were used to develop the design mix to produce the SCC drilled shafts.

On January 28, 2005, a 74 inch diameter, 30 foot long drilled shaft was constructed using ODSC near the location of one of the replacement bridges. A 24 foot long, 75 inch outside diameter temporary casing was previously installed with a vibratory hammer on January 27. Bentonite slurry was used to aid in the drilling process. A steel rebar cage similar to the one used in the production shafts was installed prior to concrete placement, and concrete maturity meters were tied to the rebar cage at positions ranging from 7½ to 27½ ft from the top of the shaft. On January 31, the concrete was placed with a tremie lowered to the bottom of the shaft.

The tremie was kept near the bottom of the shaft for the first four pours and raised 12 feet prior to placement of the fifth pour. The tremie remained at this position for the last pour. Each pour raised the level of concrete about 6 to 7 feet. The tremie plug was recovered at the end of the concrete placement. The first load of concrete was dyed black, and the fourth pour was dyed red. Following this, the casing was removed with a vibratory hammer after the shaft concrete placement was complete.

Slump flow tests were performed on each of the six pours of concrete, and a slump loss test was performed on the first and second pours.

On February 18, 2005, the shaft was exhumed by drilling a slurry-stabilized hole around the shaft, gently rocking the shaft with an excavator, and finally lifting the shaft out of the ground using a crane. The shaft was placed on closely spaced timbers and rinsed with clean water. Following this, the shaft was sawed through at



Figure 2: Longitudinal cut through bottom 6 foot section

two locations, 6 feet from the bottom and 13 feet from the top. These sections were then cut longitudinally down the center, similar to that shown in Figure 2. Twelve locations in the top section and eight locations in remaining middle section (from 13 ft to 24 ft) were cored, for a total of 20 cores.

The cores were transported to a SCDOT laboratory for strength and pulse velocity testing. Select cores were subsequently transported to Auburn University for permeability testing.

The SCC shaft, with the same dimensions of the ODSC shaft, was constructed February 1, 2005. Similarity, bentonite slurry was used to aid in the drilling process, a steel rebar cage with identical size and spacing was installed prior to concrete placement, and concrete

maturity meters were installed to the rebar cage.

On February 2, the concrete was placed with a tremie lowered to the bottom of the shaft. The exact same placement procedure was used as the ODSC placement.

On February 14, 2005, the shaft was exhumed using methods similar to that for the conventional shaft, cut at the same locations, and cores taken. The CSL testing indicated an anomaly between 12½ and 13 feet near access tube three, therefore the shaft was sawed longitudinally at 13 feet rather than the 6 foot section. Again, a total of 20 cores were extracted.

The cores were transported to a SCDOT laboratory for strength and pulse velocity testing and compared to the OSDC. Select cores were subsequently transported to Auburn University for permeability testing.

Compressive strength testing was also performed on the fresh concrete. 6 inch by 12 inch compression test cylinders were fabricated during shaft construction. The cylinders were collected and transported to an SCDOT laboratory for testing. The design mix was tested at 28-days.

3. Project Conclusions

Based on the performance of the Self Consolidating Concrete used in this project, it was a viable alternative for use in drilled shaft construction in South Carolina. The SCC performed well during the construction of the shaft with no significant problems encountered. The higher slump flow, and subsequent easier workability, could prove especially useful where seismic demands result in closely spaced horizontal reinforcement.

Below are general conclusions regarding the testing procedures used to develop the mix design:

- The use of set-retarding admixtures can significantly increase the time in which a concrete mixture will remain workable. For drilled shaft applications, the dosage of set-retarding admixture should be adjusted to provide an extended initial set necessary to ensure that the workability of the concrete mixture is maintained for the duration of the pour and to allow for any construction delays in concreting and removal of the temporary casing after concreting is completed.
- For a given dosage of set-retarding admixture, concrete mixtures can experience faster initial set times and increased slump loss when exposed to higher temperatures compared to the laboratory conditions.
- Estimating the additional amount of set-retarding admixture needed in hot weather conditions is not a sufficient measure to ensure that proper retained workability and set times are achieved. The amount of retarding admixture should be based on trial mixes under simulated conditions.
- SCC mixtures can experience an increased workability loss compared to ODSC mixtures when subject to similar mixing conditions. The rate and amount of workability loss depends on the initial workability conditions, degree of agitation, rotational speed of the mixing drum, and duration of mixing.
- The SCC mixtures prepared for this research provided a considerable increase in workability at placement compared to the ODSC mixtures. This enhanced workability may be capable of overcoming placement difficulties associated with tremie placing concrete and congested rebar cages.
- SCC mixtures are more inclined to have a larger change in workability for the same amount of time compared to the ODSC mixtures.
- The slump flow, and J-Ring tests were deemed acceptable quality control procedures for both laboratory and field conditions for drilled shaft applications.
- It is important that the stability of the SCC mixture be part of the determination of the VSI rating. This should be done by observing the SCC mixture in the wheelbarrow or mixing drum directly after the completion of the slump flow test.
- The segregation column test can be used to provide a quick and valuable testing procedure for laboratory purposes to determine the probability of a SCC mixture to segregate, especially at higher values of slump flow.
- The SCC mixtures exhibited increased stability as the water slump and water-to-cementitious materials ratio was reduced, which is more apparent at higher values of slump flow. The ODSC mixtures demonstrated a higher degree of bleeding compared to the SCC mixtures prepared with the same water-to-cementitious materials ratio.
- If the moisture variability at the batch plant can be properly controlled, and since the SCC mixtures for this research were placed at lower values of slump flow, it is likely that very workable and stable SCC mixtures can be achieved without the use of the polyethylene glycol VMA.
- Since the fine and coarse aggregates were high quality and the aggregate volume fraction was not drastically different; the modulus of elasticity of the SCC mixtures was not significantly affected by the varying sand-to-aggregate ratio, which ranged from 0.40 to 0.48.
- With these materials and mixture proportions, the equation provided by ACI 318 (2002) typically overestimated the modulus of elasticity especially at higher values of compressive strengths. Conversely, the equation provided by the ACI Committee 363 (2002) was found to provide an improved and conservative estimate of the modulus of elasticity.

- The water-to-cementitious materials ratio appeared to be the main factor influencing the drying shrinkage. The results indicate that the reduction in water-to-cementitious materials ratio decreased the concrete specimen's tendency to shrink.
- The coefficient of permeability decreases as the water-to-cementitious materials ratio is reduced.
- The introduction of silica fume can considerably reduce the permeability of concrete.

3.1 Positive Results

Listed are the specific comments provided by the State as positive results from the IBRD project:

- Wave speed data, as measured by the pulse velocity meter on cores extracted from the exhumed shafts was similar for both ODSC and SCC mixes.
- Both ODSC and SCC mixes had a 28-day design compressive strength of 4,000 psi. Measured 28-day strengths for the two ODSC mix cylinders were 6,870 and 6,740 psi, and 28-day strengths for the two SCC cylinders were 6,230 and 6,280 psi. The thirteen cores extracted from the exhumed ODSC mix had an average compressive strength of 7,026 psi, while the fourteen cores extracted from the SCC shaft had an average compressive strength of 5,903 psi.
- The shaft that used the ODSC mix was loaded to 2462 kips with a total displacement of 0.35 in. and a permanent displacement of 0.19 in. The SCC shaft was loaded to 2521 kips with a total displacement of 0.30 in. and a permanent displacement of 0.15 in. The geotechnical capacity was not fully mobilized on either shaft. However, under loading, the SCC shaft performed equally as well as the shaft that used the ODSC mix.
- SCDOT gained valuable experience using self consolidating concrete (SCC) in a drilled shaft. SCC worked well for this application due to increased flow ability of SCC.
- The use of set-retarding admixtures can significantly increase the time in which a concrete mixture will remain workable. This enhanced workability may be capable of overcoming placement difficulties associated with tremie placing concrete and congested rebar cages.

3.2 Lessons Learned

Listed are the specific comments provided by the State as lessons learned from the IBRD project:

- Based on observations of the dyed concrete, the SCC exhibited similar flow direction to the ODSC mix. The lowest slump (also the first pour placed and the one dyed black) concrete from both mixes appeared to remain at the bottom of the shaft. Subsequent pours appeared to flow up around the tremie pipe, displacing the surrounding concrete out laterally.
- One anomaly was detected in the CSL data of the SCC load test shaft, and its location was further defined by three-dimensional tomographic analysis. After the shaft was sawed, the anomaly was revealed as a soil inclusion that was lodged in the rebar cage. This is a problem that will be encountered in drilled shaft construction using any type of concrete.
- The critical sand-to-aggregate ratio for these materials for passing ability and segregation resistance is 0.44 or higher.
- The concrete maturity meters installed in the shafts prior to concrete placement indicated that the middle of both shafts experienced the highest temperature during concrete curing, and the maturity of the concrete increased the fastest from the bottom to the top. However, the SCC took longer to reach design strength. The maturity meters indicated the concrete reached design strength (4,000 psi) in approximately 4½ days instead of 2½ with the ODSC mix. This was qualitatively visible in the SCC cylinders also, which were not suitable for transport to the testing laboratory for several days.

- For load testing, the shaft constructed using the ODSC mix was loaded to 2462 kips with a total displacement of 0.35 inches and a permanent displacement of 0.19 inches. The SCC shaft was loaded to 2521 kips with a total displacement of 0.30 inches and a permanent displacement of 0.15 inches. The geotechnical capacity was not fully mobilized on either shaft. However, the SCC shaft performed equally as well.

3.3 Negative Results

Listed are the specific comments provided by the State as negative results from the IBRD project:

- The concrete maturity meters installed in the shafts prior to concrete placement indicated that the middle of both shafts experienced the highest temperature during concrete curing, and the maturity of the concrete increased the fastest from the bottom to the top. However, the SCC took longer to reach design strength. The maturity meters indicated the concrete reached design strength (4,000 psi) in approximately 4½ days instead of 2½ with the ODSC mix. This was qualitatively visible in the SCC cylinders also, which were not suitable for transport to the testing laboratory for several days.
- SCC works well but contractors are reluctant to propose as an alternate to normal concrete and SCDOT does not want to specify its use, due to increased costs and contractors lack of knowledge.

4. Costs

In the 2003 fiscal year, the state of South Carolina was granted \$225,000 in funding for development of SCC use in drilled shaft design through the FHWA Innovative Bridge Research and Construction program.

5. References

The majority of the information presented in this report, including pictures, are highlights from the Project Summary Report provided by the State and the following resource(s):

S&ME Inc. (2005). "Project Summary Report, Self Consolidating Concrete (SCC) in Drilled Shaft Research Project". September 15, 2005.

S&ME Inc. (2005). "An Evaluation of the Use of Self-Consolidating Concrete (SCC) for Drilled Shaft Applications." October, 2005.

**4.10. HPS, GIRDERS: MISSOURI - ROUTE 224 OVER ROUTE 13, HPS, BRIDGE
A6101 IN LAFAYETTE COUNTY**

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

High Performance Steel Case Study: Girders

Project

Route 224 over Route 13, HPS, Bridge A6101, Lafayette County

Project State
MISSOURI

Prepared For:
Federal Highway Administration



Prepared By:
HDR Engineering, Inc.
9987 Carver Road
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Cincinnati, OH 45242

January, 2012

1. Project Description

The purpose of this project was to design and field test a hybrid girder using high performance steel (HPS). The Missouri Department of Transportation (MoDOT) Bridge, A6101, utilized HPS70W girders in the design of a two-span bridge in Lafayette County, Missouri. Each span measures 138 feet using five girders in the design.



Figure 1: Completed A6101 bridge

In 1992, the American Iron and Steel Institute (AISI) partnered with the Carderock Division, Naval Surface Warfare Center and the Federal Highway Administration (FHWA) to develop new and improved steel alternatives for bridges. The team brought together a vast group of professionals in steel production, bridge design, bridge fabrication and welding, as well as specialists from the United States government and academia. The result was a new type of steel, known as high performance steel (HPS), which has the ability to provide up to an 18% cost savings and 28% weight savings when compared with traditional steel bridge design materials. HPS went from concept to application in five years, and is now being used by numerous states.

There are different grades of HPS which include: HPS 100W, HPS 70W and HPS 50W. These HPS grades produce bridges that are more cost-effective, higher in strength, lighter in weight, and have greater atmospheric resistance than conventional steels. They also have improved fatigue and corrosion-resistance properties.

Because of the increased strength of HPS 70W and HPS 100W, it is possible to design a girder with less cross sectional area when compared to a conventional girder that uses Grade 50 steel. However, since HPS is more expensive to produce than Grade 50 steel, it is not necessarily cost effective to build an entire girder out of HPS. Instead, using HPS only in high stress areas can be cost effective. Since two different types of steel are being used, the girders are considered to have a hybrid design. For Bridge A6101, HPS is used for the bottom flange in the composite positive moment region and for both flanges in the non-composite negative moment region. This was the State of Missouri's first bridge design that made use of the HPS technology.

The University of Missouri-Columbia worked with MoDOT to instrument, field test, analyze, and evaluate the performance of the completed Bridge A6101. The tests concentrated on the strength and serviceability behavior of the structure. For modeling of the bridge, MoDOT had the work performed by West Virginia University (WVU). WVU modeled and analyzed the bridge with finite element software.

One objective of this project was to examine deflection serviceability limits. The reason for this is because MoDOT uses more conservative deflection criteria than AASHTO. This conservative approach is best evident when comparing the deflection distribution factors and allowable deflections: for Bridge A6101, MoDOT equations predict a deflection 49% higher than AASHTO, while allowing 20% less deflection. In effect, the

bridge would need to possess 87% more stiffness than an AASHTO design to meet current MoDOT deflection criteria. The MoDOT approach significantly over-estimates the measured deflections. In addition to the deflection research, this project also evaluated acceleration and vibration characteristics of the bridge.

The other objective of this project was to perform field testing to confirm strength performance. The work involved comparing design capacities to equivalent experimental design capacities. For design, the minimum design capacity is an HS23.8 truck loading controlled by the positive moment region of an interior girder. The critical experimental design capacity is an HS26.2 controlled by the positive moment region of an exterior girder. Thus, based upon the experiment testing, this bridge does exhibit additional capacity over the design prediction.

The report summarizing the findings for this project was prepared by the University of Missouri – Columbia.

2. Project Implementation

The first step implementing this technology was the development of the hybrid design for the span length requirements of the bridge site. MoDOT designed Bridge A6101 using SIMOM, a software program that was used by many state agencies. SIMON takes initial dimensions input by the designer, and checks the design against the AASHTO code. The program can be used to optimize the design if the properties of the girder are known. In this case, the hybrid design used the material properties for HPS70W and 50 ksi steel. SIMON also estimates the live load deflection in the girder using the AASHTO provisions. However, it does not let deflection control the design. If the live load deflection is greater than allowed, a warning is printed and the strength design continues. Figure 2 shows the dimensions and the layout of the final hybrid design. This design was used for both the exterior and interior girders.

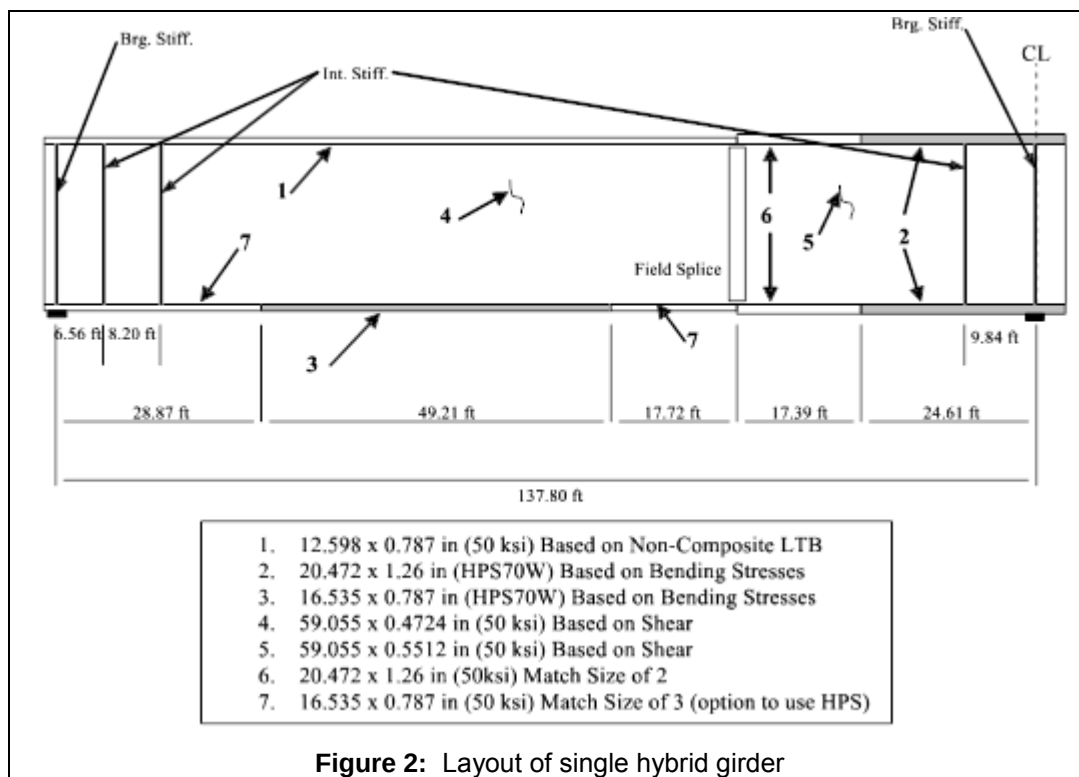


Figure 2: Layout of single hybrid girder

Once the girder design was established, and after the bridge was constructed, strength and serviceability field testing were initiated. For both tests, strain gages were placed on the girders. The critical gages were determined to be the three gages on each girder, 55.1 feet from the eastern abutment in the positive moment region and the gages 132.8 feet from the eastern abutment in the negative moment region. The bearing gages would not be installed, seeing as they were not considered critical. The strain gages were connected

to data acquisition boxes used to collect the information about the girder's performance. Only two data acquisition boxes were necessary to obtain the data for the number of strain gages used. One box was placed on the center pier for negative moment readings and the other was mounted to one of the cross frames near the maximum positive moment region.



Figure 3: Weldable strain gage



Figure 4: Data acquisition box at midspan

Once the gages were in place, a set of 12 different experimental lateral truck runs were performed. The placements of the trucks were selected so that live loads were maximized for individual girders. Dots were painted at quarter points along the bridge and a string was run along these points to show the truck operator

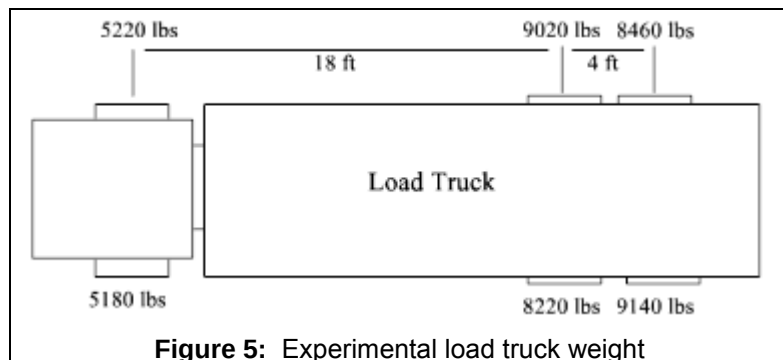


Figure 5: Experimental load truck weight

where to keep the placement of the left wheel of the truck. For each position, the truck was driven at crawl speed forward and then backed up at the same crawl speed on the same line to show redundancy and closure in the data. This was done at several locations transversely across the bridge. Once complete, the results were used to develop a best-fit stress profile of the girder cross section. Using these results, and coupled with the finite element analysis, a rating factor was found. This was used to determine the

HS20 design load capacities for the bridge.

The strength and serviceability load testing was completed using the same equipment with one exception. For the acceleration portion of the field testing during the serviceability tests; there were concerns that the load truck would not excite the bridge adequately. The road approaching the bridge had not been completed at the time of testing, so the truck did not have adequate space to gain speed or brake. In order to ensure adequate vibration, the field test team obtained the services of the construction supervisor to drive a backhoe across the bridge, as the backhoe can accelerate and brake much quicker than the load truck.

In order to measure the vertical displacement of each girder during serviceability testing, two



Figure 6: Backhoe used for serviceability acceleration testing

methods were used. The first used variable resistors in the form of string pots which were placed under the bridge. String pots measure deflection as a change in voltage as the string is pulled out of the device. The second method used laser deflection. The laser deflection device attaches directly to the girders and measures the natural frequencies of the structure which can be found through examination of the accelerations in the bridge after the load excitation and the bridge is in free vibration.



Figure 7: String pot

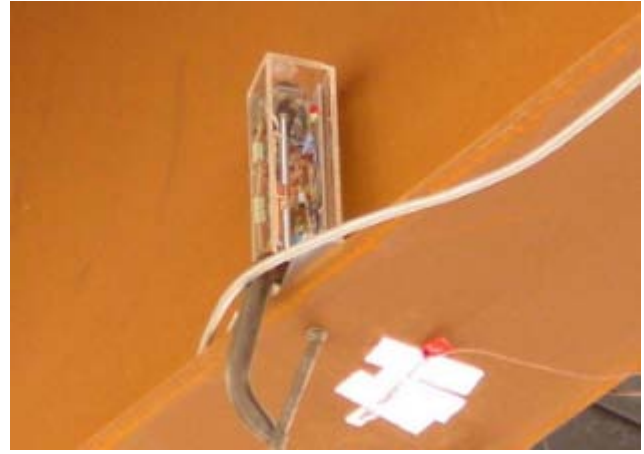


Figure 8: Laser deflection device

In addition to comparing deflection measurements to the design deflection of the girder, a finite element model of the bridge was conducted by West Virginia University. The model was designed using modeling software, and is a solid model that incorporates the conditions in the field, including the skew and parapet. Just as in the actual testing, a model of the load truck with the same wheel weights made 12 analytical test runs at varying transverse distances. The transverse positions of the truck in the model also matched the actual test runs. Data was collected on the deflection of all five girders during each analysis.

3. Project Conclusions

This project was highly successful as MoDOT's first attempt using HPS. MoDOT has been very happy with the results, and one professional publication was released by the DOT highlighting the successful results of the project.

The research suggests that HPS70W is superior steel with higher yield strength, improved weldability, greater levels of toughness, and improved weathering resistance that can lead to more economical bridges than conventional Grade 50 designs. Future use of HPS has the ability to produce a cost savings. For this project an 11 percent savings was achieved compared to a homogeneous Grade 50 design.

3.1 Positive Results

Listed are the specific comments provided by the State as positive results from the IBRD project:

- HPS is a viable option for strength.
- Design calculations show that using HPS only in the highly stressed regions (hybrid design) led to a superstructure steel weight savings of nearly 17% and an estimated cost savings of approximately 11% compared to a conventional bridge utilizing only Grade 50 steel.

3.2 Lessons Learned

Listed are the specific comments provided by the State as lessons learned from the IBRD project:

- Measured deflections were similar to those predicted in design.

- With the use of HPS, live load deflections may govern the design, thus requiring a stiffer or deeper section to meet live load deflection requirements. In cases such as these, the use of HPS may be less advantageous. The maximum measured deflections for an equivalent HS20 loading match closely to the AASHTO method of estimating deflections. The conservative serviceability procedures used by some states, such as MoDOT, will cause many HPS designs to be controlled by deflection, such as A6101 was, instead of strength parameters, which negates the benefit of using higher strength materials.
- Like in many states, the future of HPS is promising in Missouri. HPS70W is superior steel that can lead to more economical bridges than conventional Grade 50 designs. HPS can produce significant savings, especially when used in hybrid designs with 50W or HPS50W.

3.3 Negative Results

No negative results were provided by the State from the IBRD project:

4. Costs

In the 2001 fiscal year, the state of Missouri was granted \$126,000 in funding for development of HPS use in girder design through the FHWA Innovative Bridge Research and Construction program.

Utilizing an HPS hybrid girder resulted in an overall steel superstructure savings of approximately 11 percent compared to a homogeneous Grade 50 design. Below is the breakdown of the cost on a per girder basis:

	50 ksi Weight (tons/girder)	50 ksi Cost (\$/girder)	HPS70W Weight (tons/girder)	HPS70W Cost (\$/girder)	Total Weight (tons/girder)	Total Cost (\$/girder)
Homogeneous 50 ksi	34.66	83184	0	0	34.66	\$83,184.00
Hybrid 50/70	22.37	53688	6.5	20280	28.87	\$73,968.00

Figure 3: Weight and material cost of a homogeneous Grade 50 versus a hybrid Grade 50/HPS 70 girder

5. References

The majority of the information presented in this report, including pictures, are highlights from the Project Summary Report provided by the State and the following resource(s):

University of Missouri-Columbia, Missouri Department of Transportation (2005). "Performance and Serviceability of HPS Girders, MO224 Lafayette County". July, 2005.

University of Missouri-Rolla, Research, Development and Technology (2005). "In-situ Load Testing of Bridge A6358 (Part 1) and of Bridge A6101 and Bridge A6102 (Part 2)". February, 2005.

Missouri Department of Transportation (2005). *High Performance Steel Produces Durable and Economical Girders* Breakthrough, A Research Bulletin. August, 2005. 1-4.

American Iron and Steel Institute (2010). *Bridge High-Performance Steel*. Retrieved from:
http://legacy.steel.org/AM/Template.cfm?Section=High_Performance_Steel&Template=/TaggedPage/TaggedPageDisplay.cfm&TPLID=34&ContentID=9196

**4.11. HPS, CORRUGATED WEBS: PENNSYLVANIA - BRIDGE SR2024 OVER
TOWANDA CREEK**

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

**High Performance Steel
Case Study: Corrugated Webs**

Project
Bridge on SR-2024 over Towanda Creek, Bradford County

Project State
PENNSYLVANIA

Prepared For:
Federal Highway Administration



Prepared By:
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October, 2011

1. Project Description

The purpose of this project was to design and construct a demonstration bridge using corrugated web girders with high performance steel (HPS). The bridge site selected for the demonstration bridge was SR-2024 over Towanda Creek. The original bridge at this location was a pin-connected Parker through truss, which was built in 1909 and in need of replacement. The new HPS corrugated girder bridge was constructed in 2005 and has two equal spans, each measuring 127 feet.



Figure 1: Completed demonstration bridge on SR-2024 over Towanda Creek

Although there has been limited use worldwide, bridges which make use of corrugated web girders have been used since the late 1980's, especially in France and Japan. Corrugated web girders were developed because they have shown to be an efficient way of achieving adequate out-of-plane stiffness and buckling resistance, reducing the need for a thicker web plate and significantly reducing the amount of stiffeners needed. The trapezoidal corrugated web is designed for pure shear and does not contribute to the flexural capacity of the girder, which is provided by the top and bottom flanges including the concrete slab.

HPS was developed in 1992 by the American Iron and Steel Institute (AISI). They partnered with the Carderock Division, Naval Surface Warfare Center and the Federal Highway Administration (FHWA) to develop new and improved steel alternatives for bridges. The team brought together a vast group of professionals in steel production, bridge design, bridge fabrication and welding, as well as specialists from the United States government and academia. The result was a new type of steel, known as high-performance steel, which has the ability to provide up to an 18% cost savings and 28% weight savings when compared with traditional steel bridge design materials. HPS went from concept to application in five years, and is now being used by numerous states.

There are different strengths of HPS which include: HPS 100W, HPS 70W and HPS 50W. These produce bridges that are more cost-effective, higher in strength, lighter in weight, and have greater atmospheric resistance than conventional steels. They also have improved fatigue and corrosion-resistance properties.

Combining the geometric advantage of the corrugated web design with HPS creates a girder design intended to significantly reduce the amount of steel needed and the overall weight of the superstructure.

With the limited uses of corrugated web bridges world-wide, the research has been limited, which is why an extensive effort was made into looking at the design criteria for this innovative design before construction could be started.

The research to produce the final corrugated shape looked to address five main areas which required further investigation. These included: shape and strength criteria, girder fabrication, fatigue resistance, bearing stiffeners and field splices, and I-girders with flange rotational restraint braces.

The report summarizing the findings for this project was prepared by Lehigh University.

2. Project Implementation

The implementation of the corrugated webs used in this project largely involved the investigation of the five areas developed for the design criteria, those being: (1) corrugated web girder corrugation shape and strength criteria; (2) corrugated web girder fabrication; (3) fatigue resistance of corrugated web girders; (4) corrugated web girder field splices; and (5) diaphragms with flange rotational restraint braces..

The shape and strength criteria were investigated due to insufficiencies found in equations which have been used to calculate shear capacity in the past. It has been theorized that geometric imperfections in the web corrugations, or out-of-flatness of the folds, was the primary reason for this. However, no clear explanation was given regarding the discrepancy between the theoretical and the experimental results. Through analytical research, and in part using previously developed equations, a new equation was proposed in this investigation, and was the primary reason the shape and strength design criteria was developed.

To test the theoretical results using this new equation, two full-scale corrugated web girder specimens were designed, fabricated, and tested to failure in shear under monotonically increasing load. The shear strength test specimens were made identical in nominal geometry and material in order to study the effect of web geometric imperfections on the shear strength. Before loading of the girder started, the webs were fitted with a device to measure any initial geometric imperfections. This device also recorded the deflection after the loading was performed.

From this testing, the shape for the corrugations was developed. The recommended geometry is shown in Figure 3.

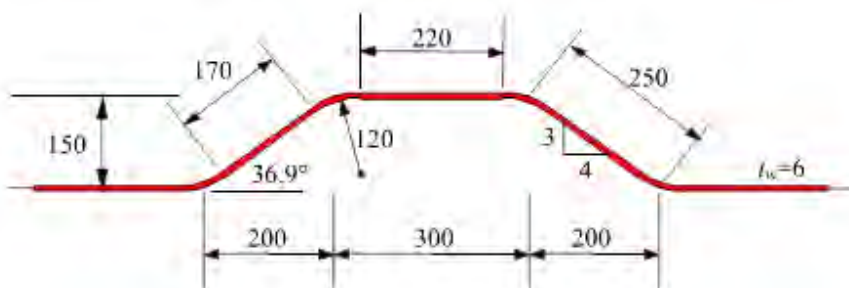


Figure 3: Recommended corrugated web fold geometry (dimensions shown in mm)



Figure 2: Deflection measurement device attached to web fold of corrugated girder

Girder fabrication methods were tested to see if there would be any difficulties in producing the corrugated web design. To do this, the fabricator which was later used for the bridge construction, produced eight test girders to be inspected.

A custom die was made to form the corrugations. For this project, a die requiring a four-stroke process with manual

incrementing was used. After the production of the corrugation, layout lines were placed on the top and bottom flange plates to center the web on the flange surface. A semi-automatic gas metal arc welding process was employed to attach the webs to the flange plates. A magnetic particle and a visual inspection were performed once the fabrication was complete.

Six of the eight test specimens which were produced during girder fabrication were used to test fatigue resistance. Previous experimental research used test specimens that were generally small in scale, and not necessarily representative of corrugated web girders for bridges. It is well established that small-scale

specimens will generally result in a higher fatigue life than large-scale specimens. Therefore, it was important to complete a large-scale effort for this project.

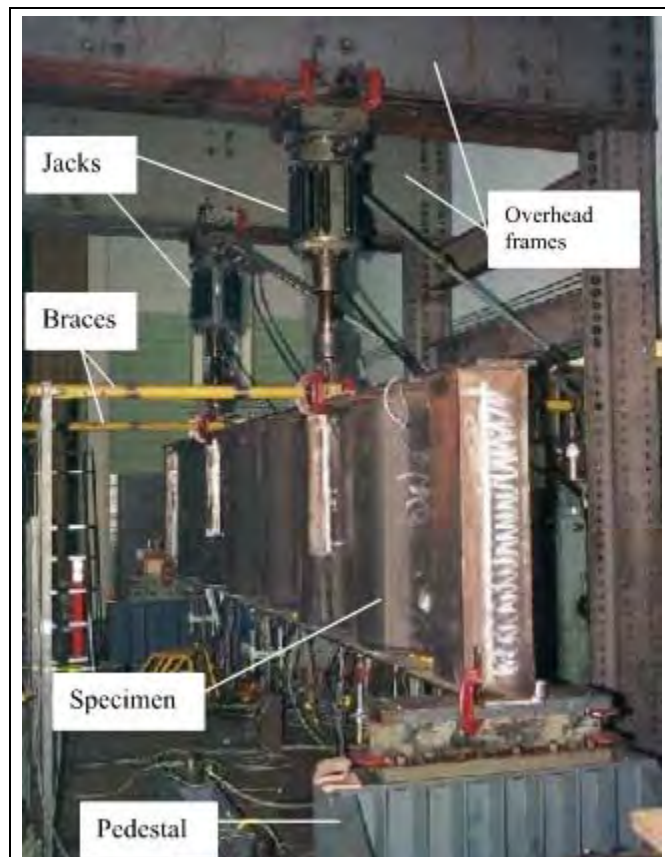


Figure 4: Fatigue test setup

The fatigue girders were tested in the dynamic test bed of Fritz Engineering Lab at Lehigh University. The setup used load jacks that were coupled onto the top of the girder and produced a synchronized load speed of 261 cycles per minute. The bottom flange was supported at four different points, one at each end and at third points, to produce the effect of a continuous beam. The minimum applied load per jack was 10 kips, which corresponds to a minimum nominal stress of approximately 2.2 ksi. The maximum load per jack was selected to provide a maximum stress needed to reach the predefined nominal stress range. Strain gages were placed near locations where fatigue cracks were likely to occur.

Bearing stiffeners and field splices were also analyzed during this project. A bearing stiffener consists of two stiffener plates, with one plate attached to each side of the web. The design requirements for bearing stiffeners for conventional flat web I-girders are outlined in the AASHTO LRFD bridge design specifications (AASHTO 1998); however, no specifications are in place for bearing stiffeners used in corrugated web I-girder design.

To evaluate the capacity of the stiffeners, two corrugated test sections were produced, each with a bearing stiffener welded to the angled portion of the fold. This is shown in Figure 5. The test sections

were then placed inside a hydraulic ram and tested in compression until failure.

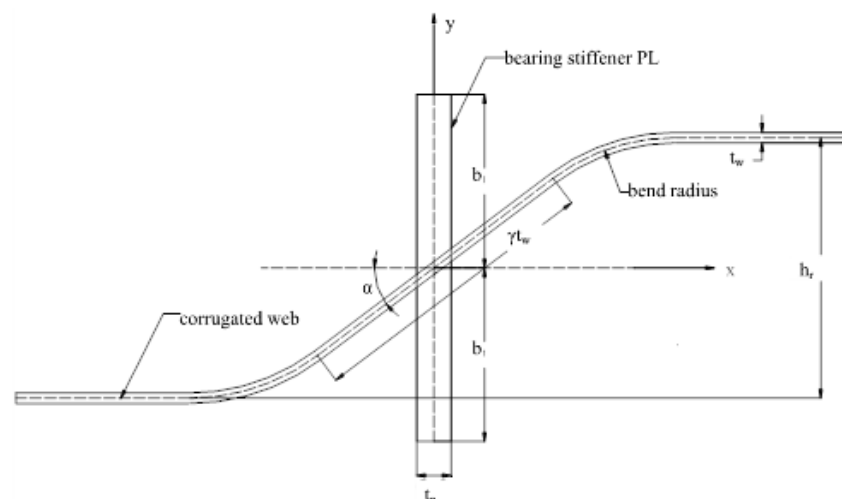


Figure 5: Bearing stiffener attached corrugated web



Figure 6: Set-up for stiffener test

Flexure and shear capacity of the field splice also needed to be investigated. For corrugated web I-girders, the bending moment is carried almost entirely by the flanges, while the shear is carried by the web. Therefore, it was possible to perform independent tests of a flange splice under flexure, and a web splice under shear. Enough corrugated web I-girder material for one test specimen was available. The two tests were conducted sequentially using this test specimen. In the first test, the largest possible bending moment was generated at the splice location to investigate the behavior of the flange splice. In the second test, a large shear was generated at the splice location to investigate the behavior of the web splice.

Finally, flange rotational restraint braces to prevent lateral-torsional buckling needed to be evaluated. In practice, lateral-torsional buckling of bridge steel I-girders is prevented by bracing the compression flange. For positive moment regions of composite I-girders, the top flange is braced by the deck and further bracing is not needed during the service stage. However, during the construction stage, before the concrete deck is

composite with the girders, girder lateral-torsional buckling under construction loads is possible, and thus bracing is needed.



Figure 7: Set-up of flange rotational restraint testing

The intermediate cross frames used for this project are shown in Figure 7. This test specimen was subjected to loading in four-point bending with hydraulic actuators applying loads at two points on each girder. In theory, this four-point loading produces a constant moment region between the intermediate cross frames and a linearly varying moment between the end and intermediate cross frames. Instrumentation was placed on the test specimen to measure the reactions, vertical deflection, lateral deflection of the top and bottom flanges, strains in the girder and braced flanges, and girder end rotations.

After these areas of research were completed and refinement of the corrugated web was sufficient, construction followed. There were no details provided regarding the construction or monitoring of the completed demonstration bridge.

3. Project Conclusions

This project was successful and extremely beneficial in regards to the development of future uses of corrugated web girders. Additionally, in 2006, the *Journal of Structural Engineering* published a paper titled, "Shear Behavior of Corrugated Web Bridge Girders", which detailed part of the investigation from this project. This paper won the J. James R. Croes Medal, the second-highest award given by the American Society of Civil Engineers (ASCE).

3.1 Positive Results

Listed are the specific comments provided by the State as positive results from the IBRD project:

- The preliminary design study showed corrugated web girders can be lighter than conventional girders by approximately 10% when using the newly developed shear strength criteria.
- Corrugated web girder fabrication can be managed in a commercial steel bridge fabrication shop.
- Gas metal arc welding can be used effectively in the process of fabrication.

- Test results showed a web splice with a single row of bolts on each side of the splice can easily develop the shear capacity of a corrugated web.
- The test results from the flange rotational restraint bracing show that analysis methods presented in the project are effective in determining the lateral-torsional buckling moment capacity of I-girders.

3.2 Lessons Learned

Listed are the specific comments provided by the State as lessons learned from the IBRD project:

- A clear reason for the discrepancy between the theory and test results was not determined, but out-of-flatness of the folds of corrugated webs may be an important factor. An alternative formula for the nominal shear strength was proposed. The large-scale shear strength tests of two of HPS-70W corrugated web girders showed that the proposed shear strength formula is conservative for girders with the corrugation shape selected for the demonstration bridge.
- Fabrication experience showed trapezoidal corrugations offer distinct advantages over sinusoidal corrugations.
- Fatigue cracks generally initiated at the web-to-flange weld toe along the inclined web folds and the bend regions adjacent to the inclined folds.
- The AASHTO LRFD specifications (AASHTO 1998) limit the web contribution to the axial resistance a bearing stiffener of a flat web I-girder to $18(t_w)$, centered on the stiffener plates. When this length of web is used in calculating the axial resistance, the axial resistance of a bearing stiffener for a corrugated web I-girder was significantly less than the axial resistance of a bearing stiffener for a flat web I-girder with the same stiffener plate size. The results for Test Specimen 1 and Test Specimen 2 suggest that the nominal axial resistance of a corrugated web I-girder bearing stiffener centered on an inclined fold can be calculated with a web contribution equal to $28(t_w)$.
- Category B design curve was found appropriate for finite fatigue design calculation, and 96.5 Mpa for the constant amplitude fatigue limit.
- Bearing Stiffener strength can be calculated from modified AASHTO LRFD column formula.

3.3 Negative Results

Listed are the specific comments provided by the State as negative results from the IBRD project:

- Shear strength theory didn't safely estimate the shear strength of corrugated web girder.

4. Costs

In the 2003 fiscal year, the state of Pennsylvania was granted \$400,000 in funding for development of HPS use in corrugated web design through the FHWA Innovative Bridge Research and Construction program.

5. References

The majority of the information presented in this report, including pictures, are highlights from the Project Summary Report provided by the State and the following resource(s):

Sause, R., Abbas, H.H., Wassef W., Driver, R.G., and Elgaaly, M. (2003). "Corrugated Web Girder Shape and Strength Criteria – Work Area 1". September, 2003.

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Bradford County's Truss Bridges (2005). *SR 2024 over Towanda Creek*. Retrieved from: <http://www.skellyloy.com/bctb/bridges/TR2024b.htm>

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**4.12. HPS, FOLDED PLATES: NEBRASKA - FOLDED STEEL PLATE BRIDGE
TECHNOLOGY: RESEARCH, DESIGN, CONSTRUCTION AND MONITORING**

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

**High Performance Steel
Case Study: Folded Plate Girders**

Project
**Folded Steel Plate Bridge Technology: Research, Design, Construction
and Monitoring**

Project State
NEBRASKA

Prepared For:
Federal Highway Administration



Prepared By:
HDR Engineering, Inc.
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Cincinnati, OH 45242

January, 2012

1. Project Description

The purpose of this project was to load test a folded plate girder to observe its behavior under construction (non-composite) loads and the overall life cycle of the structure. Following testing, a demonstration bridge using folded plate girders was constructed. The bridge site selected for the demonstration bridge was Highway N-79 over Wagon Tongue Creek in the State of Nebraska.



Figure 1: Folded plate girder during testing phase

In the United States, there are nearly 700,000 bridges with approximately 45% of those bridges being short spans measuring 60 feet or less. As many of these bridges have aged, the structures on a large number of them have become deficient and are in need of being repaired or replaced.

As a way of reducing replacement costs, an innovative girder design was developed at the National Bridge Research Organization at the University of Nebraska-Lincoln. The girder has application in short span bridges and accelerated construction situations. The design is a box girder folded from a steel plate that has a trapezoid shape with an open bottom. These types of girders are named folded plate girders.

With these girders, a typical two-lane county bridge would require just three folded girder sections placed side by side. A 40 foot long folded plate girder with precast deck weighs approximately 24,000 pounds, allowing the use of a relatively lightweight crane at the construction site.

The shape of the folded plate girder causes it to have a large amount of lateral stiffness. This stiffness eliminates the need for cross-frames between the girders. The elimination of cross frames from the system is one of the reasons the system is more cost effective than the traditional I-beam system. The open bottom geometry of the folded plate makes the inspection of the structure easy compared to traditional box girders. Simplified inspection procedures translate to reduced inspection costs. The technology used in fabrication is the same that is used in the fabrication of steel utility poles. Because the girder is fabricated using existing technology, finding fabricators with the capability of producing these girders is made easier.

The structural performance of the girder requires investigation in all stages of a bridge's lifecycle. The performance of the folded plate girder needs to be tested to determine behavior in two main aspects of a bridge's life. First, the beam must be able to handle construction loads, and second, the beam must be able to handle the loading it will experience over the life of the bridge.

A testing program has been developed for testing of the folded plate girder. This program focused on the constructability testing of two different specimens. Folded plate girders were designed to be composite girders for the service life of the bridge. During construction, the girders are not composite, so it is important that the girders are capable of resisting the construction loads. Tests were performed on two non-composite folded plate girders to determine how the girders would perform during construction.

The report summarizing the findings for this project was prepared by Atorod Azizinamini, and Luke A. Glaser, University of Nebraska at Lincoln.

2. Project Implementation

The first step to implementing this technology was fabricating the folded plate girders. The specimens were formed from a single plate of grade 65 ksi steel. The fabrication of the girder began as a flat plate. Then, the bottom flanges were formed. Finally, the corners between the top flange and the webs were formed. Figure 2 shows the fabrication steps that were developed given the application of the press in relation to the girder plate.

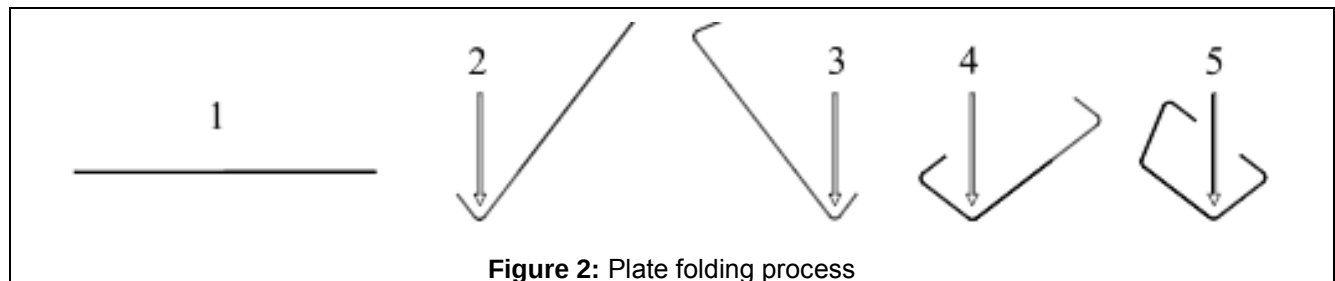


Figure 2: Plate folding process

After the folded shape was formed, bearing stiffeners and plates were welded to the girders at what was the centerline of the supports for the girder ends. Tie plates that connect the bottom flanges were then bolted into place.

Two similar folded plates were tested in this project. The girders for this evaluation were 42 feet long and tested over a span of 41 feet. The girders were fabricated using a 42 feet x 108 inch x 3/8 inch grade 65 weathering steel plate. The final depth of the girder, after the folding process, measured 24.75 inches tall.

The load testing set-up consisted of spanning the girders to a length of 41 feet. The supports were made from reinforced concrete, which was post tensioned to the floor to eliminate any movement of the supports during testing. The girder was set on rockers located directly beneath the bearing stiffener of the girder to allow for rotation of the girder during testing. The rockers were set on two layers of Teflon to allow for any horizontal movement during loading.

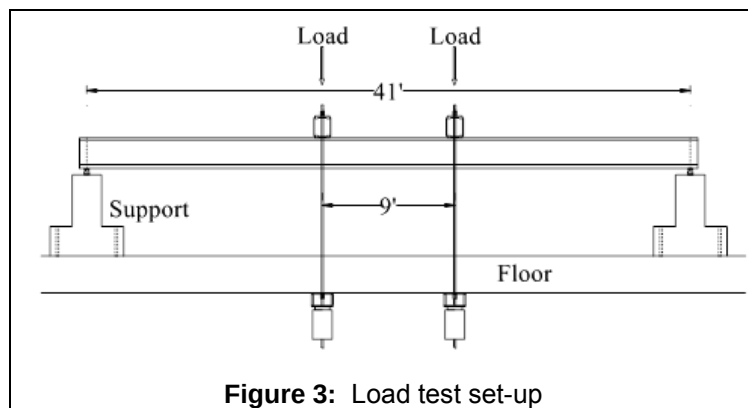


Figure 3: Load test set-up

The goal of the tests was to observe how the girders would behave in a non-composite situation, similar to what is experienced during construction. Since the continuous loading of a wet concrete slab was unable to be simulated, the system was tested using two discrete load points. The use of two load points provides a constant moment between the load points. Two symmetric load points were located 4.5 feet from the span centerline.

The load was applied using spreader beams with threaded rods which passed through the floor and into the basement.

Bearing pads were placed between the spreader beams and the top of the

girder. In the basement, there were hydraulic cylinders on each bar that created the downward loading during testing. Bracing was added between spreaders to stabilize the load setup during assembly.

The folded plate girders were loaded in flexure after the experiment was set up and the testing equipment was wired and running. Each test used the same loading configuration. Load was applied to the girders up to failure.

The first specimen had two phases. The objective of the first phase was to examine the effectiveness of the tie plates. The objective of the second phase was to test the girder when loaded to failure.

During the first phase, the girder was loaded three times at low load ranges where girder behavior was both linear and elastic. First, the girder was loaded with all tie plates in place and then unloaded. Then, the middle three tie plates were removed for the second loading. After the girder was unloaded again, the tie plates were re-installed and it was loaded again.



Figure 4: Loaded girder

In the second phase, the first specimen was loaded to failure. During ultimate loading, the middle three tie plates were not connected. The tie plates were disconnected by removing the bolts at one end of the tie plate. The first specimen was tested without stiffener plates at the loading points.

The second specimen had a similar load testing set-up, with one exception. During the testing of the first specimen, stress concentrations from the loading points caused local deformation. The second specimen added stiffener plates to the load points to reduce the deformation. Since the deformations in the first specimen were only observed during the ultimate loading, the second specimen was tested to failure only.

Loading was monitored by measuring the pressure in the cylinders using pressure cells that measured the hydraulic advance and return pressures at each cylinder in the basement. Girder deflections and bottom flange separations were measured with pots in the girder bottom flanges to monitor separation of the flanges and between the floor of the lab and the bottom of the girder to measure deflections.

Linear strain gages and rosette strain gages were the two types of bondable foil strain gages used to measure strains in the steel for the two tests. Linear gages were put parallel to main strain directions. Linear strain gages were used on the flanges and the webs of the girders. Rosettes are designed for determining principle stresses and strains and were used on the corner bend between the bottom flange and the web.

After this research completed, construction followed. There were no details provided regarding the construction or the long-term monitoring of the completed demonstration bridge.



Figure 5: Linear strain gauges installed on top flange

3. Project Conclusions

This project was very successful. Both specimens that were tested displayed stability and ductility through all stages of testing. There were no undesirable, visible, or measurable deformations in the girder at the design moments equivalent to those experienced during construction.

Additionally, the use of folded plate girders has gained some positive media attention. In the September 2009 edition of Modern Steel Construction (MSC) an article was published which highlighted the successful results from the research performed on this project.

3.1 Positive Results

Listed are the specific comments provided by the State as positive results from the IBRD project:

- Use of Folded Steel Plate Technology has the ability to reduce the labor associated with girder fabrication since the design eliminates flange to web welds and cross frame installation.
- Folded steel plate girder concept uses very thin plates for short span bridges. For instance for 50 ft. long simple span bridge, one only need plate that is 3/8 inches in thickness.
- Girder geometry will be an “Inverted Steel Box” shape. This shape is more stable much easier to inspect, compared to conventional box sections.

3.2 Lessons Learned

Listed are the specific comments provided by the State as lessons learned from the IBRD project:

- To avoid painting and issues related to corrosion, A1010 steel could be used. A1010 is almost a stainless steel and it does not corrode. The alternatives are use of A1010, A572 Grade 50, HPS-70W, HPS100W or HPS-50W steel.
- Tie plates perform a key function by maintaining the girder shape during construction, when the girder is most vulnerable to deformation. Testing confirmed that the tie plates are both necessary and effective for preventing flange separation at construction load levels and both flange separation and rotation at higher load levels, which cause deformation and buckling in the girder. More evaluation of the tie plates will be necessary to determine the optimum tie plate configuration.
- The top flange of the folded plate girder experiences the highest stress during construction. After construction of the deck the concrete is hardened, the neutral axis is shifted up near the interface between the top flange and deck. At this point, the live load and composite dead load top flange stresses are smaller because the top flange is located close to the neutral axis of the composite beam. The top flange was the weakest component of the beam during test loading due to its role as a compression element that has a slender and un-braced form. The compression in the top flange caused local buckling in the top flange even at elastic load levels. This was the cause for loss of stiffness and failure in both specimens. The addition of local deformation that resulted from stress concentrations to the buckling that occurs from compression of the top flange reduces both the stiffness and the ultimate capacity of the girder. Incorporation of a ridge at the center of the top flange of specimens, proved to resolve this buckling issue. Details regarding the implementation of this ridge were not reported.

3.3 Negative Results

No negative results were provided by the State from the IBRD project:

4. Costs

In the 2005 fiscal year, the state of Nebraska was granted \$550,000 in funding for development of folded plate girders through the FHWA Innovative Bridge Research and Construction program.

5. References

The majority of the information presented in this report, including pictures, are highlights from the Project Summary Report provided by the State and the following resource(s):

Azizinamini, A. (2009). "A New Era for Short-Span Bridges". *Modern Steel Construction*. September 2009. 53-54.

Glaser, L.A., Azizinamini, A. (2010). "Constructability Testing of Folded Plate Girders". August 2010.

Folded Plate Girder System (2011). *Discription of the Folded Plate Girder System*. Retrieved from: <http://foldedplate.com/design.html>

4.13. ABC, PRECAST ELEMENTS: TEXAS - FM1660 OVER COTTONWOOD CREEK

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

Accelerated Bridge Construction Case Study: Prefabricated/Precast Elements

Project
FM 1660 over Cottonwood Creek, Hutto

Project State
TEXAS

Prepared For:
Federal Highway Administration



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January, 2012

1. Project Description

The purpose of this project was to construct a bridge using precast concrete bridge elements that allowed for Accelerated Bridge Construction (ABC) of the Cottonwood Creek Bridge in Hutto, Texas. The new structure utilized precast concrete abutments, bents, and slab beams for the 100 foot, two-span bridge. Six prestressed girders were used in each 50 foot span, and the bridge had an overall width of 42 feet. Figure 1 shows a photograph of the completed Cottonwood Creek Bridge.



Figure 1: Completed Cottonwood Creek Bridge

ABC has been used around the United States in numerous applications and for virtually every component of a bridge. The primary benefit of constructing a bridge using ABC is to minimize the impact to traffic. Often times, especially in heavily congested traffic areas, a bridge closure lasting many weeks or months is not feasible. For ABC, bridge closures are typically reduced from months to days. The bridge elements are often prefabricated or precast off-site and not near traffic, and special equipment may be needed to set the elements into place. The cost to construct a bridge using ABC is typically higher than traditional cast-in-place methods, however, when the savings for reduced traffic disruptions is factored in the cost-benefit can be quite high.

The existing structure was built in 1953 and had a total length of 50 feet and was 20 feet wide. The structure had deteriorated since its original construction which led to a sufficiency rating of 40.1. Due to the poor condition of the bridge, it was selected for replacement.

With the exception of the piles, the new Cottonwood Creek Bridge utilizes ABC in almost every major component of the structure. Precast concrete elements included the abutments, bent cap, and the slab beam which incorporated an integral deck.

2. Project Implementation

Construction of the bridge required 33 days from start to finish. A general description of each major step in the construction sequence of the Cottonwood Creek Bridge is provided in Figures 1 through 16.



Figure 1: Rebar cages formed, H-pile connection plate with shear studs shown on bottom



Figure 2: Fabrication of the abutments at off-site location, bent cap similar



Figure 3: Demolition and removal of existing bridge



Figure 4: Site grading after bridge removal



Figure 5: Driving of the H-piles, template used to align piles to abutment plate



Figure 6: Abutment delivered to bridge site



Figure 7: Placement of abutment onto H-piles by crane



Figure 8: H-pile welded to plate cast into the underside of the abutment, as shown in Figure 1



Figure 9: Abutment header at the back face of the abutment cast with flowable concrete fill



Figure 10: Bent cap and other abutment constructed



Figure 11: First girder being set into place by crane



Figure 12: Final placement of girders

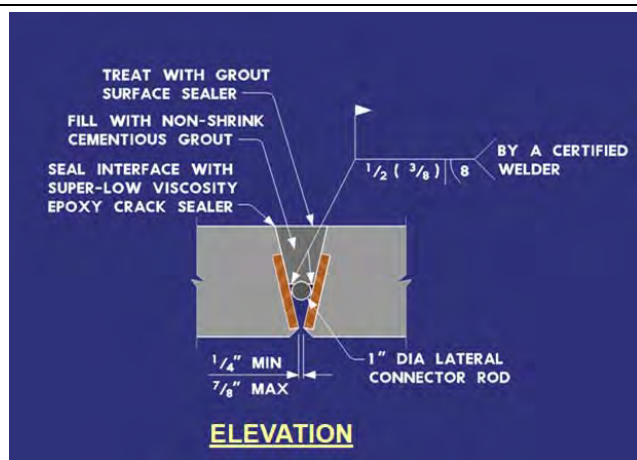


Figure 13: Detail of longitudinal joint between girders



Figure 14: Weld at one inch diameter lateral connector rod to girder plate



Figure 15: Non-shrink cementitious grout placed in longitudinal joint between girders

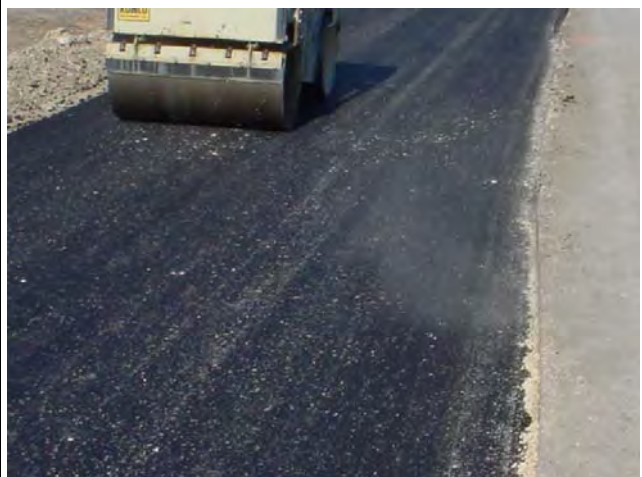


Figure 16: Asphalt overlay

3. Project Conclusions

This project was very successful. The contractor met the pre-determined construction schedule, and construction lasted 33 days. The use of ABC saved approximately 20 days in the construction of the bridge compared to traditional bridge construction techniques. Based on the success of this replacement project, TxDOT developed standard bridge details for the Decked Slab Beam for state-wide use for rapid replacement requirements.

3.1 Positive Results

Listed are the specific comments provided by the State as positive results from the IBRD project:

- The new decked slab beam design and transverse connectors eliminated the need for cast-in-place concrete in the bridge superstructure.

- The bridge was constructed in 33 days. The use of ABC saved approximately 20 days in construction time by eliminating slab forming, rebar placement, and placing and curing of concrete.
- There was minimal disruption of traffic caused by ABC and the use of a decked slab beam superstructure.

3.2 Lessons Learned

Listed are the specific comments provided by the State as lessons learned from the IBRD project:

- The elimination of cast-in-place concrete deck reduced the construction time.
- There was minimal disruption of traffic due to the use of decked slab beam superstructure.
- ABC is suitable for off system rapid replacement bridges.

3.3 Negative Results

No negative results were provided by the State for this IBRD project.

4. Costs

In the 2005 fiscal year, the state of Texas was granted \$300,000 in funding through the FHWA Innovative Bridge Research and Construction program.

The cost for constructing the bridge was \$882,124, which was determined to be nearly 30% higher than traditional bridge construction costs for this site.

5. References

The majority of the information presented in this report, including pictures, are highlights from the Project Summary Report provided by the State and the following resource(s):

Wagner J. (2007). *Accelerated Construction Techniques, Cottonwood Creek Bridge Replacement Project*. TxDOT – Austin District Presentation. 2007.

4.14. ABC, CONCRETE FRP TUBES: MAINE - NEAL BRIDGE, PITTSFIELD

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

Accelerated Bridge Construction Case Study: Concrete Filled FRP Tubes

Project
Neal Bridge, Pittsfield

Project State
MAINE

Prepared For:
Federal Highway Administration



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October, 2011

1. Project Description

The purpose of this project was to test the applicability of concrete filled fiber reinforced polymer (FRP) tubes on a bridge replacement project. This technology was first employed to replace the Neal Bridge, a 70 year-old bridge in Pittsfield, Maine. The 44 feet long bridge was completed with 23 concrete filled FRP arches. As of its opening in November, 2008, it was the only bridge in the U.S. to use this technology.



Photo 1: Completed Neal Bridge

The FRP tube technology, while a new innovation in regards to bridge design, has historically been used in applications outside the transportation industry. Examples include support tents used for temporary medical facilities, disaster-relief shelters, and numerous military projects. Typically, these applications require fast construction and benefit from the light-weight design. It should be noted that in all previous applications, hollow FRP tubes were used.

The main concern regarding hollow FRP tube technology for bridge applications is the ability of the tubes to withstand deflection and buckling under heavy loads. A detailed investigation was completed in November, 2009 to evaluate this concern by William G. Davids of the University of Maine. The study evaluated in-plane load-deflection behavior, and buckling of pressurized fabric arches with finite element analysis. The results demonstrated that the complex effects of pressure resulting from deformation-induced volume changes, and moment-curvature nonlinearity arising from fabric wrinkling must both be included in order to evaluate peak load capacity and post buckling response. Additionally, shear deformations expected for woven fabrics significantly decrease peak load capacity below that predicted using simple Euler buckling theory.

For bridge design applications the above issues are solved by filling the tube with concrete. When the concrete is poured into the hollow FRP tubes, the fully hardened arches capitalize on their inherent properties to transform vertical loads to internal axial forces; the superiority of concrete in sustaining compression loads, and the versatility and strength of the composite materials. Taking advantage of these properties can produce arch bridges up to 70 feet in length.

Utilization of the concrete filled FRP tubes on the Neal Bridge site was desirable since the materials are light-weight and had a fast construction process. In addition, the FRP material has a significantly longer projected life span compared to traditional bridge designs. This translates into bridge designs with long-term cost benefits.



Photo 2: Finished FRP arch, light enough for two people to carry

The technology uses flat, hollow tubes made of a woven carbon fiber. These tubes are inflated to take on an arch shape that is able to span the desired length. Once they have been inflated, a two-component resin is injected inside. The resin is then allowed to cure, leading to a FRP material with a tensile strength up to two times that of steel.

After the hollow, lightweight, and easily maneuverable FRP tubes have been delivered to the site, they are set in place and corrosive resistant decking formwork is

attached to the top of the arches. Next, a self-consolidating expansive concrete is pumped into each hollow arch.

Bridges that make use of this concrete filled FRP tube design have become known as “bridge-in-a-backpack”. While the entire bridge cannot fit in a single bag, the materials for one of the inflatable arches fits into a hockey equipment-sized duffel bag. As a result of this compact, light-weight design, heavy equipment usually required for traditional bridge construction is no longer necessary.

Using concrete filled FRP tube technology is considered a good method for accelerated bridge construction (ABC). After the materials are fabricated and the site is ready, the total construction time takes a matter of days. This has the advantage of shorter road closures and/or traffic diversions.

The research for Neal Bridge was performed by the University of Maine, H.J. Dagher, Director, AEWAC Advanced Structures & Composite Center.

2. Project Implementation

Since this bridge was the first of its kind, some unique procedural steps were adopted for this project. For the building of the Neal Bridge, the arches were put together at the AEWAC lab in Orono, Maine and taken to Pittsfield. Typically, the arches would be assembled, inflated and formed at the construction site. After the arch forming process was complete on this project, assembly and construction went forward as would be expected on future projects of its kind, as described below.

The first step in implementing this technology started with flat, hollow tubes made of carbon fiber, each arch separately rolled up and fit into a bag. For Neal Bridge, this was done in the shop, but typically the bags arrive at the work site, and the tubes are unrolled and placed on formwork which is built to the length and curvature specifications required for the bridge arch span.

**Photo 3.** Tube Assembly**Photo 4.** Inflating the Tube**Photo 5.** Tube bent around form during resin infusion**Photo 6.** FRP Arches being lowered into place

The carbon-fiber tubes were then inflated. After this, the next step was to infuse a vinyl ester resin using a vacuum process (similar to trenchless pipe repair technology). This new FRP material was then left to dry overnight to strengthen. The AEWCC states that the final strength was two times stronger than steel, which gave the tubes the strength and stiffness to carry the weight of the concrete poured inside of them. Once dry, the arch-shaped tubes were light enough to be lowered into place with a simple boom.

The arches were assembled and the base temporarily was secured inside a footing formwork, the arches were covered with corrosion resistant FRP corrugated decking. This was done simply by drilling screws through the decking and into the arches.

The arches were filled with concrete through a hole located near the top of the arch. It took approximately an hour to fill all 23 arches at the Neal Bridge site. As the concrete cured, the screws which were used to secure the decking became permanent anchors, and the FRP tube skin around the concrete created a completely composite structural member.

Next, workers encased the base of the arches with concrete by filling the footing forms. Once completely cured, the retaining walls were then completed and the area above the decking forms was filled in with compacted fill material as with typical arch bridge construction.



Photo 7. Final arch placement with corrosion resistant decking being installed

Finally, the new roadway was graded and paved. An additional asphalt overlay was added approximately 6 months later.

The project took less than two weeks total to construct on site, with the bridge arch construction taking only two days of schedule. Neal Bridge stands today at 44 feet long and 35 feet wide with 23, 12 inch diameter tube arches spanning the water feature below.

3. Conclusions

The concrete filled FRP technology used at the Neal Bridge site has so far been very successful and five more similar projects have been completed in Maine, with two also planned for 2012. Additionally, the technology has been reported positively in various media outlets.

Below are general observations that were made with respect to the Neal Bridge project:

- Bridge superstructure built in less than 2 weeks
- Composites utilized for all major components in superstructure
- Structure expected to provide 100+ years of service with very little maintenance
- Natural stream bed maintained, no disruption to hydraulics
- Composite structure is cost-competitive with precast concrete and steel alternatives
- Tubes are 1/250 the weight of a 70 ft concrete girder
- Technology allows for accelerated bridge construction
- Reports and on-line articles indicate that the results are aesthetically pleasing

3.1 Positive Results

Listed are the specific comments provided by the State as positive results from the IBRD project:

- The materials are lighter, which means heavy placement and transport equipment isn't necessary.
- The composite materials and fibers are as strong as a steel bridge and the whole process is quicker.

- Once the materials are fabricated and the site is ready, construction time takes a matter of days rather than weeks or months. That means shorter road closures and traffic diversions.
- The tubes require no steel reinforcing bars, or rebar, because they are stronger than steel.
- The tubes protect the concrete from water and elements, therefore extending the life of the concrete.

3.2 Lesson Learned:

The State of Maine gained valuable insight into this new bridge technology and how to implement it. The lesson learned for the State consisted of all of the positive results for this technology. The Bridge in a Backpack is being implemented statewide and is becoming a regular construction technique.

3.3 Negative Results

The State reported no negative results associated with this project.

4. Costs

In the 2003 fiscal year, the state of Maine was granted \$400,000 in funding for implementing the concrete filled FRP tube technology through the FHWA Innovative Bridge Research and Deployment program.

The overall life cycle cost for this bridge is expected to be significantly reduced. The cost for replacing Neal Bridge was approximately \$581,000 and was comparable to the cost of a traditional bridge replacement for this site. However, since this bridge was designed using FRP structural members, it requires no painting and will not rust. Furthermore, since these tubes completely encase the concrete, water penetration is prevented eliminating spalls and delaminations in the concrete. Since FRP tubes have a life expectancy of 100+ years, routine deck maintenance becomes the only concern. As a result, the life span is believed to last at least two times longer than a traditional reinforced concrete or steel girder bridge, resulting in a highly favorable long-term cost savings.

5. Additional Project References

The majority of the information presented in this report, including pictures, are highlights from the Project Summary Report provided by the State and the following resources:

Bloch, Jessica (2009). "Research Features – Bridge in a Backpack." *Bangor Daily News*.
Retrieved from: <http://engineering.umaine.edu/departments-research/research-features/bridge-in-a-backpack/>

Davids, William G. (2009). "In-Plane Load-Deflection Behavior and Buckling of Pressurized Fabric Arches." *ASCE Journal of Structural Engineering*, November 2009, 1320-1329.

The University of Maine, Maine Department of Transportation, Advanced Infrastructure Technologies, AEWC Advanced Structures & Composites Center (2011). *Bridge-in-a-Backpack™ Flyer*, May 4, 2011.

4.15. ABC, SPMT: UTAH - I-215 NB OVER 3760 SOUTH STREET

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

**Accelerated Bridge Construction
Case Study: Self Propelled Modular Transport
(SPMT)**

Project
I-215 NB over 3760 South Street, Salt Lake City

Project State
UTAH

Prepared For:
Federal Highway Administration



Prepared By:
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January, 2012

1. Project Description

The purpose of this project was to construct a bridge using a Self Propelled Modular Transporters (SPMT) and Accelerated Bridge Construction (ABC) techniques. This construction technique was used to replace I-215 NB over 3760 South Street in Salt Lake City, Utah. The bridge used a precast concrete deck on steel girders and was built off-site near the existing bridge location. SPMTs were used to move the structure to its final location.



Figure 1: Bridge lowered onto SPMT for transport to bridge site

SPMTs have become a very efficient way to construct a bridge. SPMTs are large platform vehicles designed to move entire structures. A typical SPMT has several axles, and each wheel can be controlled independently to allow for specialized movement of the vehicle. SPMTs can make side-to-side movements in addition to large radius turns. In order to keep the load level throughout all movements each wheel is also able to move vertically. Since SPMTs are very large and typically carrying heavy loads, the speed at which the vehicle moves is typically less than one mile per hour. To facilitate large moves multiple SPMTs are sometimes required.

Typically, when the SPMT process is employed, the replacement structure is built in a staging area close to the bridge site, and SPMTs are used to remove the old structure and move the new structure into place. This construction technique has shown to replace bridges quite rapidly not only in Utah, but also other locations in the United States. The use of SPMTs is also a visually stunning, media-friendly, and very compelling demonstration of agency innovation at work for highway users.

SPMTs main advantages include: Significant reduction in traffic disruption, improvement in work-zone safety, improvement in overall constructability, and lower life cycle costs. SPMT technology addresses each of these critical needs by providing a means of moving entire bridge structures in and out of place on busy highways in just a few hours.

The existing bridge located at I-215 over 3760 South Street was built in the late 1960s and was replaced in 2004 due to the deteriorating condition of the bridge. I-215 in Salt Lake City is a major artery carrying close to 34,000 vehicles a day. This high traffic volume made this structure an ideal candidate for the use of ABC and SPMT technology.

2. Project Implementation

The most important aspect of implementing SPMT technology was to first establish the need for it. The Utah Department of Transportation (UDOT) developed a decision chart to help aid in the construction selection process on whether to use conventional construction or ABC methods.

This decision chart used 11 primary factors to determine which method of construction would be ideal for the given site conditions:

1. Is average daily traffic greater than 15,000?
2. Was the detour length greater than 20 minutes?
3. Was the roadway an evacuation route?
4. Was the user cost greater than \$12,000 per day?
5. Was the material available to construct a bridge to allow for ABC?
6. Was the bridge large enough to produce an economy of scale cost benefit?
7. Were there ABC standards in place for the bridge site?
8. Was there a benefit related to increase worker safety through rapid construction?
9. Were there environmental benefits associated with rapid construction?
10. Was there railroad impacts?
11. Was there any weather limitation?

If “Yes” could be answered for any of those questions, then ABC was considered. The next step was to look at a cost comparison for each method of construction. If the cost for ABC was less than 130 percent of traditional project construction, then a concept report was developed to finalize the decision process.

With the high traffic volumes present at this bridge site (on I-215), a rapid construction method was the most obvious choice, yet several methods of ABC construction were considered. For the I-215 over 3760 South Street bridge site, the structural steel framing along with the concrete deck was built off site and moved into place using a SPMT. Before the placement of the superstructure could happen, a plan was required to prepare the existing site for the SPMT move.



Figure 2: Construction of bridge at off-site location; post-tensioning ducts, block-outs, reinforcement, and formwork over steel girders shown



Figure 3: Placement of concrete at prefabricated structure at same off-site location

This plan used a substructure on a spread footing that allowed for the completion of the new substructure without interfering with the existing bridge. Once the substructure was built, the complete removal of the entire existing bridge was performed. This was done in phases, demolishing one half of the bridge at a time to allow traffic movements throughout construction. After the existing bridge was completely removed, SPMT's moved the new structure into place. Once the SPMT lowered the steel superstructure into place, steel post-tensioned rods were installed transversely across the bridge deck and then tensioned.



Figure 4: Formwork for spread footing under existing bridge



Figure 5: Existing northbound structure removed bridge



Figure 6: Positioning bridge element into final location



Figure 7: Post tensioning bars installed and ready for tensioning

After the entire bridge was in place, approach slabs, drainage facilities, and adjacent roadway replacements of both concrete and asphalt were required at each adjacent end prior to each shift in traffic. Lastly, a polymer overlay was placed on the roadway surface of the deck.

3. Project Conclusions

This project was determined to be successful by the Utah DOT. There was a significant time savings benefit realized by replacing an entire bridge with prefabricated bridge elements, and through the use of a SPMT, provided the substructure is completed while leaving the traffic undisturbed.

3.1 Positive Results

Listed are the specific comments provided by the State as positive results from the IBRD project:

- This was Utah's second attempt at ABC construction techniques and the first in an urban interstate environment.
- A lot of positive media attention was given to this project.
- Several methods of ABC were utilized, including the use of prefabricated bridge elements and the use of SPMTs.

3.2 Lessons Learned

No lessons learned were provided by the State from the IBRD project.

3.3 Negative Results

No negative results were provided by the State from the IBRD project.

4. Costs

In the 2003 fiscal year, the state of Utah was granted \$400,000 in funding for the use of the SPMT through the FHWA Innovative Bridge Research and Construction program.

No specific construction costs pertaining to use of SPMTs were given for this project, however costs for a similar bridge in Utah were given. For this particular project, the additional cost of using the SPMT was \$900,000. The delay-related user savings generated approximately \$4,300,000. This resulted in a net savings of approximately \$3,400,000.

5. References

The majority of the information presented in this report, including pictures, are highlights from the Project Summary Report provided by the State and the following resource(s):

Dye, M.D., Utah Department of Transportation (2005). "Prefabricated Bridge Replacement Report – Lessons Learned During Construction". June 8, 2005.

Ralls, M.L. (2009). *Accelerating Bridge Construction – Modular, SPMT*. National Concrete Consortium (NCC) Meeting, San Antonio, Texas. April 1, 2009.

AASHTO Technology Implementation Group (TIG) Lead States Team. (2010). "Use of Self-Propelled Modular Transporters (SPMTs) to Remove & Install Bridges". February 2010.

**4.16. ABC, ALUMINUM BRIDGE DECK: KENTUCKY - KY 974 OVER HOWARD
CREEK IN CLARK COUNTY**

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

**Accelerated Bridge Construction
Case Study: Aluminum Bridge Deck**

Project
KY 974 over Howard Creek in Clark County

Project State
KENTUCKY

Prepared For
Federal Highway Administration

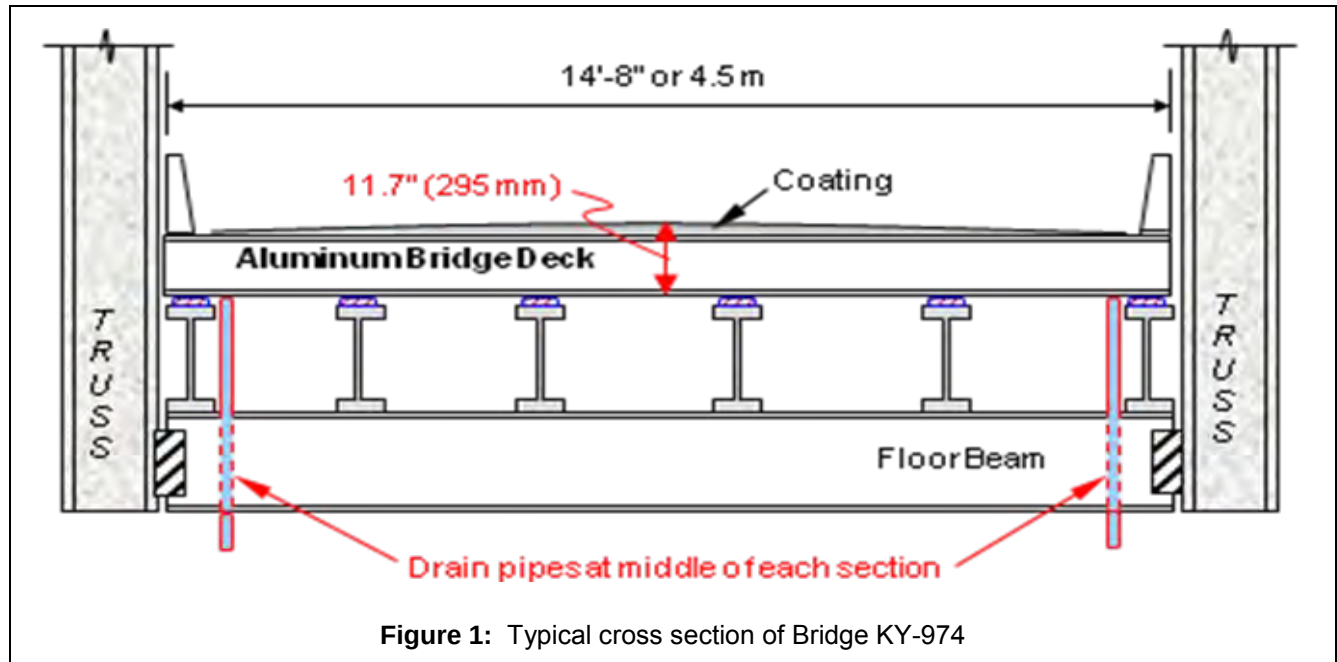


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1. Project Description

The purpose of this project was to rehabilitate an existing bridge using extruded aluminum deck panels for the deck design. The bridge selected for this project was bridge KY-974 in Clark County, Kentucky. This single-span pony truss bridge was built in 1945 spanning 81 feet over Howard Creek. The deck is 14.67 feet wide and is supported by six steel stringers. In total, the rehabilitated structure has twelve aluminum deck panels that were placed side by side covering the entire length of the bridge. It is the first aluminum bridge deck in Kentucky, and one of only a very few load-bearing aluminum transportation structures in the country. Figure 1 shows the typical cross section of the bridge after rehabilitation.



The aluminum deck panels are seen to feature three main benefits:

- Reduced dead load: the deck weighs approximately 80 percent less than the steel reinforced concrete deck it is replacing, which allows increasing the load limit for trucks crossing the bridge.
- Durability: it is expected to increase the lifespan of the deck many times over that of a conventional reinforced concrete deck due to the corrosion-resistant benefits that aluminum naturally offers.
- Rapid construction: the deck can be placed in one day and the bridge opened to traffic later that same day.

The original bridge KY-974 was in need of rehabilitation due to severely corroded fascia stringers, and extensive corrosion on interior stringers, lateral bracing, and floorbeam elements of the bridge. The existing concrete deck also exhibited cracking and efflorescence. These deficiencies are shown in Figure 2. Due to this deterioration, a load posting of 17 tons was required. The load rating of the rehabilitated structure takes advantage of the light weight design that the aluminum deck panels offers.



Figure 2: Original stringers, lateral bracing and concrete deck showing sin

There were several unique design features utilized with the aluminum deck panels. First, in lieu of the traditional bolting or welded connections, the aluminum panels were secured to the supporting beam sections and to one another using mechanical clamps. The clamps can be tightened to a desirable pre-tensioning level. Second, an isolation sheet was installed to the top each stringer flange to create a barrier between the steel and the aluminum to prevent corrosion due to dissimilar metals. Finally, T-section aluminum plates were fitted between each aluminum deck panel to fill the joint between the panels.

2. Project Implementation

No information was reported regarding the fabrication of the panels other than they were manufactured by an extrusion method. The photographs below show the construction sequence for bridge KY-974 rehabilitation project:



Figure 3: Fabrication of aluminum panels



Figure 4: Removal of existing deck and damaged/corroded members



Figure 5: Repair and replacement of removed members



Figure 6: All steel members sand blasted/repainted



Figure 7: All bearings replaced



Figure 8: Isolating sheet adhered to top flange



Figure 9: Panels delivered to site



Figure 10: Panels lowered into place



Figure 11: Aluminum connector plates installed at panel edges to join adjacent panels



Figure 12: Inserting T-sections between panels



Figure 13: Panels attached to stringers with mechanical clamps



Figure 14: Finished installation of aluminum deck panels before overlay



Figure 15: Water proofing laid on top of aluminum deck panels



Figure 16: Placement of asphalt overlay

3. Project Conclusions

The use of aluminum precast deck panels for the rehabilitation of bridge KY-974 was successful. The installation proceeded with minimal problems and was completed very quickly. The new deck system has performed as expected.

Additionally, one industry publication has given the project positive media attention. In the July/August 2006 issue of *Aluminum Now* magazine, Bridge KY-974 was highlighted as the cover story to showcase the benefits of aluminum precast deck panels.

3.1 Positive Results

Listed are the specific comments provided by the State as positive results from the IBRD project:

- Aluminum Deck is lightweight, thus reducing the dead load and increasing the allowable live load on the bridge.
- Following the placement of the first of twelve deck panels, it took 10 minutes to place one panel on the bridge. Consequently, the placement of the deck could be completed in 2 hours and traffic could be allowed on the deck while the underside of the deck was connected to the bridge beams.
- 3 years of monitoring showed that the deck is performing as expected. There were no signs of deterioration or damage.

3.2 Lessons Learned

Listed are the specific comments provided by the State as lessons learned from the IBRD project:

- Practice runs before placement on the actual bridge may be necessary to train construction workers on how to lift and place aluminum deck.

3.3 Negative Results

Listed are the specific comments provided by the State as negative results from the IBRD project:

- Cost of the aluminum deck is very high and would limit its use to steel stringer bridges in congested areas.

4. Costs

In the 2003 fiscal year, the state of Kentucky was granted \$400,000 in funding for implementing the aluminum bridge deck technology through the FHWA Innovative Bridge Research and Construction program.

The following lists the cost of materials at the time of construction for the rehabilitation of Bridge KY-974:

- Aluminum Deck ~ \$160,000 (~ \$140 per square foot)
- Beams ~ \$5,000
- Bobcat Rental ~ \$2,500
- Boom Rental ~ \$500
- Membrane ~ \$1,900
- Paint ~ \$4,700
- Paint Contractor ~ \$56,000
- Bearing Pads ~ \$2,375
- Asphalt ~ \$800
- Miscellaneous tools, etc. ~ \$500
- TOTAL ~ \$234,275

5. References

The majority of the information presented in this report, including pictures, are highlights from the Project Summary Report provided by the State and the following resource(s):

Kentucky Department of Transportation. *Replacement of Bridge Deck with Aluminum Bridge Deck Panels*. Presentation.

“Power Profile – Lightweight Extrusions Shoulder a Heavy Design Load.” *Aluminum Now*, Jul/Aug 2006, 1-2.

4.17. ABC, DECKS: WISCONSIN - IH 39/94 OVER DOOR CREEK

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

**Accelerated Bridge Construction
Case Study: Decks**

Project
IH 39/94 over Door Creek, Dane County

Project State
WISCONSIN

Prepared For:
Federal Highway Administration



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January, 2012

1. Project Description

The purpose of this project was to develop a full-depth precast concrete deck panel and to demonstrate its use for a deck replacement on an existing bridge. After construction, a monitoring system will be installed to evaluate the bridge for one year. Door Creek Bridge, the site selected for this project, is a heavily traveled section of roadway located eight miles east of downtown Madison on I-90 in Dane County, Wisconsin. This bridge is a single span steel girder structure with a span length of 83 feet. The bridge was originally constructed in 1961 and carries approximately 60,000 vehicles daily.



Figure 1: Completed deck surface at Door Creek Bridge

Traditionally, highway agencies use cast-in-place (CIP) methods for building and replacing bridge decks. During this process, the bridge must be completely closed to traffic for a long period to allow for forming and curing of the concrete. Also, part-width deck reconstruction is sometimes used, but this method also requires significant traffic restrictions and generally requires closure pours to connect the phases.

An alternative to using cast-in-place decks is the use of full-depth, segmental precast concrete deck panels. Panels are constructed off-site under controlled conditions and transported to the site ready for installation. Using precast deck panels can significantly reduce construction time, decreasing delays to motorists. It also increases work zone safety by reducing the number of workers and their exposure time near moving traffic; reduces environmental impacts by minimizing the site access footprint; and improves the constructability of bridge designs by controlling manufacturing environments. Generally, precast panels employ prestressed tendons in the design. Prestressed concrete has been proven to have enhanced durability and can serve as a basis for achieving the 100 year bridge.

Since the construction of Door Creek Bridge in 1961, deicing salts applied on the roads during Wisconsin's harsh winters and heavy truck traffic, typical of an interstate bridge, caused severe deterioration to the original cast-in-place concrete deck and steel girders. For this reason, the bridge had been targeted for replacement. Primarily due to the high traffic levels present at the Door Creek Bridge site, the development and use of precast panels to reduced construction time was a highly favorable option.

The precast panels were only used for the reconstruction of the northbound lanes of the Door Creek Bridge. Traditional CIP methods were used for the southbound lanes. The goal was to compare construction costs and durations, and the performance between the two methods over the service life of the bridge.

For the precast panels, three unique innovations were used. First, the layout of the new bridge required a longitudinal joint between the precast panels that was not located over a girder. Other projects utilizing precast concrete panels generally place the longitudinal joint over the girder flange. The new deck installation

was staged to maintain traffic, so panels were cast at approximately half the width of the bridge and no girder was present at this location.

Second, the shear studs used to develop composite action between the panels and the girders were placed farther apart than typical AASHTO standards. The wider spacing for this project was accepted based on performance measurements that resulted from laboratory testing.

Third, the panels were developed with sufficient edge strength so that wheel loads could be placed on the panel edges without causing damage. This would allow portions of an old deck to be removed during overnight construction, and replaced with new precast panels that would be able to withstand truck traffic the next day without continuity at the panel edge.

The research for the Door Creek Bridge was performed by the University of Wisconsin, College of Civil Engineering.

2. Project Implementation

The project was divided into three phases, as follows.

Phase 1 included completion of background research and preliminary engineering required to develop the proposed precast deck system, and the design of the installation procedure for the full-depth, precast, post-tensioned, concrete deck panels. Also, as part of Phase 1, and a laboratory testing procedure was developed to investigate the proposed deck panel system.

Phase 2 required a constructability study and the subsequent installation of the deck panels at the Door Creek Bridge demonstration site. The constructability study included a comparison study of the deck panel installation procedure with a traditional deck installation, as well as computations to determine the minimum prestressing force required across the joints for future projects.

Phase 3 was the monitoring portion of the project. This included monitoring the conventional and deck panel bridge decks. To determine feasibility of using prefabricated, prestressed concrete deck panels in the future, non-destructive load tests were performed, and the decks were inspected for cracking of the concrete. Lastly, Phase 3 included an analytical study of the loaded bridge.

During Phase 1, a series of serviceability and strength tests were performed to prove that the proposed design of the joints between the deck panels was adequate. Additionally, a half scale steel plate girder was constructed to investigate the composite action between the concrete deck panels and steel girder.

In total, four different types of concrete deck panel specimens were prepared for laboratory testing. Figure 2 shows which tests were performed and the purpose of each.

During the testing for edge strength, load was applied at the transverse joint edge of the panel to simulate a wheel moving onto the edge of the deck panel. The panels were subjected to several cycles with a maximum load of 20 kips and were then loaded to their ultimate capacity.

Specimen Category	Size (L x B x thick)	Quantity	Purpose
Edge Strength Panels (ES-1 & ES-2)	8'-9" x 14'-3" x 8"	2	To determine strength of panels when loaded near the edge
Longitudinal Joint Panels (LJ-1 through LJ-6)	4'-0" x 13'-3" x 8"	6	To determine joint stiffness under different post-tensioning levels
Transverse Joint Panels (TJ-1 through TJ-4)	4'-0" x 8'-0" x 8"	4	To determine joint stiffness under different post-tensioning levels
Composite Behavior Panels (CM-1 through CM-10)	4'-0" x 4'-0" x 4"	10	To determine composite behavior of panels and steel beam with different shear stud layouts

Figure 2: List of specimens constructed for testing.

The longitudinal joint capacity test was completed to measure the amount of post-tensioning force required to maintain a tight fit between panels. A total of three tests were performed, with each prestressed panel specimen constructed to simulate the panels used for the actual bridge construction. For two of the tests, immediately after the joint was cast, a cyclic load was placed on one panel for a 6 hour period. This was meant to simulate the traffic loading while the joint grout cured. For the third test, a similar process was followed except that the grout was allowed to fully cure to a compressive strength of 4,000 psi before the test was performed.

The transverse joint capacity was tested in a similar manner to the longitudinal joint tests. Two panels were placed end-to-end and grout was then poured inside the joint. Once the joint reached a compressive strength of 4000 psi, the panels were post-tensioned to tightly fit together. A total force of 44.3 kips was applied to one of the panels, creating a stress of 154 psi across the joint.

A final test was performed to determine if the deck could be attached to the steel girders with composite fasteners spaced further apart than permitted by the AASHTO standards. This test was conducted on a half-scale model of the Door Creek Bridge with the same material properties, shown in Figure 3. The loading for the composite girder testing consisted of two separate stages. The first stage was comprised of accelerated testing to 2 million cycles of load. The second stage involved loading the composite beam to its ultimate capacity.



Figure 3: Completed composite model for composite fastener spacing testing

Following conclusive testing results, Phase 2 could be started. The first step was the fabrication of the concrete deck panels. The panels required numerous foam blockouts prior to placing prestressing strands or concrete. The blockouts were used to form the pockets for the shear stud connectors that would later be used to develop the composite action with the steel girders. Next, welded wire fabric was placed at the top and bottom of the deck panel to control cracking during shipping and erection. After the wire fabric was in place, the prestressing strands were set into position, as shown in Figure 4. The stands for prestressing were stressed using a hydraulic jack. Once the strands were stressed the post-tensioning hardware was put into position. This included plastic ducts for the longitudinal and transverse directions along with anchorage hardware for the post-tensioning. The final step in reinforcing the panels was to place epoxy coated steel bars into a position to be used to connect the cast-in-place parapet wall to the bridge deck. For the panels, a Self-Consolidating Concrete (SCC) mixture was used. This concrete was poured between the panel formwork. After curing for 24 hours, the final step was releasing the stands to allow the prestress force to transfer to the deck panels. Figure 5 shows the completed precast concrete deck panel used for the Door Creek Bridge site.



Figure 4: Prestressing strand being placed between foam blockouts and wire fabric prior to tensioning



Figure 5: Completed precast concrete deck panel

Once the fabrication of the deck panels was complete, the panels were delivered to a precasting yard to be stored for a minimum of 30 days prior to placement at the bridge site. While at the yard the ends of the prestressing strands were removed flush with the surface of the panels. Additionally, the panel joint faces were blasted in order to roughen the surface for better joint bond in the field.

Once ready to be shipped to the bridge site, the panels were again loaded onto a truck and transported to the bridge site, which was approximately 65 miles away. The panels were lifted off the trucks and placed directly onto the bridge. The overall layout of the panels and the girders for each construction stage is shown in Figure 6.

For the placement of each panel, a 100-ton capacity crane was used to lift the panel off the truck. The weight of each panel was much less than 100 tons, however the demand for a long crane reach required a crane with a 100-ton capacity. Prior to setting in place, the panel leveling screws were rough-adjusted to the girder shape so the panel would sit in a position to meet the proposed roadway profile and account for camber in the girders.

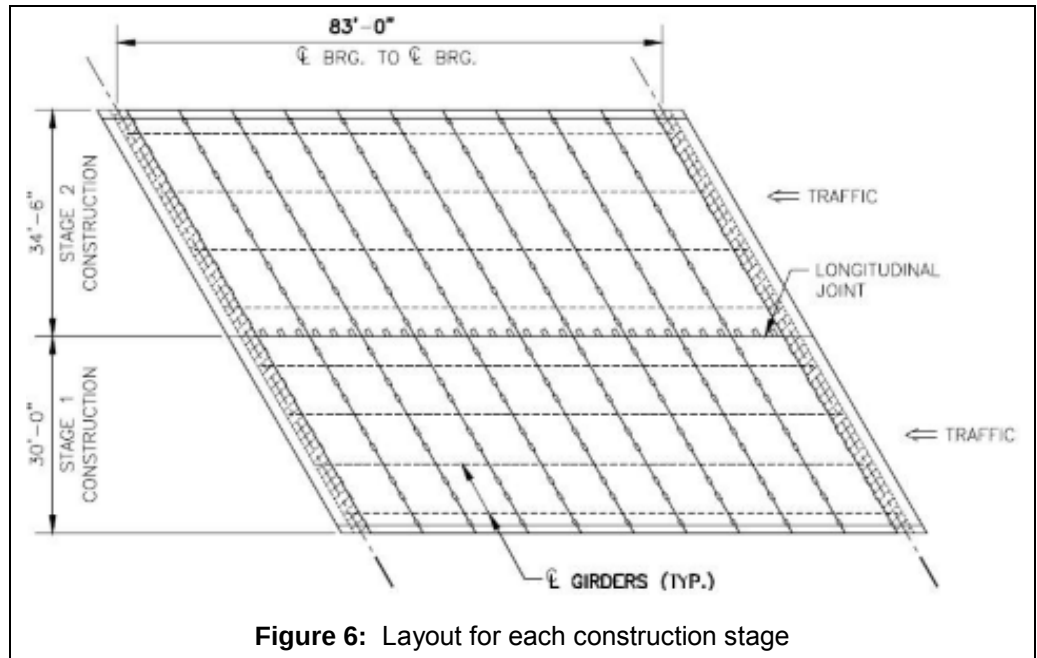


Figure 6: Layout for each construction stage



Figure 7: Placement of precast panel

For Stage 1, once all of the panels were in place, the longitudinal post-tensioning strands were pushed through the ducts by hand. At each joint the ducts between panels were spliced by use of a heat shrink tube. After the post-tensioning ducts were spliced, the panel joints were grouted. The final post-tensioning step was the

sealing of the ends to provide protection for the strands. End caps were placed over the cut ends and the ends were dry-packed with a grout mixture.

Closure pours at each end of the bridge were the next step in the construction of the bridge. Pour areas at each end of the bridge had been designed to accommodate installation of the expansion joints. Setting the elevation of the expansion joint was a critical issue. The top surface of the panels could not be used to set the elevation of the expansion joint since the panels would be ground down and have the epoxy overlay installed in the future. Since the closure pours were to be cast in place, conventional formwork had to be installed. This involved several small and unique form pieces due to the skewed ends of the bridge. A total of 4 working days was required to complete the formwork, reinforcing steel, and expansion joint installation in preparation for the closure pours.

Grouting of the shear stud blockouts and haunches followed. Grout was transported using a wheelbarrow where it was poured into the shear stud blockouts. A vibrator was used to encourage the grout to flow along the length of the haunch and fill the void under the panels.



Figure 8: Application of epoxy overlay

After the grout had cured for a 24 hour period, preparations were made to apply an epoxy overlay. The surface of the deck was ground down using a diamond grinder. Finally, a shot blaster was used to prepare the whole surface for application of the epoxy overlay. The two-part epoxy overlay was mixed in buckets with a paddle wheel and spread around using squeegees. Aggregate was then broadcast by hand to completely saturate the epoxy. After the temperature-based cure time specified, the excess aggregate was removed and the process repeated for the second lift. The application process is shown in Figure 8.

Stage 2 of the construction followed. The primary difference between the stage 1 and stage 2 panels was the presence of transverse post-tensioning ducts that were used instead of half of the prestressing strands in the stage 2 panels. The post-tensioning strands placed in the transverse ducts were spliced with the stage 1 strands left protruding from the stage 1 panels, this is

shown in Figure 9. These post-tensioning strands were installed immediately following the panel placement. After placement of the strands the joints were grouted. The transverse strands were post-tensioned after the longitudinal post-tensioning for stage 2 was complete.

After post-tensioning was finished, the epoxy overlay was placed in similar fashion and placed to match stage 1. This completed the construction of Door Creek Bridge.

Phase 3 of the project involved load testing on the bridge after the construction had completed. This was to test the performance of the panels and compare it to the performance of the adjacent CIP bridge deck for the opposite direction of traffic. Strain and displacement measurements were taken during load testing of the bridge.



Figure 9: Transverse strands at the longitudinal joint between stage 1 and stage 2

3. Project Conclusions

This project has clearly shown that full depth precast segmental concrete bridge decks can be constructed in Wisconsin. Furthermore, the fully prestressed nature of the deck, combined with the high quality of the precast concrete, is expected to provide a deck that will be more durable and will remain crack free with a longer life than conventional cast-in-place concrete decks.

The use of full depth precast panels to form a deck has the potential to achieve more rapid construction than conventional methods. The savings associated with the construction time was not proven in the Door Creek Bridge only because the contractor had no incentive to complete the project in a rapid manner.

This project also received national attention from the Precast/Prestressed Concrete Institute (PCI). PCI selected the Door Creek Bridge project as the “2006 Harry H. Edwards Industry Advancement Award Winner” for the use of the precast concrete deck panels. An article was published in their January-February 2007 journal detailing the background and positive results produced on this project.

3.1 Positive Results

Listed are the specific comments provided by the State as positive results from the IBRD project:

- The project provided a positive experience with the first SCC concrete deck in Wisconsin, and is performing well to date
- Positive experience with first precast deck panel system in Wisconsin, and is performing very well to date
- Proved capability of precast decks to be used in future partial deck replacements that are associated with night time closures
- Proved that shear connectors for composite action are acceptable at a 4 foot spacing as compared to the AASHTO maximum spacing limit of 2 feet
- Laboratory testing combined with analytic results proved that it is not necessary to design the prestressing in panel joints to completely offset load induced tension stresses
- During edge strength testing, no cracks were found on either the top or bottom surface of the panels when loaded at 20 kip service loads
- Load testing, after construction of the bridge, produced satisfactory results

3.2 Lessons Learned

Listed are the specific comments provided by the State as lessons learned from the IBRD project:

- The use of an epoxy overlay, with fine aggregate, provided superior resistance to winter icing compared to the adjacent CIP deck without an overlay
- It is essential to enforce contract special provisions regarding submittal of a prestressing plan and a grouting plan for post-tensioned construction
- Staged construction, with a longitudinal deck joint, may increase construction time by 50% and should only be used when essential
- Because of the delays in this project, there should be increased emphasis on placing incentives in the contract to meet project deadlines
- Based on the experience with this project, the Wisconsin DOT should strongly consider sponsoring a training workshop for bridge construction contractors in the State to develop familiarity and skills in prestressing and post-tensioning. At present the State contractors are not sufficiently familiar with these techniques. In the long run the cost of construction to the State can be reduced through a proactive initiative to develop skills of the contractors.

3.3 Negative Results

Listed are the specific comments provided by the State as negative results from the IBRD project:

- The lack of contractor familiarity with post-tensioning and precast decks partially resulted in a 170% increase in installed deck cost compared to the adjacent CIP bridge deck

- Contractor inexperience with post-tensioning led to a delay of 2 weeks when grout entered PT ducts before the strand was prestressed

4. Costs

In the 2004 fiscal year, the state of Wisconsin was granted \$400,000 in funding for implementing the precast concrete deck panels through the FHWA Innovative Bridge Research and Construction program.

A 30 percent cost premium should be expected for employing the precast full-depth deck panel compared to traditional CIP methods.

5. References

The majority of the information presented in this report, including pictures, are highlights from the Project Summary Report provided by the State and the following resource(s):

Carter, J., Pilgrim, T., Hubbard, F.K., Poehnelt, T., and Oliva, M. (2007) *Wisconsin's Use of Full-Depth Precast Concrete Deck Panels Keeps Interstate 90 Open to Traffic*. PCI Journal. January-February 2007. 2-16.

Oliva, M., Bank, L.C., and Russell, J.S. (2007). "Full Depth Precast Concrete Highway Bridge Decks". November 2007.

**4.18. REINFORCING BARS, FRP: NORTH CAROLINA - BRIDGE 16 ON STATE
ROUTE 1470 OVER CARTOOGECHAYE CREEK, TIP B-3485**

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

Reinforcing Bars
Case Study: Glass Fiber Reinforced Polymer

Project
Bridge 16 on State Route 1470 over Cartoogechaye Creek, TIP B-3485,
Macon County

Project State
NORTH CAROLINA

Prepared For:
Federal Highway Administration



Prepared By:
HDR Engineering, Inc.
9987 Carver Road
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January, 2012

1. Project Description

The purpose of this project was to experimentally and analytically investigate a bridge deck with glass fiber reinforced polymer (GFRP) reinforcement bars. Durability tests on four GFRP rebar types, each from a different fabricator, were also completed. The bridge deck selected for the investigation was SR 1470 over Cartoogechaye Creek in Macon County, North Carolina. The original structure consisted of timber piles with a timber abutment, and steel girders. The new bridge used traditionally reinforced prestressed concrete girders, with a GFRP reinforced concrete deck, in the 3-span design. This was the North Carolina Department of Transportation's first attempt at using GFRP in any bridge element.



Figure 1: Completed bridge deck at SR 1470 over Cartoogechaye Creek

A major maintenance expense for transportation departments is the replacement of bridge decks to repair reinforcing steel corrosion induced deterioration. Corrosion deterioration of reinforced concrete is typically brought about by the application of deicing salts to bridge decks to melt ice during winter months. Bridge decks are very susceptible to chloride ion damage because the deicing salts are placed directly on the riding surface.

The most common solution to the corrosion deterioration problem is the use of epoxy coated steel rebar. However, history has shown that these coatings can be compromised, which eventually leads to deterioration of the reinforcement underneath.

A potential solution to deterioration of reinforced concrete structures is the use of FRP reinforcement. In addition to the entire material being corrosion resistant, FRP reinforcement has a high strength and high stiffness to weight ratios. The most common FRPs used in structural systems are aramid, carbon, and glass. Of these GFRP has the least initial cost.

The bridge located on SR 1470 over Cartoogechaye Creek was replaced by a bridge that will utilize GFRP reinforcement in the deck design, instead of the traditional epoxy coated steel rebar. The new bridge has two exterior spans with span lengths of 50 feet, and an interior span with a span length of 60 feet. In this project the interior span of this bridge was investigated. The cross section of the bridge is comprised of four prestressed girders and an 8 inch cast-in-place deck reinforced with GFRP bars.



Figure 2: GFRP reinforcement

With the development of GFRP reinforcement as a substitute for steel, different manufacturers have engineered a variety of shapes and surfaces through the pultrusion process all of which are aimed at improving the bond surface. The two most common methods to improve the bond surface include the double wrapping of a helical fiber around the rebar glass fiber core and sand-coating. Standard shapes include circular cross-section, circular cross-section with helical wrapping/deformation on the surface, square cross-section, and circular rebar with square sections at mid-sides.

Both durability and experimental tests were performed on the GFRP deck.

The purpose of the durability phase for this project was to determine, for each of GFRP specimens submitted by the four fabricators, the rate of absorption and any changes that may be noticed while in the controlled alkali environment, the percentage decrease of the tensile strength of the rebar over a defined time period, and to determine the effects of the alkali environment has on the bond strength of the rebar to the concrete.

The experimental phase of this project includes large-scale laboratory tests, and in-situ static and dynamic tests of the actual bridge. In order to compare the results of the proposed experimental setup, a numerical comparison was done using finite element models created with the ANSYS (2002) advanced finite element computer program.

The research for SR 1470 over Cartoogechaye Creek was performed by the University of North Carolina at Charlotte (UNC), Department of Civil Engineering.

2. Project Implementation

The first portion of this project tested the durability of the GFRP reinforcement. A total of 456 specimens, containing four different types of GFRP reinforcement, from four different fabricators were selected for the testing. The alkalinity of the concrete which encases the GFRP rebar can potentially breakdown the fibers over time.

Two types of specimens were selected for the absorption studies: nicked and unscathed GFRP reinforcement. The unscathed specimens were selected to determine the durability of the rebar having the full benefit of the epoxy coating on the surface and at the ends while being subjected to an alkaline solution at different temperature environments. The nicked specimens, on the other hand, were considered to evaluate the potential durability of the rebar under conditions similar to those encountered in the field in which a defect arising from the construction site might compromise the integrity of these reinforcing elements. The specimens were cut into 2 inch pieces and placed in two different 100 gallon liquid chemical tanks which had a pH range similar to the concrete environment. One of the tanks was set to a temperature of 100 degrees Fahrenheit and the other to 130 degrees Fahrenheit.



Figure 3: Example of 2 inch piece after nine month duration in tank

Several tests were conducted during the 18 month period, including the testing of GFRP reinforcement for moisture uptake relative to changes in lengths, diameters, and weights; and determining the percentage degradations of tensile and stiffness properties of specimens along with simple pullout tests to observe changes in the bond strengths of the various types of the GFRP reinforcement based on differing reinforcements, outer surface coatings, and exposure to alkalinity at different temperatures.

To get an understanding of how a bridge deck reinforced with GFRP would perform under loading, UNC developed a computer model using ANSYS finite element software. In this analysis, the bridge deck was modeled with the reinforcement that had properties similar to GFRP. Only one quarter of the 60 foot bridge span was considered due to the symmetry planes in both directions. After the design vehicle loading was applied to the model, the numerical results were compared to design specifications. It was concluded that the AASHTO Standard Specifications closely calculated the shear capacity of the GFRP deck.

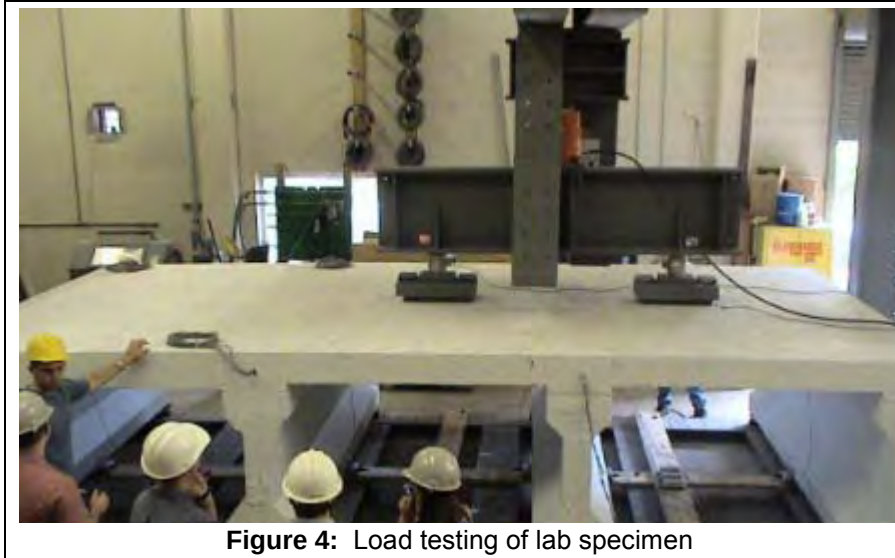


Figure 4: Load testing of lab specimen

In order to verify the theoretical behavior of the bridge evaluated by the ANSYS model, and experimental lab specimen was built and tested. The lab specimen was built based on the actual bridge design. Sixteen strain transducers and sixteen displacement transducers were used in test to monitor both the prestressed girders and the deck. The testing looked at two point loading of the deck at the controlling location in order to simulate the HS 20 design truck. To do this, two load cells were used to stress the deck until failure. This test is shown

in Figure 4.

The lab specimen behavior was similar to that predicted by the ANSYS software model. The software model showed that the deck was more flexible than the actual lab specimen; however, the load deformation curves had the same slope. This concluded the testing phase of the project.

After testing was complete, the construction followed. In order to allow the construction of the deck, stay-in-place metal forms were used between the prestressed girders. Outside the exterior girders, temporary falsework was built to facilitate the construction of the 3 foot deck overhang.

With one exception, the bridge deck contained only GFRP reinforcement in the form of deformed composite reinforcement. All composite reinforcement was placed 6 inches on center. #5 rebar was placed at the deck overhang area, #8 rebar was used in the top layer above the thru-bent diaphragms, #7 rebar was used at the bottom layer in the transverse direction, and finally, #6 rebar was used in every other position in the deck.



Figure 5: Completed deck reinforcement grid

GFRP composite reinforcement placement requires special attention, with somewhat similar measures to epoxy coated steel rebar construction. Therefore, the general contractor closely followed the rebar manufacturer's specifications with respect to storage, handling and placement of reinforcement. Prior to placement, the GFRP reinforcement was stored in a covered location in order to avoid excessive sunlight and moisture exposure. Only plastic chairs and spacers were used to place the rebar mats at the proper height. The reinforcement was tied at every other bar intersection with plastic covered wires, avoiding contact with steel and other metal parts of the formwork. After placement of the reinforcement, the concrete was poured identical to traditional cast-in-place construction.

Finally, the bridge was instrumented using strain gages, strain transducers and displacement transducers. To investigate the bridge's response to controlled live loads applied to the superstructure, two fully loaded tandem trucks were used for quasi-static and dynamic in-situ tests.

3. Project Conclusions

Overall, the project was successful. GFRP reinforcement offers a good alternative to steel or epoxy coated rebar, as a means of internal reinforcement particularly for concrete structures in or near marine environments, or for bridge decks in cold regions for which de-icing agents are used.



Figure 6: Load testing of bridge

Durability can be an issue with GFRP reinforcement when exposed to high alkaline environments, as present naturally in Portland cement mixes. Suggestions to mitigate these effects include the use of concretes with fly ash and silica fume which would create a lower pH value in the concrete; use of low-alkali cements is also recommended, though it would likely increase construction-costs.

3.1 Positive Results

Listed are the specific comments provided by the State as positive results from the IBRD project:

- GFRP reinforcement densities ranging between 80 and 130 pound per cubic foot, which is about one-quarter of density of steel rebar. This weight reduction led to a lower transportation cost and easier handling on the project site.
- GFRP reinforcing is highly resistance to corrosion
- The tensile strength of GFRP reinforcement is 30 to 50 percent higher than steel reinforcement
- GFRP reinforcing is electrically and thermally nonconductive
- The chloride durability of the GFRP reinforcement is much better than that exhibited by the epoxy coated reinforcement because the latter is still susceptible to corrosion should the epoxy coating become compromised for any reason.
- Load testing after construction was completed produced satisfactory results

3.2 Lessons Learned

Listed are the specific comments provided by the State as lessons learned from the IBRD project:

- In future GFRP reinforcement applications, the reinforcement ratio could be further reduced, making composite reinforcing a more economical alternative from a structural/construction point of view.
- GFRP reinforcement offers a good alternative to steel or epoxy coated reinforcement
- From the absorption tests, it was found that the GFRP reinforcement incurred sizable strains in the longitudinal and, even more noticeably, in the hoop directions. However, this was the case for the bare reinforcement, and in order to fully qualify this assertion for embedded reinforcement within concrete structures having adequate cover, additional tests would have to be performed to ascertain differential strain readings.

3.3 Negative Results

No negative results were provided by the State from the IBRD project.

4. Costs

In the 2003 fiscal year, the state of North Carolina was granted \$230,000 in funding for implementing the precast concrete deck panels through the FHWA Innovative Bridge Research and Construction program.

The cost for GFRP reinforcing, per linear foot, compared to traditional steel reinforcing is about three to four times as much. However, given the increased tensile strength which has the capability to reduce the reinforcement ratio, the lighter weight nature of the product, and the anticipation to produce a bridge with a longer design life, a significant portion of the initial costs are expected to be recovered.

5. References

The majority of the information presented in this report, including pictures, are highlights from the Project Summary Report provided by the State and the following resource(s):

Gergely, J. (2004). "Analysis and Testing of a Bridge Deck Reinforced with GFRP Rebars". June 14, 2004..

Gergely, J., Boyajian, D.M., Young, D.T., Frank, C.R., and Szabo, I.F. (2007). "Final Report – Analysis and Testing of a Bridge Deck Reinforced with GFRP Rebars". April 3, 2007.

**4.19. REINFORCING BARS, STAINLESS: MISSOURI - RT. 6, 0.8MI TO 0.2 MI W
SULLIVAN CITY, GALT, MO**

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

**Reinforcing Bars
Case Study: Stainless**

Project
Rt. 6, 0.8Mi to 0.2 MI W Sullivan City, Galt, MO
(Bridge 6059 in Grundy Co.)

Project State
MISSOURI

Prepared For:
Federal Highway Administration



Prepared By:
HDR Engineering, Inc.
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January, 2012

1. Project Description

The purpose of this project was to construct and evaluate the performance of a concrete bridge deck using stainless steel reinforcement as an alternative to conventional epoxy-coated reinforcing steel. For this evaluation, two bridges were constructed. Both bridges are on state highway MO-6 in Grundy County, about 100 miles northwest of Kansas City. The first, bridge A6059, utilized stainless steel reinforcement, and the other, bridge A6060, was a control bridge which was constructed using epoxy-coated rebar in its deck design. The control bridge A6060 has identical roadway width and girder spacing as bridge A6059, but has different span lengths and skew. Bridge A6060 is located approximately 600 feet east of A6059. This was Missouri's first attempt at using stainless steel reinforcement in a deck design application. The stainless steel reinforcement at bridge A6059 is shown in Figure 1.



Figure 1: Stainless steel reinforcing at bridge A6059

A major maintenance expense for many transportation departments is the replacement of bridge decks to repair corrosion induced deterioration. Corrosion deterioration of reinforced concrete is typically brought about by water infiltration and application of deicing salts to bridge decks to melt ice during winter months. Bridge decks are very susceptible to chloride ion damage because the deicing salts are placed directly on the riding surface.

The most common solution to the corrosion deterioration problem is the use of epoxy-coated steel rebar. However, history has shown that these coatings can be compromised, which eventually leads to deterioration of the reinforcement it protects.

Stainless steel reinforcement has greater corrosion resistance than that of conventional epoxy coated rebar. The type of stainless steel used on bridge A6059 was solid Type 316LN. This type of reinforcement is an alloy which contains high levels of chromium and nickel to give it the desired corrosion resistant properties. Having these properties will result in minimization of concrete cracking and spalling caused by corrosion in steel reinforcement. This results in greater durability, less maintenance and repair, a longer service life, and lower life-cycle costs. As confidence in these methods of reinforcing increase, alternative methods of reinforcing decks will become more common in Missouri.

The performance of stainless steel reinforcement was documented at the A6059 and A6060 bridge sites using non-destructive fiber optic chloride sensors, permeability testing, half-cell potentials readings and visual inspection. The additional benefits of this project were to test the epoxy-coated rebar bridge using AC

Impedance from time of construction and to test the use of non-destructive chloride testing. The objective was to monitor any early failure of the epoxy-coated rebar.

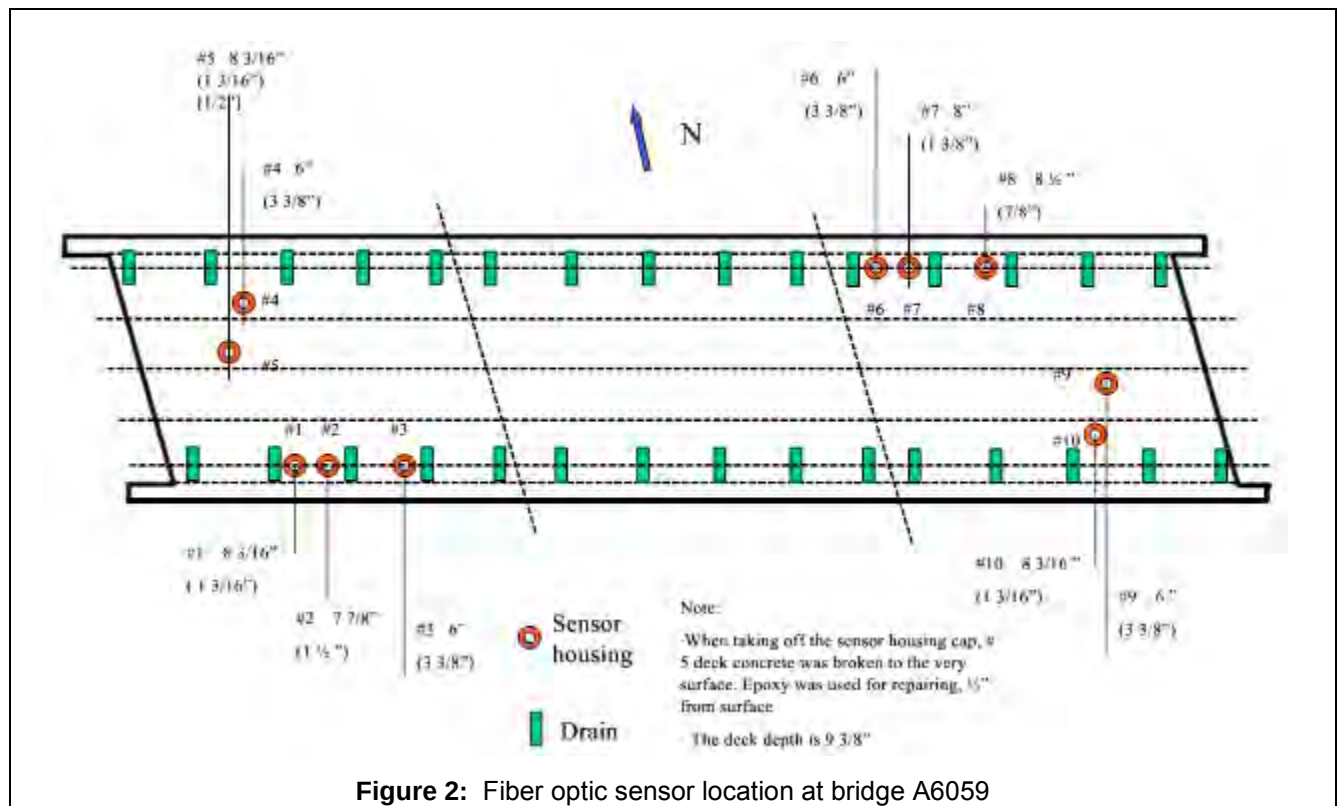
Field observations and data collection concerning the condition and performance of each bridge deck followed the construction of the bridges. The fiber optic chloride sensors were monitored every year for five years to verify any indications.

The research completed on the use of stainless steel reinforcement in a concrete deck was prepared by the Missouri Department of Transportation (MoDOT).

2. Project Implementation

The stainless steel reinforcement at the A6059 bridge site was installed similar to traditional reinforcing. The only difficulty in placing the stainless steel rebar was at splices to black rebar needed at the solid diaphragms, located at the abutments and pier caps. Specifications called for using one inch plastic spacers to prevent a reaction between the two dissimilar metals. However, these spacers did not provide a very firm connection. Instead, the contractor installed additional epoxy-coated rebar to allow the black and stainless steel rebar to be attached to the epoxy without touching each other.

Non-destructive testing originally was performed on the bridge deck using fiber optic chloride sensors. These sensors were incorporated into both bridge decks. The fiber optic chloride sensors are modular units that contain a chemical reagent. When chlorides react with this chemical, the color of a light signal sent through the fiber optic cable changes. This is a one-time reaction. Figure 2 shows the location of the sensors at bridge A6059.



Before the sensors were installed, the sensor housings needed to be equipped to the bridge during the deck construction. The sensor housings were nailed to the bottom formwork. On bridge A6060, the conventional construction using epoxy rebar, prestressed precast deck panels were used instead of forming. After measuring to make sure none of the prestressing strands would be cut, two inch diameter holes were cored in the four inch panels. Epoxy glue was used to hold the sensor housings in place. The remaining six sensor

housings were set on each side of the bridge where they could be nailed into the conventional forming needed on the overhangs. After the concrete was cured, the formwork was removed leaving the sensor housing in place, shown in Figure 3. The fiber optic chloride sensors were installed into the sensor housings shortly after the bridges were open to traffic, shown in Figure 4. Chlorides samples were also taken from cylinders to obtain base line chloride content.



Figure 3: Fiber optic sensor housing



Figure 4: Fiber optic sensor fully installed

One problem was encountered when installing sensor #6 on bridge A6059. It was found that light came through the top of that sensor housing. Later, a visual check was conducted on the bridge deck. It was found that light was caused by deck concrete which had broken. This was repaired with epoxy when preparing sensor housings.

In order to use AC impedance testing on the epoxy coated reinforcement, a test grid was set up with 22 bars made electrically continuous and a bar at each end of the bridge left protruding from the side of the deck for an electrical connection. To ensure continuity, tests were performed before and after the deck pour. Because of slight variations in temperature and moisture content in the concrete, testing could not be controlled closely enough in the field to get reliable data. Due to this issue, as a substitute for AC impedance testing, cores were taken through the epoxy-coated rebar five years after construction. These cylinders were examined and the deterioration was documented. Samples were also taken from these cores to determine the chloride content of the concrete.

Finally, the corrosion half-cell potential was measured by determining the voltage difference between regular milled steel immersed in a corrosive environment and an appropriate reference electrode located on the bridge. This was performed using a voltmeter with high input impedance. The reference electrode used in this half-cell potential measurement was a copper sulfate electrode. Figure 5 shows the results of the half-cell tests.

Original Half-Cell Tests - 2001

Range	No. Tests	Percentage
<-350 mv	1	1.3
>-350 mv, <-200 mv	6	7.8
>-200 mv	70	90.9
No Readings	3	
Total Tests	77	100.0%

Half-Cell Tests at 5 years in 2006

Range	No. Tests	Percentage
<-350 mv	9	5.2%
>-350 mv, <-200 mv	37	21.4%
>-200 mv	127	73.4%
No readings	16	
Total Tests	173	100.0%

Figure 5: Results of half-cell testing**3. Project Conclusions**

The construction of the bridge concrete deck utilizing stainless steel reinforcement and all monitoring devices was successful; however long-term performance is still being evaluated. Thus far, results are encouraging, although there have been some issues with the testing equipment. Due to the high cost of testing equipment, and unavailability of the manufacturer, the fiber optic chloride sensors installed in the deck have not been used. Additionally, electrical impedance testing has not been completed on the epoxy rebar. This is because field evaluations using this testing method have not produced accurate results. Alternatively, visual inspections of the surface of the concrete decks and more traditional forms of non-destructive testing have been utilized to evaluate the long-term performance of the bridge. While still effective, this has not yielded as much data as was originally expected.

To further build upon this technology, MoDOT constructed another bridge deck with stainless steel clad rebar in 2002. The estimated cost was 1.5 – 1.7 times the cost of black steel. This is a significant reduction in price compared to bridge A6059.

3.1 Positive Results

Listed are the specific comments provided by the State as positive results from the IBRD project:

- Construction of the bridge deck with stainless steel reinforcement proceeded quite well.
- From a 2006 deck survey, very little cracking damage on either the deck with stainless steel reinforcement or the conventional deck was found.
- From a 2006 deck survey, chloride data gained by drilling samples show only one location where the corrosion threshold was exceeded at the level of the stainless steel bars.
- The half-cell tests taken in the five year period shows a significant change. Five years after construction, the values of the test show a 26.6% more negative result at -200 milli-volts. This change signals that conditions have become more conducive to corrosion, but does not show that the stainless steel was actively corroding. Higher chloride levels in the concrete and some minor cracking allowing moisture in, especially on the skewed ends of the bridge, are the most likely reason that the environment has changed.

3.2 Lessons Learned

Listed are the specific comments provided by the State as lessons learned from the IBRD project:

- How to economically insulate stainless steel rebar from the abutment black steel rebar would be beneficial. Epoxy-coated rebar was used to tie to black steel.

3.3 Negative Results

Listed are the specific comments provided by the State as negative results from the IBRD project:

- High material costs for stainless steel reinforcement.

4. Costs

In the 2000 fiscal year, the state of Missouri was granted \$185,000 in funding for implementing stainless steel reinforcement technology through the FHWA Innovative Bridge Research and Construction program.

Material costs for the rebar on this job bid in December 1999 were \$0.64 per pound for conventional black steel, \$0.80 per pound for epoxy-coated steel, and \$2.55 per pound for the solid stainless steel. This price makes the cost of solid stainless about 3 times as expensive as Missouri's regular design with epoxy coated rebar and 4 times as expensive as black rebar. MoDOT expects to recoup some or all of the costs if the design can eliminate many of the corrosion problems and potholes caused by corrosion within the overall service life of the bridge deck.

5. References

The majority of the information presented in this report, including pictures, are highlights from the Project Summary Report provided by the State and the following resource(s):

Wenzlick, John, and Yin, Julie (2003). "Evaluation of Stainless Steel Reinforcement Construction Report." February, 2003.

Wenzlick, John (2007). "Follow up and Final Report – Evaluation of Stainless Steel Reinforcement in Bridge Decks." October, 2007.

**4.20. REINFORCING BARS, FRP: WISCONSIN - US HIGHWAY 151 OVER DE
NEVEU CREEK**

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

Reinforcing Bars
Case Study: Fiber Reinforced Polymer

Project
US Highway 151 over De Neveu Creek, Fond du Lac

Project State
WISCONSIN

Prepared For:
Federal Highway Administration



Prepared By:
HDR Engineering, Inc.
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Cincinnati, OH 45242

January, 2012

1. Project Description

The purpose of this project was to research the use of Fiber-Reinforced Polymer (FRP) as a viable method of reinforcing concrete bridge decking. The De Neveu Creek Bridge, the case study bridge utilizing FRP reinforcement, was constructed alongside a twin control bridge fabricated with conventional epoxy-coated rebar on US 151 corridor near the city of Fond Du Lac, WI. Laboratory tests and load testing were conducted as a way to validate the FRP deck design of this Wisconsin state-owned bridge structure. Each bridge deck of the twin bridge system was 8 inches thick with a skewed, two-lane, single span measuring 130 feet and a width of approximately 45 feet. 54-inch deep prestressed concrete bulb tees comprised the girders. Figure 1 shows the De Neveu Creek Bridge during load testing.



Figure 1: De Neveu Creek Bridge during load testing

The most common solution to the corrosion deterioration problem is the use of epoxy coated steel rebar. However, history has shown that these coatings can be compromised, which eventually leads to deterioration of the reinforcement underneath the coating.

A potential solution to deterioration of reinforced concrete structures is the use of FRP reinforcement. FRP composites have shown potential to alleviate the problems related to durability. Bridge decking is one promising application for which FRP composites would be advantageous because of the FRP's resistance to corrosion. The long-term durability offered by an FRP deck reinforcement system could potentially extend the service life of the bridge deck and reduce maintenance costs, thereby improving life cycle cost efficiency. FRP is of great interest to State and Federal transportation agencies due to its potential to mitigate corrosion of the reinforcement in reinforced concrete bridge decks exposed to highly corrosive environments (such as road deicing salts or marine environments) and prolong the lifespan of bridge structures.

The research process for the De Neveu Creek Bridge consisted of laboratory testing and subsequent analysis to investigate the structural adequacy, deck failure modes, serviceability, fatigue resistance, and overall behavior of the FRP-reinforced deck under simulated AASHTO design truck wheel loads. A series of five full-scale prototype deck slabs with varying support, span, and edge restraint configurations were tested under concentrated loading. As a secondary study, a series of three beams were tested in a two-span continuous configuration to determine one-way bending and negative moment capacity of the deck system. Based on results from ultimate capacity tests, empirical models for predicting the shear capacity of the FRP grating-reinforced deck system were recommended for design.

In the construction process, specifications were developed against which the quality control results submitted by the manufacturer were compared. The FRP reinforcement was prefabricated into grids and then delivered to the site. This method was used in order to minimize labor costs. After construction of the bridges, load testing was carried out to serve as a base line for a long-term monitoring program. In the summer of 2010, five years after the bridge was constructed, load testing was carried out as part of the long-term monitoring of this structure.

The research completed on the use of FRP concrete for the deck design at the De Neveu Bridge site was performed by Department of Civil and Environmental Engineering at the University of Wisconsin-Madison.

2. Project Implementation

Laboratory testing was initially completed on prototype deck panels. The purpose of this design phase was to validate the design for the FRP grid system and confirm the predicted behaviors of the FRP-reinforced deck system.

The University of Wisconsin worked with a precast concrete company to produce the test specimens. All but one of the test specimens were cast outdoors at the County Prestress plant. One was prepared and cast indoors at the University of Wisconsin Structures and Materials Testing Laboratory. Each specimen constructed for laboratory testing was a full scale representation of the proposed De Neveu Creek bridge deck design. All test specimens were 8" in thickness. Figure 2 shows the details of each specimen.

Specimen ID	Type	Width	Length	Reinforcement Type (Cage ID)	Span Configuration	Proposed Testing
1	Slab	6'-6"	7'-6"	Standard (S1-4)	Simply Supported	Service Load Performance Accelerated Fatigue Ultimate Capacity
2	Slab	6'-6"	7'-6"	Standard (S1-2)	Simply Supported	Service Load Performance Deformed Surface Ultimate Capacity
3	Slab	6'-6"	7'-6"	Fabric (S1-1)	Simply Supported	Service Load Performance Deformed Surface Ultimate Capacity
4	Beam	3'	14'	Standard (S3-2)	Two-Span	Flexural Performance (Initial Cracking) Negative Moment Capacity
5	Beam	3'	14'	Fabric (S3-1)	Two-Span	Flexural Performance (Initial Cracking) Negative Moment Capacity
6	Beam	3'	14'	Standard (S3-3)	Two-Span	Flexural Performance Accelerated Fatigue Negative Moment Capacity
7	Slab	6'-6"	14'	Standard (S2-1)	Simulated Multiple Span	Service Load Performance Ultimate Capacity
8	Slab	6'-6"	14'	Standard (S1-3)	Simulated Multiple Span	Service Load Performance Ultimate Capacity

Figure 2: Test specimen details

For each of the specimens, an FRP I-bar and cross section rod piece was used in the reinforcing grid layout. The spacing of the rods were maintained by the intersections of the grid component themselves. The modular "pick and place" nature of the FRP reinforcement cage system proposed for the De Neveu Creek Bridge construction limited the overall size of each cage. Dimensions were governed by that which could be delivered on a standard flatbed semi-truck trailer and easily hoisted by crane without damaging the grid materials in any way. A one-foot overlap splice was selected as a means of joining two adjacent FRP reinforcement cages. The reinforcing grid and lap splice is shown in Figure 3.

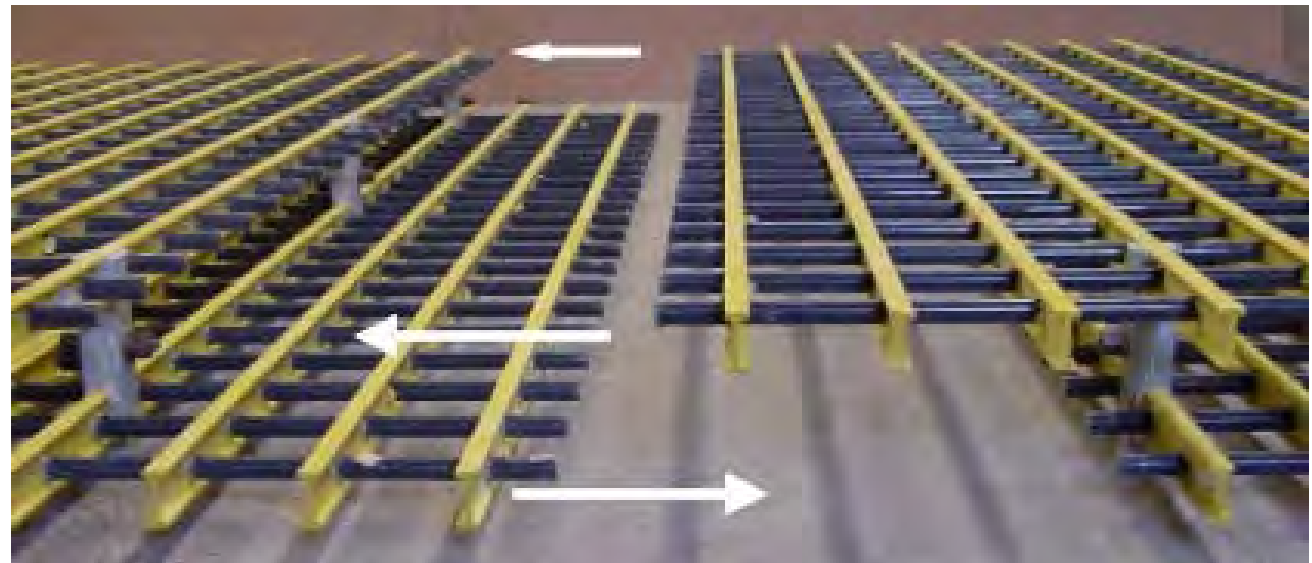


Figure 3: Reinforcing grid and lap splice

Load was applied to the center of each slab specimen using a 1.5" thick steel load plate, which was attached to a hydraulic load actuator head by bolts welded to the load plate. The load area of the plate was intended to represent the contact area of a dual-tire truck wheel.

The excavation of the site began in November 2003, and in April 2004 both the prototype bridge and its conventional twin were completed. The conventional south bound twin bridge, was similar in every aspect except that the deck reinforcing was standard epoxy coated steel and two extra girders were added to provide space for the recreational trail. This increased the width of the bridge deck to 56-feet. The parapet wall on the trail side of the bridge was doweled into the deck and a pedestrian railing was placed on the exterior of the trail foot path. Construction photographs of the bridge are on the following page.



Figure 4: Small formed span between flanges



Figure 5: Placement of the FRP reinforcement



Figure 6: Concrete pour

The load tests performed on the bridge provided a benchmark for the performance of the prototype bridge and its twin for comparison with long-term monitoring. The goal of these tests was to verify that the deck acts compositely with the girders and to determine the load distribution to individual girders. The University of Missouri Rolla (UM-Rolla) was contracted to conduct the load test utilizing a combination of deflection and strain measurements.

UM-Rolla utilized a total station system for measuring deflections during the load test. These prisms were magnetically attached to metal plates that had been bolted into place on the bottom of the bridge. These are shown in Figure 1. The total station was manually programmed to robotically cycle through all of the prisms during a given load test and record the results.

Deflection measurements from the total station provided information concerning the load distribution carried by each girder. The longitudinal composite action between the deck and girders were back calculated from the vertical deflections. The University of Wisconsin research team provided assistance by placing strain gauges on the bridges prior the load tests.

Strain gauges were placed to measure the positive moment at mid-span between the 6th and 7th girders and the negative moment over the 6th girder. Gauges were placed directly on the girders and the reinforcement prior to the concrete pour in six pairs, three on the top layer grid over the 6th girder and three on the bottom layer grid over mid-span of the deck. These pairs were spaced out in an attempt to measure the effective transverse strip of deck. This arrangement was intended to provide a strain profile comprised of three points that could be used to determine the location of the neutral axis.

On the day of the load test the WisDOT provided six trucks of varying size and weights. The trucks were filled with loose gravel and were weighed. The front axle, rear axle, and total load of the individual trucks present at each load test were recorded. The structural analysis carried out by the UM-Rolla indicated that four different patterns of static truck loads would define the performance of the bridge.

In total, four stops were made for each load test. The first stop placed the wheels of the six trucks directly over girders 2 and 6. The second stop placed the wheels of the trucks over the mid-span of the deck between girders. The third stop placed four trucks on the south side of the bridge with wheel loads over mid-span of the deck between girders 6 and 7. The fourth stop consisted of four trucks placed on the north side of the bridge with wheels placed over mid-span of girders 1 and 2. Similar load tests were carried out on the steel bridge.

After the load tests completed, a finite element model was built to simulate the approximate bridge behavior due to limiting loads.

Two in-situ load tests were conducted at the De Neveu Creek Bridge site after the original load testing as part of the long-term monitoring program. The first occurred in July 2007 and the second occurred in July 2009. Testing was performed in similar fashion as the original testing just after construction.

3. Project Conclusions

The use of a FRP reinforced concrete deck at the De Neveu Creek Bridge site was very successful. This type of reinforcing is feasible in the State of Wisconsin for rapid and durable bridge deck construction.

The project has also received an enormous amount of positive media attention. In 2005, this bridge won the ACEC of Wisconsin, “Grand Award for Best of State” and also was feature in Popular Science for “Best of What’s new 2005”. Additionally, in 2006, the research paper on this project won an award for “Best Applied Research Paper of 2006” by the ASCE Journal of Composites in Construction, and was also a semi-finalist for the 2006 NOVA award for development of a prefabricated modular FRP and forming system of highway bridge decks.

3.1 Positive Results

Listed are the specific comments provided by the State as positive results from the IBRD project:

- Construction speed for the deck can be nearly doubled using the prefabricated 2-layer FRP reinforcing grid with 93 man hours to place the reinforcing compared to 275 man hours for placing epoxy coated rebars on an identical adjacent structure. Each prefabricated FRP grid panels were installed in 10 to 12 minutes with all panels taking approximately 1.5 days.
- Laboratory testing proved that the FRP reinforced deck had a strength of 7.5 times the service wheel load.
- The prefabricated reinforcing grids could be manufactured and shipped to the bridge in lengths equal to the bridge width.
- Accelerated fatigue cycling performed upon a slab specimen did not reveal any apparent adverse fatigue effects on the ultimate strength or overall performance of the FRP-reinforced deck system after 2,000,000 load cycles.
- The FEM was able to represent the actual behavior of the bridge and can be used to determine the actual load rating of the bridges and therefore their safety over time. The results of the FEM analysis confirmed that the assumption of composite action between deck and girders was adequate when describing the response of the bridge during the load test.
- The non-destructive testing performed in 2007 and 2009 showed that De Neveu Creek bridge is in excellent condition with no significant difference in condition when compared to the adjacent traditionally reinforced bridge.

3.2 Lessons Learned

Listed are the specific comments provided by the State as lessons learned from the IBRD project:

- If the FRP grid manufacturing process could be further automated, the material costs would be considerably decreased.
- It would be very feasible to add a lightweight (1/8") FRP plate to the bottom of the grid – providing all the reinforcing and the deck forming in one prefabricated unit.
- Punching shear was the mode of failure identified in all of the slab specimens for which failure was achieved. In each case, the shear punch failure plane acted through the non-mechanically connected overlap splice between adjacent reinforcement cages. This confirmed the notion that the simple overlap splice would be the most structurally vulnerable aspect of the FRP reinforcement system, due to a lack of physical reinforcement continuity.
- Overall the installers for the FRP system were pleased with the ease of placement of the FRP cages. The reinforcement grid was easy to walk on and relatively simple to install. Minor problems were encountered during the placement of the cages. These were primarily due to the implementation of a unique system.

3.3 Negative Results

Listed are the specific comments provided by the State as negative results from the IBRD project:

- The bridge cost was higher than the adjacent bridge with a conventional steel reinforced concrete deck due to a contractor bid price higher than expected and due to the FRP grid manufacturer's use of hand fabricated spacers between the two layers of grid, which increased material costs.

4. Costs

In the 2002 fiscal year, the state of Wisconsin was granted \$499,085 in funding for implementing FRP technology into deck design through the FHWA Innovative Bridge Research and Construction program.

A material cost study done after the construction of the two bridges was completed to compare the FRP deck design to the traditional epoxy-coated reinforced deck design. Since the bridge geometry was similar, but not exactly identical, the cost comparison was carried out by normalizing the costs on a per-square-foot basis. The up-front cost of the FRP Bridge was 130 percent of the conventional steel-reinforced bridge, with the FRP Bridge costing \$76.66 per square foot and the steel-reinforced bridge costing \$57.20 per square foot.

Additionally, a comparison of the total labor hours and equipment hours spent on the construction was also completed. The total hours for the deck reinforced with epoxy-coated steel were 170 percent greater than the FRP deck. The equipment hours for the epoxy-coated steel deck were 120 percent greater than the FRP deck. The greatest contribution to this difference was the time spent placing the reinforcing. The total labor and equipment costs at time of construction were \$28,400 (or \$3.93 per square foot) for the epoxy-coated steel deck and \$14,300 (or \$2.46 per square foot) for the FRP deck.

5. References

The majority of the information presented in this report, including pictures, are highlights from the Project Summary Report provided by the State and the following resource(s):

Oliva, M., Bank, L., Russell, J., Conachen, M., Ehmke, F.G., (2005). *Reinforcing Concrete Bridge Deck with Prefabricated FRP Grids and Stay-in-place Formwork*. Presentation. April 2005.

Bank, L.C., Oliva, M.G., Russell, J.S., Jacobson, D.A., Conachen, M., Ringelstetter, T., and Spottiswoode, A. (2006). "Final Report – Bridge B-20-148 on US-151 with Fiber Reinforced Polymer Reinforced Concrete Deck." June 30, 2006.

Foley, C.M., Wan, B., Schneeman, C., Barnes, K., Komp, J., Liu, J., and Smith, A. (2010). "In-Situ Monitoring and Testing of IBRC Bridges in Wisconsin." June, 2010.

**4.21. BRIDGE MONITORING, DISPLACEMENT: NEW HAMPSHIRE - ROLLINS
ROAD OVER MAIN STREET AND B&M RAILROAD**

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

**Bridge Monitoring
Case Study: Displacement**

Project

Rollins Road over Main Street and B&M Railroad, Rollinsford

Project State

NEW HAMPSHIRE

**Prepared For:
Federal Highway Administration**



**Prepared By:
HDR Engineering, Inc.**
9987 Carver Road
Suite 200
Cincinnati, OH 45242

January, 2012

1. Project Description

The purpose of this project was to provide structural health monitoring (SHM) to an in-service bridge that utilized carbon fiber reinforced polymer (CFRP) reinforcement in the design of the bridge deck. The instrumentation was designed to validate and assess the performance of the CFRP. The bridge deck selected for SHM was the Rollins Road Bridge in Rollinsford, New Hampshire. The structure was built in the year 2000, and replaced the original four span bridge that was severely deteriorated. The new bridge is a simply supported single span of 110 feet. The cross section is comprised of a concrete deck and five prestressed New England Bulb Tee (NEBT) High Performance Concrete (HPC) girders. This bridge was the first in the United States to exclusively use CFRP for the reinforcement in the concrete bridge deck.



Figure 1: Completed Rolling Road Bridge in the year 2000

The decision to replace or repair, and how to repair each individual bridge structure is a common and difficult management issue for bridge owners. Currently, a top priority for bridge owners is corrosion in concrete bridge decks. New Hampshire uses salt and sand for ice management on roads and bridges. These salts impart chlorides onto the concrete deck. These chlorides permeate through the concrete and eventually cause corrosion in the reinforcing steel. Once the steel corrodes and expands, delamination in the deck begins. The delaminating concrete decks lose structural integrity and subsequently require replacement.

Using CFRP reinforcing in the concrete bridge deck can significantly reduce the risk of deterioration due to corrosion. The performance of the CFRP was evaluated using the Rollins Road Bridge in an to determine if it is a viable product to use on future New Hampshire Department of Transportation (NHDOT) and other state DOTs bridge construction and rehabilitation projects.

The Rollins Road Bridge project built upon previously completed research that expanded the field of SHM and model creation. Two successful load tests and an analysis investigating the behavior of carbon fiber polymer reinforcement in the cast-in-place concrete deck were previously performed on this bridge. The project discussed herein specifically addresses the durability of the CFRP. This project performed one load test in April 2008, and the collected data was compared to the data collected from the two previous projects during the December 2000 and August 2001 load tests.

The project discussed herein goes a step further, as an analytical model is developed and correlated with the field measured structural responses. A model was created and updated to the most current conditions of the bridge, using information from the April 2008 load testing. This research project also transferred information relating how the NHDOT can use tools they currently possess to enhance their current bridge management program by adding SHM, instrumentation, parameter estimation, and analytical model updating.

The data was collected by sensors that were already installed in the bridge. These instruments were installed during the construction of the bridge in 2000. All of the sensors in the deck are orientated in the lateral

direction, perpendicular to the flow of traffic. The sensors were orientated in this manner so as to understand the local flexural behavior of the deck in the transverse direction. The gauges orientated in the longitudinal direction, with the flow of traffic, were installed in the New England bulb tee prestressed concrete girders. This bulb tee was developed in conjunction with northeast state DOTs, to give concrete fabricators a standard AASTHO I-girder shape to be competitive with steel. Since the use of these girders was relatively limited at the time, monitoring of their performance was included in the bridge replacement project. These longitudinally orientated gauges were the most beneficial for the SHM program since they capture the global bending behavior of the bridge. The instrumentation plan was not designed for SHM, yet full advantage was taken of the gauges for research in SHM.

Fiber optic strain gauges were embedded in the prestressed girders and the CFRP reinforced deck before the deck concrete was placed. These strain gauges work by having two mirrors separated at a known length, and at the same time, light is allowed to pass through the fiber optic wires. As the deck is stressed during loading, the mirrors inside the fiber optic gauges will move, and the change in time it takes for the light to travel between each mirror will correlate with a specific strain. Figure 2 shows the fiber optic gauges used on the project.

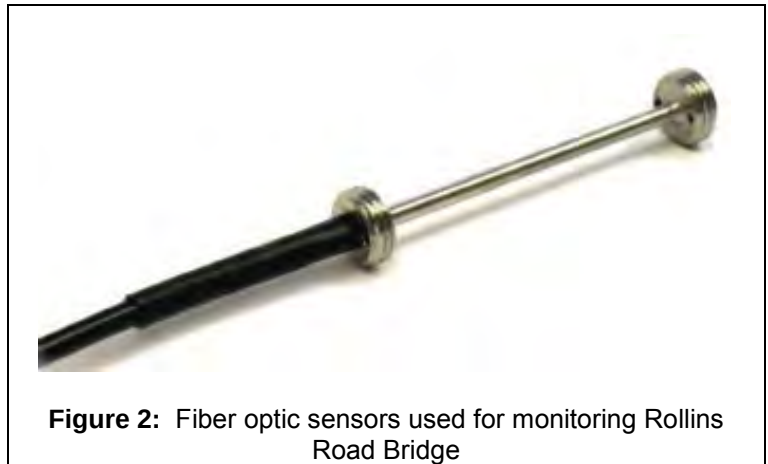


Figure 2: Fiber optic sensors used for monitoring Rollins Road Bridge

The research for Rollins Road Bridge was performed by the University of New Hampshire (UNH), Department of Civil Engineering.

2. Project Implementation

Two load tests were conducted at the Rollins Road Bridge as part of previous research endeavors. One load test was conducted 56 days after pouring the deck concrete in December 2000 to establish a comparative baseline for the analysis of the CFRP reinforcement and deck behavior. Another load test was performed in August 2001 to observe the performance of the CFRP reinforcement in the deck after eight months of service. Both tests were conducted by UNH with the cooperation of the NHDOT.

The load test performed for this particular project was done in April 2008. The trucks used to provide the live load had an axle spacing between the front and rear axle of 14-feet 9-inches. The rear dual axle had a width of 1-foot 8-½-inches. The rear axle, measured from the center of the dual wheels to the center of the opposing dual wheels, had a width of 6-feet 2-inches. The front wheel had a width of 8-inches and the length of the front axle measured from the center of wheel to the center of wheel in the transverse direction was 7-feet. Markings were painted on the deck surface to guide the trucks as they drove over the bridge. No traffic was allowed to pass while strain readings were collected.



Figure 3: Load testing of bridge with design truck

The load testing runs included four in the north-west direction and four in the south-east direction. Two separate stop location sets were marked out on the bridge. One set placed the wheel directly on the girder and the other set placed the center of gravity of the truck on the girder. Each stop location set was traveled four times, twice in each direction. In runs one through four, the trucks wheels were on girders 4 and 5. For runs five through eight, the trucks wheels straddled girder 4. The displacement readings taken during the testing runs were

implemented into a SHM program, and are used as reference dependent measurements.

Modeling was an important part of a value-added SHM program. The goal was to pass a model along to the NHDOT for use in developing their internal SHM program. In order to do this, the modeling program used in the SHM program needed to be one that the NHDOT already was familiar with. Since SAP2000® was currently owned by NHDOT, it was chosen for the research.

Using the load testing data and SAP2000®, an analytical model was created of the Rollins Road Bridge Research Project that accurately captures the behavior of the structure. After the first development of the

model, minor manual updating was needed to calibrate the model to the observed structural behavior. Once these modifications were made, trends in the behavior of the model can be observed for future use.

As the bridge ages, inspection information can be incorporated into the model as well as future load testing data. This data allows the bridge owner to know the real-time structural performance of the bridge, as the condition of the structure changes. Additionally, it will also help in determining serviceability and load capacity, investigating the reliability of the structure, and giving a record through models of the progression of the health of the bridge. This information may also be able to provide insight into how long the bridge will operate at current capacities.

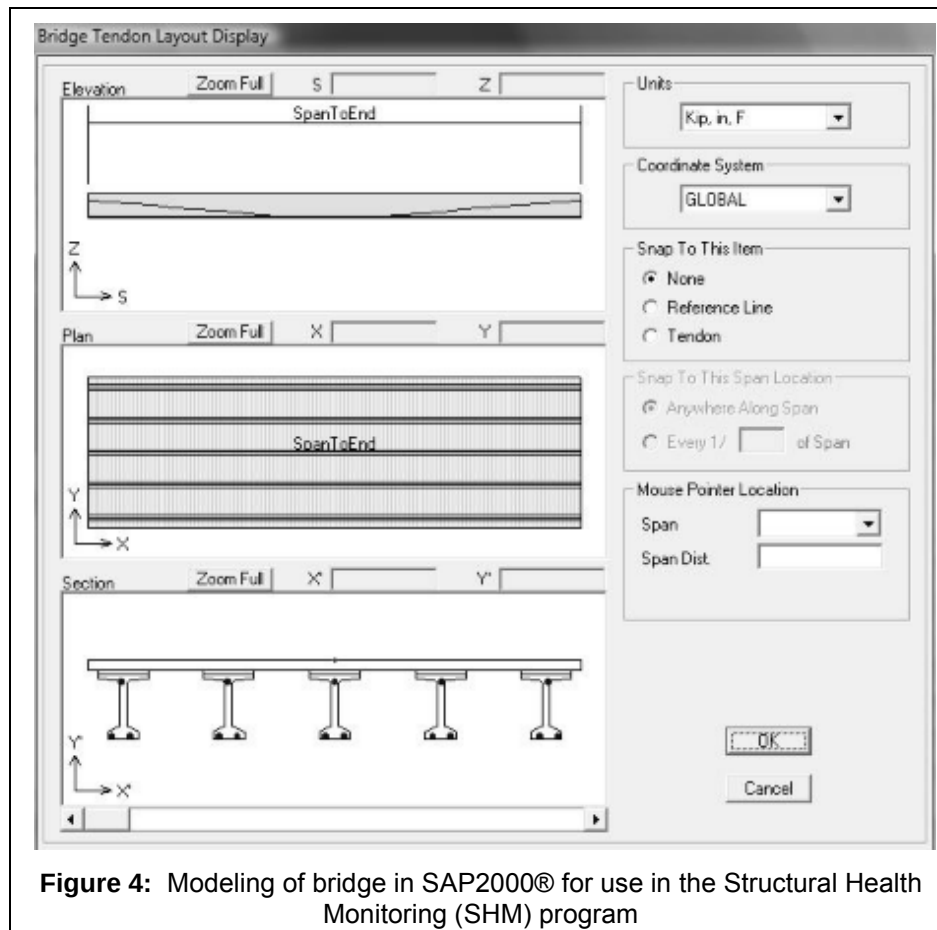


Figure 4: Modeling of bridge in SAP2000® for use in the Structural Health Monitoring (SHM) program

3. Project Conclusions

This research project successfully took the instrumentation plan and used it to find the global structural response for SHM. This same process can easily be repeated on other instrumented bridges in the state of New Hampshire and throughout the Northeast to examine structural behavior, and can eventually be included on a GIS layer linking the data acquisition and processing systems. The Rollins Road Bridge provides an invaluable field lab and research facility to collect structural response data. The bridge is performing well – the exposed concrete bridge deck is still rated 9 after 9 years of service. NHDOT is routinely using HPC in decks and prestressed girders.

The performance of the CFRP reinforcement, concrete bridge deck, and NEBT girders will continue to be monitored by collecting long-term SHM data and the occasional load test. These load tests will be performed with all the knowledge gained from this load test and will add a significant amount of new knowledge to the testing program for the Rollins Road Bridge and SHM programs for the bridges of the state of New Hampshire.

3.1 Positive Results

Listed are the specific comments provided by the State as positive results from the IBRD project:

- Bridge is performing well – the exposed concrete bridge deck is still rated 9 after 9 years of service. NHDOT is routinely using HPC in decks and prestressed girders.
- The measured strain data ranges shows the April 2008 strain readings are consistent with the ranges collected by the previous two load tests.
- The Rollins Road Bridge load test data shows that the structural performance of the CFRP reinforcement, concrete bridge deck, and concrete girders is in agreement with the excellent rating resulting from visual inspections.

3.2 Lessons Learned

Listed are the specific comments provided by the State as lessons learned from the IBRD project:

- Decks can be reinforced with carbon fiber reinforced plastic reinforcement and provide excellent service
- In many cases, traditionally reinforced concrete bridge decks show signs of cracking after 9 years of service, which is not the case for the Rollins Road Bridge deck. Furthermore, the New England bulb tee girders seem to provide a durable superstructure.
- Environmental effects, including temperature changes, had a much larger effect on load test data than originally expected. The change in temperature over the three hour load tests overshadowed the effect of the 19-ton truck. Environmental effects can be easily removed if zero-load data points are collected at several different times in the load test program.

3.3 Negative Results

No negative results were provided by the State from the IBRD project with respect to the monitoring program. However, the FRP deck does cost an estimated 10 times that of a conventional deck (see below).

4. Costs

In the 1999-2001 fiscal years, the state of New Hampshire was granted \$453,000 in funding for implementing the CFRP technology through the FHWA Innovative Bridge Research and Construction program.

Load test studies by UNH have shown good performance associated with the deck and the structure; the carbon fiber reinforced deck cost \$200,000 compared to the estimated cost of \$29,500 for a conventional deck.

5. References

The majority of the information presented in this report, including pictures, are highlights from the Project Summary Report provided by the State and the following resource(s):

Bell, E.S., Sipple, J., University of New Hampshire (2010). "In-Service Performance Monitoring of a CFRP Reinforced HPC Bridge Deck – Final Research Report". August 2010.

**4.22. BRIDGE MONITORING, FIBER OPTICS: VERMONT - BRIDGE 213
CARRYING VT RTE 100 OVER RYDER BROOK E**

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

**Bridge Monitoring
Case Study: Fiber Optics**

Project

Bridge 213 carrying VT Rte 100 over Ryder Brook, Morristown

Project State
VERMONT

Prepared For:
Federal Highway Administration



Prepared By:
HDR Engineering, Inc.
9987 Carver Road
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January, 2012

1. Project Description

The purpose of this project was to continuously evaluate an in-service bridge utilizing glass fiber reinforced polymer (GFRP) reinforcement in the design of the bridge deck. Three different load tests were performed over the course of a five year period from 2002 to 2007, with measurements taken by fiber optic sensors (FOS) used to monitor the performance of the bridge. The bridge selected for this project was Morristown Bridge in Morristown, Vermont. The structure was built in the year 2002 and includes five steel girders which span 144 feet. The top and bottom mats of deck reinforcement consist of GFRP reinforcing bars.



Figure 1: Completed Morristown Bridge in December 2005

Many bridges in the United States suffer from premature structural decay as a result of steel reinforcement corrosion. The physical evidence of this problem is certainly visible in the form of rust stained concrete, exposed and rusted reinforcement, cracked and spalled concrete, and pothole littered deck surfaces. All components of the bridge are vulnerable, including abutments, deck, wingwalls, piers, and pier caps. The structural concrete deck, however, is especially vulnerable due to its direct exposure to high concentrations of chlorides used for snow and ice control.

Attempts in recent years to address corrosion-related problems have included the development and assessment of alternatives to conventional steel reinforcement, such as epoxy-coated reinforcing steel, nonmetallic reinforcement, and other materials. One of these alternatives, Fiber-reinforced-polymer (FRP) composite reinforcement has been used successfully in many industrial applications.

Several advantages were gained by using GFRP reinforcing in the deck design for the Morristown Bridge site. Non-corrosive GFRP reinforcing bars have the potential to extend the service life, reduce maintenance costs, and improve the life-cycle cost efficiency of concrete bridge decks. This innovative material can also reduce construction costs by eliminating the need for a membrane and by reducing the top concrete cover. Typically bridge decks in the United States consist of two mats of steel bars and a top concrete cover of 2 to 3 inches is commonly used to protect the steel reinforcement. This adds weight and increases crack widths leading to the inevitable penetration of salts into the concrete deck slab. The amount of cover which can be used with GFRP reinforcing bars can be reduced to 1 to 1.5 inches.

To monitor the performance of this new technology, twelve fiber optic sensors were embedded into the deck during the construction of the bridge. The number and distribution of the sensors placed in the bridge deck were chosen to collect the very basic data about the behavior of bridge and the GFRP reinforcing bars in particular. During different stages of load testing, additional sensors were installed to the underside of the deck to gain more performance related data on the structure.

The research for Morristown Bridge was performed by the University of Sherbrooke, Department of Civil Engineering in Quebec, Canada.

2. Project Implementation

For the design of the deck, the GFRP reinforcement grid was developed according to AASHTO specifications and ACI design guidelines. This called for the transverse reinforcement to have a top mat of No. 6 bars and a bottom mat of No. 5 bars. However, to simplify construction No. 6 bars were used for both the top and bottom mat. In the longitudinal direction, No. 5 bars were used for both the top and bottom reinforcement.

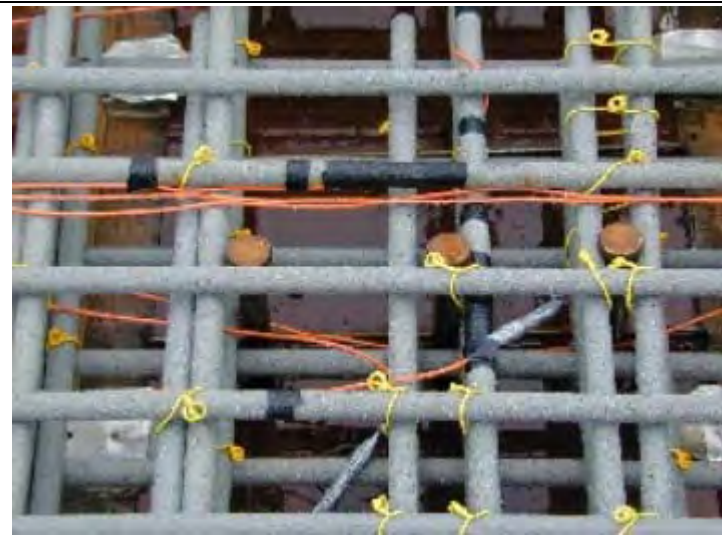


Figure 2: Fiber optic sensors installed at FRP bar locations

During construction, the workers reacted positively, indicating that more GFRP bars could be handled and placed in less time due to their light weight. Continuous plastic chairs were placed in the longitudinal direction at approximately three foot intervals under the bottom reinforcement mat to support the GFRP bars and maintain the required clear concrete cover. In the case of the top mat, single chairs at three foot intervals in both directions were used. No problems were encountered during placement of the GFRP bars.

The bridge was instrumented at critical locations to measure internal temperature and collect strain data using FOS. FOSs monitored the strains in the GFRP reinforcement and concrete deck slab, while thermocouples measured temperature effects. Installation of the FOSs was at the following locations:

1. Across the midspan of the bridge (13 total)
2. Maximum stress location of transverse top mat of transverse reinforcement (5 total)
3. Maximum stress location of transverse bottom mat of transverse reinforcement (4 total)
4. Top mat of longitudinal reinforcement over interior girder (1 total)
5. Top mat of longitudinal reinforcement over exterior girder (1 total)
6. Embedded into the concrete of the top and bottom reinforcement (2 total)

Field load testing of the bridge was completed on three different occasions, each spaced two years apart, to continuously monitor the performance of the bridge. This field testing was done in the years 2003, 2005, and 2007.



Figure 3: Load testing of bridge

Dynamic and static field tests with calibrated heavy trucks were conducted after construction in October 2003 to evaluate stress levels in the GFRP reinforcement, concrete deck, and steel girders. The static and dynamic responses of different bridge components were recorded with computer-aided logging systems since the bridge opened to traffic.

The Morristown Bridge was tested for service performance under static load using two, three-axle calibrated trucks. The trucks were equivalent to H-35 and H-32 load vehicles, shown in Figure 3. The bridge was also tested under the dynamic wheel loads of regular traffic. Seven stations stops at intervals of 24 feet were

marked along each path to give critical loading cases and influence lines at the instrumented section of the bridge at the midspan. The test was carried out using a single truck over the four paths and both trucks

simultaneously over two paths. A total of 35 readings were recorded for each gauge and deflection ruler. Readings were recorded at a 32-channel central data acquisition system for each truck station when the truck's second axle (first rear axle) was directly over the station. The data acquisition system is shown in Figure 4.

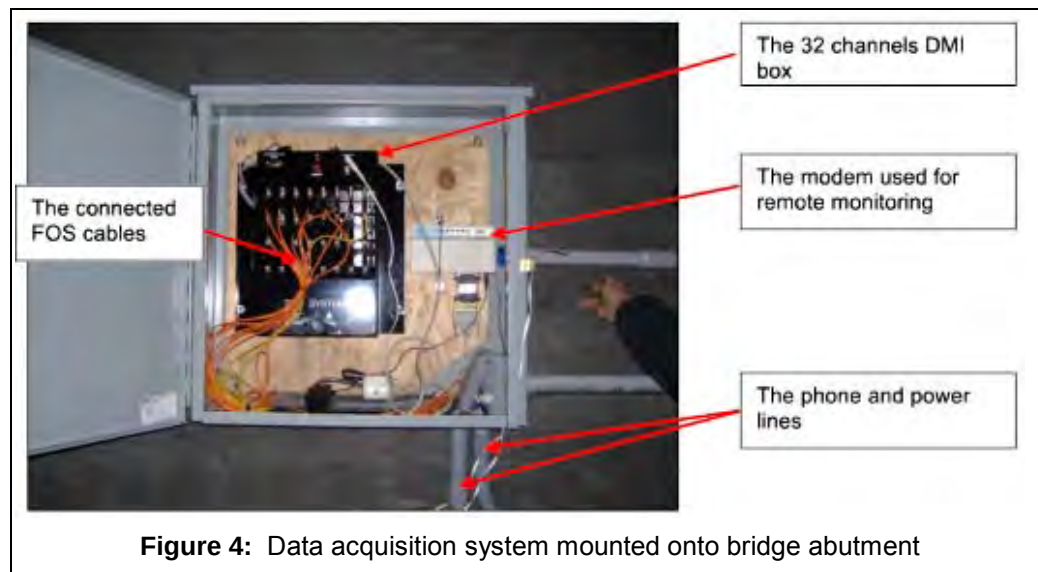


Figure 4: Data acquisition system mounted onto bridge abutment

In November of 2005, a second group of sensors were installed on the bridge. This was due to the positive results from the previous inspection in 2003, and the need for more data collection points from different locations over the bridge. The second group included 21 new surface mounted FOS. Installation of these sensors was at the following locations:



Figure 5: Cable spliced into new system for newly installed sensors

1. Bottom side of deck slab at quarter-span (4 total)
2. Bottom side of deck slab at three-quarter-span (4 total)
3. Exterior girder webs (4 total)
4. Bottom flange of each girder (5 total)

These newly installed FOSs were spliced into the current data collection system, as shown in Figure 5. In December 2005 and November 2007 the second group of instrumentation was successfully used during load testing. The procedure used for the 2005 and 2007 load testing was similar to 2003.

3. Project Conclusions

This project was very successful. As demonstrated by the monitoring system, the GFRP reinforced concrete deck has met performance expectations during all phases of testing. This evaluation included: Remote Monitoring of temperature and strain in the GFRP, HPC, and steel girders, three Live Load Tests and Progress Reports, and a Durability Study. The tests utilizing the fiber optic devices also provided Live Load Distributions from strain and deflection.

The bridge project has also been highlighted in an industry publication. The March/April 2006 issue of Journal of Bridge Engineering, published an article entitled, "Designing and Testing of Concrete Bridge Decks with Glass FRP Bars." This article detailed implementation and findings for the fiber optic sensors used in this project.

3.1 Positive Results

Listed are the specific comments provided by the State as positive results from the IBRD project:

- Fiber Optics Sensors are performing well and yielding significant data about the performance of the bridge.
- No significant degradation in the overall performance of the bridge in terms of measured deflections and strains in GFRP reinforcing bars were recorded.
- The deflection of bridge girders was well below the AASHTO allowable limits (Span/800). During all stages of testing, the maximum measured deflections for steel girders and concrete slabs were 11 and 1 mm, respectively.
- The GFRP reinforcement is performing very well as an innovative material. During the entire test, the maximum tensile strain in GFRP bars was 117 micro-strains. This value is less than 0.6 % of the ultimate strain of the GFRP bars and 3.8 % of the factored design strain. This small strain value was in accordance with strain values measured in several bridge deck slabs reinforced with steel and/or GFRP bars. This suggests that the flexural design method that neglects the compressive membrane forces (arching action) in restrained bridge deck slabs underestimates strength and overestimates design moments.

3.2 Lessons Learned

Listed are the specific comments provided by the State as lessons learned from the IBRD project:

- The study was more ambitious than the DOT had anticipated. An inadequate measurement of time and expense was realized during the project.
- Sensors could have been protected better during construction; several sensors were broken and were not able to be used after completion of the bridge. However, ten of the twelve FOSs installed during the construction of the bridge are still performing well. In addition, nine of the eleven external FOSs installed in November 2005 are properly performing.
- Remote sensing capabilities were installed at the bridge, but have not yet been used.

3.3 Negative Results

No negative results were provided by the State from the IBRD project.

4. Costs

In the 2001 fiscal year, the state of Vermont was granted \$260,000 in funding for implementing the fiber optic study through the FHWA Innovative Bridge Research and Construction program.

5. References

The majority of the information presented in this report, including pictures, are highlights from the Project Summary Report provided by the State and the following resource(s):

Benmokrane, B., El-Salakawy, E., El-Ragaby, A., and Lackey, T. (2006). *Designing and Testing of Concrete Bridge Decks Reinforced with Glass FRP Bars*. "Journal of Bridge Engineering". March/April 2006. 217-229.

El-Gamal, S., and Benmokrane, B., University of Sherbrooke, Department of Civil Engineering (2005). "Evaluation of the Performance of Glass Fiber Reinforced Polymer (GFRP) Reinforcement, an Innovative Material, in the Superstructure of Br 213 over the Ryder Brook on VT 100 in Morristown, VT". September 2005.

El-Gamal, S., El-Salakawy, E., and Benmokrane, B., University of Sherbrooke, Department of Civil Engineering (2005). "Evaluation of the Performance of Glass Fiber Reinforced Polymer (GFRP) Reinforcement, an Innovative Material, in the Superstructure of Br 213 over the Ryder Brook on VT 100 in Morristown, VT". December 2005.

El-Gamal, S., and Benmokrane, B., University of Sherbrooke, Department of Civil Engineering (2007). "Evaluation of the Performance of Glass Fiber Reinforced Polymer (GFRP) Reinforcement, an Innovative Material, in the Superstructure of Br 213 over the Ryder Brook on VT 100 in Morristown, VT". December 2007.

**4.23. BRIDGE MONITORING, SCOUR: MISSOURI - SB INTERSTATE 255 OVER
THE MISSOURI RIVER, AND BRIDGE L0534 OVER CHARITON RIVER, ADAIR
COUNTY**

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

Bridge Monitoring Case Study: Scour

Project
SB Interstate 255 over the Missouri River, and Bridge L0534 over
Chariton River, Adair County

Project State
MISSOURI

Prepared For:
Federal Highway Administration



Prepared By:
HDR Engineering, Inc.
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January, 2012

1. Project Description

The purpose of this project was to provide real-time River Channel-Bed Monitoring (RCBM) for two bridges over the Chariton River and one bridge over the Mississippi River in the State of Missouri. This was completed by equipping the bridge piers with an underwater sonar apparatus, also called an RCBM, to broadcast channel-bed movements and warn of possible scour conditions. Figure 1 shows the configuration of the pier with the monitoring device.

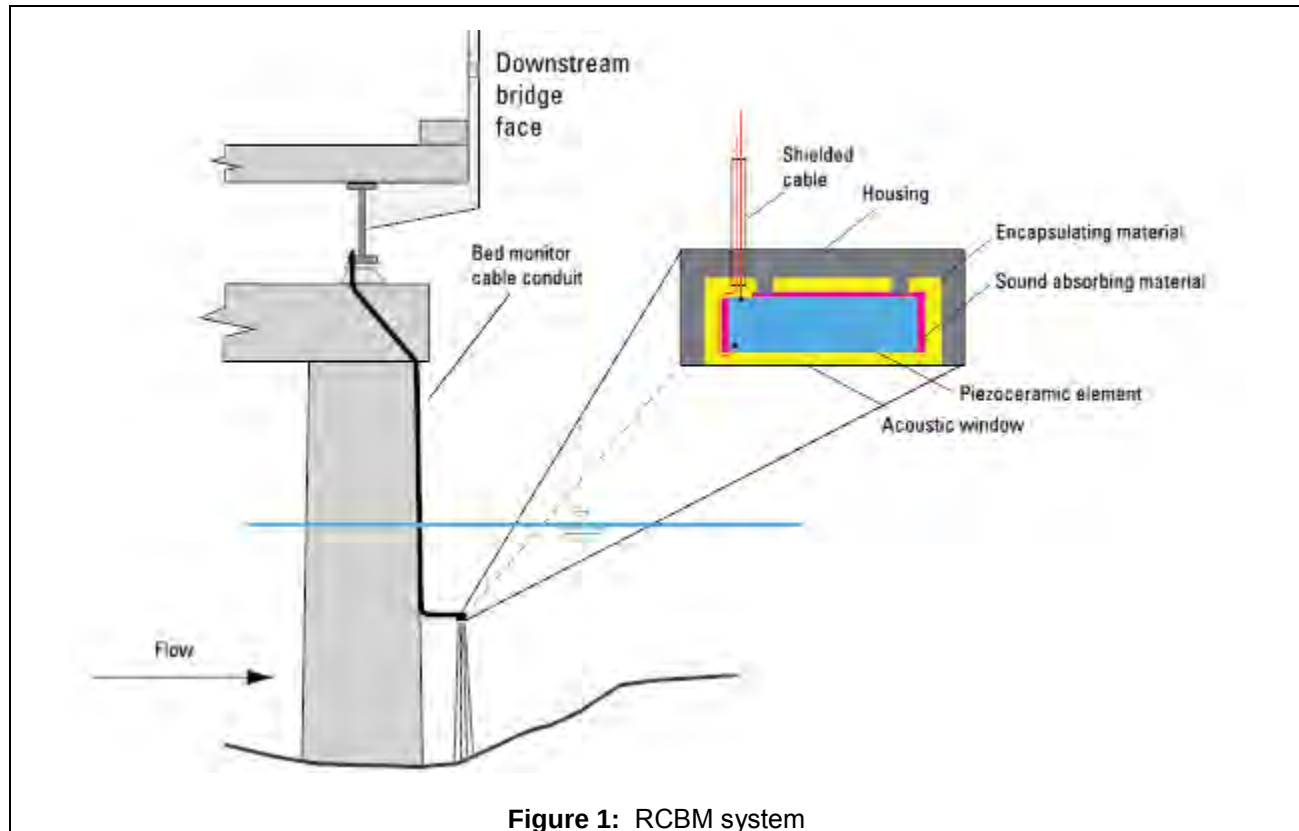


Figure 1: RCBM system

Scour is major concern for bridge substructure elements located in river and stream crossings. Water flowing around these elements has a tendency to increase in speed. Over long periods of time or during extreme flood events, this increase rate of flow can result in the lowering of the stream-bed. This lowering of the sediment around bridge piers or abutments is called scour. Scour can have a harmful effect on the overall structural integrity of the bridge by undermining footings and pile caps. . Ultimately, if scour issues are not addressed and worsen over time, the substructure could fail, which may lead to the eventual collapse of the bridge.

River channel-bed monitoring has historically been conducted before and after flood stage conditions. This requires the deployment of personnel to known scour-critical bridges. The limitation of personnel, resources, and time, make effective channel-bed monitoring during substantial flood events difficult.

A number of technologies have been developed to make scour monitoring more feasible. Many of these technologies are aimed at detecting scour holes adjacent or beneath bridge footings and are based on periodic inspections which do not provide real-time data about sudden events that may occur on a structure. Efforts to use these techniques during extreme events, such as floods, are hampered by high water velocities and increased flow depth. Technological advances in sonar, coupled with the use of data collection platforms (DCPs), satellite telemetry and integration with the internet, allow channel-bed monitoring in a real-time manner through the use of RCBMs.

The installation of RCBMs, integrated with an existing 15-minute recording DCP and hourly telemetry, provide a means by which to investigate the relation between scour and the channel-bed hydrographically in comparison with the river stage.

The RCBMs used in this application are composed of a single-beam transducer commonly used in the light- and leisure-marine markets. The transducer utilizes a technology composed of active electronics within the transducer body allowing functionality of both the transducer element and signal processor. The structure of the transducer is a piezoceramic element partially surrounded by sound-absorbing material such as cork or foam that aids in dampening unwanted vibrations. The piezoceramic element and sound-absorbing material are contained within encapsulating material composed of urethane and sealant that fills the housing. The housing is a sturdy composition of stainless steel that protects the brittle ceramic element within. A shielded cable enclosing conductors of electrical current is permanently attached to the transducer.

RCBM's were installed at the Chariton and Mississippi River bridge locations because of the high susceptibility for scour conditions.

The research for the real-time river channel-bed monitoring was performed by the United States Geological Survey (USGS) and the Missouri Department of Transportation (MoDOT).

2. Project Implementation

The three bridges that were instrumented with RCBMs were as followed:

1. Structure L-344 over Chariton River near Prairie Hill
2. Structure L-534 over Chariton River near Novinger
3. Structures A-1850 and A-4936 over Mississippi River at Mehlville

Each monitoring location was established to provide channel-bed data near the bridge piers. For both structures on the Chariton River, an RCBM device was installed to record the channel-bed elevation at both the upstream and downstream columns. For the Mississippi River structure, RCBM readings recorded channel-bed elevation directly below the footing of the pier.

At structure L-344, a USGS existing streamgage was already in operation. This streamgage utilizes a pressure sensor that collects water stage measurements, or surface elevations of the river. The RCBM was installed at pier 4 and was integrated with the existing streamgage.

A three inch section of pipe was used as a conduit to protect the transducer head and shielded the cable at the lower portion of the pier. Steel pipe was used to protect the transducer head and cable from debris and also provided stability to overall installation. After installation was finished, power, data and ground wires were connected to the DCP and the initial channel-bed elevation was taken. Once the initial elevation was measured, a Local Readout Ground Station (LRGS) decoded the data every 15 minutes.

For this structure only, the data collected during this portion of the project was not uploaded to the internet. Instead, it was internally held within USGS to be monitored as a pilot study. This study was monitored for a year before the other two structures were chosen for RCBM installation.

Once it was determined the RCBM was working as anticipated for the first site, the remaining two bridges could be instrumented with the RCBM device.

For structure L-524, the RCBM was installed at pier 7. Conduit was installed similar to the first structure in order to run the cables into the water. Before that could be done, a reducer was installed to the end of the



Figure 2: Installed conduit for RCBM at structure L-344, pier 4

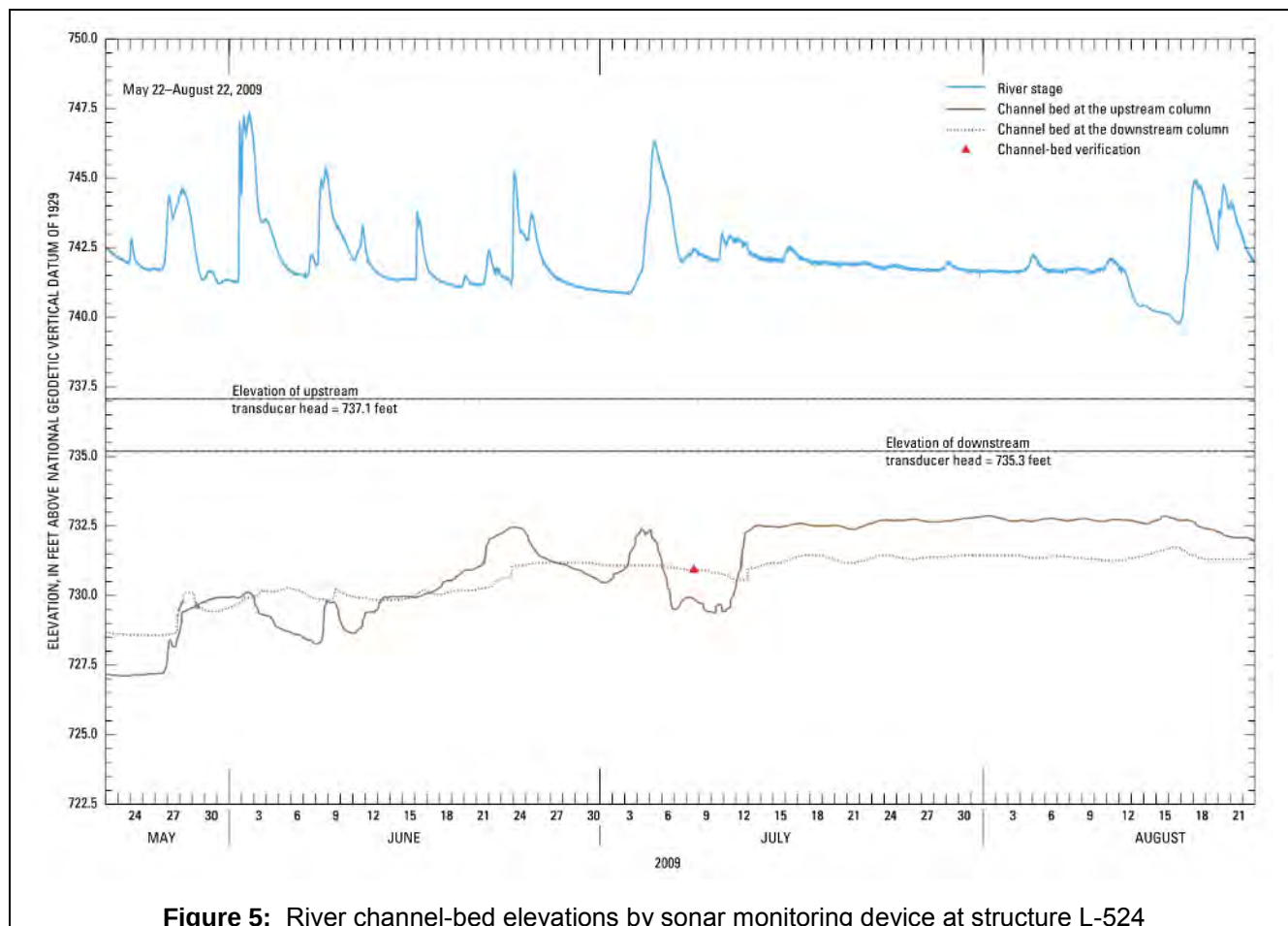
pipe so that the three pipe required to house the transducer could be installed. An existing streamgage was also present on this structure, so installation followed similar to that of structure L-344. Along with the streamgage, an existing shelter was also present. This was used to house all of the wiring to transmit and record the channel-bed data, as shown in Figures 3 and 4. Transmitted data from this location was processed and made available on the USGS website. Figure 5 shows an example of the data collected for the channel-bed at structure L-344.



Figure 3: Installed conduit and existing streamgage shelter at structure L-524 site



Figure 4: Transmission devices in streamgage shelter used to report channel-bed data



For structures A-1850 and A-4936, a scour assessment conducted by USGS in 2003 showed potential local pier scour at piers 7 through 12. Installation of RCBMs at piers 7 through 11 was not feasible because the pier columns were substantially recessed under the bridge deck. Due to this recess, RCBMs could not be installed since a large oblique angle would be required for the transducer head to be unobstructed. Pier 12 did not have a large recess and was an acceptable location for the RCBM placement.

Similar to the other two structures, steel conduit was used to house the wiring and transducer. Installation of the RCBM at this location required a crane and suspended basket to work for the water surface up to the cap along the upstream and downstream nose of pier 12, as shown in Figure 6. Also, in contrast the Chariton River sites, this location did not have an existing streamgage. This required the installation of a water stage sensor and DCP to provide a corresponding hydrographic record shown in Figure 7.



Figure 6: Basket used for RCBM installation



Figure 7: Wiring of river channel-bed monitors

3. Project Conclusions

To date, the real-time monitoring has been very successful. The data from the RCBMs have provided an accurate measurement of channel-bed variations. USGS collects data automatically and it is available on their website. Data is collected every 15 minutes.

3.1 Positive Results

Listed are the specific comments provided by the State as positive results from the IBRD project:

- Throughout data collection periods, Chariton River locations near Prairie Hill and Novinger reflected bed changes as much as 13 feet and 5 feet respectively. Nearly all of the bed changes correlated well with the hydrographic record at these locations.
- Based on manufacturing specifications and independent depth measurements, the monitored channel bottom was typically within 0.5 foot of the physical measurement and never varied more than 1 foot during substantial hydrologic events.

3.2 Lessons Learned

Listed are the specific comments provided by the State as lessons learned from the IBRD project:

- At one location, drift has damaged the upstream monitor. How to better protect from drift in future installations would be of benefit.

3.3 Negative Results

No negative results were provided by the State from the IBRD project.

4. Costs

In the 2006 fiscal year, the state of Missouri was granted \$130,000 in funding for implementing RCBM technology through the FHWA Innovative Bridge Research and Construction program.

5. References

The majority of the information presented in this report, including pictures, are highlights from the Project Summary Report provided by the State and the following resource(s):

Missouri University, and Missouri Department of Transportation (2009). "Remote Health Monitoring for Asset Management". March 2009.

United States Geological Survey, and Missouri Department of Transportation (2010). "Real-Time River Channel-Bed Monitoring at the Chariton and Mississippi Rivers in Missouri". January 2010.

**4.24. COATINGS AND CORROSION, CP ANODES: MINNESOTA - I-394 OVER
DUNWOODY BOULEVARD**

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

**Coatings and Corrosion
Case Study: CP Anodes**

Project
I-394 over Dunwoody Boulevard, Minneapolis

Project State
MINNESOTA

Prepared For:
Federal Highway Administration



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9987 Carver Road
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January, 2012

1. Project Description

The purpose of this project was to mitigate concrete reinforcing steel corrosion using two different methods. The first method was through the use of fiber reinforced plastic (FRP) wraps. The second method was electrochemical chloride extraction (ECE) by use of cathodic protection (CP) anodes. For this project the substructure at Bridge No. 27831 on I-394 over Dunwoody Boulevard in Minneapolis, Minnesota was selected. The primary focus of this report will be on the CP anode technology. Figure 1 shows a photograph of Bridge No. 27831, and figure 2 shows the locations where ECE was employed on the various substructure units.



Figure 1: Bridge No. 27831 on I-394 over Dunwoody Boulevard

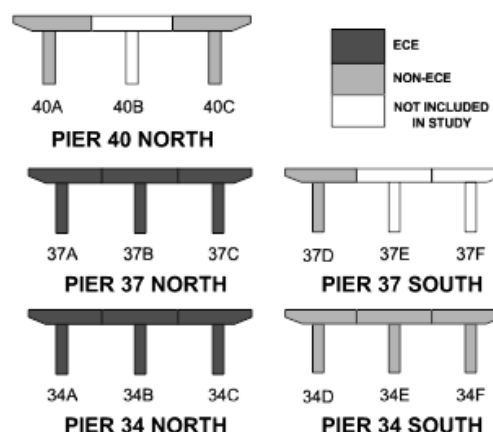


Figure 2: Location of electrochemical chloride extraction (ECE) at piers

Concrete provides the ideal environment for reinforcing steel because the high alkalinity causes the development of a thin, passive film on the surface of the steel, providing corrosion protection. However, in states where de-icing salts are used to clear roadways, reinforced concrete structures can often become contaminated with chloride ions. Chloride-contaminated concrete can lead to a breakdown in the passivity of the reinforcing steel and the initiate the corrosion processes. This is common in bridge decks and bridge substructures where the exposure to high levels of de-icing salts can be severe. Unchecked corrosion will often lead to cracking, spalling, and delamination of the concrete cover resulting in either excessive maintenance costs or a reduced service life of the structure. Extensive corrosion, causing a reduction in the

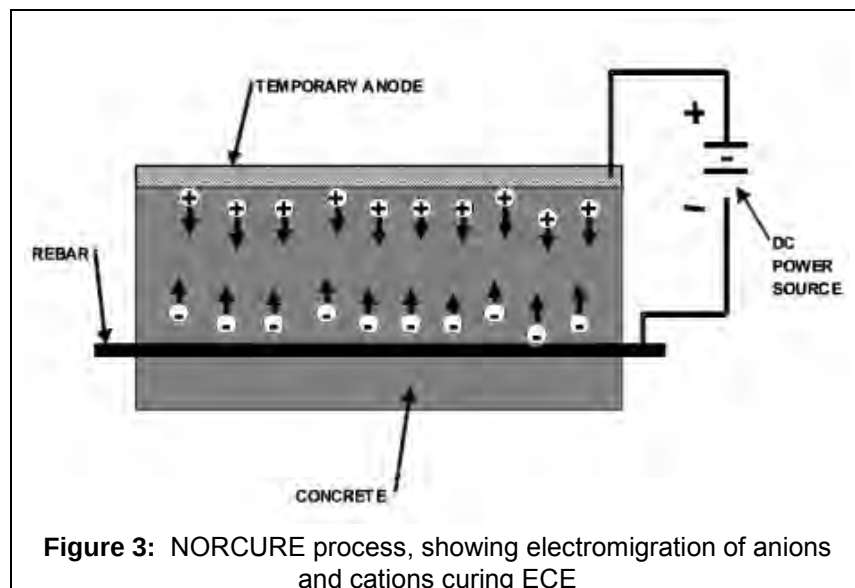


Figure 3: NORCURE process, showing electromigration of anions and cations curing ECE

cross-sectional area of steel reinforcement and concrete spalling, can possibly result in structural collapse. Traditional methods of corrosion repair consist of the removal of corrosion damaged concrete, or chipping and patching. This repair technique treats the symptoms, rather than the source of corrosion problems, resulting in a temporary solution.

A technique was developed in Norway in the 1980s called the NORCURE process which aids in the fight against corrosion. This process permanently removes chloride ions from reinforced concrete structures through a temporary process called

electrochemical chloride extraction or ECE. ECE can reduce the chloride concentrations of a contaminated structure, and re-passivate the reinforcing steel, through the application of an electric field between the reinforcing steel and a temporary external CP anode mesh embedded in a cellulose fiber electrolyte. The NORCURE process is shown in Figure 3.

During treatment, negatively charged chloride ions were driven away from the negatively charged rebar, and out of the concrete. The electrochemical reactions that take place at the reinforcing steel during treatment increase the alkalinity of the surrounding concrete through the creation of hydroxyl ions, which act to re-passivate the rebar. Corrosion will not re-initiate unless either sufficient chloride ions remain within the structure after ECE treatment and migrate back to the level of reinforcing steel, or new chloride ions re-contaminate the concrete.

The structure chosen for this investigation was constructed in 1970 and was widened in 1989. A bridge rehabilitation project, to replace many of the strip seals, immediately followed the deck widening in 1989. The bridge consisted of prestressed concrete girders and reinforced concrete pier caps and columns. The bridge had a history of corrosion related problems, especially in the substructure, initiated primarily by leaking expansion joints located in the bridge deck. These faulty joints allowed significant amounts of melted snow and ice, often containing chlorides, to flow through the bridge deck and onto the pier caps and columns below. This accelerated the corrosion process in these structures as shown in Figure 4. Although the expansion joints were since replaced, corrosion problems persisted due to previous chloride ingress in both the bridge columns and pier caps.

A total twelve columns and three full pier caps and a portion of two additional pier caps were included. Six of the structural elements were wrapped with three types of FRP, three of the structural elements were sealed with conventional sealers, and three of the structural elements were used as controls. Sealing of the piers with wraps and conventional sealers was used to prevent ingress of new chloride ions in ECE treated structures. Half of the wrapped structural elements and all of the sealed structural elements were subjected to ECE using CP anodes prior to being wrapped or sealed.

The research for the CP anode technology was performed by the University of Minnesota.

2. Project Implementation

To prepare the selected structures for ECE treatment, chipping and patching of spalled and delaminated concrete along with grouting of surface cracks was first completed, as shown in Figure 4. Delaminated concrete was located using a hammer to sound the concrete, and areas of concrete cover less than three-eighths of an inch were located with a pachometer and subsequently patched with a cement based repair mortar.

With the necessary concrete surface repairs in place, the NORCURE system, or ECE phase was initiated. The structural components selected to receive ECE treatment were Pier 34 North and Pier 37 North. The extraction treatment included the entire pier cap and the three columns. Multiple connections were made from the CP anode mesh to the reinforcing steel cages in each of the piers. After determining that there was sufficient continuity in each of the structures, wooden battens were applied to the concrete surface to support the steel mesh anode. With the anode mesh in place, all necessary electrical connections which provided the overall system power, were made. Figure 5 shows the ECE in place at Pier 37.

A system of drip hoses running along the tops of the pier caps was installed in order to maintain a steady flow of water down the faces of the pier caps and columns to ensure that the CP anode mesh stayed



damp for the entire process. This is needed for electromigration to occur. The pier caps and columns were also wrapped in thick plastic sheets to minimize the amount of water evaporation from the electrolyte.

Overall treatment was required to last either a minimum of 60 days, or until the levels of chloride found in samples taken in the vicinity of reinforcing steel had decreased by 50%.



Figure 5: ECE system in place at Pier 37

During the treatment period, daily voltage and amperage readings were collected to ensure that the system was operational, that it was not operating higher than 40V, and most importantly to monitor chloride extraction. Although exact measurements of chloride removal or extraction were not made, decreasing current through the columns and pier caps at a steady system voltage of 40V indicated an increase in concrete resistivity. A relatively steady decline rate followed for approximately six weeks. Current readings then began to plateau, indicating that the system was no longer removing chlorides.

This reduction in efficiency is related to the declining levels of chloride within the treated structures. As the level of

chlorides in the concrete fall, the driving force for removal also decreases. Therefore, a situation of diminishing returns develops where the energy used to draw out the remaining chloride ions in the concrete, outweighs the amount of chloride removed. Once the readings began to plateau, the extraction process was complete, and was no longer worthwhile to continue the extraction treatment.

Several concrete powder samples were collected from Pier 34 North and Pier 37 once the extraction treatment was finished. These samples were collected to determine whether or not the ECE treatment process should be continued, by evaluating the reduction in chloride content from pre-ECE levels. These samples showed the overall decrease in chloride content was approximately 50 percent, and varied between 40 to 90 percent. On average, approximately 57 percent of the chlorides were removed from the first inch of concrete, and 38 percent was removed from the deepest sample depth of approximately three inches.

Before concrete wrapping and sealing could be started, the columns and piers subjected to ECE were given two months to dry out. There was concern that if the columns were not given sufficient time to dry, excessive retained water in the concrete from the ECE process could be sealed into the columns which could potentially accelerate the corrosion rate.

Once the piers were determined to be sufficiently dry, surface preparations were made for concrete wrapping and sealing of the piers. This was done by sand blasting all of the surfaces whether they were subjected to ECE or not. After the wrapping and sealing process was completed, as shown in Figure 6, embeddable corrosion monitoring instruments were installed to determine if corrosion was occurring within the columns and pier caps included in the study. Instruments embedded within the structure itself were required. These instruments were placed in all the columns and piers that were included in this study. Embeddable silver/silver-chloride half-cells, humidity sleeves, and resistivity probes developed at the University of Minnesota were selected to instrument the structures in the study.



Figure 6: Installed wraps at pier cap

3. Project Conclusions

The system was successfully installed and activated for several months. The effectiveness of the ECE treatment in this investigation, as determined through chloride concentration sampling and half-cell potential mapping, correlated well with results published from other similar studies. Large reductions in chloride concentration were observed in this study with an average reduction of 50 percent. Several areas containing chloride contents in excess of the established threshold for corrosion were reported following ECE treatment.

The system was deactivated at the conclusion of the project but data has continued to be collected on a regular basis to monitor the corrosion rate. Multiple studies have identified similar increases in passivity of the treated structures. It appears from this data that the rate of corrosion has been reduced as a result of the system.

MnDOT would consider installing a similar ECE system on future projects based on the positive results associated with this project.

3.1 Positive Results

Listed are the specific comments provided by the State as positive results from the IBRD project:

- Large reductions in chloride concentration, an average reduction of 50 percent, were observed.

3.2 Lessons Learned

Listed are the specific comments provided by the State as lessons learned from the IBRD project:

- Use larger-scale embeddable corrosion monitoring probes that can more closely model the corrosion rates of the reinforcing steel, such as the “3LP” or “polarization resistance” techniques, in unwrapped structures, or a galvanic corrosion cell containing an embedded anode and cathode, for wrapped structures.
- Extensively monitor one or two treated structures that report high initial chloride concentrations and large areas of active corrosion potential. By collecting chloride samples and installing corrosion monitoring instruments at several locations, more specific conclusions on the effectiveness of the treatment on the entire structure could be drawn (i.e. 10-15 sample and instrument locations per column, or more, as opposed to three).
- Resistivity probe failures that occurred at some of these locations indicated corrosion within the treated structures could still occur, despite re-passivation of the reinforcing steel following ECE treatment. Continued monitoring of the installed instrumentation is required to evaluate the long-term effectiveness of ECE treatment and concrete wrapping/sealing as a corrosion mitigation technique.
- For future corrosion rehabilitation projects, the use of concrete sealers, as opposed to FRP wraps, to prevent the ingress of new chloride ions in ECE treated structures is recommended. Concrete sealers have been proven in previous studies to be more effective barriers against chloride intrusion than water or solvent based epoxies, especially on structures in which traffic wear is not a concern, and they do not obscure the concrete surface.

3.3 Negative Results

Listed are the specific comments provided by the State as negative results from the IBRD project:

- Although the ECE process reduced average chloride levels in the treated structures by approximately 50 percent, several locations still had chloride concentrations in excess of the established 50 percent corrosion threshold following ECE treatment.

4. Costs

In the 1999 fiscal year, the state of Minnesota was granted \$86,000 in funding for researching ECE and FRP technologies through the FHWA Innovative Bridge Research and Construction program.

5. References

The majority of the information presented in this report, including pictures, are highlights from the Project Summary Report provided by the State and the following resource(s):

Minnesota Department of Transportation (2000). "Evaluation of Electrochemical Chloride Extraction (ECE) and Fiber Reinforced Polymer (FRP) Wrap Technology". June 2000.

**4.25. COATINGS AND CORROSION, OVERCOATING: INDIANA - US-30 OVER
JAIN CREEK**

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

Coatings and Corrosion Case Study: Overcoating

Project
US-30 over Jain Creek

Project State
INDIANA

Prepared For:
Federal Highway Administration



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January, 2012

1. Project Description

The purpose of this project was to evaluate the AASHTO LRFD (2004) and ACI 318 design recommendations for the development and splice length of with respect to overcoating thickness of epoxy coated reinforcing bars. Additionally, the deck reinforcement in a demonstration bridge was built based on the findings from this evaluation. The structure selected for this project was US-30 over Jain Creek in the State of Indiana. Details regarding the construction of the bridge were not provided by the DOT; consequently, this report will focus primarily on the development and experimental results related to the epoxy overcoating.



Figure 1: Epoxy coated rebar used during testing

In reinforced concrete structures exposed to harsh corrosive environments, epoxy-coating has been used to protect the reinforcement against corrosion. It is important to avoid damage to the coating to prevent corrosion. Coating can be damaged at various instances during construction. A possible strategy to minimize damage to the coating is to increase its thickness. Thicker epoxy-coating has the ability to decrease imperfections during the construction process by providing a more flexible coating and better protection to the steel.

Performance of reinforced concrete structures are closely connected to the bond between the concrete and the steel reinforcement. The steel

reinforcement provides tensile strength to the concrete. As reinforcement has evolved through the years an improved understanding of this aspect of reinforced concrete behavior has been developed.

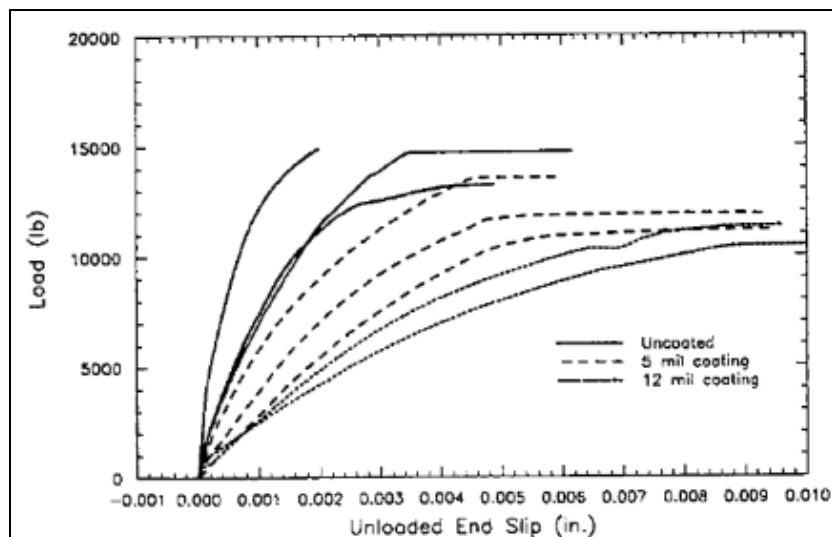


Figure 2: Load-slip curve for epoxy coated rebars

ACI Committee 408, Bond and Development of Reinforcement, issued its first report on the subject in 1966. The report emphasized the importance of eliminating cracks in governing bond strength. The pioneering concepts on the bond strength of reinforcing bars in concrete represented it in terms of the shear stress at the interface between the reinforcing bar and the concrete, effectively treating it as a material property. Research performed in the past has shown that bond strength is a structural property, dependent not only on the materials, but also on the geometry of the reinforcing bar and the structural member itself. Once this bond between the concrete and the

epoxy coated rebar is broken, the overall structural integrity of the member can be compromised. This is most evident by the appearance of cracks forming in the concrete.

In the United States, most design specifications are written for bars with epoxy-coating thickness in the range of 7 to 12 mils. A “mil” is a unit of measurement which represents one-thousandth (1/1000) of an inch. In these specifications, No. 5 bars with a bonded length of 3.5 inches and a clear cover of 1.25 inches were tested. The tests were carried out on three different types of coated bars: 1) uncoated, 2) epoxy-coated with 5 mils, 3) epoxy-coated with 12 mils. The slip was measured at the unloaded end, and splitting bond failure occurred in all tests. As the load was increased and bond failure was approached, the load-slip curves converged for both coating thicknesses. This is shown in Figure 2.

The difficulty with increasing the thickness of epoxy coating on reinforcing bars is that the effective rib height, which impacts bond strength, can be decreased to a point that the rib is not as effective, as shown in Figure 3. Furthermore, there is a bar size effect with the rib height being proportional to the bar diameter, and therefore the effect is more pronounced in smaller diameter bars where the same epoxy-coating thickness covers more of the valley. Very few test programs have evaluated the bond strength as it relates to the thickness of the epoxy. The programs that have been completed have primarily been based on empirical observations. To address this, parameters that affected the bond strength were held constant so that the main parameter of thickness of epoxy-coating could be studied.

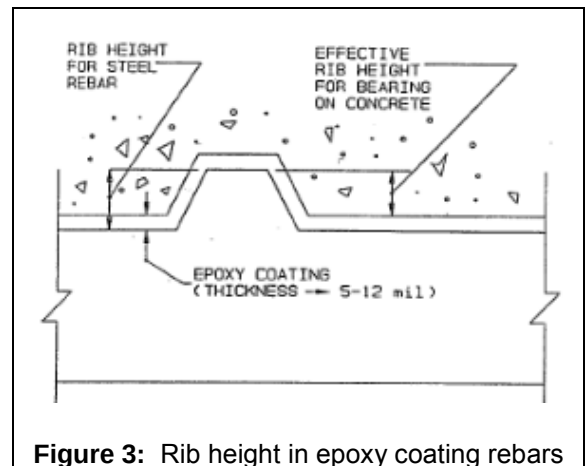


Figure 3: Rib height in epoxy coating rebars

The research for the epoxy coating technology was performed by Purdue University.

2. Project Implementation

Twenty splice specimens were tested. The specimens were grouped into four groups in accordance with the research objectives:

- Group 1:** Eight specimens to study the effect of epoxy-coating thickness on bundled bars for No. 5 and No. 9 bars
- Group 2:** Four specimens to evaluate the current specifications in ACI 318-05 for splice length for 18-21 mils of epoxy coating thickness for No. 5 and No. 9 bars
- Group 3:** Four specimens to study the effect of epoxy-coating thickness at 12 to 15 mils and 18 to 21 mils for No. 5 bars
- Group 4:** Four specimens to study the effect of epoxy-coating thickness at 12 to 15 mils and 18 to 21 mils for No. 9 bars

Epoxy-coating thickness measurements for each group were recorded at two different times. First, surveys of epoxy-coating thicknesses were recorded for all the bars supplied. Then when the bars were selected and cut to the appropriate length for the specimens, epoxy-coating thickness measurements were recorded for every portion of epoxy-coated bar in the splice-region.

The splice specimens tested in this research project were instrumented to record three different measurements during a test: the strain in the epoxy-coated reinforcement and the compression zone in the concrete, the vertical deflection along the length of the beam, and the load applied to the ends of the beam.

The construction of the splice specimens started with the epoxy-coated bars. After these bars were cut to appropriate lengths, instrumented with strain gages, and measurements taken of epoxy-coating thicknesses,

they were assembled into rebar cages. The cages consisted of the epoxy-coated longitudinal bars on the top row of which bar size and configuration varies depending on the specimen. Two No. 6 black (no epoxy) bars were used for the bottom row. The longitudinal bars were attached using wire ties to the No. 3 black steel stirrups, which were only present in the ends of the beam. These stirrups were used as transverse reinforcement to help provide shear resistance in this region so that the specimen would not fail in shear before the splice region failed due to flexure. Figure 4 shows the rebar cage layout.

A 14 foot long, 12 inch wide and 20 inch deep concrete beam was built using wooden formwork. Form oil was used as a release agent and was sprayed on the formwork before the steel chairs were placed. The reinforcement cage was then placed in the formwork on top of the chairs. This placement was done so that the top and side cover of the epoxy-coated reinforcement in the splice-region was 2 inches.

After casting, the concrete specimens were covered with wet burlap and plastic for wet curing. The burlap was kept wet during this curing time. All the forms were stripped off the specimens after wet curing was done, and then they were air-cured until their respective test date. No splice specimen was tested until after the concrete aged of 28 days.

Once fully cured, the concrete specimen was placed on two supports (pin connection at right and roller connection at left) and loaded at both ends with pin connections. Between the supports, a constant moment region was created at the midspan where the lap-splice is located.

Several variations of the loading point test setup were performed. A mixture of loading system configurations were used in an attempt to eliminate excessive bending in the anchored threaded rods at high loads. Each variation was an attempt at decreasing this effect. In general,



Figure 4: Reinforcement cage

hydraulic rams were used to apply load at the ends of the blue steel beam by reacting against anchored threaded rods. The steel beam transferred the applied force to the pin connection, which transferred the force to the concrete specimen. A hydraulic hand pump was used to control the load applied by the hydraulic rams by applying the same pressure to the rams. The loading setup is shown in Figure 5.

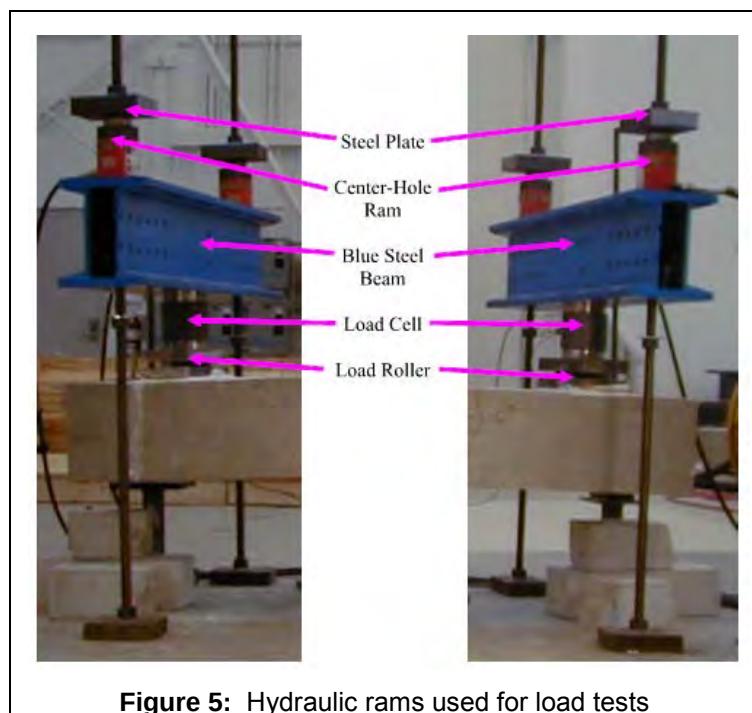


Figure 5: Hydraulic rams used for load tests

Before each test, all sensors were zeroed and an initial reading was recorded using a personal computer that controlled the data acquisition system. During each test, small increments of load were manually applied using the hydraulic hand pump. Sensor readings were recorded and new crack patterns were marked at each load increment after the applied load stabilized for at least 5 seconds. Load increments depended on the bar size used in the specimen because specimens with larger bars fail at higher loads. Specimens with No. 5 bars had

loading increments of 1000 pounds, and specimens with No. 9 bars had loading increments of 2000 pounds. When the beam approached failure, sensor readings were recorded more frequently to capture the failure response of the beam. Figure 6 shows an example of cracks marked on the beam after loading.

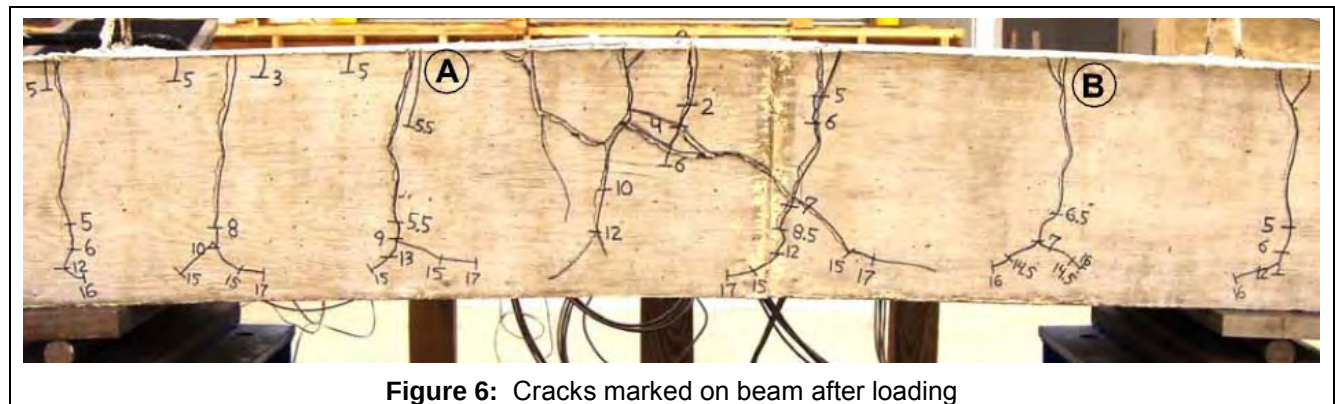


Figure 6: Cracks marked on beam after loading

A monitoring plan for the concrete bridge deck at the US30 over Jain Creek demonstration site was built in Indiana using coated bars with thickness of coating up to 18 mils. No details were reported by the DOT regarding construction; however, the proposed monitoring plan was developed.

The proposed monitoring plan included three stages. The first stage was prior to construction and included sampling of the reinforcement, specifically coating thickness, and number of defects upon arrival to the job site and after placement. In addition, the contractor, coater and epoxy powder manufacturer were selected. Concrete specifications and epoxy-coated reinforcing steel specifications were documented. Also, quality assurance test results and inspection records including coating patching requirements and material and site storage length and conditions were recorded.

During construction in the second stage, the number of defects after casting of the concrete was evaluated using the same technique as provided in the "Methods of Corrosion Protection and Durability of Concrete Bridge Decks Reinforced with Epoxy-Coated Bars."

Finally, the third stage involved the monitoring of the deck in-service performance. It was proposed to evaluate the long term performance with a combination of regularly scheduled visits to obtain chloride levels in the concrete at various depths, survey for delaminating concrete, and obtain cores to inspect the concrete and the reinforcement.

3. Project Conclusions

The increase in thickness of the epoxy coating was generally successful. In the case of No. 9 bar specimens with 12 to 15 mils coating thickness, bundling of bars resulted in an increase of the average crack spacing compared to that observed in single splice specimens.

In the other three cases considered the bundling of bars resulted in a decrease in the average crack spacing when compared to similar single splice specimens (No. 5 bar specimens with 12 to 15 mils coating thickness, No. 5 bar specimens with 18 to 21 mils coating thickness, and No. 9 bar specimens with 18 to 21 mils coating thickness). The largest reduction in average crack spacing was observed in the No. 5 bar specimens with coating thickness in the range of 18 to 21 mils.

As a result of this project, the Indiana Department of Transportation has increased the minimum epoxy coating thickness for reinforcement bars. The change in minimum epoxy thickness influences the range of allowable thickness for quality control.

3.1 Positive Results

Listed are the specific comments provided by the State as positive results from the IBRD project:

- For each bar size specimen designed for half of the yield stress, the stress at failure obtained using beam theory analysis at the failure load were similar when comparing the bundled bar with the single splice specimens.
- The specimens containing bars with coatings thickness in the range of 18 to 21 mils did not show significantly different deflections at failure when compared to the deflections of the companion specimens with bars having a coating thickness range of 12 to 15 mils.
- For the No. 9 single bar splices the increase in coating thickness resulted in a reduction in the average crack width. The reduction was less significant than that observed in the No. 9 bundled bar specimens.
- For the No. 5 single splice specimens designed for half of the yield stress, a thicker coating thickness resulted in an increase of average crack spacing and average crack width.

3.2 Lessons Learned

Listed are the specific comments provided by the State as lessons learned from the IBRD project:

- Increasing the coating thickness up to 21 mils resulted in ratios of test to calculated values at failure greater than 1.0 when the calculated values were determined using the AASHTO LRFD (2004) Specifications and the ACI 318-05 Code. ACI 318-05 calculated values resulted in an average test/calculated ratio greater than the average for test/calculated ratios using the AASHTO LRFD (2004) Specifications. The No. 9 single splice bars however, were slightly lower for ACI than for AASHTO.
- The use of the current provisions for development and splice length of epoxy-coated bars in tension in both the AASHTO LRFD (2004) and ACI 318-08 is supported by the test findings of the experimental program up to a coating thickness not to exceed 21 mils. However, since the ACI 318-08 specifications consider the critical parameters of cover and transverse reinforcement, the authors encouraged the Indiana Department of Transportation to use these provisions in the design of development and splice length of bars with coating thickness up to 18 mils.

3.3 Negative Results

No negative results were provided by the State from the IBRD project:

4. Costs

In the 2003 fiscal year, the state of Indiana was granted \$200,000 in funding for researching reinforcement with extra thick epoxy coating through the FHWA Innovative Bridge Research and Construction program.

5. References

The majority of the information presented in this report, including pictures, are highlights from the Project Summary Report provided by the State and the following resource(s):

Ramirez, J.A., Henkhaus, R.E., Purdue University (2008). "Deck Replacement – Use of Extra Coating Thickness Epoxy-Coated Bars". July 2008.

**4.26. FOUNDATIONS, MICROPILES: NORTH CAROLINA - BRIDGE NO 117 ON SR
1118 OVER NEW RIVER**

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

Foundations
Case Study: Micropiles

Project

Bridge No. 117 on SR 1118 over New River, Ashe County

Project State

NORTH CAROLINA

Prepared For:

Federal Highway Administration



Prepared By:

HDR Engineering, Inc.

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January, 2012

1. Project Description

The purpose of this project was to perform lateral load testing on micropiles to demonstrate the impact of casing joints and rock socket embedment. The site selected for this project was at Bridge No. 117 on SR 1118 over New River in Ashe County, North Carolina.



Figure 1: Load test showing load frame, reference beams, and actuators

Micropiles are relatively new deep foundation technology in the United States. Typically they have been used in retrofit and remediation; however, micropiles are an option for new foundations in cases where bedrock is close to the surface. Following recent developments in the United States, micropiles have evolved into high-capacity load bearing elements with some micropiles designed for ultimate load carrying capacities exceeding 1200 kips. Generally for bridge foundations, micropiles must also resist some amount of lateral load.

Micropiles are steel casings that are often drilled and grouted into place forming end bearing foundations. Similar to conventional drilled shafts, an auger is used to remove a column of soil. Once the shaft is drilled, it is reinforced with an external casing and a typically a single large diameter rebar, then filled with grout. Installation of the shaft sections are usually assembled with a threaded joint. Since micropiles have a smaller diameter, typically 12 inches or less, the size and amount of equipment needed for their installation and assembly is less than for conventional drilled shafts.

Micropiles are used in two different applications: structural and in-situ reinforcement. The advantage of micropiles is that they can be installed in conditions which are typically difficult for conventional drilled shafts. These include variable or unpredictable geologic conditions such as cobbles or boulders, fills with buried utilities and miscellaneous debris, and irregular lenses of competent and weak materials. Additionally, soft clays, running sand and high groundwater typically difficult for conventional drilled shaft systems cause

minimal impact on micropile installation. Preferred areas of construction for micropiles over conventional drilled shafts include challenging urban areas that feature mixed fills, nearby buildings and difficult access.

Previous research regarding the bearing application of micropiles is limited. This project addresses some of the questions that remain about micropiles. Specifically this includes:

- Determine how the joints in the casings affect lateral load response
- Determine if the design depth for micropile casings extended into rock sockets are sufficient to carry the lateral load.

In order to evaluate these two issues, a series of lateral load tests were carried out on ten, 10.75 inch diameter, 0.5 inch thick micropiles installed in 6.5 feet sections with casing joints and variable rock socket depths. The piles were load tested by pulling piles together in pairs using a purpose built loading frame. Load, deflection, and strain were measured during each load test.

The research for the micropile technology was performed by Auburn University and the North Carolina Department of Transportation.

2. Project Implementation

The micropile installation process began with drilling through soil into the bedrock using a specialized drill rig. The micropile casing was advanced during drilling with a specialized drill head capable of passing inside the casing. When the required depth was reached, the micropile drill is removed, leaving the casing in the rock socket. Grout was pumped or pressure-fed into the casings and the casings are lifted to the mouth of the sockets to allow bonding to the socket. Finally, the micropile tops were cut to the required elevation and capped for foundation rebar. Micropiles were then load tested subsequently to prove the design.

The goals of the load testing program were to investigate the behavior of the threaded joints, the impact of casing embedment into the rock socket, and the response of a micropile subjected to lateral loading. In total 16 micropiles were installed for the research program. Of the 16, 10 were load tested in single pile configurations.



Figure 3: Assembly of the inclinometer and strain gages

The load tests were instrumented and loaded in a similar fashion throughout the system and followed ASTM D3966. Force, ground line deflection, deflection with depth, and bending strain were all monitored. Force at the pile heads was measured using a pair of load cells. Displacements of the pile heads were monitored using string potentiometers. Inclinometer casings with PVC centralizers were installed in all test piles to record angle measurements. Figure 3 shows the assembly of the inclinometer and strain gages at bridge site.

In order to assess the impact of the casing embedment into the rock, three pairs of micropiles were installed with 1.0 feet, 2.0 feet, and 5.0 feet of casing embedment. The remaining ten piles

were constructed with 10 feet of casing embedment. The approximate dimensions of all the piles were sections 6.5 foot long, 10.75 inch diameter, and 0.5 inch thick. The contractor extended the casing the full length of the micropile without the use of reinforcing bars. The piles were pulled together using a loading frame; this simulated each load test to act as a single pile load test with a reaction pile being tested simultaneously. As a result of using this method, the weakest pile will govern.

A simple load frame was constructed to simultaneously load two micropiles. Two key aspects of the design of this frame were economy and portability. The reaction system consisted of two steel channels that would be pulled together using high strength all thread bars. Two attachments were manufactured and installed on the piles to centralize the load at the top. These attachments had a small amount of articulation to allow pile top rotation during large deflections. Two identical 60 kip hydraulic jacks were used to pull the all thread bars. The load cells were mounted between the jack and the securing end nut.

3. Project Conclusions

The micropiles performed well under lateral load conditions. The load tests demonstrated the impact of threaded joints and the embedment length of the casing into rock on the behavior of micropiles that are used for bridge foundations.

3.1 Positive Results

Listed are the specific comments provided by the State as positive results from the IBRD project:

- The micropiles with rock embedment of 2.0 feet, 5.0 feet, and 10 feet carried lateral loads in excess of approximately 18 kips, well above typical lateral design lateral loads.
- Embedding vibrating wire rebar strain meters in the grout effectively captured the bending moment profile of the micropiles, as compared to the preliminary numerical models.
- Strain gage measurements from Test I showed that the bending moment was reduced at the rock socket

3.2 Lessons Learned

Listed are the specific comments provided by the State as lessons learned from the IBRD project:

- A casing embedment into rock of 1.0 foot appears to be insufficient to resist lateral loads on micropiles.

3.3 Negative Results

No negative results were provided by the State from the IBRD project:

4. Costs

In the 2006 fiscal year, the state of North Carolina was granted \$150,000 in funding for researching micropile technology through the FHWA Innovative Bridge Research and Construction program.

5. References

The majority of the information presented in this report, including pictures, are highlights from the Project Summary Report provided by the State and the following resource(s):

Anderson, B.J., Babalola, M.R., Fargher, J., Hardister, D. and Pilipchuck, J. (2010). "Lateral Load Testing Micropiles to Evaluate the Impact of Threaded Joints and Casing Embedment on Short Micropiles in Shallow Rock". November 15, 2010.

**4.27. FOUNDATIONS, FENDER SYSTEMS: FLORIDA - KEY ROYALE DRIVE
BRIDGE OVER BIMINI BAY**

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

Foundations
Case Study: Concrete Admixtures to Improve
Service Life of Fender Systems

Project
Key Royale Drive Bridge over Bimini Bay, Anna Maria

Project State
FLORIDA

Prepared For:
Federal Highway Administration



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January, 2012

1. Project Description

The purpose of this project was to assess the use of alternative mineral admixtures to improve the service life of bridges constructed in severe marine environments. The study evaluated the effects of highly reactive pozzolanic materials in conjunction with fly ash and the effects it has on the durability, plastic, and mechanical properties of Portland cement concrete. Additionally, mixtures using these highly reactive pozzolans were design for use in the precast, prestressed concrete piling and fender system used for the Key Royale bridge replacement project in Anna Maria, Florida. Figure 1 shows the concrete piles at the Key Royale bridge site before rehabilitation.



Figure 1: Condition of existing concrete piles at the Key Royale Bridge site before rehabilitation

The Florida Department of Transportation (FDOT) has set a goal to build bridges that will last at least 100 years. Currently, the acceptance criteria for concrete consists of measuring the plastic properties, water-to-cementitious ratio and compressive strength. None of these acceptance criteria can be used to predict the ultimate service life of the structure.

Current design standards (FDOT 2004 Structures Design Guidelines for Load and Resistance Factor Design) allow only corrosion inhibitors or silica fume for reducing permeability of the concrete. Silica fume is currently specified in Florida as acceptable for use only when the environmental classification is 'extremely aggressive', and cannot be used for drilled shafts. Under new specifications proposed by AASHTO, other materials could be allowed in place of silica fume for concrete placed under such conditions.

Mixtures containing highly-reactive pozzolans such as metakaolin and ultrafine fly ash provide an alternative to silica fume. A pozzolan is a material which, when combined with calcium hydroxide, exhibits cementitious properties. Pozzolans are commonly used as an additive to Portland cement concrete mixtures to increase the long-term strength and other material properties. Highly-reactive pozzolans are expected to lower permeability, increase durability, achieve high strengths, and improve workability when compared to traditional pozzolans currently available.

Before these new highly-reactive pozzolan materials can be used, investigation was required to determine which mixture design criteria should be implemented in order to provide the desired service life to FDOT structures.

Several alternative materials were tested to provide the FDOT with the means to assess the applicability for utilization in a severely aggressive environment. These materials include slag, metakaolin, and ultrafine fly ash. Research was conducted on the effects of implementing these highly reactive pozzolanic materials in conjunction with fly ash to the plastic, mechanical, and durability properties of portland cement concrete. Additionally, this project provided FDOT with a recommendation for the most effective mixtures containing various pozzolans for utilization in the piling of the Key Royale bridge replacement project.

Six different supplementary cementitious materials (SCM) were used to construct the bridge and fender piles for Key Royale project to allow monitoring under realistic exposure conditions at real time rather than accelerated corrosion testing in laboratory conditions. Corrosion sensors were embedded in the bridge piles for periodic future monitoring. Removable fender piles were also installed with the same mixtures and will be removed in 15-20 years to be examined for ingress of chlorides and corrosion damage. In addition, durability segments were constructed using the same concrete and prestressing strand as the fender piles. These segments were hung from the fender piles for consistent exposure conditions and instrumented with corrosion sensors and temperature sensors for long-term corrosion and temperature monitoring. These segments will also be cored for evaluating the chloride ion penetration and concrete hydration over time.

The research completed on the use of highly-reactive pozzolans at the Key Royale bridge site was performed by Edward K. Roske as a mater thesis at the University of Florida.

2. Project Implementation

In total, there were thirteen different trial mixes evaluated in this project. Two of the thirteen were control mixtures of which one contained only Portland cement and the other contained 18% fly ash. The remaining eleven mixtures contained 18% fly ash with varying proportions of slag, metakaolin, ultrafine fly ash, and silica fume. Evaluating the durability of the concrete made with highly reactive pozzolans involved durability tests and also investigating plastic and mechanical properties. When possible, standard test were used; however, in some cases it was necessary to deviate from standard procedures or specimen configurations.

With the goal of FDOT's 100 year design life in mind, durability tests were considered the most important part of the testing phase of this evaluation. The durability tests performed in this investigation involved the assessment of the physical characteristics and response of chemical attack for each mix design. The use of mineral admixtures will alter the concrete structure by creating a stronger, more homogeneous matrix, less permeable void space, and refined capillary pore structure, all of which will improve the overall durability of the concrete, and create the desired longer design life. The durability tests conducted for this project were all used to determine the effect the addition of the mineral admixtures had on the concrete mixtures. These included:

1. Linear shrinkage test to assess the volumetric expansion or contraction of concrete. Because of the reduction of capillary porosity, the use of mineral admixtures will reduce linear shrinkage with the decrease in porosity in the concrete.
2. Volume of voids in the concrete. If concrete is exposed to a corrosive environment, an excess amount of voids will become filled with harmful chemicals, and eventually deteriorate the concrete. Mineral admixtures will reduce the volume of voids.
3. Sulfate expansion test to determine the sulfate resistance in the concrete. This was done by fully immersing the concrete samples in a sulfate solution. As the sulfate ions combine with the gypsum

and calcium hydroxide in the concrete, an expansive reaction is created. Mineral admixtures can limit the effects of this reaction due its properties of reducing capillary porosity and reducing the amount of calcium hydroxide in the concrete.

4. Absorption of harmful chemicals. Mineral admixture will reduce absorption.
5. Corrosion of embedded steel reinforcement. Each concrete specimen was tested by using a mold which contained three No. 4 deformed steel reinforcing bars and a titanium reference electrode (Shown in Figure 2). After 24 hours of curing, each specimen was removed from the molds and allowed to cure in a controlled environment. After 56 days, the specimens were placed in a ponding solution, which was an environment designed to accelerate the corrosion process in a two week time frame. After this time, the reinforcement was evaluated.
6. Background chloride level test to measure the absolute levels of chloride intrusion.
7. Surface resistivity test was performed to measure the electrical resistivity across the face of the concrete to provide an indication of its permeability. A surface resistivity meter was used for this test. The mineral admixtures will increase the surface resistivity by lowering the permeability of the concrete.
8. Rapid migration test. This procedure was used to determine the chloride migration coefficient in concrete from non-steady-state migration experiments. A low migration coefficient effectively indicates that the porosity is low enough to limit the migration of chloride ion into a concrete. The implementation of mineral admixtures will create a denser, less permeable concrete.

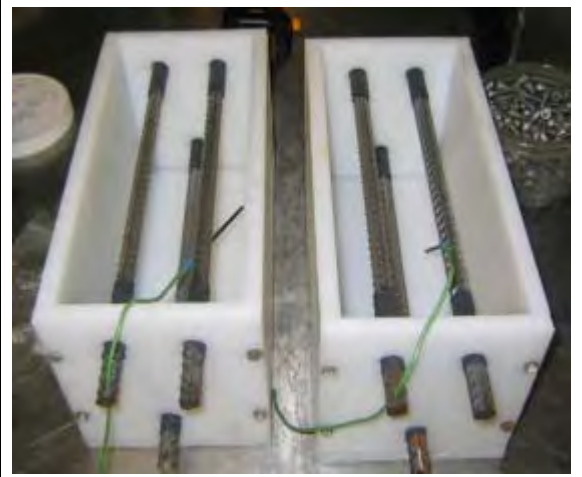


Figure 2: Molds used for corrosion test

Plastic properties tests were conducted to check the consistencies between mixtures and evaluate the affects of the mineral admixtures to the properties of the fresh concrete. The plastic property tests included the following:

1. Density test to provide a yield estimation of the amount of concrete used.
2. Slump test to establish the workability of the concrete.
3. Air content to measure the amount of air contained in the concrete, and to evaluate the effects of an air entrained admixture.
4. Bleeding of concrete to measure the percentage of water bleeding out of the fresh concrete mixture. Different pozzolan materials such as silica fume, ultrafine fly ash, and metakaolin have small particles that allow it to pack between cement grains which reduce porosity, leading to less bleeding.
5. Time of concrete setting to predict maximum mixing and transit times and to gauge the effectiveness of set-controlling admixtures. Additionally, excessively long or short set times can indicate problems with cement manufacturing, adverse chemical admixture reactions, or excess gypsum.
6. Temperature of the concrete was taken to ensure that the mixture was not getting too hot or cold. High temperatures can cause plastic shrinkage cracking, loss of workability, and decreased setting times. Conversely, cold weather conditions can cause a slowing at which the rate of the hydration is occurring. This has the potential to decrease the strength of the mix design.

Mechanical properties tests were conducted to determine the mechanical characteristics of the concrete. These characteristics are frequently used in structural design to estimate a variety of other concrete properties. Physical behavior can also be predicted based on the results of these mechanical tests, such as deflection and prestressing losses. The mechanical tests included the following:

1. Compressive strength test to evaluate the effectiveness of the admixtures. The addition of admixtures had a significant affect on the compressive strength of concrete. This test was performed on the concrete cylinders at the ages of 3, 7, 28, 91, and 365 days. The load frame used for testing is shown in Figure 3.



Figure 3: Load frame for testing compressive strength of concrete cylinders

2. Static modulus of elasticity was evaluated to test the effectiveness of the admixtures. Mineral admixtures will increase the modulus of elasticity of the concrete at late ages.
3. Poisson's ratio was monitored to ensure that there was no adverse affect when the admixtures were used. Very little research had been conducted to find the relationship of various mineral admixtures to the Poisson's ratio at the time of the project.
4. Splitting tensile strength was tested to monitor the effects the mineral admixtures had on the tensile strength of the concrete. The mineral admixtures will improve the tensile strength of a concrete as the pozzolanic reactions take place. This test was performed on the concrete cylinders at the ages of 3, 7, 28, 91, and 365 days.

After testing was completed, the six concrete mix designs most ideal for construction were selected. These six different SCMs were used to construct the bridge and fender piles for Key Royale project. Construction then followed. Embedded Data Collectors (EDCs) were installed in the bridge piles, as shown in Figure 5, and used for monitoring pile driving. Reduced strain and acceleration, pile driving stresses, and static pile capacities collected from EDC were compared to the data collected from the conventional monitoring system, Pile Driving Analyzer (PDA). CAPWAP analyses were performed on PDA data to separate the skin and tip resistances. The results of CAPWAP analyses were also compared to the EDC's results. A detailed summary of the construction was not reported; however, several photos during placement of the concrete were taken and are shown on the following page.



Figure 4: Placement of concrete in the pile molds



Figure 5: Installed data collectors used during pile driving



Figure 6: Piles being driven

3. Project Conclusions

The concrete mixes developed for the Key Royale Bridge project were very successful. A durable mix was achieved with excellent workability and no special treatment for handling and drying. Based on the results from the decision matrix, the most efficient proportions of mineral admixtures to be used in conjunction with 18% fly ash were (in percent of total cement content): 30% slag, 10% metakaolin, 12% ultrafine fly ash, and 9% silica fume.

3.1 Positive Results

Listed are the specific comments provided by the State as positive results from the IBRD project:

- The chloride ion penetrability was significantly improved.
- It was found that the plastic properties, volume of voids, and absorption were not significantly affected by the implementation of any of the mineral admixtures.
- At 28 days, each mixture exhibited nearly equal compressive strength in which the silica fume mixtures showed the highest. However, at 365 days each mixture containing mineral admixtures were nearly equal.
- Poisson's ratio appeared to be unaffected by the use of mineral admixtures
- The use of mineral admixtures improved the resistance to shrinkage. Each mixture exhibited lower linear shrinkage than the control.
- The surface resistivity was greater increased when compared to the control

3.2 Lessons Learned

Listed are the specific comments provided by the State as lessons learned from the IBRD project:

- The metakaolin mixture showed the best results for modulus of elasticity (MOE), as they were nearly equal to the control at all ages. The silica fume mixtures displayed the lowest MOE at 7 days, and the highest at 365 days.

3.3 Negative Results

Listed are the specific comments provided by the State as negative results from the IBRD project:

- Initial cost of concrete piles is higher than that of normal concrete. Also, the cost of EDC is higher than the conventional PDA cost.

4. Costs

In the 2004 fiscal year, the state of Florida was granted \$400,000 in funding for implementing this innovative technology through the FHWA Innovative Bridge Research and Construction program.

Material costs for the concrete mix were presented in the report. Water, coarse aggregate and fine aggregate quantities are relatively constant among the possible mixtures; consequently, the only relative costs of the cement and mineral admixtures were included. Market costs (\$/ton) were collected for cement, fly ash, slag, metakaolin, ultrafine fly ash, and silica fume in 2007 dollars. The relative costs are the ratio of the mineral admixture to that of the cement. These material costs are shown in Figure 7.

	Cost (\$/Ton)	Relative Cost
Cement	95	1.000
Fly Ash	42	0.442
Slag	90	0.947
Metakaolin	480	5.053
Ultrafine Fly Ash	1000	10.526
Silica Fume	600	6.316

Figure 7: Material cost for concrete mix (2007 dollars)

5. References

The majority of the information presented in this report, including pictures, are highlights from the Project Summary Report provided by the State and the following resource(s):

Roske, E.K., University of Florida (2007). "Implementation of Highly Reactive Pozzolans in the Key Royale Bridge Replacement." 2007.

Szyniszewske, S. and Hamilton III, H.R., University of Florida. *Prestressed Concrete Piles for the Key Royal Bridge*. Presentation.

**4.28. DECK COATINGS, OVERLAYS (DEICING): TEXAS - US 40 (OLD ROUTE 66)
WEST BOUND OVERPASS IN GRAY COUNTY**

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

**Deck Coatings
Case Study: Overlays (Deicing)**

Project
US 40 (Old Route 66) West Bound Overpass in Gray County

Project State
TEXAS

Prepared For:
Federal Highway Administration

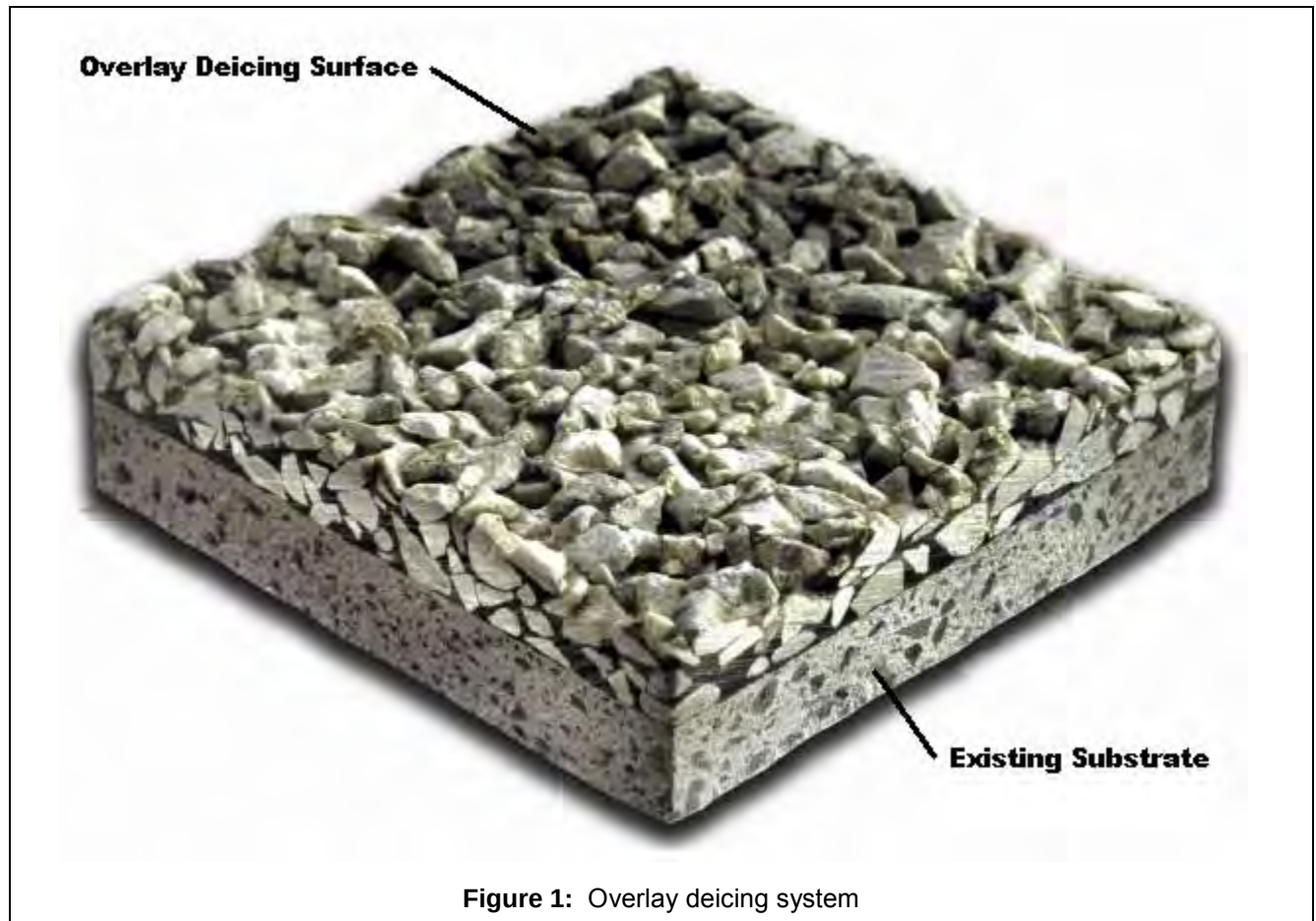


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January, 2012

1. Project Description

The purpose of this project was to install an overlay deicing system to improve skid resistance over the bridge deck surface during winter travel. This proprietary deicing system utilizes “charged” aggregates which store deicing materials that automatically leach out of its surface when the roadway comes into contact with ice or snow. The site selected for this project was westbound I-40 in Gary County, Texas. The total deck surface area covered was 11,628 square feet. The existing surface prior to the overlay treatment was a concrete deck with an asphalt overlay.



Safety is a top concern for winter maintenance operations. As a way to make roadways and bridges safer during winter travel, deicing materials such as salt or sand are traditionally spread over the roadway surface to increase skid resistance.

Intrusion of deicing materials and surface water into concrete bridge decks is a main contributor in deck reinforcing steel corrosion and concrete delamination. Salt, spread on bridge decks to melt ice, dissolves in water and permeates voids in the concrete deck. When the chloride content of the concrete is in contact with reinforcing steel and reaches a high enough concentration, the steel begins oxidizing, and the accompanying expansion results in delamination and cracking of the concrete deck.

In addition to chloride intrusion, traditional methods of deicing also have an assortment of other issues which have been known to cause problems. The process for traditional application can be delayed due to traffic conditions and typically more deicing material is used than what is needed. This can cause environmental concerns with excess runoff.

An alternative to traditional methods has been developed for deicing roadway surfaces. This method uses an epoxy-aggregate pavement surface that stores deicing chemicals for long periods of time during and releases them after snowstorms on an as-needed basis. The advantages of the system include accident reduction,

possibility of an overall life-cycle cost savings for the bridge site, less reliance on weather forecasting, prolonged bridge life, and reduced environmental impact.

Safer roadway travel is gained from this system due to the nature of the product. Typically, when winter snowstorms occur or ice forms on the roadway surface, a maintenance crew is sent out to apply deicing salts or sand to the needed areas. The time it takes for the maintenance crew to arrive to the site, leaves a window for motorists to travel on a hazardous roadway. Since the epoxy-aggregate deicing overlay is activated by weather conditions, the deicing capabilities are instantly achieved.

This system is fully capable of handling almost any winter weather condition which eliminates the need for traditional methods of applying deicing materials. This result is a deck surface that has a high skid resistance and virtually eliminates chloride intrusion to significantly increase the lifespan of the bridge deck. An added benefit with using an epoxy overlay is that it seals the existing substrate and prevents water seepage into the concrete. Since water infiltration into the concrete deck surface is the primary cause of corrosion in steel reinforcing, this barrier will create ideal conditions for maintaining a long service life.

This overlay deicing system has an expected life span of 15 years and can be applied to bridge decks, overpasses, exit and entrance ramps, steep inclines, toll barrier approaches, and dangerous intersection, curves or stretches of roads.

This bridge overlay for westbound I-40 project was installed in November 2005, and was the first attempt to use this type of deicing technology in the state of Texas. The performance of the overlay has been closely monitored by inspection since it was first installed.

The research for the overlay deicing technology was performed by the Texas Department of Transportation.

2. Project Implementation

Installation of the epoxy-aggregate deicing overlay at the bridge located on westbound I-40 bridge was implemented as shown in the series of photographs in figures 2 through 8:



Figure 2: Grinding off existing striping



Figure 3: Sand blasting of existing surface to remove any dust, contaminants or other loose material



Figure 4: Epoxy mixed on site and applied using squeegees to the existing pavement surface



Figure 5: Aggregate spread over epoxy surface using spreader box



Figure 6: Surface is allowed to cure and is weather dependant – with an 85 degree air temperature curing time took 3 hours, a 60 degree air temperature would have taken 6.5 hours



Figure 7: Sweeping of overlay after curing



Figure 8: Finished lane

3. Project Conclusions

This product has performed very well. After 5 years of service, there has been a significant decrease in both traffic accidents and the amount of deicing chemicals traditionally seen at this bridge site. Friction values have remained at highly effective levels and there has not been any significant wearing or delaminations on the surface.

The Texas Department of Transportation has been very satisfied with the results, and based on the performance of this bridge site, three other sites have utilized this technology; one in Amarillo and two in the Dallas-Fort Worth area.

3.1 Positive Results

Listed are the specific comments provided by the State as positive results from the IBRD project:

- There has been a decrease in chemical use and accidents during winter storms.
- The friction values have remained high and there has not been any significant wearing or delamination to the surface.

3.2 Lessons Learned

Listed are the specific comments provided by the State as lessons learned from the IBRD project:

- Since this first pilot project was performed, there have been advancements in the equipment used to apply the overlay system. This decreases the labor cost for installation and the cost per square yard. TxDOT is planning on using state maintenance forces to apply the overlay in the future to further reduce the costs.

3.3 Negative Results

Listed are the specific comments provided by the State as negative results from the IBRD project:

- The only negative regarding the use of this product was that the aggregate was proprietary and the cost was higher than other epoxy overlay systems the department uses. However, the deicing chemical absorption characteristic of the aggregate and its ability to reduce the amount of chemical used during winter storms, potentially out-weigh the increased cost.

4. Costs

In the 2005 fiscal year, the state of Texas was granted \$117,576 funding for use of the overlay deicing technology through the FHWA Innovative Bridge Research and Construction program.

5. References

The majority of the information presented in this report, including pictures, are highlights from the Project Summary Report provided by the State and the following resource(s):

Sims, T.B., Texas Department of Transportation (2006). *Bridge Deck Overlay System*. Texas Department of Transportation, Specail Projects Engineer, Maintenance Division Presentation. 2006.

Cargill (2011). *SafeLane® Surface Overlay for Increased Safety, Ice Prevention and Infrastructure Protection*. Retrieved from: <http://www.cargill.com/products/salt/winter/safelane/index.jsp>

**4.29. DECK COATINGS, OVERLAY (NON-DEICING): OKLAHOMA - I-40 EB OVER
I-44 (I-40 BRIDGE IN OKLAHOMA CITY)**

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

Deck Coatings
Case Study: Overlay (Non-deicing)

Project
I-40 EB over I-44 (I-40 Bridge, Oklahoma City)

Project State
OKLAHOMA

Prepared For:
Federal Highway Administration



Prepared By:
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January, 2012

1. Project Description

The purpose of this project was to apply and evaluate a polymer overlay to an existing concrete bridge deck to provide an impermeable, and skid resistant surface. Two adjacent two-lane bridges, entering into Oklahoma City, Oklahoma on Interstate 40 were chosen for this project. The bridge decks at this location were originally constructed in 1967 and have an approximate ADT of 106,000 vehicles per day. Since 1967, the bridge decks have had significant wear and have been patched in several locations. Figure 1 shows the project site at deck level after one lane has been treated with the polymer overlay.



Figure 1: Westbound bridge with one lane treated with polymer overlay

The Oklahoma Department of Transportation (ODOT) has approximately 7,300 bridges throughout the state. The concrete bridge decks on these structures, and specifically a number of older ones which do not use epoxy coated reinforcement, are susceptible to corrosion due to water penetration. When deicing salt laden moisture penetrates into the concrete deck and comes into contact with the steel reinforcing, corrosion is likely to occur. Since this corroded steel has a density of roughly two to four times that of its original volume, this can result in a loss of bond between the steel and the concrete, which ultimately leads to delamination and spalling of the deck surface. Once these bridge decks have deteriorated extensively, replacement may be necessary.

As an alternative to costly and time-consuming deck replacement, rehabilitation of these decks is an option. Typically this is done by repairing delaminated areas and overlaying the deck with a wearing surface.

The two most common types of overlays which are traditionally used include microsilica concrete and bituminous. Microsilica concrete overlays have been used with some success, but require seven days to cure and are sensitive to weather conditions. Bituminous overlays tend to delaminate and crack relatively easy and lose skid resistance in high traffic areas.

As a third option, polymer overlays can be used. These overlays have the ability to provide a durable and impermeable surface with high skid resistance properties for 15 years. In addition, the total thickness of the overlay is approximately 0.25 inches. This can be useful in reducing the dead load on bridges when compared to a traditional overlay.

In the past, polymer overlay systems have suffered from problems such as insufficient flexibility, sensitivity to moisture, poor freeze-thaw resistance, poor abrasion and skid resistance, and long curing periods. However, modern polymer overlays have benefited from the advancement in resins and the use of more durable

aggregates. This, in conjunction with improved construction practices has given them the potential to overcome many of these earlier problems.

The polymer overlay placed at the I-40 project site was a proprietary material which consisted of two layers of aggregates embedded in epoxy. The total thickness of the overlay measured between 0.25 inches and 0.375 inches. To improve the elasticity and compressive properties of the overlay, a construction method called the “broom-and-seed” method was employed.

The aggregate used for both layers had 80 to 100 percent passing a number 6 sieve and was placed at 13 to 14 pounds per square yard. The aggregate was also durable having a Mohs hardness of 6.5 to 7 with fragmented edges. The epoxy was a hybridized copolymer with a combination of epoxy and urethane consisting of 100 percent solids, two-part liquid polymer that was mixed at the project site. The epoxy was spread at rate of 30 square feet per gallon for the first coat and 15 square feet per gallon on the second coat.

The research completed for the use of polymer overlays on bridge deck systems was performed by the Planning & Research Division of the Oklahoma Department of Transportation.

2. Project Implementation

Due to the high traffic volumes at this site on Interstate 40, the project was specified to be constructed by ODOT between the hours of 7:00 p.m. and 6:00 a.m. with the lanes being open to traffic during the day. In order to do this a rapid set mix was used, so that both lanes on each bridge would be open to morning traffic

Surface preparations started on both the eastbound outside driving lane and the westbound outside driving lane. Surface preparations started on the remaining lanes on the following nights. Application of the overlay took 8 separate nights and the total project length was 12 days. Four layers were required for successful application of the overlay. This included the prime coat (epoxy layer), first aggregate layer, second aggregate layer, and finally, a tie coat sprayed over the finished overlay.

The application method used in this project is called the “broom-and-seed” method which is used to provide the highest degree of elasticity and compressive values. In this method, the resin components are mixed and spread with notched squeegees. The aggregate is applied immediately thereafter either by a mechanical spread or by hand. Excess aggregate is removed and the process is repeated until the desired overlay thickness is met.

The construction sequence for this project was as follows:

- Night 1: Shotblasting of both the eastbound inside driving lane and the westbound inside driving lane were completed to provide an improved bond between the existing concrete deck and the overlay. The shoulders could not be shotblasted and were alternatively sandblasted. This is shown in Figure 3.
- Night 2: Prime coat was placed on the westbound inside driving lane followed by the first layer of aggregate. Excess aggregate, after application, was removed with a vacuum truck. This is shown in Figure 4.
- Night 3: Prime coat was placed on the eastbound inside driving lane followed by the first layer of aggregate. Excess aggregate, after application, was removed with a vacuum truck.
- Night 4: Prime coat was placed on the westbound outside driving lane followed by the first layer of aggregate. Excess aggregate, after application, was removed with a vacuum truck.
- Night 5: Prime coat was placed on the eastbound outside driving lane followed by the first layer of aggregate. Additionally, the second layer of epoxy and aggregate was placed on half of the westbound inside lane. Excess aggregate, after each application, was removed with a vacuum truck.

Night 6: The second layer of epoxy and aggregate was placed on the westbound outside lane. Additionally, the second layer of epoxy and aggregate was placed on the eastbound inside lane. Excess aggregate, after each application, was removed with a vacuum truck.

Night 7: No work took place due to rain.

Night 8: The second layer of epoxy and aggregate was finished on the last half of the westbound inside lane. Excess aggregate, after application, was removed with a vacuum truck.

Night 9: Application of the tie coat on both westbound lanes was placed. This completed the overlay for the westbound bridge. Additionally, the second layer of epoxy and aggregate on the eastbound outside lane was completed. Excess aggregate, after the eastbound inside lane application, was removed with a vacuum truck. Finally, the expansion joints between adjacent lanes on both structures were prepared to be sealed.

Night 10: No work took place due to rain.

Night 11: Application of the tie coat on both eastbound lanes was placed. This completed the overlay for the eastbound bridge. Additionally, the expansion joint seals for both structures were installed.

Night 12: Paint striping on both structures was performed.

Photos of the application process:



Figure 2: Truck mounted epoxy dispenser with mechanical spreader



Figure 3: Shot blasting of existing concrete deck surface



Figure 4: Spreading of epoxy onto concrete deck surface

3. Project Conclusions

The long-term durability of the overlay still needs to be determined, however, short-term results indicate a successful implementation. The results from the technology implementation are presented below.

3.1 Positive Results

Listed are the specific comments provided by the State as positive results from the IBRD project:

- Preliminary data have shown tremendous increase in the overall skid resistance of the concrete surface. The original resistance of the existing concrete deck was 25.4, and was measured as 61.9 after the overlay application.
- Short construction duration while keeping the bridge open during times of high traffic volume.

3.2 Lessons Learned

Listed are the specific comments provided by the State as lessons learned from the IBRD project:

- Experienced contractor with this material and proper equipment are essential for better application.
- Due to a rough riding surface following the final surface treatment of the polymer overlay, future applications should consider smoothness specifications for the completed overlay.

3.3 Negative Results

Listed are the specific comments provided by the State as negative results from the IBRD project:

- Higher material and labor cost compared to traditional bridge deck overlays. However, this does not factor in the cost benefit of keeping the bridge open during high traffic periods. Also, as contractors become more experienced with the product, the labor cost is expected to decline.

4. Costs

In the 2004 fiscal year, the state of Oklahoma was granted \$366,103 in funding for implementing the polymer deck overlay technology through the FHWA Innovative Bridge Research and Construction program.

5. References

The majority of the information presented in this report, including pictures, are highlights from the Project Summary Report provided by the State and the following resource(s):

Williams, G., and Humphrey, D.Q., (2004). Oklahoma Department of Transportation. "Evaluation of 'Flexogrid®' Bridge Deck Overlay System – Construction Report". February, 2004.

**4.30. OTHER TECHNOLOGIES, CONCRETE FILLED TUBULAR FLANGE
GIRDERS: PENNSYLVANIA - SR 1003 OVER TIONESTA CREEK**

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

Other Technologies
Case Study: Concrete-Filled Tubular Flange
Girders

Project
SR 1003 over Tionesta Creek, Forest County

Project State
PENNSYLVANIA

Prepared For:
Federal Highway Administration



Prepared By:
HDR Engineering, Inc.
9987 Carver Road
Suite 200
Cincinnati, OH 45242

January, 2012

1. Project Description

The purpose of this project was to develop design criteria and perform preliminary design for a demonstration bridge which utilizes concrete-filled tubular flange girders (CFTFG) for its superstructure elements. The site selected for this project was CR 1003 over Tionesta Creek. The two-span continuous bridge utilizes CFTFGs girders comprised of a conventional web plate and bottom flange plate, and a top flange fabricated from a rectangular tube that is then filled with concrete.



Figure 1: Concrete-filled tubular flange girder section

CFTFGs have several advantages. The concrete-filled tubular flange provides more strength, stiffness, and lateral torsional stability than a flat plate flange with the same amount of steel. The second advantage is that the vertical dimension of the tube reduces the web depth, thereby reducing the web slenderness. Increasing the torsional stability of the girders will reduce the number of diaphragms needed in the design. This will reduce the time and cost of both fabrication and construction. Since the overall cost to fabricate and install a diaphragm can approach 10 times the cost of the steel per unit weight, this can produce a more cost-effective bridge design.

For this project, CFTFGs were designed to be constructed as simple spans for dead loads, and were then made continuous for superimposed dead loads and live loads by splicing the CFTFGs at the pier. This particular bridge is a two-span structure, so only one field splice was needed. Incorporating this field splice into the construction sequence reduced the design moments and shears for the interior-pier sections of the CFTFGs and for the field splices at the pier.

The bridge was also designed to be constructed with precast deck panels to promote accelerated construction. The size of the panels was selected based on shipping and handling considerations. The panels were designed with a concrete compressive strength of 4 ksi. Each panel was designed with mild steel reinforcing bars, pre-tensioned strands, and post-tensioned strands.

To understand the possible buckling modes, a finite element (FE) model was developed followed by an elastic buckling analysis. To investigate the lateral-torsional buckling strength, nonlinear load-displacement analyses of the FE model, including both material and geometric nonlinearity, were conducted. Single girder and

multiple girder models were developed and analyzed to investigate the influence of adjacent girders. Two different diaphragm arrangements were studied. One had three diaphragms, including two end diaphragms and one interior diaphragm. The other had only the two end diaphragms.

To advance the bridge towards construction, the following tasks were first completed:

- Develop design criteria
- Preliminary design of CFTFGs for the demonstration bridge
- Preliminary design of the field splice
- Preliminary design of the precast concrete deck
- Finite element analyses.

The demonstration bridge cross-section was provided by the Pennsylvania Department of Transportation and consists of four girders spaced at 8.458 feet on center, with 3 foot overhangs. The concrete deck was 8 inches thick. Grade 50 steel and concrete with a compressive strength of 4 ksi were used. The design study considers the 2004 AASHTO LRFD Bridge Design Specifications, the Pennsylvania Department of Transportation Design Manual, and the design criteria developed by the project. Figure 2 shows the typical section used for the bridge site.

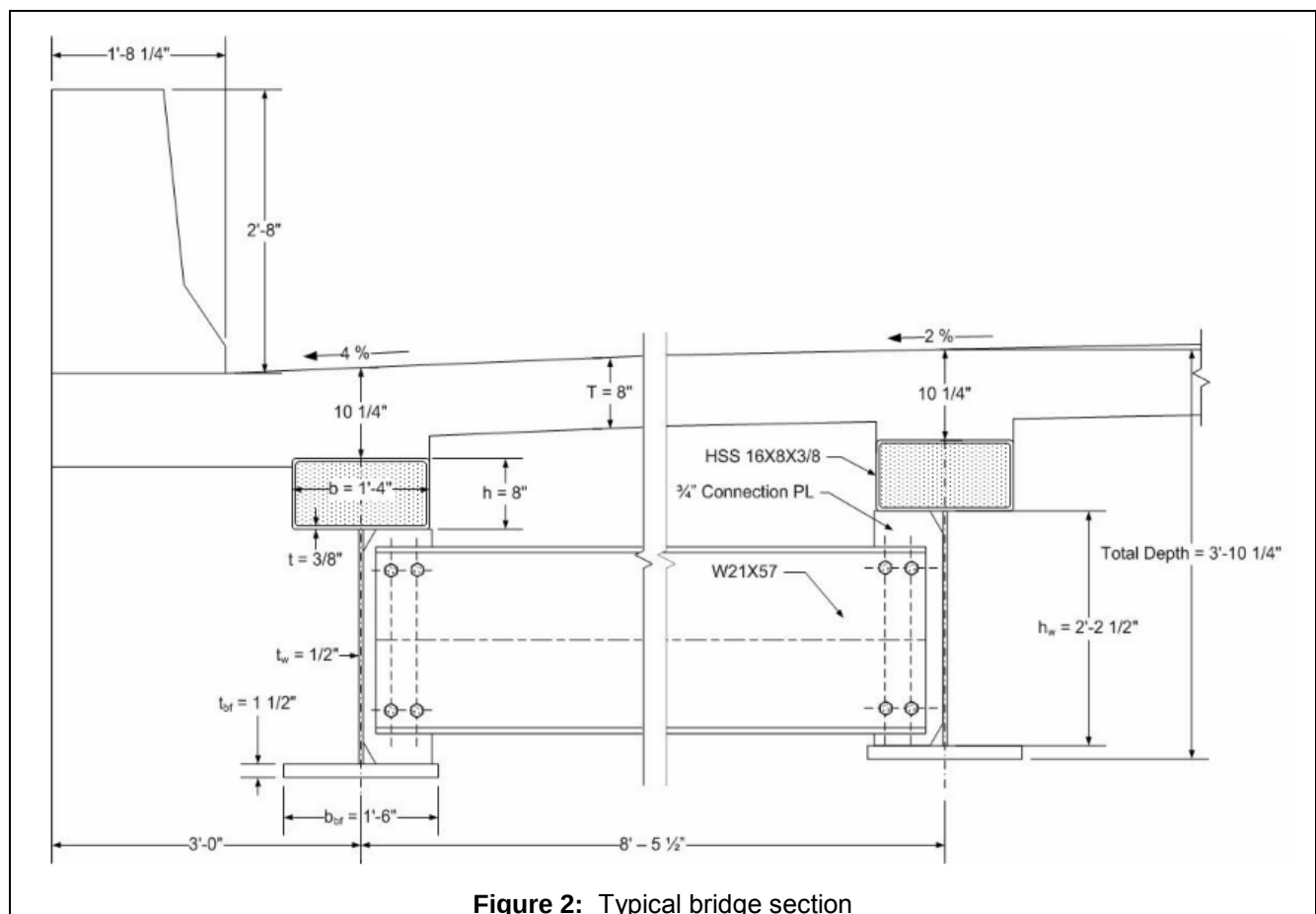


Figure 2: Typical bridge section

The research for the CFTFG technology was performed by Lehigh University.

2. Project Implementation

The project implementation was divided into two phases. The first phase included developing design criteria for the design of the CFTFGs, the field splice, and precast concrete deck. The second phase looked at lateral torsional stability by use of a finite element model.

The dead loads considered include the weight of all components of the structure, the wearing surface, and the attached appurtenances. The dead load was divided into the weight of the bridge components and girders (Dc) and the weight of the future wearing surfaces (Dw). Dc included the weight of the girders, deck, haunch, diaphragms/miscellaneous steel, and barriers. Dc loads were further divided into two categories based on the construction sequence of the field splice. Dc1 refers to simple span loading before the installation of the field splice and Dc2 refers to the load once the spans become continuous after the field splice installation. Dw includes the weight of the non-integral wearing surface. The dead loads were computed as a weight per linear foot of bridge girder. The design vehicle used for live load was an HS-20 truck.

To design the positive moment section of CFTFG, Dc1 was applied to the simple-span girders, which creates the maximum positive moment at midspan. When loads were applied to the continuous girders, the maximum positive moment was at 40 percent of the span length from the abutment end of the girders. For simplicity, these maximum positive moments were treated as if they acted at the same cross section. More accurate design calculations would treat these two cross sections independently. For the negative moment region and splice at the pier, Dc1 was omitted for the simple-span girders. Dc2 was applied to continuous girders. Even though the haunch was placed when the girders are non-composite, the weight was small and this simplification had no effect on the final design results.

The bolted field splice was located at the pier to simplify the erection of the bridge. The alternative of putting the splice at the location of where the dead load moment switch from negative to positive would either increase the number of field pieces and number of splices for each girder, or increase the length of the longer of the two field pieces. This placement of the field splice the girders need to be designed as simple spans for dead load and continuous for superimposed dead load and live loads. Figure 3 shows the field splice connection at the pier.



Figure 3: Field splice at pier

The moment capacity of the bottom flange field splice was calculated from the girder moment at the splice location. The number of bolts was determined by looking at the Strength I design force in the flange with the bolts in bearing and developing the Service II design force in the flange with the bolts designed as slip-critical. A single splice plate was used for the bottom flange. Yielding and fracture of the splice plate and of the flange plate were checked based on the Strength I design force. Also, the Fatigue limit state was checked for the splice plate and the flange plate. Based on these design considerations, the dimensions of the splice plate were determined.

For the design of top flange, tube section splice, the approach was similar to that used for the bottom flange splice.

However, instead of using single splice plate, double splice plates were used on both the top and bottom walls of the tube. Load-induced fatigue conditions were checked for this area.

For the design of the web splice, the portion of the moment resisted by the web, and the horizontal force carried by the web, due to the difference in design forces carried by the top and bottom flanges, were considered. Double splice plates were used on the web.

From the field splice design results, it was found that more bolts are required for the bearing-type connection under Strength I loading than for the slip-critical connection under Service II loading. Based on these findings, the field splice was designed as a bearing-type connection based on Strength I loading. Slip does not occur under Service II loading.

To allow for accelerated construction, the demonstration bridge was designed with precast deck panels. This design reduced the effort needed to cast a concrete deck in the field, including installation of forms and steel reinforcement. This deck design also eliminated the time required for the concrete to cure.

An analytical study was also completed to look at the performance the CFTFGs under torsional loading. To complete this finite element (FE) model of the CFTFGs used at the demonstration bridge was conducted. The study simulated construction loading conditions before the field splice was made and before the girders were connected with shear connectors to the precast deck. The FE models were simple span girders. The results of the study validated the design criteria for the lateral-torsional buckling strength of the arrangement of girders and diaphragms in the demonstration bridge.

The FE models were developed using ABAQUS. To understand the possible buckling modes, elastic buckling analyses of the FE models were conducted. To investigate the flexural strength, nonlinear load-displacement analyses of the FE models, including both material and geometric nonlinearity were conducted.

Following the completed development of the girder cross section, field splice, concrete deck, and the FE model to measure the performance of the structure under torsional loading, the construction of the bridge was initiated. Figure 4 shows the construction of the bridge located on SR 1003 over Tionesta Creek. No details were provided regarding the construction of this demonstration bridge.



Figure 4: Construction of bridge on SR 1003 over Tionesta utilizing CFTFGs

3. Project Conclusions

Conclusions were not made regarding the overall performance of the demonstration bridge; however, general conclusions were made regarding the development of the design criteria. These results are listed below.

3.1 Positive Results

Listed are the specific comments provided by the State as positive results from the IBRD project:

- The CFTFGs designed for the demonstration bridge have sufficient lateral torsional stability under the construction loadings that were considered, even with no interior bracing within the span. By eliminating diaphragms, the fabrication and erection effort can be reduced.
- The field splice at the pier can simplify fabrication and erection and reduce the dead load effects in the girder pier section.
- The precast concrete deck can reduce the time needed for construction, compared to a cast-in-place concrete deck, by reducing the time needed to place forms and reinforcing steel, and eliminating the time needed for the concrete to cure.

3.2 Lessons Learned

Listed are the specific comments provided by the State as lessons learned from the IBRD project:

- The CFTFGs designed for the demonstration bridge with either one interior diaphragm and two end diaphragms or no interior diaphragm and two end diaphragms bracing arrangement are adequate for the construction loading conditions that were considered in the study.
- Excessive grout injection pressure can deform the Structural Tube and needs to be considered as a parameter for installation.

3.3 Negative Results

No negative results were provided by the State from the IBRD project:

4. Costs

In the 2006 fiscal year, the state of Pennsylvania was granted \$200,000 funding for use of the concrete-filled tubular flange girder technology through the FHWA Innovative Bridge Research and Construction program.

5. References

The majority of the information presented in this report, including pictures, are highlights from the Project Summary Report provided by the State and the following resource(s):

Kim, B.G., and Sause, R. (2008). "Study of Two-Span Continuous Tubular Flange Girder Demonstration Bridge – Final Report to Commonwealth of Pennsylvania Department of Transportation. February, 2008.

Sause, R., Schoedel, R., and Baker M. (2010). *PennDOT Demonstration Bridge – Concrete Filled Tubular Flange Girders*. October 28, 2010.

**4.31. OTHER TECHNOLOGIES, SANDWICH PLATES: TEXAS - MARTIN BRANCH
BRIDGE, WISE COUNTY, COUNTY ROAD 419 (EIGHTEEN MILE CREEK
BRIDGE)**

FHWA IDIQ – DTFH61-07-D-00004
Task Order 003 / Technical Directive 004:
Project Case Studies for IBRC and IBRD Programs

Other Technologies
Case Study: Sandwich Plates

Project
Martin Branch Bridge, Wise County, County Road 419
(Eighteen Mile Creek Bridge)

Project State
TEXAS

Prepared For:
Federal Highway Administration



Prepared By:
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January, 2012

1. Project Description

The purpose of this project was to construct a bridge with a sandwich plate system (SPS) for the deck design, and document its performance under live load testing. The bridge selected for this project was the Eighteen Mile Creek Bridge in Wise County, Texas. This three span structure was one of the first bridges in the United States to utilize the sandwich plate design and is shown in Figure 1. The SPS material used for the deck was a composite of two 5/16 inch thick weathering steel plates bonded to a one inch thick polyurethane elastomeric core. This is shown in Figure 2.



Figure 1: Completed Eighteen Mile Creek bridge

Incorporating the use of sandwich plates in the bridge deck design has several advantages. The elastomeric core provides continuous support for the steel plates which prevents local buckling and eliminates the need for closely spaced stiffeners. Furthermore, the core can be adjusted to any thickness based on the structural load requirements.

A considerable amount of money can be saved by using sandwich plate bridge deck panels. The savings come from the increased stiffness of the composite deck, ease and short duration of construction, and savings in repair costs over the life time of the structure.

When compared to a traditional reinforced concrete deck, the sandwich plate bridge deck is lighter with a similar thickness. Traditionally, orthotropic steel decks have been used to decrease the dead load and create a lightweight design. These lightweight decks are important on bridges which are sensitive to large dead loads. This includes movable bridges and temporary bridges, including military applications, to simplify erection and dismantling. The widest application of orthotropic steel decks has been for long span bridges, particularly cable stayed and suspension bridges. Orthotropic decks come with high initial cost due to tight fabrication tolerances plus extensive welding with complex weld details. Although they have generally performed satisfactorily there have been some operational problems noted.

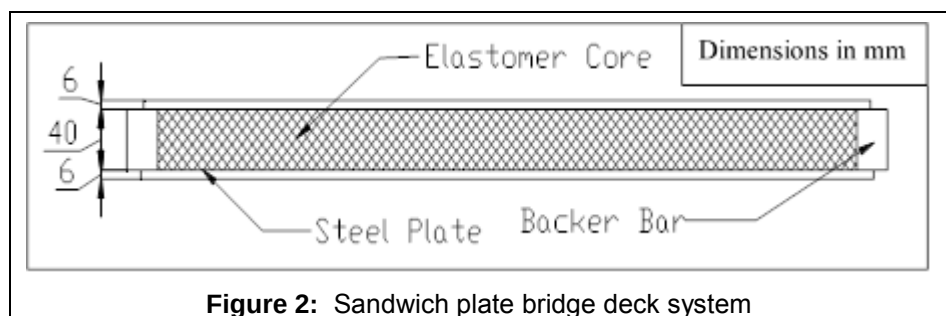


Figure 2: Sandwich plate bridge deck system

SPS decks are an attractive alternative to orthotropic steel decks. They are light and simple to construct, and large sections can be fabricated in the shop and delivered to the project site. Additionally, SPS have better welding and fatigue resistance, as compared to a typical orthotropic steel deck. Also, the elastomeric core also doubles as a vibration dampener.

Eighteen Mile Creek Bridge was constructed in six sections and erected at the site. The erection required two longitudinal splices, a field splice down the longitudinal centerline of the bridge, and a shop splice. An epoxy-type broadcast wearing surface was applied directly to the top of the SPS as the sole wearing surface. Figure 3 shows a partial cross section at the centerline of the Eighteen Mile Creek Bridge.

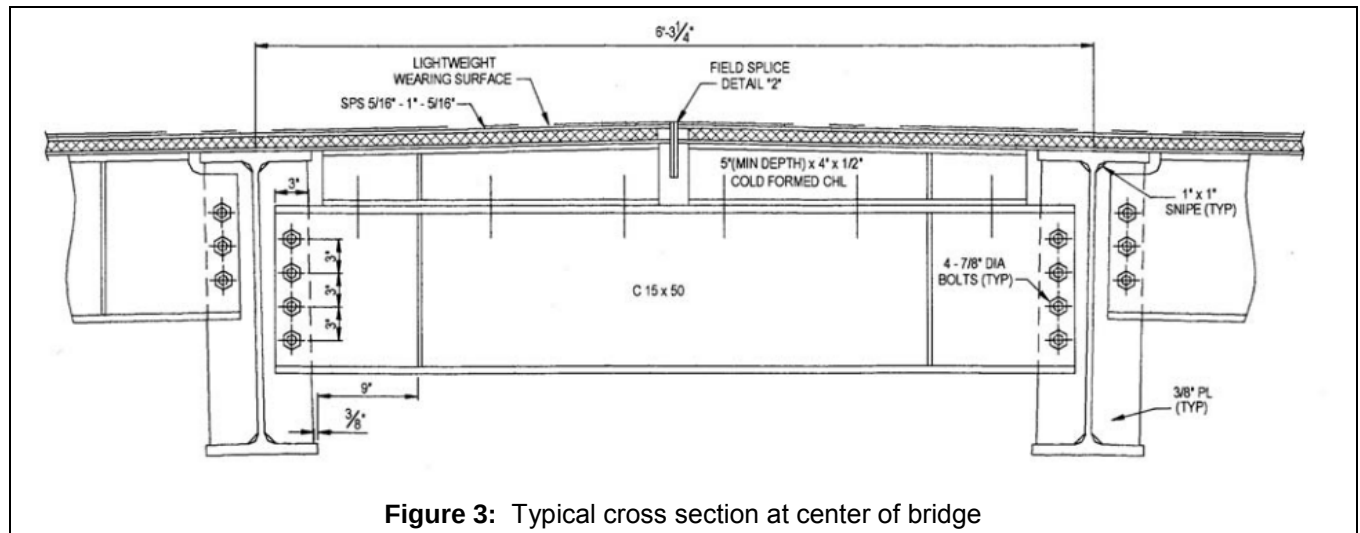


Figure 3: Typical cross section at center of bridge

The research completed on the use of SPS in the bridge deck design on this project was performed by Center for Multidisciplinary Research in Transportation, Texas Tech University.

2. Project Implementation

The sandwich plate design used for this project was developed by the Virginia Polytechnic Institute and State University (Va. Tech).

Limited data was reported regarding the construction of Eighteen Mile Creek Bridge. However, some delays were documented during construction. The delays were not directly attributable to the SPS technology, but provided details which will be beneficial in future applications.

Several of the beams did not rest properly on the bearings when the bridge sections were initially set. Typically, when a traditional concrete bridge deck is constructed, the beams are set on the bearings and the deck is then placed. This allows the beams to rest evenly on the bearings. For the SPS structure, the bridge was assembled in sections that contained three beams each. These sections, which had the SPS deck already welded to the beams, had a gap existed between some of the beams and the bearings. To correct this, the bearings were raised so that the beams would rest evenly. The bearings were also modified in the field to prevent sliding underneath the beams.



Figure 4: Truck used for live load testing

After construction, live load testing was initiated. There were four main goals for this testing. First, for future design of SPS bridges, designers must know how the live load is distributed to the longitudinal beams. Determining the live load distribution factor was the primary focus of the testing. Second, since SPS decks inherently must contain longitudinal joints that are either field welded or shop welded, the ability of these joints to transfer the load needed to be confirmed. Third, designers need to know how much increase in live load occurs due to the dynamic impact of vehicles on the bridge. Fourth, roadway noise was monitored. There was concern that a metal surfaced bridge deck with a thin broadcast overlay might be louder than a traditional concrete bridge deck.

The live load test truck was provided by TxDOT and is pictured in Figure 4. The 42,280-pound dump truck had wheel lines that were approximately 6'-0" side to side, a front to center axle spacing of 13'-7", and a center to back axle spacing of 4'-5".

Several methods were employed for monitoring the results of the live load testing. Eight wire potentiometers were installed on the bridge to measure deflections. These were installed under the center of the span for the each beam. This is shown in Figure 5.

Additionally, six bolts were gauged by the researchers in order to record bolt tension during testing. Existing bolts in the bridge at two locations of the field splice were temporarily removed and replaced with these gauged bolts in order to measure the tension. The test bolts were then replaced with original bolts following testing. The fabrication of these bolts was unique. To record measurements, a small hole was drilled through the top of each bolt and a longitudinal strain gauge was installed. The hole was then filled with epoxy with the wire projected out of the top of the bolt. This is shown in Figure 6.



Figure 5: Potentiometers installed at midspan



Figure 6: Strain gauges installed to bolted connections

A scanner recorded all of the gauges and instruments. The system utilized six strain gauge input cards to allow for a total of 48 channels to be read at the same time. The scanner was powered by a car battery during testing.

An informal sound study was also performed to investigate if vehicular traffic on the SPS deck with the thin broadcast overlay would be significantly louder than the same traffic on a conventional concrete deck. To investigate this, an impulse sound meter was used to monitor the loudness of each test. The meter was set to a decibel (dB) range of 40 to 100. The meter was set to record the maximum dB for each test, and this information was manually recorded.

In total, 32 live load tests were performed. The procedures for each test series were essentially the same. First, all traffic was stopped by TxDOT personnel. The location for the test truck driver to align the truck's western-most wheels was then measured and marked on the deck by placing two target sheets of paper held to the deck with magnets. The test truck driver was signaled to start once the computer had zeroed all instruments. Once the truck was in sight, the person recording the sound information made sure that the maximum dB setting had been reset and held the device facing the center of the bridge. After the truck passed over the bridge, the software was used to stop the recording of data and the file was saved. The person holding the sound device also wrote down the maximum value.

After testing had been completed the raw data files of the measured responses were converted over to a spreadsheet format to calculate the live load distribution factors.

3. Project Conclusions

The use of SPS for the deck design at the Eighteen Mile Creek bridge site had mostly positive results. Aside from the construction delays and a few negative results from testing, the primary goal of the project, which was to determine how the live load distributed to beams, was successful. In addition, the sound that was produced by the SPS deck technology was comparable to the noise produced by a traditional concrete deck.

3.1 Positive Results

Listed are the specific comments provided by the State as positive results from the IBRD project:

- It took approximately 3 days to install the superstructure for three 50' spans, not including the overlay or railing.
- The calculated distribution factors were consistent indicating that the data was reliable. An upper limit distribution factor of 0.37 was measured using the single test truck. This value is less than the current AASHTO recommended value of 0.51 for a single lane concrete-deck bridge. On a separate project, measured distribution factors for the Shenley Bridge in Quebec, Canada were also generally less than the code recommended values. Therefore, the AASHTO recommended distribution factor for a concrete-deck bridge can be used conservatively for new design until enough field tests are performed to generate specific recommendations for the calculation of distribution factors for SPS decks.
- The sound generated by the test truck on the SPS deck was slightly, but not significantly, higher than the sound generated by the test truck on the concrete deck. The difference of approximately 3.5 dB is considered "barely perceptible". Both sound levels were less than the maximum recommended level of 80 dB.

3.2 Lessons Learned

Listed are the specific comments provided by the State as lessons learned from the IBRD project:

- Prior to letting project, the manufacturer of Sandwich Plate System (SPS) presented technology to numerous likely bidding contractors. This effort is deemed successful due to the closeness of all bids received.
- Size of prefabricated elements should have been smaller to lessen fit-up problems in the field and weld-induced distortion. These problems were not prevented even with the requirement to shop assemble elements prior to delivery.

3.3 Negative Results

Listed are the specific comments provided by the State as negative results from the IBRD project:

- Excessive camber. Attributed to either weld distortion or incorrect beam camber. Problem not attributable to the SPS technology.
- Lack of contact between superstructure and bearings, attributed to low dead load and stiffness of large prefabricated superstructure elements. Shims were fabricated to provide bearing contact. Bearing pad slippage is occurring.
- System is expensive when compared to other prefabricated superstructure systems capable of accelerated bridge construction.

4. Costs

In the 2004 fiscal year, the state of Texas was granted \$400,000 in funding for implementing SPS deck technology through the FHWA Innovative Bridge Research and Construction program.

5. References

The majority of the information presented in this report, including pictures, are highlights from the Project Summary Report provided by the State and the following resource(s):

Newhouse, C., Wood T., and Nash, P., Center for Multidisciplinary Research in Transportation, Texas Tech University (2010). "Live Load Testing of Sandwich Plate System (SPS) Bridge in Wise County, Texas." October, 2010.

Martin, J., Murray, T., Cousins, T., and Roberts-Wollmann, Carin (2005). "Sandwich Plate System Bridge Deck Tests." March 29, 2005.

APPENDIX A – PROJECT TRACKING

TRACKING SPREADSHEETS

The following spreadsheets report and organize the data that was collected for the summary sheets. Several projects had funding changes or project location (and name) changes.

The first set of data indicates the project and reported technology and the amount of information delivered by the States, as well as any financial information. The second spreadsheet differentiates the major technology categories and subcategories and indicates if a report was completed, not recommended, or if the project information was not reported by the State.

Report Form Tracking Spreadsheet

Report Form Tracking

record #	Completed Contact Report Forms	Technology	Delivered by State (y/n)	Expected Delivery Date		Project Status @ Time of Report	No. of External Papers	Summary Sheet recomd.?	FHWA Funds Allotted	FHWA Funds Used at Time of Report	Redistributed	to/from	Returned	Award Year	COMMENTS	NAME HISTORY
1	AK Kodiak HRBR CHNNL# 1189	Seismic bearing monitoring	y			completed	1	y	\$ 20,000.00	\$ 20,000.00				2000	Associated with 2 - This project is monitoring the bearings that were installed	
2	AK Statewide Sesimic Retrofit	Seismic bearings	y			completed	1	y	\$ 330,400.00	\$ 330,400.00				2000		
3	AK Parks Highway at Sustina River, MP 69.3	Polyester Concrete Overlay	y			ongoing	1	y	\$ 200,000.00	\$ 200,000.00				2006		
4	AL SR 81 over Uphapee Creek	FRP Bonded Reinforcement to Concrete Tee Girders	y			completed	1	y	\$ 299,400.00	\$ 299,400.00				2000	Associated with 5, 9, and 10	
5	AL Surles Road Bridge over Bedsole Creek	Timber/FRP Glulam	y			completed	0	n	\$ 126,000.00	\$ 126,000.00	\$50,000	from 6		2000	Associated with 4, 9, and 10	
6	AL Suppliment to Surles Road/Bedsole Creek	FRP Glulam	y			completed	0	n	\$ 50,000.00	\$ 50,000.00	\$50,000	to 5		2001	Supplement to Project 5	
7	AL County Rte. 409 over Short Creek	HPC Prestressed Girders	y			completed	1	y	\$ 500,000.00	\$ 500,000.00				2000		
8	AL Marshall County Rt. 409 over Short Creek	High Performance Concrete	y			withdrawn	0	n	\$ 500,000.00				\$ 500,000.00	2001		
9	AL Repair of Girder Ends on I-565 Str # 015821, Huntsville, AL	FRP Bonded Repair to Prestressed Concrete Girder Ends	y			ongoing	0	n	\$ 400,000.00	\$ 373,939.38				2003	Associated with 4, 5, and 10	
10	AL -97 Bridge over I-65 near City of Letohatchie	FRP Bonded Reinforcement in Concrete T-Beams	y			initiated	0	y	\$ 400,000.00	\$ 78,639.00				2004	Associated with 4, 5, and 9	NBI Str. No 008847
11	AL B.B. Comer Southbound Bridge U.S. 431 over Tennessee River	Self Consolidated Concrete in Drilled Shafts	y			initiated	1 Prog Rpt.	y	\$ 400,000.00	\$ 298,498.60				2005		
12	AL Wald Park Pedestrian Crossover of US31 near MP 268 & near Intersection of Merryvale Rd, 2mi	Thoermosetting Composite Plastic	y			initiated	0	n	\$ 200,000.00	\$ -				2006		
13	AR State Hwy. 245 Bridge over Interstate 30 (Texarkana)	High Performance Concrete in Bridge Rails and Deck Slab	y			completed	2	y	\$ 347,500.00	\$ 347,500.00				2004		
14	AR State Hwy. 49 over I-40 (Brinkley)	High Performance Steel in I-Girders	y			completed	0	y	\$ 282,000.00	\$ 202,000.00				2005	Remaining \$80,000 for monitoring	
15	AZ I-40 Sunshine BNSFRR OP WB, MP 237.10	High Performance Concrete, Low Corrosion Steel in Deck Slab	y			completed	2	y	\$ 400,000.00	\$ 400,000.00				2004		
16	AZ Virgin River Gorge Structure #7 Interstate 15, @ MP 22.55 Crossing Virgin River	Innovative construction phasing and erection techniques used to maintain full	y			completed	0	y	\$ 200,000.00	\$ 200,000.00				2006		
17	CA I-5 Gilman Advanced Technology Bridge, UCSD Campus	FRP Deck Panels	n	not submitted				n						1999		
18	CA I-5 Bridges in Los Angelos	HPC	n	not submitted				n						1999		
19	CA (Unnamed project)		n	not submitted				n	\$ 150,000.00					2000		
20	CA Gilman Dr. O/C 0.5 M No of LA Jolla Village D		n	not submitted				n	\$ 1,500,000.00					2000		
21	CA 02-SHA-36-7.57	Other - "Smart Power Pebbles"	n	not submitted				n						2000		
22	CA Gilman Rd./I-5 UCSD Campus	FRP Deck Panel	n	not submitted				n	\$ 1,500,000.00					2001		
23	CA Rte. 36 post 7.57		n	not submitted				n	\$ 164,956.00					2001		
24	CA White's Hill Viaduct Sir Frances Drake Blvd.	High Performance Steel in Plate Girders	n	not submitted				n	\$ 500,000.00					2001		
25	CA Dorman Dr./Garrard Blvd. Tunnel	FRP Deck Panel	n	not submitted				n	\$ 500,000.00					2002		
26	CA Danley/Fairview Rd. over Glenn Colusa	High Performance Steel in Box Girders	n	not submitted				n	\$ 396,000.00					2002		
27	CA Gilman Road over I-5; Advanced Technology Bridge		n	not submitted				n	\$ -					2003		
28	CA Tower Bridge over Sacramento River	FRP Deck Panel	n	not submitted				n	\$ 400,000.00					2004		
29	CA US 395 over LA aqueduct	FRP Deck Panel	n	not submitted				n	\$ -					2005		
30	CA Del Amo Avenue Bridge	FRP Deck Panel	n	not submitted				n	\$ -					2005		
31	CA Bridge No. 17-0072L/Indian Springs Under Crossing, I-80, Nevada County Mile Post 62.15		n	not submitted				n	\$ -					2006		
32	CA Uvas Creek Bridge, Rte. 152		n	not submitted				n	\$ -					2006		
33	CA Bridge No 19-0123L / Indian Springs Undercrossing, I-80		n	not submitted				n						2009		
34	CA Slide Canyon Bridge, SR2		n	not submitted				n						2009		
35	CO I-225 & Parker Rd. Phase III	Carbon FRP prestress deck panels and glass fiber reinforcement. Further	y			completed	3	y	\$ 400,000.00	\$ 400,000.00				2000		

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36	CO	(unnammed record of funding)	y			withdrawn		n	\$ 300,000.00					2000	Cancelled; No record of Project	
37	CO	Denver Parks O'Fallon Park Bridge over Bear Creek	FRP Deck Panel and Glass fiber reinforcement	y		completed	2	y	\$ 499,759.00	\$ 499,759.00				2001	Formerly: O'fallon Prak Bridge	Labeled Welch Gulch City of Golden Ped in PW, adjusted 7/14/10
38	CO	Castlewood Canyon Bridge, SH 83 over Cherry Creek	Demonstration of CFRP wrap repair and accelerated construction for historic arch	y		completed	1	y	\$ 400,000.00	\$ 400,000.00				2003		
39	CO	I-25NB over Purgatoire River I-25; I-25 NB over Main Street;	High Performance Concrete in Abutments, Deck Slab and Pier Columns	y		completed	1	y	\$ 247,300.00	\$ 247,300.00				2004		Also known as the "Trinidad Project" Associated with project 40
40	CO	I-25 over Great Western RR	Utilizing SCC in an abutment bridge repair for 2 bridges	y		withdrawn	1	y	\$ 152,700.00	\$ 106,149.00			\$ 46,551.00	2004	remaining funds expired; see Trinidad Report	Associated with project 39
41	CO	SH 52 over Vrain Creek	Rapid construction technique	y		initiated	0	n	\$ 181,000.00	\$ -				2006		Formerly: SH 52 over Boulder Creek
42	CO	Pedestrian Underpass on SH7 (Arapahoe Ave) @ Bear Canyon Creek. SH7 Mp 53.5 Just east of	Demonstrated Xypex admixture to seal concrete	y		completed	0	y	\$ 78,000.00	\$ 78,000.00				2006	Manufacturer is being sued by Boulder County	
43	CT	East Lyme:SR449 over I-95	CP Anodes in Deck Slab	n	not submitted			n	\$ 6,200.00					2000		
44	CT	New Haven: Church St. ext. Hwy. Bridge over RR	High Performance Concrete in Deck Slab, High Performance Steel in Truss Chords	n	not submitted			n	\$ 700,000.00					2000		
45	CT	Rte.34/the Housatonic River (Lake Zoar)		n	not submitted			n	\$ 500,000.00					2001		
46	CT	US RT. 1 over Housatonic River	FRP Deck Panel	n	not submitted			n	\$ 500,000.00					2002		
47	CT	SR 598 EB over SR 598 WB & Conn. Southern RR		n	not submitted			n	\$ 356,000.00					2003		
48	CT	Rt. 151 Bridge over Salmon River (State Project 40-128)	High Performance Steel in Plate Girders	n	not submitted			n	\$ 400,000.00					2004		
49	CT	Pearl Harbor Memorial Bridge	High Performance Concrete in Box Girders	n	not submitted			n	\$ 255,000.00					2005		
50	DC	Rehabilitation of Jefferson St. Bridge, 29th St. Bridge	FRP Bridge Deck	y		initiated	0	n	\$ 1,496,934.00					2004		
51	DE	Linked with Award for 1-680	HPC beams, deck and piles	n	duplicate of 52			n	\$ 950,000.00	\$ -				1999	duplicate record of "Bridge 2-008F"	
52	DE	Bridge 2-008F	High Performance Steel Beams	y		completed	1	y	\$ 450,000.00	\$ 450,000.00				1999	Formerly: Bridge I-680	
53	DE	BR 119 on SR 82 over Red Clay Creek	HPC deck, MMFX Rebar and CFRP reinforcing strips on steel beams	y		completed	1	y	\$ 220,000.00	\$ 208,552.77				2000		
54	DE	BR 712B, Ramp J, I95 Service Area, Newark	MMFX rebar	y		completed		y	\$ 350,000.00	\$ 200,000.00	\$150,000	to 55		2001		
55	DE	BR 26 on Faulk Rd Over Naaman's Creek	CFRP reinforcement in precast concrete beams	y		completed	1	y	\$ -	\$ 91,200.00	\$150,000	from 55	\$ 58,800.00	2001	Split off of 1-712B project	
56	DE	US 113 Bridge over the St. Jones	Lithium Treatment for ASR	n	no record			n	\$ -					2001		
57	DE	Churchman's Road over I-95	High Performance Steel	y		completed	1	y	\$ 500,000.00					2002	Funds were reallocated but were never transferred to Smiths' Bridge; all funds used for this project	
58	DE	Indian River Inlet Bridge on SR 1 over Indian River Inlet	High Performance Concrete in Arch and Pier Caps and Construction Monitoring	y		withdrawn		n	\$ 200,000.00					2004	started in 2004, extended to 2006, then cancelled	
59	DE	Indian River Inlet Bridge (extension)	Monitoring of Construction Loads on the Tied Arch	y				n	\$ 300,000.00					2005	extention, fund change	
60	DE	Indian River Inlet Bridge (extension)	Monitoring of Construction Loads for Approach Embankments	y				n	\$ 150,000.00					2006	extention, fund change	
61	FL	Jensen Beach Causeway - Stainless	Clad Stainless Steel Rebars in footers & columns	y		completed	1	y	\$ 128,250.00	\$ 128,250.00				2000	Technology moved to Jensen Causeway combined project	Formerly: SR 679 over Burnces
62	FL	Jensen Beach Causeway - MMFX	MMFX Rebars in deck slab	y		completed	1	y	\$ 289,000.00	\$ 289,000.00				2001	Technology moved to Jensen Causeway combined project	Formerly: US1/Key Deer N. Channel
63	FL	University Blvd. Bridge over Arlington River	FRP Bonded Reinforcement	y		completed	1	y	\$ 350,000.00	\$ 345,947.00				2002		
64	FL	Key Royale Drive Bridge over Bimini Bay	High Performance Concrete in Piles	y		completed	1	y	\$ 400,000.00	\$ 400,000.00				2004		
65	FL	Hillsboro Canal Bridge - FRP	FRP Deck Panel	y		initiated		y	\$ 300,000.00	\$ 300,000.00				2005		
66	FL	Hillsboro Canal Bridge - Monitoring	Monitoring	y				n	\$ 200,000.00					2006		
67	GA	I-75 @ SR 37/Adel (FM 1500 ft West to 650 ft East I-75), Rowa, Peng	High Performance Steel in Plate Girders	y		completed	0	y	\$ 656,039.04	\$ 656,039.04				2000		
68	GA	CR 289-Bearden Rd @ Jacks Creek NW of Good Hope, Bridges	FRP Rebar in Concrete T-Beams	y		withdrawn		n	\$ -	\$ -				2000		
69	GA	SR 92 over Noonday Creek Bridge Rehabilitation	FRP project	y		completed	0	y	\$ 154,148.41	\$ 154,148.41				2000		
70	GA	SR 337/GA SW RR	FRP Bonded Reinforcement	y		withdrawn	0	n	\$ -	\$ -				2001		

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71	GA	SR 282 Bridge Replacement over Tails Creek West of Ellijay	Clad Stainless Steel Rebars	y		withdrawn	0	n	\$ -	\$ -				2002		
72	GA	I-85 @ SR 34 Ramp Reconstruction Southeast Quadrant	Lightweight High Performance Concrete in I-Girders	y		initiated	0	n	\$ 265,000.00					2005		
73	HI	Route 19 / Kealakaha Stream Bridge	Fiber optic instrumentation for seismic, dynamic loads	y		completed	3	n	\$ 691,947.00	\$ 682,000.00				2000		
74	HI	Salt Lake Blvd. Bridge over Halawa Stream	FRP shear strengthening of prestressed girders	y		completed	2	y	\$ 360,886.00	\$ 310,329.66				2003		
75	HI	North Kahana Stream Bridge	Self Consolidated Concrete in Drilled Shafts	y		initiated	1	y	\$ 400,000.00	\$ 285,046.00				2004		
76	HI	Honolua Stream Bridge	FRP Deck Panel	y		initiated	1	n	\$ 300,000.00	\$ 28,500.00				2005	2-4-10 progress report	
77	HI	Kahoma Stream Bridge on Lahaina ByPass	SHM using Smart Sensor Technology	y		initiated	0	y	\$ 350,000.00	\$ 73,324.00				2009	application of gages summer 2010	
78	IA	53rd Ave. over Crow Creek Bettendorf	FRP	y		completed	1	y	\$ 220,000.00	\$ 294,559.80	\$75,000	from 84		1999	combined with 84, same projectas "53rd Ave. Bridge over Crow Creek"	
79	IA	Section 13-96N-RSW over Bridge Yellow River	HPC	y		completed	1	n	\$ 7,000.00	\$ 6,419.05				1999	Report is noted but no electronic copy of report	
80	IA	4th Ave. over Ralston Creek	FRP Deck Panels	y		withdrawn		n	\$ 135,000.00		\$135,000	to 89		2000		
81	IA	Rt 141 over Willow Cr.	FRP Prestressing	y		completed	1	y	\$ 230,000.00	\$ 229,893.00				2000		
82	IA	US 20/South Beaver Creek Proj. NHSX-520-5(78)	MMFX Rebars in Deck Slab	y		completed	1	y	\$ 200,000.00	\$ 140,396.39				2001		
83	IA	215 Avenue Bridge over Lime Creek	FRP Glulam	y		completed	1	y	\$ 285,000.00	\$ 265,440.93				2001		
84	IA	53rd Ave. Bridge over Crow Creek	FRP Deck Panels	y				y	\$ 75,000.00		\$75,000	to 78		2001	suppliment to 78, same project as "53rd Ave. over Crow Creek Bettendorf"	
85	IA	East 12th Street over I-235	HPS	y		completed	1	y	\$ 320,000.00	\$ 320,000.00				2002		
86	IA	Hwy. E64 over Small Creek East of US 63	Steel-free concrete bridge deck	y		completed	1	y	\$ 170,000.00	\$ 163,469.40				2002		
87	IA	I-A-92 over Walnut Creek	FRP strengthening of steel girders	y		completed	2	y	\$ 130,000.00	\$ 116,082.82				2002		
88	IA	100th Avenue over Little Soap Creek, Keokuk Township	UHPC	y		completed	1	y	\$ 300,000.00	\$ 300,000.00				2003		
89	IA	Iowa 24 over Goddard Creek	FRP deck slab	y		completed	1	y	\$ 340,000.00	\$ 281,219.58	\$135,000	from 80		2003	Funds combined with project 80	
90	IA	Boone County Bridge (ID 85-25-031) 120th street over Squaw Creek	High Performance Concrete in Deck Slab, acclecrated construction techniques	y		completed	1	y	\$ 400,000.00	\$ 399,526.08				2004	Associated with Project 91	
91	IA	Madison County Bridge (14B-551-100) 290th street over unnamed creek	High Performance Concrete Box beams using accelerated construction	y		completed	2	y	\$ 200,000.00	\$ 200,000.00				2004	Associated with Project 90	
92	IA	24th St. over I-80/I-29 Council Bluffs	High Performance Concrete precast Deck Slabs using accelerated construction	y		initiated	1	y	\$ 400,000.00	\$ 124,349.78				2005		
93	IA	136th ave over Buffalo Creek	UHPC PI girder bridge	y		initiated	1	y	\$ 400,000.00	\$ 554,260.62	\$300,000	from 93		2005		
93a	IA	136th ave over Buffalo Creek (supplement)	UHPC PI girder bridge	y		initiated	1	y	\$ 300,000.00		\$300,000	to 93		2007	supplement to Project 93	
94	IA	County Bridge ID 86 on local road between Sections 23/26 Providence Township (Sec. 23/26	Accelerated construction using precast elements	y		initiated	0	n	\$ 200,000.00					2006	Missing amount expended, no Report	
95	IA	US6 and IA192 over UP&CC RR, streets, & Perry Cr. Conduit		y		initiated	0	n	\$ 400,000.00	\$ 400,000.00				2009	No record of Project	
96	ID	SR 21over Mores Creek @New York Gulch	MMFX Rebar	y		completed	0	y	\$ 32,200.00	\$ 32,200.00				2001		
97	ID	Westmond Bridge;US 95 over BSFRR	MMFX Rebar	y		completed	0	y	\$ 50,000.00	\$ 50,000.00				2003		
98	ID	Sunnyside Road (I-15B) Interchange over I-15	High Performance Steel Girders	y		completed	0	y	\$ 400,000.00	\$ 400,000.00				2003		
99	ID	I-15 Bridge over Center Street IC	Polyester Concrete Overlay	y		completed	0	y	\$ 260,000.00	\$ 260,000.00				2005		
100	ID	State Hwy. 200 over Mosquito Creek	SafeLane	y		completed	0	y	\$ 151,000.00	\$ 151,000.00				2006		
101	ID	SH200 over Trestle Creek		y		initiated	0	n	\$ 150,000.00	\$ -				2009		
102	IL	I-39 over Kishwaukee River	FRP Bonded Reinf.	y		completed	1	y	\$ 150,000.00	\$ 150,000.00				1999	Project was changed to Health Moniotring system (HMS)	
103	IL	I-55/ I-70 Poplar Street Complex	HPS	y		completed	1	y	\$ 99,000.00	\$ 99,000.00				1999	Associated with IL 83 and US 45 over the Wisconsin Central RR (project 116)	
104	IL	Wacker Dr. Viaduct	HPC	y		completed	2	y	\$ 2,200,000.00	\$ 2,700,000.00	\$500,000	from 114		1999	City of Chicago Wacker Dr. to Franklin St. was combined with this project	City of Chicago Wacker Dr. to Franklin St.

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105	IL Quincy 18th Street over Ceda Creek	Galvanized Rebar and Structural Steel	y			completed	1	y	\$ 450,000.00	\$ 450,000.00				1999		
106	IL Jacksonville, S Fayette Street over Town Brook	FRP Deck	y			completed	1	y	\$ 170,000.00	\$ 170,000.00				1999		
107	IL Adeline Rd, Freeport Rd, Eagle Pt. Road	HPC Deck Slab Overlays	y			completed	0	n	\$ 122,000.00	\$ 122,000.00				1999		
108	IL 170 FR 2.5 M E 115/70 To Bond Co. Line	HPC Deck	y			completed	1	y	\$ 58,800.00	\$ 58,800.00				2000	Associated with Project 115	
109	IL US -51 from 0.6 mile north of Macon to Shelby	HPC Deck	y			completed	1	n	\$ 53,000.00	\$ 53,000.00				2000		
110	IL IL 104 over Brush Cr..3 E. of Kincaid & E of I-55	HPC Deck	y			completed	1	n	\$ 49,960.00	\$ 49,960.00				2000		
111	IL IL 54 OV Spring Creek 1.5 MN Thawville Bridge	HPC Deck	y			completed	1	n	\$ 23,240.00	\$ 23,240.00				2000		
112	IL I474 FR 174 to Illinois River	Mettallizing Concrete Beam Ends	y			completed	1	y	\$ 45,000.00	\$ 45,000.00				2000		FORMERLY: 1474 FR 174 to Illinois River
113	IL 7 bridges	HPC Deck Slab	n	compilation of projects				n						2000		
114	IL City of Chicago Wacker Dr. to Franklin St.	HPC	y			completed	2	y	\$ 500,000.00	\$ 500,000.00	\$500,000	to 104		2001	See project 104 - combined with Whacker Dr. Viaduct	
115	IL Corenzo Rd. over I55;I-80 Kean Ave.	HPC Deck	y			completed	1	n	\$ 500,000.00	\$ 500,000.00				2002	Combined with 170 FR 2.5 ME 115/70; 2002 Funds for 17 Bridges - combined into one report	
116	IL IL 83 and US 45 over the Wisconsin Central RR in Lake Villa, IL; IL 49S over I-74; IL 49N over I-74	High Performance Steel	y			completed	1	y	\$ 331,000.00	\$ 331,000.00				2003	Associated with Project 103	
117	IL Babylon Bridge over Spoon River, Lee Township	FRP Bridge Deck and Hillman composite bridge system	y			withdrawn	0	n	\$ 400,000.00		\$ 100,000.00	to 119	\$ 227,700.00	2004		
118	IL Pleasant Ridge Rd. over Little Canteen Creek	FRP Deck Panel	y			initiated	1	n	\$ 392,200.00	\$ 377,200.00	\$ 87,200.00	to 118		2005		
119	IL High Road Bridge carrying High Road over Long Run Creek in Lockport Township, Illinois	Hybrid-Composite Beams - self-consolidating concrete for the	y			completed	0	n	\$ 150,000.00	\$ 250,000.00	\$100,000	from 117		2006	Report in by consultant	
120	IN Thayer Road over I-65	Clad Stainless Steel Rebars in Deck Slab. Material changed to FRP reinforcement in	y			completed	4	y	\$ 85,000.00	\$ 66,116.30				2000	Missing Federal-Aid Project No.	
121	IN County Bridge #153	FRP deck panel	y			initiated	0	y	\$ 475,000.00	\$ 475,000.00				2002	Missing Federal-Aid Project No.	
122	IN US 30 over Jain Creek	Extra thick epoxy coated reinforcement.	y			completed	3	y	\$ 200,000.00	\$ 200,000.00				2003	Missing Federal-Aid Project No.	
123	IN US-50 Bridge over Tanners Creek and Service Road, Lawrenceburg	Full Depth Precast Bridge Deck System	y			initiated	3	y	\$ 300,000.00	\$ 200,000.00				2004	Missing Federal-Aid Project No.	
124	IN 21st Street over I-465	High Performance Concrete	y			completed	1	y	\$ 400,000.00	\$ 400,000.00				2005	Missing Federal-Aid Project No.	
125	KS RS 1070 over Kansas River SE of Belvue Kansas	FRP Railing	n	not submitted				n						1999		
126	KS I-470W to I-70W	CP Anodes	n	not submitted				n						2000		
127	KS Detour Bridge	FRP Deck Panel	n	not submitted				n	\$ 500,000.00					2001		
128	KS Detour Bridge	FRP Deck Panels	n	not submitted				n	\$ 500,000.00					2002		
129	KS K-14 over Salt Creek	Self Consolidating Concrete	n	not submitted				n	\$ -					2003		
130	KS RS-831 Bridge over Walnut Creek	Light Weight Concrete Mix / Laterally Loaded Pile Behind MSE Wall	n	not submitted				n	\$ 400,000.00					2004		
131	KS Detour Bridge / Br Rail on FRP Deck	FRP Deck Panels	n	not submitted				n	\$ 400,000.00					2004		
132	KS RS 17 over Stream	FRP Reinforced Beams	n	not submitted				n	\$ -					2005		
133	KY 025* 1210* C0029 Co RD. S. Winchester		n	not submitted				n	\$ 75,000.00					2000		
134	KY KY 1577 RR Underpass in Somerset		n	not submitted				n	\$ 500,000.00					2000		
135	KY Montecello Street Undepass	FRP Panel Deck	n	not submitted				n						2000		
136	KY Clark County Bridge , located on CR1210 over Two Mile Creek	FRP Rebar	y			completed	1	y	\$ 35,000.00	\$ 35,000.00				2000		KY595 over West Fork Silver Creek
137	KY Kentucky Route 3297 over Liittle Sandy River	FRP Bonded Reinforcement	y			completed	1	y	\$ 105,000.00	\$ 105,000.00				2001		
138	KY Scott County Rd. 5218 over North Elkhorn Creek	Stainless steel clad and MMFX reinforcing steel	y			completed	1	y	\$ 70,000.00	\$ 70,000.00				2001		
139	KY Louisa- Fort Gay Bridge	FRP Laminates	y			completed	1	y	\$ 195,000.00	\$ 195,000.00				2002		

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140	KY	KY974 over Howard Creek	Aluminum Bridge Deck	y			completed	0	y	\$ 400,000.00	\$ 400,000.00				2003		KY-92 over Jellico Creek
141	KY	I-65 over Jacob, Broadway, and Gray Streets	FRP Strengthening	y			completed	0	y	\$ 305,000.00	\$ 305,000.00				2003	Combined with I-65 Bridge over Main St. Louisville, project 142	
142	KY	I-65 Bridge over Main St. Louisville	Use of Carbon FRP	y			completed	0	y	\$ 140,000.00	\$ 140,000.00				2004	Combined with I-65 over Jacob, Broadway, and Gray Streets, project 141	
143	KY	Webster County Bridge 50, Crab Orchard Creek	Aluminum Bridge Deck	y			initiated	0	y	\$ 345,000.00	\$ 240,000.00				2004		
144	KY	KY 32 over Lytles Creek	FRP	y			initiated	0	n	\$ 260,000.00	\$ 100,000.00				2005		I-65 over Main Street
145	KY	KY 3302 over Sugar Tree Branch	FRP Rebars in Deck Slab	y			initiated	0	n	\$ 240,000.00	\$ 10,000.00				2005	Technology was changed to FRP Stay-in-Place forms for Deck Salbs	Galloway Road over N. Elkhorn Cr.
146	KY	KY 3302 over Sugar Tree Branch	Solid Stainless Rebars in Deck Slab	y			initiated	0	n	\$ 95,000.00	\$ 10,000.00				2005		Galloway Road over N. Elkhorn Cr.
147	KY	KY 714 over Jephtha Creek	Use of Carbon FRP	y			initiated	0	y	\$ 150,000.00	\$ 55,000.00				2005		
148	KY	Indian Gap Road over Camp Pleasant Branch	ABC with SCC	y			not started	0	n	\$ 255,000.00	\$ -				2009		
149	KY	KY11 over CSX RR and Strodes Run	High Strength Steel Wire Fabric	y			not started	0	n	\$ 210,000.00	\$ -				2009		
150	LA	Bridge on LA Rt. 1@ Leeville/Lafourche Parish	Maintenance Protective Coating over an existing Lead Paint System	n	not submitted				n	\$ 575,000.00					2000		
151	LA	LA 378 over West Fork Calcasieu River	Fiber Reinforced Polymer (FRP) Bridge Fender Sytem	n	not submitted				n	\$ 488,000.00					2002		
152	LA	Louisiana Route 70, Bayou Pierre Part	Composite Fiber Reinforced Polymer (FRP) Bridge Deck	y			initiated	1	y	\$ 400,000.00	\$ 320,000.00				2003		
153	LA	Elm Grove Garden Road Bridge	FRP Reinforcing in Pier Columns	y			completed	3	y	\$ 225,000.00	\$ 216,434.00				2004		
154	LA	Caminada Bay, LA 1 near Grand Isle, LA	Integral Abutment In LA Soft and Stiff Soils	y			initiated	1	y	\$ 400,000.00	\$ 250,484.00				2005		
155	LA	Structure Health Monitoring (I-10 Twin Span Bridge)	Element health Monitoring using Embedded Sensor Technology: "Structure	y			initiated	1	y	\$ 650,000.00	\$ 333,999.00				2005		
156	LA	Caminada Bay Bridge	FRP Strand: "Repairing/Strengthening of Bridges with Post Tension FRP Strands &	y			initiated	1	y	\$ 200,000.00	\$ 60,000.00				2005		
157	LA	Structure Health Monitoring (I-10 Twin Span Bridge)	High Performance Concrete	y					y	see 155					2005	Combined with project 155 of same name	
158	LA	Amite River Bridge and Approaches (US 190)	Scour Monitoring using Fiber Optic Sensors	y			initiated	0	n	\$ 200,000.00	\$ 20,000.00				2006		
159	LA	I-49 over Dooley Bayou	elimination of deck joints - FRP grid	y			not started	0	n	\$ 270,000.00	\$ -				2009		
160	LA	LA6 Red River at Grand Encore Bridge		y			not started	0	n	\$ 250,000.00	\$ -				2009		
161	LA	I-49 over Dooley Bayou - Geosynthetic Reinf Soil at Abuts		y			initiated	0	n	\$ 250,000.00	\$ -				2009		
162	MA	Franklin I-495 over MBTA Bridge	FRP Bonded Reinforcement in P/S Slab Bridge	y			completed	1	n	\$ 57,500.00	\$ 57,500.00				2000		
163	MA	State Rte. 13 over aNordth Branch Nashua River		y			completed	0	n	\$ 500,000.00	\$ 500,000.00				2001		
164	MA	Central Street over Quequechan River		y			withdrawn	0	n	\$ 500,000.00				\$ 500,000.00	2002		
165	MA	City of Randolph, Metropolitan District Commission Access Road over State Route 24 NB and SB		y			withdrawn	0	n	\$ 400,000.00	\$ -				2003		
166	MA	US 1 NB Bridge over I-95 NB & SB	High Performance Concrete in Bridge Rails and MMFX Rebars in Deck Slab	y			initiated	0	n	\$ 400,000.00	\$ -				2004		
167	MA	Long Hill Road over CSX R.R.	Self Consolidated Concrete in Superstructure	y			initiated	0	n	\$ 110,000.00					2005		
168	MA	Bridge to HQ Complex	High Performance Concrete in Deck Slab	y			see comment		n	\$ 346,730.00					2005	project not claimed by MA	
169	MD	MD 335 Br 09011 over Wallace Creek - Bridge Replacement		n	not submitted				n	\$ -					0		
170	MD	MD 24 Rehab. Br. 12016 Deer Cr.	FRP Deck Panel	y			completed	1	y	\$ 40,000.00		\$40,000	to 171		2000	suppliment to 171	
171	MD	MD 24 Rehab. Br. 12016 Deer Cr.		y			completed	1	y	\$ 322,500.00	\$ 362,500.00	\$40,000	from 170		2000		
172	MD	I-95/I295 Interchange	Innovative Bridge Research & Construction Program - Smart Aggregate -	n	not submitted				n	\$ 315,000.00					2002		
173	MD	Innovative Bridge Research & Construction Program - Smart Aggregate - Phase II		y			completed	0	y	\$ 315,000.00	\$ 315,000.00				2002		
174	MD	MD 140 over MD 27, Maryland Midland Railway and West Branch		n	not submitted				n	\$ 400,000.00					2003		

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175	MD	Blacks Mill Road over Little Hunting Creek	Bridge Rehabilitation: replacement of the superstructure for the existing bridge	n	not submitted				n	\$ 87,000.00					2003		
176	MD	Subsituted Project : MD 335 over Wallace Creek contract # 1329(009)	FRP Deck Panel	n	not submitted				n	\$ 400,000.00					2004		
177	MD	Subsituted Project : US 1 over Octoraro Creek contract # 1231(034)	Coating/Paint	n					y	\$ -					2005	Combined with 178	US 1 Br #0700300 over Octoraro Creek
178	MD	US 1 Br #0700300 over Octoraro Creek Clean & Paint Bridge for Evaluation of Two Two-Coat Paint		n			completed	1	y	\$ 400,000.00	\$ 351,000.00				2006	Combined with 177	Clean & Paint Bridge for Evaluation of
179	ME	Municipal Pier in Millbridge	FRP Reinforced Glulam Deck Panels	y			completed	1	y	\$ 246,000.00	\$ 246,000.00				1999		
180	ME	Union-Washington Skidmore	FRP glulaminated deck system	y			completed	1	y	\$ 270,000.00	\$ 211,582.00				1999	linked with 190, "Union-Washington Skidmore/Medomak"	
181	ME	Winterport & Beaver Cove	FRP Bridge Drains	y			completed	1	n	\$ 18,000.00	\$ -				1999		
182	ME	New Meadows Bridge in Sagadahoc, ME	FRP-Timber Bridge Railroad Ties	y			completed	1	y	\$ 135,000.00	\$ 135,000.00				1999		Waldoboro
183	ME	Androscoggin River Bridge	FRP Bonded Reinf	n	not submitted				n						1999	No record of Project	
184	ME	Marston Bridge	FRP Deck Panel	n	not submitted				n						1999	No record of Project	
185	ME	Town of Cumberland	FRP Deck Panel	n	not submitted				n						1999	No record of Project	
186	ME	Fairfield	FRP Reinforced Glulaminated Beams with Integral Concrete Deck	y			completed	1	y	\$ 350,000.00	\$ 323,085.00				2000		
187	ME	State-wide, IBRC program (Rolin's Road)	Concrete Filled FRP Arch System	y			initiated	0	y	\$ 270,000.00	\$ 219,378.93				2001	Looking for demonstration project	
188	ME	State-wide, IBRC Program (Ricker's Bridge)	FRP Deck Panel	y			initiated	0	n	\$ 210,000.00	\$ 201,731.07				2001	Looking for demonstration project	
189	ME	Island Ave. over Penobscot River Overflow	FRP and High Performance Concrete	y			initiated	0	n	\$ 500,000.00	\$ 132,266.65				2002	looking for new candidate	
190	ME	Union-Washington Skidmore/Medomak	FRP glulaminated deck system	y			completed	1	y	\$ 32,000.00	\$ 21,581.99				2002	linked with 180, "Union-Washington Skidmore"	
191	ME	Neal Bridge, Pittsfield	FRP concrete filled arches	y			not started	0	n	\$ 400,000.00	\$ -				2003		FORMERLY Mill Pond Bridge
192	ME	Waldo-Hancock Bridge over Penobscot River	same project; substituted cable stay system for inert gas	y			completed	1	y	\$ 400,000.00	\$ 400,000.00				2004		
193	ME	New Mills Bridge	Light weight laser welded steel sandwich panels	n	not submitted				n						2005	No DOT response	
194	ME	Wando-Hancock Bridge, Tt. 1 over Penobscot River	FRP Cable Stay Strands	y			initiated	1	n	\$ 150,000.00	\$ 115,640.00				2005	report started; monitoring for 192	
195	ME	Milford St. Bridge Over Grand Lake Stream	Precast Super- and Sub- Structure	y			not started	0	n	\$ 250,000.00	\$ 250,000.00				2006		FORMERLY: Boom Birdge Bridge on Rt. 116 over Birch Stream
196	MI	I96 over I-69 BR (Lansing Rd)	FPR Bonded Reinforcement	y			completed	1	y	\$ 37,000.00	\$ 37,000.00				1999		
197	MI	City of Southfield Bridges	FRP Prestressing & Rebar	y			completed	1	y	\$ 700,000.00	\$ 700,000.00				1999		
198	MI	M-15 @ Over Gooding Creek	FRP Rebar in Deck Slab	y			completed	0	y	\$ 156,000.00	\$ 158,433.06				2000		
199	MI	M-15 @ Over Gooding Creek	FRP Rebar in Deck Slab	y					y	\$ 156,000.00	see 198				2000	SAME AS 198	
200	MI	EB I-496 over CSX RR and Holmes SD Rd. R12-4	Solid stainless steel rebar in deck (substituted for stainless-clad reinforcing	y			completed	0	y	\$ 270,000.00	\$ 270,000.00				2001	report due in Sept 2010	
201	MI	I-96 Ramp over Land 82123-S11-0	Column wrapping with FRP	y			completed	0	n	\$ 90,000.00	\$ 90,000.00				2003	flag for more info	
202	MI	I-94 over Shook road and C&O RR	MMFX rebar	y			completed	1	y	\$ 137,000.00	\$ 137,000.00				2003		
203	MI	M-50 Bridge over Grand River	Self Consolidated Concrete in Concrete Box Girders	y			completed	1	y	\$ 200,000.00	\$ 200,000.00				2004		
204	MI	M-43 Bridge over Sebewa Drain	Solid stainless steel rebar in deck (substituted for stainless-clad reinforcing	y			completed	0	y	\$ 58,000.00	\$ 58,000.00				2004	report due in Sept 2010	
205	MI	M-153 (Ford Road) under Greenfield	High Performance Concrete in Deck Slab	y			withdrawn	0	n	\$ 120,000.00	\$ -				2005		
206	MI	Custer Drive over the Kalamazoo River	Conductive concrete	y			withdrawn	0	n	\$ 200,000.00	\$ -				2006		
207	MI	I94EB & WB over Riverside Drive		y			initiated	1	y	\$ 400,000.00	\$ 400,000.00				2009		
208	MI	Parkview over US131		y			completed	1	y	\$ 80,000.00	\$ 80,000.00				2009		
209	MN	I94 and Glenwood Ave I35 at Maryland Ave	CP Anodes	y			completed	1	y	\$ 86,000.00	\$ 86,000.00				1999		

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210	MN	Innovative Bridge Research	Large Diameter high density pipe under shallow fill	y			completed	1	y	\$ 290,000.00	\$ 290,000.00				2000		
211	MN	I-35 over Miss.River & TH 62 over 1-35W	Prefabricated Fusion Bonded Epoxy Coated Rebars	y			not started	0	y	\$ 500,000.00	\$ -				2001	Merged with Lexington Project, see 212	
212	MN	Lexington Ave Bridge	Other - Deck Slab	y			completed	0	y	\$ 500,000.00	\$ 500,000.00				2001		
213	MN	Glen Road over TH61, City of Newport	High strength high performance steel girders	y			completed	0	y	\$ 500,000.00	\$ 500,000.00				2002		
214	MN	TH 610 from 0.6 Mi.W. Fernbrook Ln. to 0.1 Mi. W. 93rd Ave. in Maple Grove	Precast deck panels to speed construction	y			completed	0	y	\$ 400,000.00	\$ 400,000.00				2003		Stillwater Bridge
215	MN	TH 8 over Center Lake Channel, 0.8 miles east of Center City; TH 72 over Tamarac River near	Precast concrete inverted T beams for rapid construction	y			completed	1	y	\$ 400,000.00	\$ 400,000.00				2004		
216	MN	Diamond Lake Road over I-35W	Concrete mix for the deck modified to limit deck cracking	y			completed	1	y	\$ 200,000.00	\$ 200,000.00				2005		Associated with 211
217	MN	EB & WB SH23 over CP RR	Stainless Steel Deck Rienforcement	y			not started	0	n	\$ 300,000.00	\$ -				2009		
218	MO	Adelaid Ave over I70	HPC Deck	y			completed	2	y	\$ 650,000.00	\$ 650,000.00				1999		
219	MO	Route 291 over Route 150		y			completed	1	n	\$ 190,000.00	\$ 190,000.00				1999		
220	MO	Bridge 6059 in Grundy Co. (Rt. 6 0.8Mi to 0.2 MI W Sullivan City, Galt, MO)		y			completed	3	y	\$ 185,000.00	\$ 165,754.96				2000		
221	MO	RT 412 FRM RT B/Z to 2.3 mi. W	High Performance Concrete in Deck Slab and I-Beams	y			completed	2	y	\$ 45,000.00	\$ 45,000.00				2000		
222	MO	Rt 64 1.5M SW of Pomme De Terre Lk		y			completed	3	y	\$ 160,000.00	\$ 160,000.00				2000		Hickory Creek, Rt 59 at Neosho - Replace Bridge
223	MO	Route 224 over Route13	High Performance Steel in Plate Girders	y			completed	5	y	\$ 126,000.00	\$ 126,000.00				2001		
224	MO	RT 64 1.5M SW of Pomme De Terre Lk	Clad Stainless Steel Rebars in Deck Slab	y	duplicate of 222				n	\$ 160,000.00					2001		
225	MO	Route I-44		y			completed	1	y	\$ 118,000.00	\$ 118,000.00				2001		
226	MO	US Route 54 over Osage River		y	duplicate of 228				n	\$ 500,000.00					2002		Duplicate of A6358 over Osage River
227	MO	Southview Drive over Carter Creek	FRP Prestressing and Rebars	y			completed	1	y	\$ 60,000.00	\$ 60,000.00				2002		
228	MO	Bridge A6358, HPS, Route 54 over Osage River	HPS	y			completed	3	y	\$ 500,000.00	\$ 500,000.00				2002		
229	MO	Route 61/67 over Mattese Creek		y			completed	0	n	\$ 216,000.00	\$ 216,000.00				2003		
230	MO	X0596 Rte. C over Creek, P0962 Rte. B over Creek, T0530 Rte. M over Crooked Creek, Y0298 Rte. U		y			completed	3	y	\$ 250,000.00	\$ 250,000.00				2003		
231	MO	State Route T Bridge over Fiddle Creek		y			completed	0	y	\$ 35,000.00	\$ 35,000.00				2004	report is pending	
232	MO	Route Y, Boone-Callaway Counties	FRP Reinforcing in Deck Slab	y			completed	0	y	\$ 108,200.00	\$ 108,200.00				2004		US 69 Bridge over I-35
233	MO	Big Bend NB over I-44	Galvanic Cathodic Protection Applied Over Concrete Repairs	y			completed	1	y	\$ 25,000.00	\$ 25,000.00				2004		
234	MO	FR-148 Bridge over Pearson Creek	FRP Deck Panel	y			completed	4	y	\$ 32,000.00	\$ 32,000.00				2004		
235	MO	Rt. 150 over RR & Big Creek	High Performance Concrete in Deck Slab	y			initiated	0	n	\$ 225,000.00					2005	new location is being sought due to contractor	Route 71 over CST Old HwyY, Cass County
236	MO	Pat Daly Road over Arnault Branch	FRP Bonded Reinforcement in	y			initiated	0	n	\$ 190,000.00					2005		
237	MO	SB Interstate 255 over the Missouri River in St. Louis County and US 24 E over the Grand River in		y			completed	3	y	\$ 130,000.00	\$ 78,600.00				2006	\$51,400 reallocated to pile monitoring program	
238	MS	I-110 Back Bay Bridge	Zinc Based Coating- Corrosion Protection	n	not submitted				n	\$ 500,000.00					2000		
239	MS	Withdrawn - see remarks	Zinc Based Coating On Steel Girders	n	not submitted				n	\$ 130,000.00					2000		SR 26 over Red River Paint Zinga System
240	MT	US 2 over Middle Fork Flathead River Essex	Solid Stainless Steel Rebars	y			completed	4	y	\$ 459,000.00	\$ 459,000.00				2001		
241	MT	Three Structures on Secondary Rt. 243		y			completed	1	y	\$ 250,000.00	\$ 250,000.00				2002		
242	MT	I-15/I-90 over BNSF RR	High Performance Steel in Box Girders	y			initiated	0	y	\$ 362,000.00					2005		
243	NC	NC157 Durham Road over Eno River	HPS	y			completed	0	n						1999		
244	NC	US64 West-bound over Haw River	FRP Bonded Rienf	y					n						2000		

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245	NC	US17 Wilmington Bypass & I-40 Interchange	Coating/Metalizing	y			completed	0	n						2000		
246	NC	NBIS bridge 00630085, State Route (SR) 1814 over Little Lick Creek	FRP Bridge Deck (Martin Marrietta's DuraSpan System)	y			completed	1	y	\$ 375,000.00	\$ 375,000.00				2001		
247	NC	State Route 1178 over I-95, Town of Four Oaks, TIP: I-2704, 2-span cont. steel structure (6 beam)	MMFX reinforced concrete steel	y			completed	1	y	\$ 385,000.00	\$ 385,000.00				2002		
248	NC	Fast Clad Urethane Paint System on Three Bridges over US 64	Evaluation of Sherwin Williams Fast Clad Urethane Paint System on Three Bridges	y			completed	1	y	\$ 400,000.00	\$ 400,000.00				2003		
249	NC	Bridge 16 on State Route 1470 over Cartoogechaye Creek, TIP B-3485	Bridge Deck reinforced with GFRP bars	y			completed	1	y	\$ 230,000.00	\$ 203,893.00				2003		
250	NC	Bridge 28 on SR 1102 over I-77 (TIP: I-4411)	High Performance Steel Plate Girders (Hybrid 100/70W) (100 for flanges, 70 for	y			completed	1	n	\$ 400,000.00	\$ 400,000.00				2004		
251	NC	Bridge 80 on SR 1214 over Long Creek (TIP: B-3700)	HPC Deck Girder Bridge	y			completed	1	y	\$ 400,000.00	\$ 400,000.00				2004		
252	NC	Bridge 36 (B-4188) on SR 1523 over Smithwick Creek, South of Williamston	HPC Full-depth precast bridge deck panels (longitudinally postention)	y			completed	1	n	\$ 400,000.00	\$ 400,000.00				2005		
253	NC	Bridge 60 on US 70 Business over Trent River	Bridge Fender System (Piles with Hight Density Polyethylene Shell)	y			completed	0	n	\$ 200,000.00	\$ 200,000.00				2005		
254	NC	US 19 NBL over SR1781, Buncombe Co.; And US 25 over Ivy River, Madison Co. (I-26 over SR 1839)	Cargill's SafeLane Ice Prevention Overlay (Type III epoxy) System	y			completed	1	n	\$ 150,000.00					2005		
255	NC	Bridge 117 on SR 1118 over North Fork of New River (B-4012)	Use of Micropiles to support pier and abutment footings on shallow rock depth	y			initiated	1	y	\$ 150,000.00	\$ 150,000.00				2006		
256	NC	SR 1124 over Branch of Band Creek (B-3625)	HPC Prestress Precast concrete elements for accelerated bridge construction. 3	y			completed	0	y	\$ 200,000.00	\$ 200,000.00				2006		
257	NC	NC81 over Swannanoa River	ABC using precast deck unit system	y			completed	0	n	\$ 11,000.00	\$ 110,000.00				2009		
258	ND	I-94 from Oakes INT E to E Valley City	Stainless Steel Clad Reinforcing Bars	y			completed	1	y	\$ 42,466.00	\$ 42,466.00				2000		
259	ND	I-94 from Oakes INT E to E Valley City	Stainless Steel Clad Reinforcing Bars	y			completed	1	y	\$ 15,534.00	\$ 15,534.00				2000	suppliment to 258	
260	ND	Cass County 4 locations 17th Ave. & 13th Ave.	High Performance Concrete	y			completed	1	y	\$ 147,938.00	\$ 147,938.00				2002		
261	ND	I-29 over 17th Ave. S, Texas Turn & 9th Ave. S (3 Bridges)	High Performance Concrete	y			completed	1	y	\$ 119,171.00	\$ 119,171.00				2003		
262	NE	Omaha dodge St over I480	HPS	y			completed	4	y						1999		
263	NE	Skyline Dr. over hwy. 6 (Dodge Street)		y			completed	1	y	\$ 150,000.00	\$ 150,000.00				2001		
264	NE	168th Street over I-80		n	not submitted				n	\$ 500,000.00					2002		
265	NE	Nebraska Highway 68 over the BNSF Railroad in Ravenna		y			completed	1	y	\$ 400,049.00	\$ 400,049.00				2003		
266	NE	Pacific Bridge over I-680	High Performance Concrete in I-Girders	y			completed	0	y	\$ 300,000.00	\$ 300,000.00				2004	final report pending	
267	NE	262nd Street Bridge over I-80	High Performance Steel in Box Girders	y			completed	0	y	\$ 400,000.00	\$ 400,000.00				2004		
268	NE	Folded Stee Plate Bridge Technology	Folded Stee Plate Bridge Technology	y			initiated	0	y	\$ 550,000.00	\$ 181,789.21				2005		FORMERLY : Wagon Tongue Creek on Hw N-79
269	NE	Wagon Tongue Creek	High Performance Steel in I-Girders	n	not submitted				n						2005		
270	NH	I293 over Frontage Rd.	Galvanized Deck Reinforcing	y			completed	0	y	\$ 131,630.00	\$ 102,166.60	\$29,436			2002		
271	NH	I293 over Brown Rd.	Galvanized Deck Reinforcing	y			completed	0	y	\$ 287,000.00	\$ 152,168.49	\$134,832			2002		
272	NH	Rollins Road over Main Street and BMRR	FRP Rebar, HPC	y			completed	1	y	\$ 100,000.00	\$ 100,000.00				1999		
273	NH	Rollins Road over Main Street and B&M Railroad	FRP Rebar in Deck Slab and High Performance Concrete in I-Beams and	y			completed	1	y	\$ 300,000.00	\$ 300,000.00				2000	Supplement to 272	
274	NH	Rollins Rd. over Main St. and B&M Railroad	FRP Rebars in Deck and High Performance Concrete in Deck Slab and I Beams	y			completed	1	y	\$ 53,000.00	\$ 53,000.00				2001	Supplement to 272	
275	NH	Mill Street over the Lamprey River in Epping, NH	Approved as Solid Stainless Steel Deck Reinforcing, Changed to Galvanized Deck	y			completed	3	y	\$ 690,000.00	\$ 835,773.00	\$164,295	from 270, 271		2002		
276	NH	Mill Street over the Lamprey River in Epping, NH	Approved as Clad Stainless Steel Deck Reinforcing, Changed to Galvanized Deck	y					y	see 275		\$18,522	to 279		2002	Supplement to 275	
277	NH	Mill Street over Lamprey River	Accelerated bridge Construction - Completely Precast Bridge	y					y	see 275					2002	Supplement to 275	
278	NH	I93SB / BMRR	HPC, MMFX Rebars	n	not submitted				n						2002		
279	NH	Newbury Road Project	Accelerated bridge Construction - Completely Precast Bridge	y	not submitted				n	\$ -					2003	no record see 282 & 283	

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280	NH	NH Rte. 111 By-Pass over Flatrock Brook and Harris Road	High Performance Steel in Girder Flanges over the Piers	y			completed	1	y	\$ 300,000.00	\$ 300,000.00				2003		
281	NH	Mosquito Bridge US Rt.3 & NH Route 11 over Lake Winnisquam	Full Depth Precast Deck Panels used for Rapid Bridge Deck Replacement	y			completed	1	y	\$ 400,000.00	\$ 400,000.00				2004		
282	NH	Newbury Road over Connecticut River	Full Depth Precast HPC Deck Panels used for Rapid Bridge Deck Replacement	y			completed	1	y	\$ 600,000.00	\$ 618,522.00	\$18,522	from 276		2005		
283	NH	Newbury Road over the Connecticut River	Precast Full Depth HPC Deck Panels used in Rapid Bridge Deck Replacement	y					y	see 283					2006		
284	NJ	Scotch Road over I-95	High Performance Steel in Plate Girders	y			completed	0	y	\$ 500,000.00	\$ 490,000.00				2001		
285	NJ	Edison Bridge-Route U.S. 9 SB over Raritan River	High Performance Concrete in Deck Slab	y			completed	1	y	\$ 500,000.00	\$ 500,000.00				2001		
286	NJ	US RT. 46, NJ Rt.23 & Interstate 80	FRP/Stainless Steel Rebar	y			withdrawn	0	n	\$ 500,000.00	\$ -				2002		
287	NJ	US 46/NJ 23/I-80 Interchange	Reinforcing Bars	y			completed	0	n	\$ 400,000.00	\$ 400,000.00				2003		
288	NJ	Route I-280/Garden State Parkway Interchange 145	Self Consolidated Concrete in Drilled Shafts	y			completed	0	y	\$ 400,000.00	\$ 400,000.00				2005		formerly Alexander Road over Amtrak
289	NJ	Route 23 over Peckman's Brook	Hybrid (Hillman) Composite Beams	y			completed	0	y	\$ 200,000.00	\$ 200,000.00				2006		
290	NM	I-10 Bridges over University Ave.Main St.RR in Las Cruces NM (Dona Ana County)	High Performance Concrete	y			completed	4	y	\$ 500,000.00	\$ 500,000.00				2001		US 70 Roadrunner & Parkway Bridge
291	NM	Mountain Valley Road over I-40	HPC prestressed box girders and precast pier caps for rapid bridge construction.	y			completed	1	y	\$ 500,000.00	\$ 470,151.22				2002		
292	NM	NM 602 Bridge over Rio Nutria near Zuni NM	precast superstructure and substructure components.	y			completed	0	y	\$ 400,000.00	\$ 400,000.00				2003		I-40 over NM 371 @ Thoreau
293	NM	Dona Ana Interchange Bridge	High Performance Concrete in Bulb Tees (Utilize embedded MUST optical fiber	y			completed	4	n	\$ 400,000.00	\$ 400,000.00				2004		
294	NM	US 64 over the Amargo River in Dulce, NM	MMFX Rebars in Deck Slab	y			completed	0	y	\$ 65,000.00	\$ 65,000.00				2004		Gobernador Crossing
295	NM	I-25 South Bound at Rowe Interchange	High Performance Concrete in Superstructure	y			completed	0	y	\$ 200,000.00	\$ 200,000.00				2005		I-25 Frontage Road over Wolf Creek
296	NM	I-25 South Bound at Rowe Interchange	High Performance Concrete in Superstructure	y			completed	0	y	\$ 190,000.00	\$ 190,000.00				2005		NM 161 over Cebolla Creek
297	NM	I-40 Tucumcari/E. Interchange	Fiber Reinforced Polymer Deck Overlay	y			completed	1	y	\$ 120,000.00	\$ 120,000.00				2006		
298	NV	580-1(024) Galena Creek Bridge; I-580 NB/Galena	High Performance Concrete	y			initiated	0	n	\$ 500,000.00	\$ 187,000.00				2002		formerly 395 Carson City Freeway Phase 1B
299	NV	US 93 Colorado River Bridge at Hoover Dam		n	not submitted				n	\$ -					2003	HDR associated project, check with HDR offices	
300	NV	On SR 170, Bunkerville Road over Virgin River	High Performance Steel	y	not submitted				y	\$ -					2003		
301	NY	I95 over Midland Ave	Galvanizing, HPC, HPS	y			completed	0	y	\$ 600,000.00	\$ 600,000.00				1999		
302	NY	South Bend Street over Dyke Creek	FRP Deck	n	not submitted				n						1999		
303	NY	Everett Road Over I90 Route 2 over Hudson river, Route 20 over Route 85, Route 378 Over Wyantkill	FRP Bonded rinf, FRP Other	n	not submitted				n						1999		
304	NY	Route 9W over Conrail	FRP Bonded Reinf	n	not submitted				n						1999		
305	NY	Wood Road Over Cohocton River	FRP Deck Panel	n	not submitted				n						1999		
306	NY	Rt 418 over Schroon River (2)	FRP Deck Panel	n	not submitted				n						1999		
307	NY	NYS Thruway over Gravel Road	HPS	y			completed	0	y	\$ 93,000.00	\$ 93,000.00				1999		
308	NY	Co. Rd. 52 (Triphammer Road) / Conesus Lake Outlet	FRP box beams and FRP deck.	n	not submitted				n	\$ 220,000.00					2000		
309	NY	East Street Bridge	research on bracing requirements for HP steel	n	not submitted				n	\$ 95,000.00					2000		
310	NY	Red Spring run over Colonel Bill's Creek	FRP Deck PAnel	n	not submitted				n						2000		
311	NY	CR 50 (Park Ave) over Carl's River	FRP Deck Panel and High Performance Concrete	n	not submitted				n	\$ 500,000.00					2001		
312	NY	County Route 153 over White Creek	Either FRP deck, or composite concrete deck.	n	not submitted				n	\$ 177,100.00					2001		
313	NY	CR 46 (Osceola Rd) over East Branch Salmon Riv.	FRP deck (Martin Marietta Composites system)	n	not submitted				n	\$ 153,000.00					2001		
314	NY	Fitch Road Bridge over Twelve Mile Creek	FRP Glulam	y			withdrawn	0	n	\$ 282,000.00				\$ 282,000.00	2002		

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315	NYCR 38 (Railroad street) over North Branch Little Salmon Riv.	FRP deck slab (system by Martin Marietta Composites)	y			withdrawn	0	n	\$ 195,000.00				\$ 195,000.00	2002		
316	NYErie Canal Road over Independence	FRP composit deck (system by Martin Marietta Composites)	n	not submitted				n	\$ 255,000.00					2002		
317	NYAnnandale Rd over Staten Island Rapid Transit	Stainless clad reinf steel, with 4-yr corrosion monitoring program.	y			initiated	1	y	\$ 360,000.00	\$ 165,506.00				2003		
318	NYCR 32 (Glendale Rd.) over Roaring Brook	FRP deck (system by Martin Marietta Composites).	n	not submitted				n	\$ 227,000.00					2003		
319	NYCR 68 Bridge over Little White Creek	FRP Rebars in Deck Slab and Galvanizing of Steel I-Beams.	n	not submitted				n	\$ 153,700.00					2004		
320	NYBemus-Ellery Road Bridge over Bermus Creek	Accelerated Bridge Construction using Prefabrication.	n	not submitted				n	\$ 250,000.00					2004		
321	NYCounty Road 23	Geofoam and accelerated construction techniques.	n	not submitted				n	\$ 385,000.00					2005		
322	NYCR 78 over Little Stony Creek	Modular bridge units for Rapid Bridge Installation System for short span bridges.	n	not submitted				n	\$ 107,000.00					2005		
323	NY28th Creek Road over 28th Creek	HPC box beams; FRP prestressing tendons; and stainless steel rebars in	y			withdrawn	0	n	\$ 377,000.00				\$ 377,000.00	2005		
324	NYCR 30 (Cemetery Road) over Roaring Brook	FRP Rebar in Reinforced Slab.	y			withdrawn	0	n	\$ 100,000.00				\$ 100,000.00	2005		
325	NYCounty Route 55 over Deer River	FRP deck.	n	not submitted				n	\$ -					2006		
326	OHRoute 380 - 0032	FRP Bonded Reinforcement	n	not submitted				n						1999		
327	OHRoute 79 - 0955	FRP Prestressing	y			completed	1	y						1999	Associated with 328	
328	OHBridge No. SCI-23-0166, US Rte. No. 23, City of Portsmouth	FRP Prestressing	y			completed	1	y						1999	Associated with 327	
329	OHRoute 49-0103, Dayton	FRP Deck Panel	y			completed	3	y						1999		
330	OHStelzer Road, Columbus	High Performance Concrete	y			completed	1	y						1999		
331	OHRoute 22 - 2290	FRP Deck Panel, High Performance Concrete	n	not submitted				n						1999	no record of project	
332	OHRoute 705 - 04.255	FRP Other	n	not submitted				n						1999	no record of project	
333	OHSmith Road off of Route 128	FRP Deck Panel	n	not submitted				n						1999	no record of project	
334	OHTR-175 .05 MI. N of Sr -37	Composite FRP Deck Pannels	n	not submitted				n	\$ 326,842.00					2000	no record of project	
335	OHRegional Pooled Fund Study	FRP Composite Prestressing Strands	n	not submitted				n	\$ 123,158.00					2000	no record of project	
336	OHRoute 49-2002	FRP Deck Panel, FRP Prestressing, FRP Rebar,	y			completed	3	y	see 329					2000		
337	OHFAI-33-1309 Delmont Road over US33	High Performance Steel in Plate Girders	y			completed	1	y	\$ 377,574.00	\$ 377,574.00				2001		
338	OHOver-Height Collision Protection System of Sandwich Polymer Composites	Over-Height Collision Protection System of	y			completed	2	y	\$ 220,000.00	\$ 219,999.00				2002		
339	OHEight Mile Road	HPC pre-cast concrete slab members	y			see 340		n	\$ 400,000.00		\$400,000	to 340		2003		Prviously POR 88 1250 over Eagle Creek; Not a project - see other Eight Mile topic
340	OHEight Mile Road over Eight Mile Creek	FRP Beams	y			completed	1	y	\$ 400,000.00	\$ 695,602.16	\$400,000	from 339		2004		
341	OHCasebeer-Miller Rd.	FRP tub floor beams with composit concrete deck	y			completed	2	y	\$ 74,500.00		\$74,500	to 343		2004	Russell Road project cancelled - funds moved to Casebeer Miller Road	Russell_Rd_Bridge_over_Mill_Creek
342	OHCasebeer-Miller Rd/TR-114/SR-185	FRP Deck Panel	y			completed	2	y	\$ 241,000.00		\$241,000	to 343		2005	Walker Run canceled - funds moved to tasebeer Miller	Walker Bridge, Irish Run over Leith Run Raod
343	OHCasebeer-Miller Rd. over tributary of South Fork Gordon Creek	FRP Beam	y			completed	2	y	\$ 100,000.00	\$ 225,348.64	\$315,500	from 341, 342		2005		
344	OHFA-114-01.64 over stream	FRP Deck Panel	y			initiated	5	y	\$ 155,500.00	\$ 107,158.87				2005		
345	OHStever Road (CR153) over the Tiffin River	Goesynthetically Reinforced Soil abutments	y			completed	1	y	\$ 250,000.00	\$ 250,000.00				2006		
346	OKI-35 over Chickaskia River	Clad Stainless Steel Rebars in Deck Slab	y			completed	0	n	\$ 300,000.00	Not Reported				2001	The techonology changed to MMFX and Ipanex. No report was submitted	
347	OKI - 40 EB over I-44	Thin Bonded overlay	y			completed	1	y	\$ 366,103.00	\$ 10,002.67				2004		
348	OKSH-7 over Branch Creek	Sandwich Plate System	y			withdrawn	0	n	\$ 400,000.00	\$ 71,985.31				2005	Excessive cost - project not constructed	
349	OKI-40 Bridge over Business I-40 In Sayre	High Performance Concrete in Deck Slab	y			completed	1	y	\$ 225,000.00	\$ 229,079.64				2006		

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350	OKI-35 over Hickory River	Ipanex corrosion inhibitor	y			completed	0	y	\$ 70,000.00	\$ 17,924.97				2007		
351	OKSH-150 over Lake Eufaula	Surtreat Chemical placed on concrete to abate corrosion	y			initiated	1	y	\$ 150,000.00	\$ 15,299.34				2007		
352	ORSavie Island Bridge	Fiber Deck Panels	y	not submitted			2	y	\$ 54,000.00					2000		
353	ORState Hwy #105 MP4.78 & MP 6.89	FRP Deck Panel	y			completed	0	y	\$ 330,000.00	\$ 330,000.00				2000		
354	ORUS Highway 101 over Bethel Creek	Stainless Steel Clad Rebar	y			withdrawn		n	\$ 230,000.00					2001		
355	ORSylvan Bridge over Sunset Highway	High Performance Steel	y	not submitted			1	y	\$ 80,000.00					2002		
356	ORBlevins Bridge - Tangent Drive Calapooia River	Debris Deflection Device	y			completed	0	y	\$ 11,550.00	\$ 11,500.00				2002		
357	ORThe Broadway Bridge, NW Broadway over Williamette River	Fiber Deck Panels	y	not submitted			3	y	\$ 400,000.00					2003		
358	ORI-84 Irigon Junction - Hilgard Interchange	High Performance Steel in Plate Girders	y			completed	0	y	\$ 400,000.00	\$ 350,560.00				2004		
359	ORI-84 over Fifteenmile Creek		y			withdrawn		n	\$ -					2005		
360	ORI-84 over Mosier Creek	High Performance Steel in I-Girders	y			withdrawn		n	\$ -					2005		
361	ORI-84 over Herman Creek		y			withdrawn		n	\$ -					2005		
362	OROchoco Creek Bridge near Prineville	Accelerated Construction	y	not submitted		initiated	0	n	\$ -					2006		
363	OROxing Posetti Road, Br 07424, Hwy 009, MP 62.94, crossing the Kilchis River		y	not submitted				n						2006		
364	ORWilliamson River Hw422 and Bridge Creek, Hw41 R/W		y	not submitted		initiated	0	n						2009		
365	ORUS30 @ Mill Creek		y	not submitted		initiated	0	n						2009		
366	PAT-565 over Dunning Creek	FRP Deck Panel	y			completed	0	y	\$ 464,000.00	\$ 464,000.00				2000		
367	PAT-391 over Sideling Hill Creek	FRP Deck Panel	y			withdrawn	0	n	\$ -	\$ -				2000		
368	PASR 1037 over Dubois Creek	FRP Slab	y			completed	1	y	\$ 500,000.00	\$ 360,728.00				2001		
369	PASR 4012 over Slippery Rock Creek	FRP Deck	y			completed	1	y	\$ 120,000.00	\$ 119,763.00				2003	Revision of 373	
370	PADeck Replacements with Timber-Glulam Panels	Timber Glulam	y			withdrawn	0	n	\$ 455,000.00	\$ -			\$ 455,000.00	2001		
371	PASR 4034 over Wintergreen Gorge	High Performance Steel	y			completed	0	y	\$ 500,000.00	\$ 500,000.00				2002		
372	PASR 2024 over Towanda Creek (same technology)	Corrugated Web	y			completed	5	y	\$ 400,000.00	\$ 400,000.00				2003		
373	PASR 4012 over Slippery Rock Creek	FRP Deck	y			withdrawn	0	n	\$ 100,110.00	\$ -			\$ 100,110.00	2001	project revised to 369	
374	PASR 0885 Boulevard of the Allies over Forbes Ave.	High Performance Steel in I-Girders	y			completed	0	n	\$ 332,000.00	\$ 332,000.00				2004		
375	PATR -776 Bridge over English Run	FRP Deck Panel	y			completed	1	y	\$ 134,000.00	\$ 133,883.00				2004		
376	PA SR 8043 (California Ave) over SR 65 (Ohio River Blvd)	Coating/Paint	y			completed	1	y	\$ 185,300.00	\$ 185,284.00				2005		
377	PA SR 4012 over Shamokin Creek (same technology)	FRP Bonded Reinforcement in Deck Slab	y			completed	1	y	\$ 200,000.00	\$ 187,513.00				2005		
378	PA SR 15 over Johnson Creek and SR 2016	Epoxy Overlay Deicing System	y			completed	0	y	\$ 150,000.00	\$ 150,000.00				2005		
379	PABurd Run Road over Bird Run	Glulam Deck on Steel Girders	y			completed	1	y	\$ 400,000.00	\$ 400,000.00				2005		FORMERLY:SR 307 (Fogelsonger Road) over Burd Run
380	PASR 1003 over Tionesta Creek	Tubular Flange	y			completed	2	y	\$ 200,000.00	\$ 200,000.00				2006		
381	PR Bridges #2028 and #2029 on PR-52 over PR-1	FRP Bonded Reinforcement	y			completed	5	y	\$ 500,000.00	\$ 500,000.00				2001		FORMERLY:Bridge No. 2028 on Psdr-52 NB over PR-1
382	PR Bridge no. 206 on PR - 102 over Laguna Channel	Stainless steel in Deck	y			completed	0	n	\$ 84,000.00	\$ 84,000.00				2002		
383	PR PR-250 Bridge over Lobina Channel	ABC	y			withdrawn	0	n	\$ 400,000.00	\$ -			\$ 400,000.00	2003		
384	PR Bridge 281 at PR -139 (Km 2.5)	FRP Deck	y			completed	1	y	\$ 400,000.00	\$ 400,000.00				2004		

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385	PR	Bridge over Toita Creek		y			not started	0	n	\$ 100,000.00	\$ -				2005		
386	RI	Silver Spring Cove-US Route 1	FRP Bonded Reinforcement	n	not submitted		completed	1	n	\$ 400,000.00					2001		
387	RI	Eastbound I-95, Washington Bridge	Galvanic Anodes in bridge deck	y			completed	0	y	\$ 46,000.00	\$ 46,000.00				2001		
388	RI	Iway Contract 7, Arch Span	Strain Gauges & Load Cell Instrumentation	y			completed	1	y	\$ 320,000.00	\$ 320,000.00				2004	Report is noted but no electronic copy of report	Providence River Bridge
389	RI	Great Rd. Bridge 447	Seismic Roller Isolation Bearings	y			initiated	0	y	\$ 390,000.00	\$ 135,000.00				2005		formerly Garden Street over I 95
390	SC	SC RTE 73 Myrtle Beach	Solid Stainless Steel Rebar in Bridge Deck	y			completed	1	y	\$ 184,500.00	\$ 184,500.00				2000		
391	SC	S-42-655 over Norfolk/Southern RR	FRP Deck Panel	y			completed	1	y	\$ 369,000.00	\$ 369,000.00				2001		
392	SC	SC 171 over Wappoo Creek	FRP Pier Protection - Dolphins	y			completed	0	y	\$ 205,000.00	\$ 205,000.00				2002		
393	SC	US 29 over Thicketty Creek	HPS 70W Steel Girders	y			completed	1	y	\$ 405,000.00	\$ 418,698.00	\$13,698	from 394		2002		BR11 (006)
394	SC	SC Rte. S-54 over Tidal Creek	Various steel reinforcing steel technologies (MMFX, SS Clad, SS) in	y			completed	1	y	\$ 298,782.00	\$ 285,084.00	\$13,698	to 393		2003		
395	SC	US 76 over Lumber River and Swamp	SCC drilled shafts	y			completed	1	y	\$ 225,000.00					2003		
396	SC	SC 377 Bridge over Black River	Self Consolidated Concrete in I-Beams	y			completed	1	y	\$ 390,933.00	\$ 390,933.00				2004		
397	SC	US76 Lynches River Bridge	Prestressed Concrete Decked Bulb Tee Girders	y			initiated	0	n	\$ 400,000.00	\$ -				2005		
398	SC	US 378 over the Pee Dee River	Prestressed Precast Cylinder piles	y			completed	1	y	\$ 250,000.00	\$ 250,000.00				2006		
399	SC	Stare Raod SC31 over Waccamaw River Swamp		y			not started	0	n	\$ 300,000.00	\$ -				2009		
400	SD	Russell St over I-29, Maple Ave	Clad Stainless Steel Rebars in Deck Slab	y			initiated	0	n	\$ 160,000.00	\$ 160,000.00				2001		FORMERLY US281 Over BNSF RR in Aberdeen
401	SD	I-29 Madison Street Interchange	Stainless Steel Reinforcing	y			withdrawn	0	n	\$ 200,000.00	\$ -	\$200,000			2002		FORMERLY: Russell Ave.
402	SD	Madison Street over I-29; I-29 over RR	Stainless Steel Reinforcing	y			completed	0	n	\$ 330,000.00	\$ 330,000.00				2003		
403	SD	Tea Interchange	HPC in deck	y					n	\$ 96,000.00					2004		
404	SD	From the end of the concrete in Rapid City to the junction with Airport Road	Self Consolidated Concrete in Culvert	y			completed	0	n	\$ 150,000.00	\$ 150,000.00				2005		
405	TN	SR-53 over Martin Creek	High Performance Steel in Plate Girders	y			completed	2	y	\$ 42,800.00	\$ 42,800.00				2000		
406	TN	Massman Drive / I-40		y			completed	1	y	\$ 114,443.00	\$ 114,443.00				2003		
407	TX	RM 1061 at Draw Creek	FRP Rebar	y			completed	20	y	\$ 580,000.00	\$ 567,590.10				1999		
408	TX	On FM 3284 FR. 10M S. Drainage Ditch	FRP in Box Beams	y			completed	2	y	\$ 150,000.00	\$ 150,000.00				2000		
409	TX	Farm to Market Road 1362 over Sue Creek	FRP laminate sheet strengthening of existing parn form bridge	y			completed	1	y	\$ 95,000.00	\$ 95,000.00				2001		
410	TX	Texas State Hwy SH 66 OVER Lake Hubbard	High Performance Concrete - Utilize GGBFS in conjunction with Maturity	y			completed	1	y	\$ 300,000.00	\$ 300,000.00				2001		
411	TX	FM 3284 over Drainage Ditch Gregory Texas	FRP Deck Panel	y			completed	0	y	\$ 300,000.00	\$ 300,000.00				2002		
412	TX	Washington Street Under IH-40	MMFX Rebars	y			completed	0	y	\$ 85,071.00	\$ 85,071.00				2002		
413	TX	US 82 WB at Park Rd.18;Spur 327 Conn US 62	Embedded galvanic anode protection system	y			completed	0	y	\$ 95,000.00	\$ 95,000.00				2002		
414	TX	EB Loop 340 - SH6 Overpass (Mainlanes and Frontage Road over IH35	Prefabricated bridge construction system	y			completed	1	y	\$ 400,000.00	\$ 400,000.00				2003		
415	TX	FM 1684, Drainage Ditch Bridge	FRP beams and deck	y			completed	1	y	\$ 370,000.00	\$ 370,000.00				2003		
416	TX	IH35 NB & SB ML over Hill Road	Prefabricated bridge superstructure assemblies rolled into place	y			completed	0	y	\$ 400,000.00	\$ 400,000.00				2004		
417	TX	Live Oak Creek Bridge	Full depth precast deck panels and precast bent caps	y			completed	1	y	\$ 270,000.00	\$ 269,939.60				2004		
418	TX	Martin Branch Bridge, Wise County, County Road 419	SPS deck system	y			completed	2	y	\$ 400,000.00	\$ 370,310.36				2004		Eighteen Mile Creek Bridge carrying FM 1961
419	TX	All future pecast segmental concrete bridge construction	TxDOT Research Project: Corrosion Resistance of Grouted Post-Tensioning	y			initiated	1	y	\$ 150,000.00	\$ 150,000.00				2005		

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420	TX	FM 1660 over Cottonwood Creek	Replacement bridge with abutment steel sheet piling, H-piling bent foundation, & Anti-icing Pavement Overlay System	y			completed	0	y	\$ 300,000.00	\$ 300,000.00				2005		
421	TX	US 40 (Old Route 66) West Bound Overpass in Gray County		y			completed	2	y	\$ 117,576.00	\$ 117,576.00				2005		
422	TX	IH-35: SH 6 Interchange	Prefabricated concrete U-beams with portion of concrete deck cast onto the	y			completed	2	y	\$ 57,362.00	\$ -	\$0			2005		
423	TX	US 83 & SH 359 Interchange	Graffiti Proofer and concrete curing agent	y			completed	1	y	\$ 6,150.00	\$ 5,000.00			\$ 1,500.00	2005		Formerly Chacon Creek
424	TX	IH 35 at FM 2063 & at Crossover Rd.	Prefabricated concrete U-beams with portion of concrete deck cast onto the	y			completed	1	y	\$ 400,000.00	\$ 326,895.46			\$ 73,104.54	2005		
425	UT	I80 at State Street		y			unknown		n	\$ 156,000.00	\$ 66,858.00				1999		
426	UT	Route 89 MP 388 6 Cache CO	High Performance Concrete in Box Girders	n	not submitted				n	\$ 156,000.00					2000		
427	UT	East Bound State Rte 79 Grade Separation/Reeves Rd.	Clad Stainless Steel Rebars in Deck Slab	y			completed	0	y	\$ 68,500.00	\$ 78,320.77				2001		
428	UT	County Road over I-80 in Wanship, UT	Accelerated Bridge Construction - Precast deck panels	y			completed	0	n	\$ 459,000.00	\$ 492,671.61				2002		I-80 over UPRR near Lakepoint
429	UT	(unnammed record of funding)	Coating/Painting, HPC	n	not submitted				n						2002		
430	UT	I-215 NB over 3760 South Street at 3300 East Salt Lake City	ABC	y			completed	1	y	\$ 400,000.00	\$ 400,000.00				2003		
431	UT	US 6 Bridge over UPRR	High Performance Steel in I-Beams and MMFX Rebars in Deck Slab	y			completed	0	n	\$ 400,000.00	\$ 63,309.00				2004		
432	UT	F-54,F-156 and C846	Instrumentation of deck to evaluate long term performance.	y			initiated	0	n	\$ 250,000.00	\$ 165,122.00				2005	long term - funds available	
433	UT	I-84 Weber Canyon ABC	ABC - Precast bent caps, pre-cast post tensioned columns.	y			completed	0	y	\$ 200,000.00	\$ 200,000.00				2006		SR-105 (Parish Lane)over I-15 NB & SB
434	UT	I80 at Summit Park Crossing interchange		y			not started	0	n	\$ 300,000.00					2009		
435	VA	---	--	n	not submitted				n	\$ -					1999	three unnamed projects listed in original database supplied by FHWA	
436	VA	--	--	n	not submitted				n	\$ -					1999	three unnamed projects listed in original database supplied by FHWA	
437	VA		--	n	not submitted				n	\$ -					1999	three unnamed projects listed in original database supplied by FHWA	
438	VA	Route 40 over Nottoway River - 1999 IBRC # 2 - Composite Piles	Composite Piles	n	not submitted				n	\$ 150,000.00					1999		
439	VA	Route 11 over Maury River - IBRC # 6 - FRP Fibers with HPC	FRP Fibers used in High Performance Concrete	y			completed	1	y	\$ 85,000.00	\$ 85,000.00				1999		
440	VA	Relocated WBL Rt. 460 over Rt. 29 Bypass - 1999 IBRC # 1 - SSC Reinforcement	Stainless Steel Clad Reinforcement	y			completed	2	y	\$ 124,000.00	\$ 118,795.00				1999		
441	VA	Trouteville Weight Station Ramp - 1999 IBRC # 4 - FRP Panel	FRP Composite Deck Panels	y			completed	3	y	\$ 228,000.00	\$ 228,045.00				1999		
442	VA	Route 106 over Chickahominy River - IBRC # 5 - LW HPC	Lightweight High Performance Concrete used on AASHTO Girders	y			completed	1	y	\$ 155,000.00	\$ 155,000.00				1999		
443	VA	Route 250 over Tuckahoe Creek - 2000 IBRC # 2 - FRP Rebar	FRP Reinforcement, Corrosion Resistance, and Lightweight Construction	y			completed	7	y	\$ 32,997.00	\$ 32,997.00				2000		
444	VA	Route 601 over Dickey Creek, Sugar Grove - 2000 IBRC # 1 - FRP Beams	FRP Superstructure, Done with Maint. Forces, Lightweight Construction,	y			completed	1	y	\$ 558,150.00	\$ 550,327.00				2000		
445	VA	Route 123 @ Occoquan River - IBRC # 1 - Corrosion Resistent Reinforcement	Clad Stainless Steel Rebars in Deck Slab. MMFX2 Bars substituted for Clad	y			completed	4	y	\$ 228,580.00	\$ 228,580.00				2001	E & W George Washington Memorial Parkway over I-495	
446	VA	Route 668 over Gills Creek - 2002 IBRC # 1 - FRP Rebar	FRP (GFRP) Rebar	y			completed	7	y	\$ 250,000.00	\$ 237,736.00				2002		
447	VA	Route 33 over Pamunkey River - 2002 IBRC # 2 - HPC, SCC and Bulb Tee	High Performance Concrete, Self Consolidating Concrete, PCEF (Bulb Tees)	y			completed	1	y	\$ 300,000.00	\$ 300,000.00				2002	NB Lnaes I-81 over Route 11	
448	VA	Hawthorne Street over C&O (CSX) Railroad - 2003 IBRD # 1 - FRP Panels	FRP deck panels, strength and life prediction of FRP panels, panel to panel	y			completed	6	y	\$ 346,239.00	\$ 345,499.00				2003		
449	VA	Route 624 over Cat Point Creek - 2003 IBRC # 2 - UHPC for Bulb-Tee Girders	Ultra-High Performance Concrete for Prestressed Bulb-Tee Girders	y			completed	3	y	\$ 400,000.00					2003	associated with project VA Route 58 Buisness over Route 58 Bypass - 2003 IBRC #2	
450	VA	Rte. 33 over Pamunkey River - Lightweight High Performance Concrete Bulb-T Beams - 2003 IBRC #	Lightweight High Perf. Concr., New Precast shapes (PCEF), Low Permeability	y			completed	3	y	\$ 308,000.00	\$ 275,670.00				2003	associated with project Route 33 over Mattaponi River - 2003 IBRC #3	
451	VA	Rt.17 Bridge over Rt.15 and Rt. 29	High Performance Concrete in Deck Slab and Self Consolidated Concrete in Bulb	n	not submitted				n	\$ 400,000.00					2004		
452	VA	Route 58 over Cove Creek	Steel Sandwich Panel Deck System	n	not submitted				n	\$ 400,000.00					2004		
453	VA	Route 58 over Big Moccasin Creek (NBL) - IBRD # 3 - Grade 300 strands, High Performance 300ksi Prestressing Strand	Concrete, Bulb Tees	n	not submitted				n	\$ 400,000.00					2004		
454	VA	FRP Deck Panel Systems Island - 2005 IBRC # 1 - Tangier Island	FRP Deck Panels (Two systems)	n	not submitted				n	\$ 400,000.00					2005		

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455	VA	Route 16 over Fox Creek - 2005 IBRC # 2 - (Full Depth Prestressed High Performance Concrete	Full Depth Prestressed Precast High Performance Concrete Deck Slab, HP	n	not submitted				n	\$ 400,000.00					2005		
456	VA	Route 28 over Broad Run - 2005 IBRC # 3 - SC concrete in Drilled Shaft	Use of Self Consolidating Concrete (High Performance Concrete) in Drilled Shaft	n	not submitted				n	\$ 350,000.00					2005		
457	VA	Nimmo Parkway over West Neck Creek - 2006 IBRD # 1 - SCC in Super and Substructure	Self Consolidated Concrete in Superstructure and Substructure	n	not submitted				n	\$ 200,000.00					2006		
458	VA	Bridge on Route 712 over Route 29		n	not submitted				n						2009		
459	VT	Bridge 213 carrying VT Rte 100 over Ryder Brook	FRP Rebars and High Performance Concrete in Deck Slab	y			completed	7	y	\$ 260,000.00	\$ 259,999.97				2001		
460	VT	VT Bridge 64, VT 105 over Clyde River	MMFX Rebars	y			completed	1	y	\$ 153,000.00	\$ 152,519.63				2002		
461	VT	Moretown Bridge, Lovers Lane over Mad River	FRP Deck (to reduce dead load for historic truss)	y			not started	0	n	\$ 150,000.00	\$ -				2003		
462	VT	Bridge #8 FAS 0166 over White River	High Performance Steel in I-Girders	y			completed	0	y	\$ 168,000.00	\$ 106,519.05				2004		
463	VT	Route 50 over Ottauquechee River	Accelerated Bridge Construction with precast deck elements	y			completed	0	y	\$ 200,000.00	\$ 200,000.00				2005		
464	VT	Bridge 2, Readsboro	Accelerated Bridge Construction with precast box culvert, wings, and headwall	y			completed	0	y	\$ 200,000.00	\$ 200,000.00				2005		
465	WA	SR 20, Twisp River Bridge	High performace concrete in pre-tensioned and post-tensioned girders	y			completed	1	y	\$ 975,000.00	\$ 975,000.00				1999		
466	WA	US Route 2 - Barclay Creek Bridge	High Performance Steel in Plate Girders	y			completed	0	y	\$ 700,000.00	\$ 700,000.00				2000		
467	WA	Chief Joseph Dam Br. - Pearl Rd. over Foster Creek	FRP Deck Panels	y			completed	1	y	\$ 500,000.00	\$ 500,000.00				2001		
468	WA	Ever's Bridge - Shelton-Matlock Rd over Decker Creek	FRP Bonded Reinforcement	y			completed	1	y	\$ 425,000.00	\$ 425,000.00				2001		
469	WA	Monroe Street Bridge over Spokane River	Precast deck panels with a thin, reinforced high performance concrete	y			completed	1	y	\$ 268,000.00	\$ 268,000.00				2002		
470	WA	Granite Falls Bridge #102 over the South Fork of the Stillaguamish River	FRP Deck Panels	y			completed	0	y	\$ 400,000.00	\$ 115,454.00				2003		
471	WA	William Bugge Bridge, SR 104 across the Hood Canal	High performance steel in truss pipe members	y			completed	1	y	\$ 300,000.00	\$ 300,000.00				2003		
472	WA	William Bugge Bridge, SR 104 over Hood Canal	Rapid move of new 605-ft long precast concrete superstructure in high seismic	y			completed	1	y	\$ 400,000.00	\$ 400,000.00				2004		
473	WA	SR 20, Fredonia Shaft Test	Self Consolidated Concrete in Piles	y			completed	0	y	\$ 400,000.00	\$ 684,546.00				2005		
474	WA	Congestion Reduction in the Lake Washington Corridor - SR 520 Bridge Replacement and	Design of Toll System and Active Traffic Management Techniques to Rapidly	y			completed	0	y	\$ 5,100,000.00	\$ 8,050.00				2007		
475	WA	US12 over Tieton River		n			completed		y						2009		
476	WI	STI 131 Winchel Valley Land Br. Rockton	HPC	n	not submitted				n	\$ 450,000.00					2000		
477	WI	SHT131 New Land Bridge B-62-187	HPS	n	not submitted				n	\$ 250,000.00					2000		
478	WI	STH 172 USH 41, IH43 Ashland Ave. Bridge	Clad Stainless Steel Rebars in Deck Slab	n	not submitted				n	\$ 120,000.00					2000		
479	WI	Highway 151 over State Highway 26	FRP Deck Panel	y			completed	1	y	\$ 499,336.00	\$ 499,366.00				2001		
480	WI	US Highway 151 over De Neveu Creek	FRP grid reinforced concrete deck	y			completed	3	y	\$ 499,085.00	\$ 499,085.00				2002		
481	WI	IH 39/94 over Door Crk.	Precast full width deck pannel	y			completed	2	y	\$ 400,000.00	\$ 400,000.00				2003		
482	WI	North Bound off ramp from North Bount I-43 to Tory Hill of the Marquette Interchange	Solid Stainless Steel Rebars	n	not submitted				n	\$ 400,000.00					2004		
483	WI	USH 12, Coffee Cr Crossing	FRP Deck Panel/ struted tied deck arch	y			completed	1	y	\$ 400,000.00	\$ 256,016.51				2005		
484	WI	USH 063 USH 63 over Rush River	Accelerateed bridge construction.	y			completed	1	y	\$ 400,000.00	\$ 400,000.00				2005		
485	WV	Market Street Bridge	FRP Deck Panel	y			completed	1	y	\$ 3,531,889.00	\$ 3,531,889.00				1999		
486	WV	East Street Viaduct carries CSX RR over WV Alt 14A	FRP Bonded Reinforcement	y			completed	0	y						1999		
487	WV	Hanover Bridge	FRP Deck Panel	n	not submitted				n						1999		
488	WV	Katy Truss carrying WV 250 / 11	FRP Deck Panel	n	not submitted				n						1999		
489	WV	Veterans Hospital; County Road 98	FRP Bonded Reinforcement	n	not submitted				n						1999		

Report Form Tracking

record #	Completed Contact Report Forms		Technology	Delivered by State (y/n)	Expected Delivery Date		Project Status @ Time of Report	No. of External Papers	Summary Sheet recomd.?	FHWA Funds Allotted	FHWA Funds Used at Time of Report	Redistributed	to/from	Returned	Award Year	COMMENTS	NAME HISTORY
490	WV	Big Arch Bridge		n	not submitted				n	\$ -					2000	no record of project	
491	WV	CO39 Wesr Buckeye Br./Dunkard CR.09.mi E WV7		n	not submitted				n	\$ 25,000.00					2000		
492	WV	CO39 Wesr Buckeye Br./Dunkard CR.09.mi E WV7		n	not submitted				n	\$ 410,000.00					2000		
493	WV	Howells Mill Bridge CR 1 over Mud River	FRP Deck Panel	y			completed	0	y	\$ 475,000.00	\$ 475,000.00				2001		
494	WV	Big Arch Bridge	FRP Bonded Reinforcement	n	not submitted				n	\$ 11,000.00					2001	no record of project	
495	WV	Cedar Creek Truss on CR 119/13	Steel clad deck reinforcement and high performance steel girders.	n	not submitted				n	\$ 500,000.00					2002		
496	WV	Bigley Ave. Interchange Charleston, WV	Very early strength latex modified concrete overlay patching for accelerated	y			completed	0	y	\$ 357,000.00	\$ 244,500.00	\$ 112,500.00	to 501		2002		
497	WV	Powell Branch Bridge		n	not submitted				n	\$ -					2003	no record of project	
498	WV	Culloden Railroad Overpass Bridge	Use of hybrid steel girders (100 W, 70 W, and 50 W).	y			completed	0	y	\$ 400,000.00	\$ 400,000.00				2003		
499	WV	Honey Creek Bridge	High Performance Concrete in Deck Slab, High Performance Steel in I-Girders, and	y			completed	0	n	\$ 400,000.00	\$ 400,000.00				2005		
500	WV	Stalnakar Run Bridge County Route 219/86 (MP 3.18) over Stalnakar Run	Self-consolidating concrete.	y			completed	1	y	\$ 250,000.00					2006		
501	WV	Man Bridge in Logan Co	Use of a polmer deck sealant for penetrating cracked bridge decks.	y			completed	1	y	\$ 112,500.00	\$ 112,500.00	\$112,500	from 496		2007		
502	WY	Statewide Sign Structures	Other - Sign Structures	y			completed	1	y		\$ 42,000.00				1999		
503	WY	Ranch_Rd_Interchange_over_I25	High Performance Steel	y			completed	0	y	\$ 49,000.00	\$ 49,000.00				2002		

Total # of Projects:	504

submitted	reports expected	not received	reports in limbo
393	0	111	0

Statistics:			
Percent submitted	78.0%		
Percent not expected to receive	22.0%	Summary Sheet Reccomended:	284
Percent in Limbo	0.0%	% submitted reccommended:	72.3%
total	100.0%	% of 300	95%

Technology Categorization and Summary Sheet Completion Tracking

Summary Sheet Tracking						Status		Award	COMMENTS
	Completed Contact Report Forms		Technology	Category	Sub-Category	(initiated / needs input / complete)	year		
1	AK	Kodiak HRBR CHNNL# 1189	Seismic bearing monitoring	Monitoring	Displacement	complete		2000	Associated with projects 5, 9, and 10 Similar Project under same researcher as 10 (AL-97)
2	AK	Statewide Sesimic Retrofit	Seismic bearings	Other	Bearings	complete		2000	
3	AK	Parks Highway at Sustina River, MP 69.3	Polyester Concrete Overlay	Deck Coatings	Polyester	complete		2006	
4	AL	SR 81 over Uphabee Creek	FRP Bonded Reinforcement to Concrete Tee Girders	FRP	Wraps	complete		2000	
5	AL	Surles Road Bridge over Bedsole Creek	Timber/FRP Glulam	FRP	Timber Strengthening	not recommended		2000	
6	AL	Suppliment to Surles Road/Bedsole Creek	FRP Glulam	FRP	Timber Strengthening	not recommended	See 5	2000	Supplement to prject 5
7	AL	County Rte. 409 over Short Creek	HPC Prestressed Girders	HPC	Girders	complete		2001	Supplement to prject 7
8	AL	Marshall County Rt. 409 over Short Creek	High Performance Concrete	HPC	Girders	complete	See 7	2001	
9	AL	Repair of Girder Ends on I-565 Str # 015821, Huntsville, AL	FRP Bonded Repair to Prestressed Concrete Girder Ends	FRP	Wraps	not recommended		2003	
10	AL	AL -97 Bridge over I-65 near City of Letohatchie	FRP Bonded Reinforcement in Concrete T-Beams	FRP	Wraps	complete		2004	
11	AL	B.B. Comer Southbound Bridge U.S. 431 over Tennessee River	Self Consolidated Concrete in Drilled Shafts	SCC	(none)	complete		2005	
12	AL	Wald Park Pedestrian Crossover of US31 near MP 268 & near Intersection of Merryvale Rd, 2mi	Thoermosetting Composite Plastic	FRP		not recommended		2006	Remaining \$80,000 for monitoring
13	AR	State Hwy. 245 Bridge over Interstate 30 (Texarkana)	High Performance Concrete in Bridge Rails and Deck Slab	HPC	Decks	complete		2004	
14	AR	State Hwy. 49 over I-40 (Brinkley)	High Performance Steel in I-Girders	HPS	Beams/Girders	complete		2005	
15	AZ	I-40 Sunshine BNSFRR OP WB, MP 237.10	High Performance Concrete, Low Corrosion Steel in Deck Slab	HPC	Decks	complete		2004	
16	AZ	Virgin River Gorge Structure #7 Interstate 15, @ MP 22.55 Crossing Virgin River	Innovative construction phasing and erection techniques used to maintain full	Other	Construction Technique	complete		2006	
17	CA	I-5 Gilman Advanced Technology Bridge, UCSD Campus	FRP Deck Panels	FRP	Decks	no report		1999	Technology not reported
18	CA	I-5 Bridges in Los Angelos	HPC	HPC		no report		1999	
19	CA	(unnammed record of funding)				no report		2000	
20	CA	Gilman Dr. O/C 0.5 M No of LA Jolla Village D	FRP Deck Panel	FRP	Decks	no report		2000	
21	CA	02-SHA-36-7.57	Other - "Smart Power Pebbles"	Other		no report		2000	
22	CA	Gilman Rd./I-5 UCSD Campus	FRP Deck Panel	FRP	Decks	no report		2001	Technology not reported
23	CA	Rte. 36 post 7.57				no report		2001	
24	CA	White's Hill Viaduct Sir Frances Drake Blvd.	High Performance Steel in Plate Girders	HPS	Beams/Girders	no report		2001	
25	CA	Dorman Dr./Garrard Blvd. Tunnel	FRP Deck Panel	FRP	Decks	no report		2002	
26	CA	Danley/Fairview Rd. over Glenn Colusa	High Performance Steel in Box Girders	HPS	Beams/Girders	no report		2002	
27	CA	Gilman Road over I-5; Advanced Technology Bridge	FRP Deck Panel	FRP	Decks	no report		2003	Technology not reported
28	CA	Tower Bridge over Sacramento River	FRP Deck Panel	FRP	Decks	no report		2004	
29	CA	US 395 over LA aqueduct	FRP Deck Panel	FRP	Decks	no report		2005	
30	CA	Del Amo Avenue Bridge	FRP Deck Panel	FRP	Decks	no report		2005	
31	CA	Bridge No. 17-0072L/Indian Springs Under Crossing, I-80, Nevada County Mile Post 62.15				no report		2006	
32	CA	Uvas Creek Bridge, Rte. 152				no report		2006	Technology not reported
33	CA	Bridge No 19-0123L / Indian Springs Undercrossing, I-80				no report		2009	Technology not reported
34	CA	Slide Canyon Bridge, SR2				no report		2009	Technology not reported
35	CO	I-225 & Parker Rd. Phase III	Carbon FRP prestress deck panels and glass fiber reinforcement. Further development		Decks	complete		2000	Cancelled; No record of Project
36	CO	(unnammed record of funding)				no report		2000	
37	CO	Denver Parks O'Fallon Park Bridge over Bear Creek	FRP Deck Panel and Glass fiber reinforcement	FRP	Decks	complete		2001	
									Formerly: O'fallon Prak Bridge Similar projec to I-255 & Parker Rd.

Summary Sheet Tracking						Status		Award	COMMENTS
Completed Contact Report Forms			Technology	Category	Sub-Category	(initiated / needs input / complete)	year		
38	CO	Castlewood Canyon Bridge, SH 83 over Cherry Creek	Demonstration of CFRP wrap repair and accelerated construction for historic arch	FRP	Wraps	complete		2003	
39	CO	I-25NB over Purgatoire River I-25; I-25 NB over Main Street;	High Performance Concrete in Abutments, Deck Slab and Pier Columns	SCC	(none)	complete		2004	Also known as the "Trinidad Project" Associated with project 40
40	CO	I-25 over Great Western RR	Utilizing SCC in an abutment bridge repair for 2 bridges	SCC	(none)	complete		2004	remaining funds expired; see Trinidad Report Associated with project 39
41	CO	SH 52 over Vrain Creek	Rapid construction technique	ABC	Other	not recommended		2006	Formerly: SH 52 over Boulder Creek
42	CO	Pedestrian Underpass on SH7 (Arapahoe Ave) @ Bear Canyon Creek. SH7 Mp 53.5 Just east of	Demonstrated Xypex admixture to seal concrete	Coatings & Corrosion	Xypex	not recommended		2006	Manufacturer is being sued by Boulder County
43	CT	East Lyme:SR449 over I-95	CP Anodes in Deck Slab	Coatings & Corrosion	CP anodes	no report		2000	
44	CT	New Haven: Church St. ext. Hwy. Bridge over RR	High Performance Concrete in Deck Slab, High Performance Steel in Truss Chords and	HPC	Decks	no report		2000	
45	CT	Rte.34/the Housatonic River (Lake Zoar)				no report		2001	Technology not reported
46	CT	US RT. 1 over Housatonic River	FRP Deck Panel	FRP	Decks	no report		2002	
47	CT	SR 598 EB over SR 598 WB & Conn. Southern RR				no report		2003	Technology not reported
48	CT	Rt. 151 Bridge over Salmon River (State Project 40-128)	High Performance Steel in Plate Girders	HPS	Beams/Girders	no report		2004	
49	CT	Pearl Harbor Memorial Bridge	High Performance Concrete in Box Girders	HPS	Beams/Girders	no report		2005	
50	DC	Rehabilitation of Jefferson St. Bridge, 29th St. Bridge	FRP Bridge Deck	FRP	Decks	not recommended		2004	No information provided by DOT
51	DE	Linked with Award for 1-680	HPC beams, deck and piles	HPC	Decks	no report		1999	duplicate of 8F
52	DE	Bridge 2-008F	High Performance Steel Beams	HPC	Girders	complete		1999	Formerly: Bridge I-680
53	DE	BR 119 on SR 82 over Red Clay Creek	HPC deck, MMFX Rebar and CFRP reinforcing strips on steel beams	Reinforcing Bars	MMFX	complete		2000	MMXF substituted for Stainless
54	DE	BR 712B, Ramp J, I95 Service Area, Newark	MMFX rebar	Reinforcing Bars	MMFX	complete		2001	
55	DE	BR 26 on Faulk Rd Over Naaman's Creek	CFRP reinforcement in precast concrete beams	FRP	Wraps	complete		2001	Split off of 1-712B project
56	DE	US 113 Bridge over the St. Jones	Lithium Treatment for ASR	Coatings & Corrosion	Lithium ASR	no report		2001	
57	DE	Churchman's Road over I-95	High Performance Steel	HPS	Beams/Girders	complete		2002	Funds were reallocated but were never transferred to Smiths' Bridge; all funds used for this project
58	DE	Indian River Inlet Bridge on SR 1 over Indian River Inlet	High Performance Concrete in Arch and Pier Caps and Construction Monitoring	HPC	Other	not recommended		2004	Project reported as cancelled; No information provided by DOT
59	DE	Indian River Inlet Bridge (extension)	Monitoring of Construction Loads on the Tied Arch	Monitoring		not recommended		2005	see project 58
60	DE	Indian River Inlet Bridge (extension)	Monitoring of Construction Loads for Approach Embankments	Monitoring		not recommended		2006	see project 58
61	FL	Jensen Beach Causeway - Stainless	Clad Stainless Steel Rebars in footers & columns	Reinforcing Bars	Stainless	complete		2000	Formerly: SR 679 over Burnces, Technology moved to Jensen Causeway combined project
62	FL	Jensen Beach Causeway - MMFX	MMFX Rebars in deck slab	Reinforcing Bars	MMFX	complete		2001	Formerly: US1/Key Deer N. Channel, Technology moved to Jensen Causeway combined project
63	FL	University Blvd. Bridge over Arlington River	FRP Bonded Reinforcement	Reinforcing Bars	FRP	complete		2002	
64	FL	Key Royale Drive Bridge over Bimini Bay	High Performance Concrete in Piles	Foundations	Fender System	complete		2004	
65	FL	Hillsboro Canal Bridge - FRP	FRP Deck Panel	FRP	Decks	complete		2005	reports are ongoing
66	FL	Hillsboro Canal Bridge - Monitoring	FRP Deck Panel	Monitoring		not recommended		2006	reports are ongoing
67	GA	I-75 @ SR 37/Adel (FM 1500 ft West to 650 ft East I-75), Rowa, Peng	High Performance Steel in Plate Girders	HPS	Beams/Girders	complete		2000	
68	GA	CR 289-Bearden Rd @ Jacks Creek NW of Good Hope, Bridges	FRP Rebar in Concrete T-Beams	Reinforcing Bars	FRP	not recommended		2000	
69	GA	SR 92 over Noonday Creek Bridge Rehabilitation	FRP project	FRP	Conc Strengthening	complete		2000	
70	GA	SR 337/GA SW RR	FRP Bonded Reinforcement	FRP	Wraps	not recommended		2001	
71	GA	SR 282 Bridge Replacement over Tails Creek West of Ellijay	Clad Stainless Steel Rebars	Reinforcing Bars	Stainless	not recommended		2002	
72	GA	I-85 @ SR 34 Ramp Reconstruction Southeast Quadrant	Lightweight High Performance Concerete in I-Girders	HPC	Girders	complete		2005	
73	HI	Route 19 / Kealakaha Stream Bridge	Fiber optic instrumentation for seismic, dynamic loads	Monitoring	Fiber Optics	not recommended		2000	
74	HI	Salt Lake Blvd. Bridge over Halawa Stream	FRP shear strengthening of prestressed girders	FRP	Conc Strengthening	complete		2003	

Summary Sheet Tracking						Status		Award	COMMENTS
Completed Contact Report Forms			Technology	Category	Sub-Category	(initiated / needs input / complete)		year	
75	HI	North Kahana Stream Bridge	Self Consolidated Concrete in Drilled Shafts	SCC	(none)	complete		2004	
76	HI	Honolua Stream Bridge	FRP Deck Panel	FRP	Decks	not recommended		2005	2-4-10 progress report
77	HI	Kahoma Stream Bridge on Lahaina ByPass	SHM using Smart Sensor Technology	Monitoring	Smart sensors	complete		2009	application of gages summer 2010
78	IA	53rd Ave. over Crow Creek Bettendorf	FRP	FRP	Decks	complete		1999	Combined with Project 84 (same project)
79	IA	Section 13-96N-R5W over Bridge Yellow River	HPC	HPC	Overlay	not recommended		1999	
80	IA	4th Ave. over Ralston Creek	FRP Deck Panels	FRP	Decks	complete		2000	Results combined with project 89
81	IA	Rt 141 over Willow Cr.	FRP Prestressing	FRP	Steel Strengthening	complete		2000	
82	IA	US 20/South Beaver Creek Proj. NHSX-520-5(78)	MMFX Rebars in Deck Slab	Reinforcing Bars	MMFX	complete		2001	
83	IA	215 Avenue Bridge over Lime Creek	FRP Glulam	FRP	Timber Strengthening	complete		2001	
84	IA	53rd Ave. Bridge over Crow Creek	FRP Deck Panels	FRP	Decks	not recommended		2001	Supplement to Project 78 (same project)
85	IA	East 12th Street over I-235	HPS	Monitoring	Fiber Optics	complete		2002	
86	IA	Hwy. E64 over Small Creek East of US 63	Steel-free concrete bridge deck	FRP	Decks	complete		2002	
87	IA	I-A-92 over Walnut Creek	FRP strengthening of steel girders	FRP	Steel Strengthening	complete		2002	
88	IA	100th Avenue over Little Soap Creek, Keokuk Township	UHPC	HPC	Girders	complete		2003	
89	IA	Iowa 24 over Goddard Creek	FRP deck slab	FRP	Decks	complete		2003	
90	IA	Boone County Bridge (ID 85-25-031) 120th street over Squaw Creek	High Performance Concrete in Deck Slab, acclecrated construction techniques	HPC	Decks	complete		2004	
91	IA	Madison County Bridge (14B-551-100) 290th street over unnamed creek	High Performance Concrete Box beams using accelerated construction techniques	HPC	Girders	complete		2004	
92	IA	24th St. over I-80/I-29 Council Bluffs	High Performance Concrete precast Deck Slabs using accelerated construction	HPC	Decks	complete		2005	
93	IA	136th ave over Buffalo Creek	UHPC PI girder bridge	HPC	Girders	complete		2005	
93a	IA	136th ave over Buffalo Creek (supplement)	UHPC PI girder bridge	HPC	Girders	complete	see 93	2007	supplement to Project 93
94	IA	County Bridge ID 86 on local road between Sections 23/26 Providence Township (Sec. 23/26	Accelerated construction using precast elements	HPC	Girders	not recommended		2006	
95	IA	US6 and IA192 over UP&CC RR, streets, & Perry Cr. Conduit	Post-grouted drilled shafts, light weight concrete fill	Other		not recommended		2009	Very little information provided by DOT
96	ID	SR 21over Mores Creek @New York Gulch	MMFX Rebar	Reinforcing Bars	MMFX	complete		2001	
97	ID	Westmond Bridge;US 95 over BSFRR	MMFX Rebar	Reinforcing Bars	MMFX	complete		2003	
98	ID	Sunnyside Road (I-15B) Interchange over I-15	High Performance Steel Girders	HPS	Beams/Girders	complete		2003	
99	ID	I-15 Bridge over Center Street IC	Polyester Concrete Overlay	Deck Coatings	Polyester	complete		2005	
100	ID	State Hwy. 200 over Mosquito Creek	SafeLane	Deck Coatings	Overlay (Deicing)	complete		2006	
101	ID	SH200 over Trestle Creek	Accelerated construction all precast bridge components	ABC	Precast	not recommended		2009	
102	IL	I-39 over Kishwaukee River	FRP Bonded Reinf. Changed to Health Monitoring System (HMS)	Monitoring	Displacement	complete		1999	
103	IL	I-55/ I-70 Poplar Street Complex	HPS	HPS	Beams/Girders	complete		1999	Associated with Project 116
104	IL	Wacker Dr. Viaduct	HPC	HPC	Decks	complete		1999	
105	IL	Quincy 18th Street over Ceda Creek	Galvanized Rebar and Structural Steel	Reinforcing Bars	Galvanized	complete		1999	
106	IL	Jacksonville, S Fayette Street over Town Brook	FRP Deck	FRP	Decks	complete		1999	
107	IL	Adeline Rd, Freeport Rd, Eagle Pt. Road	HPC Deck Slab Overlays	HPC	Overlay	not recommended		1999	
108	IL	170 FR 2.5 M E 115/70 To Bond Co. Line	HPC Deck	HPC	Decks	complete		2000	Associated with Project 115
109	IL	US -51 from 0.6 mile north of Macon to Shelby	HPC Deck	HPC	Decks	complete	see 110	2000	Associated with 110, Report combined with 110
110	IL	IL 104 over Brush Cr..3 E. of Kincaid & E of I-55	HPC Deck	HPC	Decks	complete		2000	Associated with 109, 111

Summary Sheet Tracking			Technology	Category	Sub-Category	Status		Award year	COMMENTS
Completed Contact Report Forms						(initiated / needs input / complete)			
111	IL	IL 54 OV Spring Creek 1.5 MN Thawville Bridge	HPC Deck	HPC	Decks	complete	see 110	2000	Associated with 110, Report combined with 110
112	IL	I474 FR 174 to Illinois River	Mettallizing Concrete Beam Ends	Coatings & Corrosion	Metalizing	complete		2000	FORMERLY: 1474 FR 174 to Illinois River
113	IL	7 bridges	HPC Deck Slab	HPC	Decks	no report	compilation of projects	2000	See other projects as this appears to be a placeholder recongnizing several projects are similar
114	IL	City of Chicago Wacker Dr. to Franklin St.	HPC	HPC	Decks	complete	see 104	2001	See project 104 - combined with Whacker Dr. Viaduct
115	IL	Corenzo Rd. over I55;I-80 Kean Ave.	HPC Deck	HPC	Decks	not recommended		2002	Should be combined with 170 FR 2.5 ME 115/70
116	IL	IL 83 and US 45 over the Wisconsin Central RR in Lake Villa, IL; IL 49S over I-74; IL 49N over I-74	High Performance Steel	HPS	Beams/Girders	complete		2003	2002 Funds for 17 Bridges - combined into one report Associated with Project 103
117	IL	Babylon Bridge over Spoon River, Lee Township	FRP Bridge Deck and Hillman composite bridge system	FRP	Decks	not recommended		2004	Project was not constructed
118	IL	Pleasant Ridge Rd. over Little Canteen Creek	FRP Deck Panel	FRP	Decks	complete		2005	
119	IL	High Road Bridge carrying High Road over Long Run Creek in Lockport Township, Illinois	Hybrid-Composite Beams - self-consolidating concrete for the compression	SCC	(none)	complete		2006	
120	IN	Thayer Road over I-65	Clad Stainless Steel Rebars in Deck Slab. Material changed to FRP reinforcement in	Reinforcing Bars	FRP	complete		2000	
121	IN	County Bridge #153	FRP deck panel	FRP	Decks	complete		2002	
122	IN	US 30 over Jain Creek	Extra thick epoxy coated reinforcement.	Coatings & Corrosion	Overcoating	complete		2003	
123	IN	US-50 Bridge over Tanners Creek and Service Road, Lawrenceburg	Full Depth Precast Bridge Deck System	ABC	Precast	complete		2004	
124	IN	21st Street over I-465	High Performance Concrete	HPC	Girders	complete		2005	
125	KS	RS 1070 over Kansas River SE of Belvue Kansas	FRP Railing	FRP	Conc Strengthening	no report		1999	
126	KS	I-470W to I-70W	CP Anodes	Coatings & Corrosion	CP anodes	no report		2000	
127	KS	Detour Bridge	FRP Deck Panel	FRP	Decks	no report		2001	
128	KS	Detour Bridge	FRP Deck Panels	FRP	Decks	no report		2002	
129	KS	K-14 over Salt Creek	Self Consolidating Concrete	SCC	(none)	no report		2003	
130	KS	RS-831 Bridge over Walnut Creek	Light Weight Concrete Mix / Laterally Loaded Pile Behind MSE Wall	Other		no report		2004	
131	KS	Detour Bridge / Br Rail on FRP Deck	FRP Deck Panels	FRP	Decks	no report		2004	
132	KS	RS 17 over Stream	FRP Reinforced Beams	Reinforcing Bars	FRP	no report		2005	
133	KY	025* 1210* C0029 Co RD. S. Winchester	CFRP Bars	Reinforcing Bars	FRP	not recommended		2000	No DOT response
134	KY	KY 1577 RR Underpass in Somerset				no report		2000	Technology not reported/No DOT response
135	KY	Montecello Street Undepass	FRP Panel Deck	FRP	Decks	no report		2000	No DOT response
136	KY	Clark County Bridge , located on CR1210 over Two Mile Creek	FRP Rebar	Reinforcing Bars	FRP	complete		2000	Formerly: KY595 over West Fork Silver Creek
137	KY	Kentucky Route 3297 over Little Sandy River	FRP Bonded Reinforcement	FRP	Wraps	complete		2001	
138	KY	Scott County Rd. 5218 over North Elkhorn Creek	Stainless steel clad and MMFX reinforcing steel	Reinforcing Bars	Stainless Steel clad and MMFX	complete		2001	Federal-Aid Project number should be 113
139	KY	Louisa- Fort Gay Bridge	CFRP Laminates	FRP	Conc Strengthening	complete		2002	
140	KY	KY974 over Howard Creek	Aluminum Bridge Decks	Other	Aluminum Bridge Deck	complete		2003	Project name changed from KY-92 over Jellico Creek
141	KY	I-65 over Jacob, Broadway, and Gray Streets	CFRP Fabric	FRP	Wraps	complete		2003	Combined with I-65 Bridge over Main St. Louisville, project 142
142	KY	I-65 Bridge over Main St. Louisville	CFRP Fabric	FRP	Wraps	complete		2004	Combined with I-65 over Jacob, Broadway, and Gray Streets, project 141
143	KY	Webster County Bridge 50, Crab Orchard Creek	Aluminum Bridge Decks	Other	Aluminum Bridge Deck	complete		2004	
144	KY	KY 32 over Lytles Creek	FRP Laminates	FRP	Steel Strengthening	not recommended		2005	CRP laminates have not been attached, Draft Report due 2013
145	KY	KY 3302 over Sugar Tree Branch	FRP Rebars in Deck Slab changed to FRP Stay-in-Place deck forms	Reinforcing Bars	FRP	not recommended		2005	Technology was changed to FRP Stay-in-Place deck forms for deck slab. Bridge construction was scheduled for summer 2010. Draft Report due July 2014
146	KY	KY 3302 over Sugar Tree Branch	Solid Stainless Rebars in Deck Slab	Reinforcing Bars	Stainless	not recommended		2005	Bridge construction was scheduled for summer 2010. Draft Report due July 2014

Summary Sheet Tracking			Technology	Category	Sub-Category	Status		Award year	COMMENTS
Completed Contact Report Forms						(initiated / needs input / complete)			
147	KY	KY 714 over Jephtha Creek	CFRP	FRP	Wraps	complete		2005	Monitoring is on going, Draft Report due July 2012
148	KY	Indian Gap Road over Camp Pleasant Branch	Rapid Construction and Self Consolidating Concrete	ABC	Other	not recommended		2009	Funds have not yet been allocated for project
149	KY	KY11 over CSX RR and Strodes Run	High Strength Steel wire fabric	HPS		not recommended		2009	Funds have not yet been allocated for project
150	LA	Bridge on LA Rt. 1@ Leeville/Lafourche Parish	Maintenance Protective Coating over an existing Lead Paint System	Coatings & Corrosion	Paint systems	no report		2000	
151	LA	LA 378 over West Fork Calcasieu River	Fiber Reinforced Polymer (FRP) Bridge Fender Sytem	FRP	Decks	no report		2002	
152	LA	Louisiana Route 70, Bayou Pierre Part	Composite Fiber Reinforced Polymer (FRP) Bridge Deck	FRP	Decks	complete		2003	
153	LA	Elm Grove Garden Road Bridge	FRP Reinforcing in Pier Columns	Reinforcing Bars	FRP	complete		2004	
154	LA	Caminada Bay, LA 1 near Grand Isle, LA	Integral Abutment In LA Soft and Stiff Soils	Monitoring	Displacement	not recommended		2005	
155	LA	Structure Health Monitoring (I-10 Twin Span Bridge)	Element health Monitoring using Embedded Sensor Technology: "Structure	Monitoring	Displacement	complete		2005	
156	LA	Caminada Bay Bridge	FRP Strand: "Repairing/Strengthening of Bridges with Post Tension FRP Strands &	FRP	Conc Strengthening	complete		2005	
157	LA	Structure Health Monitoring (I-10 Twin Span Bridge)	High Performance Concrete	Monitoring		complete		2005	Combined with #155
158	LA	Amite River Bridge and Approaches (US 190)	Scour Monitoring using Fiber Optic Sensors	Monitoring	Scour	not recommended		2006	Project still ongoing, results inconclusive
159	LA	I-49 over Dooley Bayou	elimination of deck joints - FRP grid	FRP	Decks	not recommended		2009	Very little information provided by DOT
160	LA	LA6 Red River at Grand Encore Bridge	Monitoring System for Bridges Subject to Heavy Loads	Monitoring		not recommended		2009	Very little information provided by DOT
161	LA	I-49 over Dooley Bayou - Geosynthetic Reinf Soil at Abuts	GRS for Bridge Abutments	Foundations	Geofoam	not recommended		2009	Very little information provided by DOT
162	MA	Franklin I-495 over MBTA Bridge	FRP Bonded Reinforcement in P/S Slab Bridge	FRP	Decks	complete		2000	
163	MA	State Rte. 13 over aNordth Branch Nashua River	Archtec to Stengthen Arch Barrels	Other		not recommended		2001	
164	MA	Central Street over Quequechan River				not recommended		2002	Technology not reported
165	MA	City of Randolph, Metropolitan District Commission Access Road over State Route 24 NB and SB	Segmental Post-Tension Channel Superstructure Replacement	ABC	Precast	not recommended		2003	Very little information provided by DOT
166	MA	US 1 NB Bridge over I-95 NB & SB	High Performance Concrete in Bridge Rails and MMFX Rebars in Deck Slab	Reinforcing Bars	MMFX	not recommended		2004	No information provided by DOT
167	MA	Long Hill Road over CSX R.R.	Self Consolidated Concrete in Superstructure	SCC	(none)	not recommended		2005	No information provided by DOT
168	MA	Bridge to HQ Complex	High Performance Concrete in Deck Slab	HPC	Decks	not recommended		2005	project not claimed by MA
169	MD	MD 335 Br 09011 over Wallace Creek - Bridge Replacement				no report		0	Technology not reported
170	MD	Rehabilitation of Bridge No. 12016 on MD 24 over Deer Creek	FRP Deck Panel	FRP	Decks	complete		2000	suppliment to 171
171	MD	Rehabilitation of Bridge No. 12016 on MD 24 over Deer Creek	FRP Deck Panel	FRP	Decks	complete	see 170	2000	
172	MD	I-95/I295 Interchange	Innovative Bridge Research & Construction Program - Smart Aggregate - Phase II			complete		2002	
173	MD	Innovative Bridge Research & Construction Program - Smart Aggregate - Phase II	Innovative Bridge Research & Construction Program - Smart Aggregate - Phase II	Monitoring	Smart Aggregate	not recommended		2002	
174	MD	MD 140 over MD 27, Maryland Midland Railway and West Branch				no report		2003	Technology not reported
175	MD	Blacks Mill Road over Little Hunting Creek	Bridge Rehabilitation: replacement of the superstructure for the existing bridge using	FRP	Conc Strengthening	no report		2003	
176	MD	Subsituted Project : MD 335 over Wallace Creek contract # 1329(009)	FRP Deck Panel	FRP	Decks	no report		2004	
177	MD	Subsituted Project : US 1 over Octoraro Creek contract # 1231(034)	Coating/Paint	Coatings & Corrosion	Paint systems	complete		2005	Combined with 178
178	MD	US 1 Br #0700300 over Octoraro Creek Clean & Paint Bridge for Evaluation of Two Two-Coat	Clean and Paint Bridge for Evaluation of Two-Cost Painty System	Coatings & Corrosion	Paint systems	complete		2006	Combined with 177
179	ME	Municipal Pier in Milbridge	FRP Reinforced Glulam Deck Panels	FRP	Timber Strengthening	complete		1999	
180	ME	Union-Washington Skidmore	FRP glulaminated deck system	FRP	Timber Strengthening	no report		1999	linked with 190
181	ME	Winterport & Beaver Cove	FRP Bridge Drains	FRP	Conc Strengthening	complete		1999	
182	ME	New Meadows Bridge in Sagadahoc, ME	FRP-Timber Bridge Railroad Ties	Other	Advanced Engineered Lumber	complete		1999	Technology was changed toAdvanced Engineered Lumber
183	ME	Androscoggin River Bridge	FRP Bonded Reinf	Reinforcing Bars	FRP	no report		1999	

Summary Sheet Tracking							Status		Award	
Completed Contact Report Forms			Technology	Category	Sub-Category	(initiated / needs input / complete)		year	COMMENTS	
184	ME	Marston Bridge	FRP Deck Panel	FRP	Decks	no report		1999		
185	ME	Town of Cumberland	FRP Deck Panel	FRP	Decks	no report		1999		
186	ME	Fairfield	FRP Reinforced Glulaminated Beams with Integral Concrete Deck	FRP	Decks	complete		2000		
187	ME	State-wide, IBRC program (Rolin's Road)	Concrete Filled FRP Arch System	ABC	Conc. Filled FRP	not recommended		2001		
188	ME	State-wide, IBRC Program (Ricker's Bridge)	FRP Deck Panel	FRP	Decks	not recommended		2001		
189	ME	Island Ave. over Penobscot River Overflow	FRP and High Performance Concrete	FRP		not recommended		2002	looking for new candidate	
190	ME	Union-Washington Skidmore/Medomak	FRP glulaminated deck system	FRP	Decks	complete		2002	linked with 180	
191	ME	Neal Bridge, Pittsfield	FRP concrete filled arches	FRP	Conc Strengthening	complete		2003	FORMERLY Mill Pond Bridge	
192	ME	Waldo-Hancock Bridge over Penobscot River	same project; substituted cradle stay system for inert gas	Coatings & Corrosion	Inert Gas	complete		2004		
193	ME	New Mills Bridge	Light weight laser welded steel sandwich panels	Other	Laser Weld	no report		2005		
194	ME	Wando-Hancock Bridge, Tt. 1 over Penobscot River	FRP Cable Stay Strands	Coatings & Corrosion	Inert Gas	not recommended		2005	report started; monitoring for 192	
195	ME	Milford St. Bridge Over Grand Lake Stream	Precast Super- and Sub- Structure	ABC	Precast	not recommended		2006	FORMERLY: Boom Birdge Bridge on Rt. 116 over Birch Stream	
196	MI	I96 over I-69 BR (Lansing Rd)	FPR Bonded Reinforcement	FRP	Wraps	complete		1999		
197	MI	City of Southfield Bridges	FRP Prestressing & Rebar	Reinforcing Bars	FRP	complete		1999		
198	MI	M-15 @ Over Gooding Creek	FRP Rebar in Deck Slab	Reinforcing Bars	FRP	complete		2000		
199	MI	M-15 @ Over Gooding Creek	FRP Rebar in Deck Slab	Reinforcing Bars	FRP	complete		2000	see 198 SAME AS 198	
200	MI	EB I-496 over CSX RR and Holmes SD Rd. R12-4	Solid stainless steel rebar in deck (substituted for stainless-clad reinforcing	Reinforcing Bars	Stainless	complete		2001		
201	MI	I-96 Ramp over Land 82123-S11-0	Column wrapping with FRP	FRP	Wraps	not recommended		2003	flag for more info	
202	MI	I-94 over Shook road and C&O RR	MMFX rebar	Reinforcing Bars	MMFX	complete		2003		
203	MI	M-50 Bridge over Grand River	Self Consolidated Concrete in Concrete Box Girders	SCC	(none)	complete		2004		
204	MI	M-43 Bridge over Sebewa Drain	Solid stainless steel rebar in deck (substituted for stainless-clad reinforcing	Reinforcing Bars	Stainless	complete		2004		
205	MI	M-153 (Ford Road) under Greenfield	High Performance Concrete in Deck Slab	HPC	Decks	not recommended		2005	No information provided by DOT	
206	MI	Custer Drive over the Kalamazoo River	Conductive concrete	Coatings & Corrosion		not recommended		2006	No information provided by DOT	
207	MI	I94EB & WB over Riverside Drive		Reinforcing Bars	MMFX	complete		2009		
208	MI	Parkview over US131		Monitoring	Smart sensors	complete		2009		
209	MN	I94 and Glenwood Ave I35 at Maryland Ave	CP Anodes	Coatings & Corrosion	CP anodes	complete		1999		
210	MN	Innovative Bridge Research	Large Diameter high density pipe under shallow fill	Other		complete		2000		
211	MN	I-35 over Miss.River & TH 62 over I-35W	Prefabricated Fusion Bonded Epoxy Coated Rebars	Reinforcing Bars		complete		2001	See 212 Merged with Lexington Project, see 212	
212	MN	Lexington Ave Bridge	Other - Deck Slab	Reinforcing Bars		complete		2001		
213	MN	Glen Road over TH61, City of Newport	High strength high performance steel girders	HPS	Beams/Girders	complete		2002		
214	MN	TH 610 from 0.6 Mi.W. Fernbrook Ln. to 0.1 Mi. W. 93rd Ave. in Maple Grove	Precast deck panels to speed construction	ABC	Precast	complete		2003		
215	MN	TH 8 over Center Lake Channel, 0.8 miles east of Center City; TH 72 over Tamarac River near	Precast concrete inverted T beams for rapid construction	ABC	Precast	complete		2004		
216	MN	Diamond Lake Road over I-35W	Concrete mix for the deck modified to limit deck cracking	HPC	Decks	complete		2005	Associated with 211	
217	MN	EB & WB SH23 over CP RR	Stainless Steel Deck Rienforcement	Reinforcing Bars	Stainless	not recommended		2009	Project has not started, or is ongoing, results inconclusive	
218	MO	Adelaid Ave over I70	HPC Deck	HPC	Decks	complete		1999		
219	MO	Route 291 over Route 150		HPC	Girders	not recommended		1999		
220	MO	Bridge 6059 in Grundy Co. (Rt. 6 0.8Mi to 0.2 MI W Sullivan City, Galt, MO)		Reinforcing Bars	Stainless	complete		2000		

Summary Sheet Tracking							Status		Award	COMMENTS
Completed Contact Report Forms			Technology	Category	Sub-Category	(initiated / needs input / complete)	year			
221	MO	RT 412 FRM RT B/Z to 2.3 mi. West, Bridge A6130	High Performance Concrete in Deck Slab and I-Beams	HPC	Girders	complete		2000		
222	MO	Rt 64 1.5M SW of Pomme De Terre Lk	Precast Deck Panels	ABC	Precast	complete		2000		
223	MO	Route 224 over Route13	High Performance Steel in Plate Girders	HPS	Beams/Girders	complete		2001		
224	MO	RT 64 1.5M SW of Pomme De Terre Lk	Clad Stainless Steel Rebars in Deck Slab			no report		2001	Appears to be duplicate record or record of name change for Hickory Creek Project	
225	MO	Route I-44	Galvonic Annodes	Coatings & Corrosion	Galvanic Protection	complete		2001		
226	MO	US Route 54 over Osage River				no report		2002	Duplicate of A6358 over Osage River	
227	MO	Southview Drive over Carter Creek	FRP Prestressing and Rebars	Reinforcing Bars	FRP	complete		2002		
228	MO	Bridge A6358, HPS, Route 54 over Osage River	HPS	HPS	Beams/Girders	complete		2002		
229	MO	Route 61/67 over Mattese Creek	High Performance Concrete Girders	HPC	Girders	not recommended		2003		
230	MO	X0596 Rte. C over Creek, P0962 Rte. B over Creek, T0530 Rte. M over Crooked Creek, Y0298 Rte. U	Fiber Reinforced Polymer Girders	FRP	Conc Strengthening	complete		2003		
231	MO	State Route T Bridge over Fiddle Creek	Precast pier caps oon superelevated, skewed bridge	ABC	Precast	complete		2004		
232	MO	Route Y, Boone-Callaway County, Deck Replacement, Bridge N0038	FRP Reinforcing in Deck Slab	FRP	Decks	complete		2004	Project changed from US69 Bridge over I-35	
233	MO	Big Bend NB over I-44	Galvanic Cathodic Protection Applied Over Concrete Repairs	Coatings & Corrosion	Galvanic Protection	complete		2004		
234	MO	FR-148 Bridge over Pearson Creek	FRP Deck Panel	FRP	Decks	complete		2004		
235	MO	Rt. 150 over RR & Big Creek	High Performance Concrete in Deck Slab	HPC	Decks	not recommended		2005	Project location changed, has not been completed	
236	MO	Pat Daly Road over Arnault Branch	FRP Bonded Reinforcement in	FRP	Steel Strengthening	not recommended		2005	Very little information provided by DOT	
237	MO	SB Interstate 255 over the Missouri River in St. Louis County and US 24 E over the Grand River in	Scour Monitoring using SONAR	Monitoring	Scour	complete		2006		
238	MS	I-110 Back Bay Bridge	Zinc Based Coating- Corrosion Protection	Coatings & Corrosion	Zinc Based	no report		2000		
239	MS	Withdrawn - see remarks	Zinc Based Coating On Steel Girders	Coatings & Corrosion	Zinc Based	no report		2000		
240	MT	US 2 over Middle Fork Flathead River Essex	Solid Stainless Steel Rebars	Reinforcing Bars	Stainless	complete		2001		
241	MT	Three Structures on Secondary Rt. 243	High Performance Concrete	Monitoring	Displacement	complete		2002		
242	MT	I-15/I-90 over BNSF RR	High Performance Steel in Box Girders	HPS	Beams/Girders	complete		2005		
243	NC	NC157 Durham Road over Eno River	HPS	HPS		not recommended		1999	No information provided by DOT	
244	NC	US64 West-bound over Haw River	FRP Bonded Rief	Reinforcing Bars	FRP	not recommended		2000	No information provided by DOT	
245	NC	US17 Wilmington Bypass & I-40 Interchange	Coating/Metalizing	Coatings & Corrosion		not recommended		2000	Very little information provided by DOT	
246	NC	NBIS bridge 00630085, State Route (SR) 1814 over Little Lick Creek	FRP Bridge Deck (Martin Marrietta's DuraSpan System)	FRP	Decks	complete		2001		
247	NC	State Route 1178 over I-95, Town of Four Oaks, TIP: I-2704, 2-span cont. steel structure (6 beam)	MMFX reinforced concrete steel	Reinforcing Bars	MMFX	complete		2002		
248	NC	Fast Clad Urethane Paint System on Three Bridges over US 64	Evaluation of Sherwin Williams Fast Clad Urethane Paint System on Three Bridges	Coatings & Corrosion	Paint systems	complete		2003		
249	NC	Bridge 16 on State Route 1470 over Cartoogechaye Creek, TIP B-3485	Bridge Deck reinforced with GFRP bars	Reinforcing Bars	FRP	complete		2003		
250	NC	Bridge 28 on SR 1102 over I-77 (TIP: I-4411)	High Performance Steel Plate Girders (Hybrid 100/70W) (100 for flanges, 70 for HPC Deck Girder Bridge	HPS	Beams/Girders	not recommended		2004		
251	NC	Bridge 80 on SR 1214 over Long Creek (TIP: B-3700)		HPC	Decks	complete		2004		
252	NC	Bridge 36 (B-4188) on SR 1523 over Smithwick Creek, South of Williamston	HPC Full-depth precast bridge deck panels (longitudinally postention)	HPC	Decks	not recommended		2005	Very little information provided by DOT	
253	NC	Bridge 60 on US 70 Business over Trent River	Bridge Fender System (Piles with High Density Polyethylene Shell)	Foundations	Fender System	not recommended		2005	Very little information provided by DOT	
254	NC	US 19 NBL over SR1781, Buncombe Co.; And US 25 over Ivy River, Madison Co. (I-26 over SR 1839)	Cargill's SafeLane Ice Prevention Overlay (Type III epoxy) System	Deck Coatings	Overlay (Deicing)	not recommended		2005	Very little information provided by DOT	
255	NC	Bridge 117 on SR 1118 over North Fork of New River (B-4012)	Use of Micropiles to support pier and abutment footings on shallow rock depth	Foundations	Micropiles	complete		2006	Very little information provided by DOT; TRB presentation found in DMP library	
256	NC	SR 1124 over Branch of Band Creek (B-3625)	HPC Prestress Precast concrete elements for accelerated bridge construction. 3 span	HPC	Girders	not recommended		2006	Very little information provided by DOT	
257	NC	NC81 over Swannanoa River	ABC using precast deck unit system	ABC	Precast	not recommended		2009	No information provided by DOT	

Summary Sheet Tracking						Status		Award	COMMENTS	
Completed Contact Report Forms			Technology	Category	Sub-Category	(initiated / needs input / complete)		year		
258	ND	I-94 from Oakes INT E to E Valley City	Stainless Steel Clad Reinforcing Bars	Reinforcing Bars	Stainless	complete		2000		
259	ND	I-94 from Oakes INT E to E Valley City	Stainless Steel Clad Reinforcing Bars	Reinforcing Bars	Stainless	complete		2000	Suppliment to 258	
260	ND	Cass County Southbound I-29 at 17th Ave. & 13th Ave.	High Performance Concrete	HPC	Decks	complete		2002		
261	ND	I-29 over 17th Ave. S, Texas Turn & 9th Ave. S (3 Bridges)	High Performance Concrete	Monitoring		complete		2003		
262	NE	Omaha dodge St over I480	HPS	HPS	Beams/Girders	complete		1999		
263	NE	Skyline Dr. over hwy. 6 (Dodge Street)	HPC	HPC	Decks	complete		2001		
264	NE	168th Street over I-80				no report		2002	Technology not reported	
265	NE	Nebraska Highway 68 over the BNSF Railroad in Ravenna	SCC	SCC		complete		2003		
266	NE	Pacific Bridge over I-680	High Performance Concrete in I-Girders	HPC	Girders	complete		2004	final report pending	
267	NE	262nd Street Bridge over I-80	High Performance Steel in Box Girders	HPC	Girders	complete		2004		
268	NE	Folded Stee Plate Bridge Technology	Folded Steel Plate Bridge Technology	Other	Folded Steel Plates	complete		2005	FORMERLY : Wagon Tongue Creek on Hw N-79	
269	NE	Wagon Tongue Creek	High Performance Steel in I-Girders	HPS	Beams/Girders	no report		2005	Project Changed to 268	
270	NH	I293 over Frontage Rd.	Galvanized Deck Reinforing	Reinforcing Bars	Galvanized	complete		2002		
271	NH	I293 over Brown Rd.	Galvanized Deck Reinforing	Reinforcing Bars	Galvanized	complete		2002		
272	NH	Rollins Road over Main Street and BMRR	FRP Rebar, HPC	Reinforcing Bars	FRP	complete		1999		
273	NH	Rollins Road over Main Street and B&M Railroad	FRP Rebar in Deck Slab and High Performance Concrete in I-Beams and Deck	Reinforcing Bars	FRP	complete		see 272	2000	Supplement to 272
274	NH	Rollins Rd. over Main St. and B&M Railroad	FRP Rebars in Deck and High Performance Concrete in Deck Slab and I Beams	Reinforcing Bars	FRP	complete		see 272	2001	Supplement to 272
275	NH	Mill Street over the Lamprey River in Epping, NH	Approved as Solid Stainless Steel Deck Reinforcing, Changed to Galvanized Deck	ABC	Precast	complete			2002	
276	NH	Mill Street over the Lamprey River in Epping, NH	Approved as Clad Stainless Steel Deck Reinforcing, Changed to Galvanized Deck	ABC	Precast	complete		see 275	2002	Supplement to 275
277	NH	Mill Street over Lamprey River	Accelerated bridge Construction - Completely Precast Bridge	ABC	Precast	complete		see 275	2002	Supplement to 275
278	NH	I93SB / BMRR	HPC, MMFX Rebars	HPC	Decks	no report			2002	
279	NH	Newbury Road Project	Accelerated bridge Construction - Completely Precast Bridge	ABC	Precast	no report			2003	
280	NH	NH Rte. 111 By-Pass over Flatrock Brook and Harris Road	High Performance Steel in Girder Flanges over the Piers	HPS	Beams/Girders	complete			2003	
281	NH	Mosquito Bridge US Rt.3 & NH Route 11 over Lake Winnisquam	Full Depth Precast Deck Panels used for Rapid Bridge Deck Replacement	ABC	Precast	complete			2004	
282	NH	Newbury Road over Connecticut River	Full Depth Precast HPC Deck Panels used for Rapid Bridge Deck Replacement	ABC	Precast	complete			2005	
283	NH	Newbury Road over the Connecticut River	Precast Full Depth HPC Deck Panels used in Rapid Bridge Deck Replacement	ABC	Precast	complete		see 282	2006	
284	NJ	Scotch Road over I-95	High Performance Steel in Plate Girders	HPS	Beams/Girders	complete			2001	
285	NJ	Edison Bridge-Route U.S. 9 SB over Raritan River	High Performance Concrete in Deck Slab	HPC	Decks	complete			2001	
286	NJ	US RT. 46, NJ Rt.23 & Interstate 80	FRP/Stainless Steel Rebar	Reinforcing Bars	FRP	not recommended		see 287	2002	No information provided by DOT
287	NJ	US 46/NJ 23/I-80 Interchange	GFRP reinforcement for sign structure foundations	Reinforcing Bars	FRP	not recommended			2003	
288	NJ	Route I-280/Garden State Parkway Interchange 145	Self Consolidated Concrete in Drilled Shafts	SCC	(none)	complete			2005	
289	NJ	Route 23 over Peckman's Brook	Hybrid (Hillman) Composite Beams	HPC	Girders	complete			2006	
290	NM	I-10 Bridges over University Ave.Main St.RR in Las Cruces NM (Dona Ana County)	High Performance Concrete	HPC	Decks	complete			2001	
291	NM	Mountain Valley Road over I-40	HPC prestressed box girders and precast pier caps for rapid bridge construction.	HPC	Girders	complete			2002	
292	NM	NM 602 Bridge over Rio Nutria near Zuni NM	precast superstructure and substructure components.	ABC	Precast	complete			2003	
293	NM	Dona Ana Interchange Bridge	High Performance Concrete in Bulb Tees (Utilize embedded MUST optical fiber	Monitoring	Fiber Optics	not recommended			2004	
294	NM	US 64 over the Amargo River in Dulce, NM	MMFX Rebars in Deck Slab	Reinforcing Bars	MMFX	complete			2004	

Summary Sheet Tracking						Status		Award	COMMENTS
Completed Contact Report Forms			Technology	Category	Sub-Category	(initiated / needs input / complete)		year	
295	NM	I-25 South Bound at Rowe Interchange	High Performance Concrete in Superstructure	HPC	Girders	complete		2005	
296	NM	I-25 South Bound at Rowe Interchange	High Performance Concrete in Superstructure	HPC	Girders	complete		2005	
297	NM	I-40 Tucumcari/E. Interchange	Fiber Reinforced Polymer Deck Overlay	Monitoring	Smart sensors	complete		2006	
298	NV	580-1(024) Galena Creek Bridge; I-580 NB/Galena	High Performance Concrete	HPC	Decks	not recommended		2002	Project not completed, anticipated to be completed by Sept. 2011
299	NV	US 93 Colorado River Bridge at Hoover Dam	HPC for Arch	HPC	Other	no report		2003	
300	NV	On SR 170, Bunkerville Road over Virgin River	High Performance Steel	HPS	Beams/Girders	complete		2003	
301	NY	I95 over Midland Ave	Galvanizing, HPC, HPS	Reinforcing Bars	Galvanized	complete		1999	
302	NY	South Bend Street over Dyke Creek	FRP Deck	FRP	Decks	no report		1999	
303	NY	Everett Road Over I90 Route 2 over Hudson river, Route 20 over Route 85, Route 378 Over	FRP Bonded rinf, FRP Other	Reinforcing Bars	FRP	no report		1999	
304	NY	Route 9W over Conrail	FRP Bonded Reinf	Reinforcing Bars	FRP	no report		1999	
305	NY	Wood Road Over Cohocton River	FRP Deck Panel	FRP	Decks	no report		1999	
306	NY	Rt 418 over Schroon River (2)	FRP Deck Panel	FRP	Decks	no report		1999	
307	NY	NYS Thruway over Gravel Road	HPS	Reinforcing Bars	Galvanized	complete		1999	
308	NY	Co. Rd. 52 (Triphammer Road) / Conesus Lake Outlet	FRP box beams and FRP deck.	FRP	Decks	no report		2000	
309	NY	East Street Bridge	research on bracing requirements for HP steel	HPS	Beams/Girders	no report		2000	
310	NY	Red Spring run over Colonel Bill's Creek	FRP Deck Panel	FRP	Decks	no report		2000	
311	NY	CR 50 (Park Ave) over Carl's River	FRP Deck Panel and High Performance Concrete	FRP	Decks	no report		2001	
312	NY	County Route 153 over White Creek	Either FRP deck, or composite concrete deck.	FRP	Decks	no report		2001	
313	NY	CR 46 (Osceola Rd) over East Branch Salmon Riv.	FRP deck (Martin Marietta Composites system)	FRP	Decks	no report		2001	
314	NY	Fitch Road Bridge over Twelve Mile Creek	FRP Glulam	FRP	Timber Strengthening	not recommended		2002	No information provided by DOT
315	NY	CR 38 (Railroad street) over North Branch Little Salmon Riv.	FRP deck slab (system by Martin Marietta Composites)	FRP	Decks	not recommended		2002	No information provided by DOT
316	NY	Erie Canal Road over Independence	FRP composit deck (system by Martin Marietta Composites)	FRP	Decks	no report		2002	
317	NY	Annandale Rd over Staten Island Rapid Transit	Stainless clad reinf steel, with 4-yr corrosion monitoring program.	Reinforcing Bars	Stainless	complete		2003	
318	NY	CR 32 (Glendale Rd.) over Roaring Brook	FRP deck (system by Martin Marietta Composites).	FRP	Decks	no report		2003	
319	NY	CR 68 Bridge over Little White Creek	FRP Rebars in Deck Slab and Galvanizing of Steel I-Beams.	Reinforcing Bars	FRP	no report		2004	
320	NY	Bemus-Ellery Road Bridge over Bermus Creek	Accelerated Bridge Construction using Prefabrication.	ABC	Prefabrication	not recommended		2004	Corrupt DOT file
321	NY	County Road 23	Geofoam and accelerated construction techniques.	ABC	Other	no report		2005	
322	NY	CR 78 over Little Stony Creek	Modular bridge units for Rapid Bridge Installation System for short span bridges.	ABC	Prefabrication	no report		2005	
323	NY	28th Creek Road over 28th Creek	HPC box beams; FRP prestressing tendons; and stainless steel rebars in deck.	FRP	Conc Strengthening	not recommended		2005	No information provided by DOT
324	NY	CR 30 (Cemetery Road) over Roaring Brook	FRP Rebar in Reinforced Slab.	Reinforcing Bars	FRP	not recommended		2005	No information provided by DOT
325	NY	County Route 55 over Deer River	FRP deck.	FRP	Decks	no report		2006	
326	OH	Route 380 - 0032	FRP Bonded Reinforcement	Reinforcing Bars	FRP	no report		1999	
327	OH	Route 79 - 0955	FRP Prestressing	FRP	Conc Strengthening	complete		1999	Associated with 328
328	OH	Bridge No. SCI-23-0166, US Rte. No. 23, City of Portsmouth	FRP Prestressing	FRP	Conc Strengthening	complete		1999	Associated with 327
329	OH	Route 49-0103, Dayton	FRP Deck Panel	FRP	Decks	complete		1999	
330	OH	Stelzer Road, Columbus	High Performance Concrete	HPC		complete		1999	
331	OH	Route 22 - 2290	FRP Deck Panel, High Performance Concrete	FRP	Conc Strengthening	no report		1999	

Summary Sheet Tracking						Status		Award	COMMENTS
Completed Contact Report Forms			Technology	Category	Sub-Category	(initiated / needs input / complete)		year	
332	OH	Route 705 - 04.255	FRP Other				no report	1999	
333	OH	Smith Road off of Route 128	FRP Deck Panel	FRP	Decks		no report	1999	
334	OH	TR-175).05 MI. N of Sr -37	Composite FRP Deck Pannels	FRP	Decks		no report	2000	
335	OH	Regional Pooled Fund Study	FRP Composite Prestressing Strands	FRP	Conc Strengthening		no report	2000	
336	OH	Route 49-2002	FRP Deck Panel, FRP Prestressing, FRP Rebar, High Performance Concrete	FRP	Decks		complete	2000	
337	OH	FAI-33-1309 Delmont Road over US33	High Performance Steel in Plate Girders	HPS	Beams/Girders		complete	2001	
338	OH	Over-Height Collision Protection System of Sandwich Polymer Composites	Over-Height Collision Protection System of Sandwich Polymer Composites	Other	Overheight Systems		complete	2002	
339	OH	Eight Mile Road	HPC pre-cast concrete slab members	HPC	Decks		no report	2003	See 340
340	OH	Eight Mile Road over Eight Mile Creek	FRP Beams	FRP	Conc Strengthening		complete	2004	
341	OH	Casebeer-Miller Rd.	FRP tub floor beams with composite concrete deck	Foundations	Reinforced Soils		complete	2004	See 343
342	OH	Casebeer-Miller Rd/TR-114/SR-185	FRP Deck Panel	Foundations	Reinforced Soils		complete	2005	See 343
343	OH	Casebeer-Miller Rd. over tributary of South Fork Gordon Creek	FRP Beam	FRP	Conc Strengthening		complete	2005	
344	OH	FA-114-01.64 over stream	FRP Deck Panel	FRP	Decks		complete	2005	
345	OH	Stever Road (CR153) over the Tiffin River	Geosynthetically Reinforced Soil abutments	Foundations	Reinforced Soils		complete	2006	
346	OK	I-35 over Chickaskia River	Clad Stainless Steel Rebars in Deck Slab	Reinforcing Bars	MMFX		not recommended	2001	limited results available
347	OK	I - 40 EB over I-44	Thin Bonded overlay	Deck Coatings	Overlay (non Deicing)		complete	2004	
348	OK	SH-7 over Branch Creek	Sandwich Plate System	Other	Sandwich Plates		not recommended	2005	excessive cost - not constructed
349	OK	I-40 Bridge over Business I-40 In Sayre	High Performance Concrete in Deck Slab	HPC	Decks		complete	2006	
350	OK	I-35 over Hickory River	Ipanex corrosion inhibitor	Reinforcing Bars	MMFX		complete	2007	
351	OK	SH-150 over Lake Eufaula	Surtreat Chemical placed on concrete to abate corrosion	Coatings & Corrosion	Surtreat TPS		complete	2007	
352	OR	Savie Island Bridge	Fiber Deck Panels	FRP	Wraps		complete	2000	Form not returned by State DOT
353	OR	State Hwy #105 MP4.78 & MP 6.89	FRP Deck Panel	FRP	Decks		complete	2000	
354	OR	US Highway 101 over Bethel Creek	Stainless Steel Clad Rebar	Reinforcing Bars	Stainless		not recommended	2001	Project was withdrawn
355	OR	Sylvan Bridge over Sunset Highway	High Performance Steel	HPS	Beams/Girders		complete	2002	
356	OR	Blevins Bridge - Tangent Drive Calapooia River	Debris Deflection Device	Other	Debris Deflection		complete	2002	
357	OR	The Broadway Bridge, NW Broadway over Williamette River	Fiber Deck Panels	FRP	Decks		complete	2003	
358	OR	I-84 Irigon Junction - Hilgard Interchange	High Performance Steel in Plate Girders	HPS	Beams/Girders		complete	2004	
359	OR	I-84 over Fifteenmile Creek					not recommended	2005	Project was withdrawn
360	OR	I-84 over Mosier Creek	High Performance Steel in I-Girders	HPS	Beams/Girders		not recommended	2005	Project was withdrawn
361	OR	I-84 over Herman Creek					not recommended	2005	Project was withdrawn
362	OR	Ochoco Creek Bridge near Prineville	Accelerated Construction	ABC	Other		no report	2006	
363	OR	Oxing Posetti Road, Br 07424, Hwy 009, MP 62.94, crossing the Kilchis River					no report	2006	Technology not reported
364	OR	Williamson River Hw422 and Bridge Creek, Hw41 R/W					no report	2009	Technology not reported
365	OR	US30 @ Mill Creek					no report	2009	Technology not reported
366	PA	T-565 over Dunning Creek	FRP Deck Panel	FRP	Decks		complete	2000	
367	PA	T-391 over Sideling Hill Creek	FRP Deck Panel	FRP	Decks		not recommended	2000	No information provided by DOT
368	PA	SR 1037 over Dubois Creek	FRP Slab	FRP	Decks		complete	2001	

Summary Sheet Tracking							Status		Award	COMMENTS
Completed Contact Report Forms			Technology	Category	Sub-Category	(initiated / needs input / complete)	year			
369	PA	SR 4012 over Slippery Rock Creek	FRP Deck	FRP	Decks	complete		2003	Revised submittal of 373	
370	PA	Deck Replacements with Timber-Glulam Panels	Timber Glulam	Other	Timber Deck	not recommended		2001	Project was withdrawn	
371	PA	SR 4034 over Wintergreen Gorge	High Performance Steel	HPS	Beams/Girders	complete		2002		
372	PA	SR 2024 over Towanda Creek	Corrugated Web	HPS	Corrugated Webs	complete		2003		
373	PA	SR 4012 over Slippery Rock Creek	FRP Deck	FRP	Decks	not recommended		2001	Project revised to 369	
374	PA	SR 0885 Boulevard of the Allies over Forbes Ave.	High Performance Steel in I-Girders	HPS	Beams/Girders	not recommended		2004		
375	PA	TR -776 Bridge over English Run	FRP Deck Panel	FRP	Decks	complete		2004		
376	PA	SR 8043 (California Ave) over SR 65 (Ohio River Blvd)	Coating/Paint	Coatings & Corrosion	Paint systems	complete		2005		
377	PA	SR 4012 over Shamokin Creek (same technology)	FRP Bonded Reinforcement in Deck Slab	Reinforcing Bars	FRP	complete		2005		
378	PA	SR 15 over Johnson Creek and SR 2016	Epoxy Overlay Deicing System	Deck Coatings	Overlay (Deicing)	complete		2005		
379	PA	Burd Run Road over Bird Run	Glulam Deck on Steel Girders	Other	Timber Deck	complete		2005	FORMERLY:SR 307 (Fogelsonger Road) over Burd Run	
380	PA	SR 1003 over Tionesta Creek	Tubular Flange	Other	CFTFG	complete		2006		
381	PR	Bridges #2028 and #2029 on PR-52 over PR-1	CFRP Bonded Reinforcement	FRP	Wraps	complete		2001	FORMERLY:Bridge No. 2028 on Psdr-52 NB over PR-1	
382	PR	Bridge no. 206 on PR - 102 over Laguna Channel	Stainless steel on deck	Coatings & Corrosion		not recommended		2002	Very little information provided by DOT	
383	PR	PR-250 Bridge over Lobina Channel	Precast Construction	ABC	Precast	not recommended		2003	Very little information provided by DOT	
384	PR	Bridge 281 at PR -139 (Km 2.5)	FRP Composite Deck	FRP	Decks	complete		2004		
385	PR	Bridge over Toita Creek				not recommended		2005	Technology not reported	
386	RI	Silver Spring Cove-US Route 1	FRP Bonded Reinforcement	Reinforcing Bars	FRP	no report		2001		
387	RI	Eastbound I-95, Washington Bridge	Galvanic Anodes in bridge deck	Coatings & Corrosion	Galvanic Protection	complete		2001		
388	RI	Iway Contract 7, Arch Span	Strain Gauges & Load Cell Instrumentation	Monitoring	Displacement	complete		2004		
389	RI	Great Rd. Bridge 446	Seismic Roller Isolation Bearings	Other	Bearings	complete		2005		
390	SC	SC RTE 73 Myrtle Beach	Solid Stainless Steel Rebar in Bridge Deck	Reinforcing Bars	Stainless	complete		2000		
391	SC	S-42-655 over Norfolk/Southern RR	FRP Deck Panel	FRP	Decks	complete		2001		
392	SC	SC 171 over Wappoo Creek	FRP Pier Protection - Dolphins	FRP	Conc Strengthening	complete		2002		
393	SC	US 29 over Thicketty Creek	HPS 70W Steel Girders	HPS	Beams/Girders	complete		2002		
394	SC	SC Rte. S-54 over Tidal Creek	Various steel reinforcing steel technologies (MMFX, SS Clad, SS) in bridge deck	Reinforcing Bars	MMFX	complete		2003		
395	SC	US 76 over Lumber River and Swamp	SCC drilled shafts	SCC	(none)	complete		2003		
396	SC	SC 377 Bridge over Black River	Self Consolidated Concrete in I-Beams	SCC	(none)	complete		2004		
397	SC	US76 Lynches River Bridge	Prestressed Concrete Decked Bulb Tee Girders	Other		not recommended		2005	Very little information provided by DOT	
398	SC	US 378 over the Pee Dee River	Prestressed Precast Cylinder piles	ABC	Precast	complete		2006		
399	SC	Stare Raod SC31 over Waccamaw River Swamp	Precast reinforced concrete bent caps	Foundations		not recommended		2009	Very little information provided by DOT	
400	SD	Russell St over I-29, Maple Ave	Clad Stainless Steel Rebars in Deck Slab	Reinforcing Bars	Stainless	not recommended		2001	FORMERLY US281 Over BNSF RR in Aberdeen	
401	SD	I-29 Madison Street Interchange	Stainless Steel Reinforcing	Reinforcing Bars	Stainless	not recommended		2002	FORMERLY: Russell Ave.	
402	SD	Madison Street over I-29; I-29 over RR	Stainless Steel Reinforcing	Reinforcing Bars	Stainless	not recommended		2003	Very little information provided by DOT	
403	SD	Tea Interchange	Optimized Mix Design for Concrete in Deck	HPC		not recommended		2004	Very little information provided by DOT	
404	SD	From the end of the concrete in Rapid City to the junction with Airport Road	Self Consolidated Concrete in Culvert	SCC	(none)	not recommended		2005	Very little information provided by DOT	
405	TN	SR-53 over Martin Creek	High Performance Steel in Plate Girders - Fabrication Studies	HPS	Folded Plates	complete		2000		

Summary Sheet Tracking						Status		Award	
Completed Contact Report Forms			Technology	Category	Sub-Category	(initiated / needs input / complete)		year	COMMENTS
406	TN	Massman Drive / I-40	Verify Continuity Asumptions	Monitoring		complete		2003	
407	TX	RM 1061 at Draw Creek	FRP Rebar	Reinforcing Bars	FRP	complete		1999	
408	TX	FRP Bridge, FM 3284 FR. 10M South Drainage Ditch	FRP in Box Beams	FRP	Conc Strengthening	complete		2000	Project report is combination of this project and 411
409	TX	Farm to Market Road 1362 over Sue Creek	FRP laminate sheet strengthening of existing parn form bridge	FRP	Wraps	complete		2001	
410	TX	Texas State Hwy SH 66 OVER Lake Hubbard	High Performance Concrete - Utilize GGBFS in conjunction with Maturity Testing	HPC	Other	complete		2001	
411	TX	FM 3284 over Drainage Ditch Gregory Texas	FRP Deck Panel	FRP	Decks	complete	see 408	2002	Project report is combination of this project and 408
412	TX	Washington Street Under IH-40	MMFX Rebars	Reinforcing Bars	MMFX	complete		2002	
413	TX	US 82 WB at Park Rd.18;Spur 327 Conn US 62	Embedded galvanic anode protection system	Coatings & Corrosion	Galvanic Protection	complete		2002	
414	TX	EB Loop 340 - SH6 Overpass (Mainlanes and Frontage Road over IH35	Prefabricated bridge construction system	ABC	Prefabrication	complete		2003	
415	TX	FM 1684, Drainage Ditch Bridge	FRP beams and deck	FRP	Conc Strengthening	complete		2003	
416	TX	IH35 NB & SB ML over Hill Road	Prefabricated bridge superstructure assemblies rolled into place	ABC	Prefabrication	complete		2004	
417	TX	Live Oak Creek Bridge	Full depth precast deck panels and precast bent caps	ABC	Precast	complete		2004	
418	TX	Martin Branch Bridge, Wise County, County Road 419	SPS deck system	Other	Sandwich Plates	complete		2004	
419	TX	All future pecast segmental concrete bridge construction	TxDOT Research Project: Corrosion Resistance of Grouted Post-Tensioning	Coatings & Corrosion	Overcoating	complete		2005	
420	TX	FM 1660 over Cottonwood Creek	Replacement bridge with abutment steel sheet piling, H-piling bent foundation, & Anti-icing Pavement Overlay System	ABC	Other	complete		2005	
421	TX	US 40 (Old Route 66) West Bound Overpass in Gray County		Deck Coatings	Overlay (Deicing)	complete		2005	
422	TX	IH-35: SH 6 Interchange	Prefabricated concrete U-beams with portion of concrete deck cast onto the	ABC	Precast	complete		2005	
423	TX	US 83 & SH 359 Interchange	Graffiti Proofer and concrete curing agent	Coatings & Corrosion	Paint systems	complete		2005	
424	TX	IH 35 at FM 2063 & at Crossover Rd.	Prefabricated concrete U-beams with portion of concrete deck cast onto the	ABC	Precast	complete	see 422	2005	
425	UT	I80 at State Street	High Strength Concrete Deck	HPC	Decks	not recommended		1999	No information provided by DOT
426	UT	Route 89 MP 388 6 Cache CO	High Performance Concrete in Box Girders	HPC	Girders	no report		2000	
427	UT	East Bound State Rte 79 Grade Separation/Reeves Rd.	Clad Stainless Steel Rebars in Deck Slab (changed to MMFX)	Reinforcing Bars	MMFX	complete		2001	
428	UT	County Road over I-80 in Wanship, UT	Accelerated Bridge Construction - Precast deck panels	ABC	Precast	not recommended		2002	
429	UT	(unnammed record of funding)	Coating/Painting, HPC	Coatings & Corrosion	Paint systems	no report		2002	
430	UT	I-215 NB over 3760 South Street at 3300 East Salt Lake City	Multiple ABC Projects	ABC	SPMT	complete		2003	
431	UT	US 6 Bridge over UPRR	High Performance Steel in I-Beams and MMFX Rebars in Deck Slab	Reinforcing Bars	MMFX	not recommended		2004	Very little information provided by DOT
432	UT	F-54,F-156 and C846	Instrumentation of deck to evaluate long term performance.	Monitoring		not recommended		2005	long term - funds available
433	UT	I-84 Weber Canyon ABC	ABC - Precast bent caps, pre-cast post tensioned columns.	ABC	Precast	complete		2006	
434	UT	I80 at Summit Park Crossing interchange				not recommended		2009	Technology not reported
435	VA	(unnammed record of funding)	See individual projects			no report		1999	Technology not reported
436	VA	(unnammed record of funding)				no report		1999	Technology not reported
437	VA	(unnammed record of funding)				no report		1999	Technology not reported
438	VA	Route 40 over Nottoway River - 1999 IBRC # 2 - Composite Piles	Composite Piles	Foundations		no report		1999	
439	VA	Route 11 over Maury River - IBRC # 6 - FRP Fibers with HPC	FRP Fibers used in High Performance Concrete	FRP	Conc Strengthening	complete		1999	
440	VA	Relocated WBL Rt. 460 over Rt. 29 Bypass - 1999 IBRC # 1 - SSC Reinforcement	Stainless Steel Clad Reinforcement	Reinforcing Bars	Stainless	complete		1999	
441	VA	Trouteville Weight Station Ramp - 1999 IBRC # 4 - FRP Panel	FRP Composite Deck Panels	FRP	Decks	complete		1999	
442	VA	Route 106 over Chickahominy River - IBRC # 5 - LW HPC	Lightweight High Performance Concrete used on AASHTO Girders	HPC	Girders	complete		1999	

Summary Sheet Tracking

Completed Contact Report Forms			Technology	Category	Sub-Category	Status (initiated / needs input / complete)	Award year	COMMENTS
443	VA	Route 250 over Tuckahoe Creek - 2000 IBRC # 2 - FRP Rebar	FRP Reinforcement, Corrosion Resistance, and Lightweight Construction	Reinforcing Bars	FRP	complete	2000	
444	VA	Route 601 over Dickey Creek, Sugar Grove - 2000 IBRC # 1 - FRP Beams	FRP Superstructure, Done with Maint. Forces, Lightweight Construction, Corrosion	FRP	Conc Strengthening	complete	2000	
445	VA	Route 123 @ Occoquan River - IBRC # 1 - Corrosion Resistent Reinforcement	Clad Stainless Steel Rebars in Deck Slab. MMFX2 Bars substituted for Clad Stainless	Reinforcing Bars	Stainless	complete	2001	
446	VA	Route 668 over Gills Creek - 2002 IBRC # 1 - FRP Rebar	FRP (GFRP) Rebar	Reinforcing Bars	FRP	complete	2002	
447	VA	Route 33 over Pamunkey River - 2002 IBRC # 2 - HPC, SCC and Bulb Tee	High Performance Concrete, Self Consolidating Concrete, PCEF (Bulb Tees)	HPC	Girders	complete	2002	
448	VA	Hawthorne Street over C&O (CSX) Railroad - 2003 IBRD # 1 - FRP Panels	FRP deck panels, strength and life prediction of FRP panels, panel to panel	FRP	Decks	complete	2003	
449	VA	Route 624 over Cat Point Creek - 2003 IBRC # 2 - UHPC for Bulb-Tee Girders	Ultra-High Performance Concrete for Prestressed Bulb-Tee Girders	HPC	Girders	complete	2003	
450	VA	Rte. 33 over Pamunkey River - Lightweight High Performance Concrete Bulb-T Beams - 2003 IBRC	Lightweight High Perf. Concr., New Precast shapes (PCEF), Low Permeability	HPC	Girders	complete	2003	
451	VA	Rt.17 Bridge over Rt.15 and Rt. 29	High Performance Concrete in Deck Slab and Self Consolidated Concrete in Bulb Tees	HPC	Decks	no report	2004	
452	VA	Route 58 over Cove Creek	Steel Sandwich Panel Deck System	Other	Sandwich Plates	no report	2004	Talk to Bill Wright
453	VA	Route 58 over Big Moccasin Creek (NBL) - IBRD # 3 - 300ksi Prestressing Strand	Grade 300 strands, High Performance Concrete, Bulb Tees	HPC	Girders	no report	2004	
454	VA	FRP Deck Panel Systems Island - 2005 IBRC # 1 - Tangier Island	FRP Deck Panels (Two systems)	FRP	Decks	no report	2005	
455	VA	Route 16 over Fox Creek - 2005 IBRC # 2 - (Full Depth Prestressed High Performance Concrete	Full Depth Prestressed Precast High Performance Concrete Deck Slab, HP	HPC	Decks	no report	2005	
456	VA	Route 28 over Broad Run - 2005 IBRC # 3 - SC concrete in Drilled Shaft	Use of Self Consolidating Concrete (High Performance Concrete) in Drilled Shaft	SCC	(none)	no report	2005	
457	VA	Nimmo Parkway over West Neck Creek - 2006 IBRD # 1 - SCC in Super and Substructure	Self Consolidated Concrete in Superstructure and Substructure	SCC	(none)	no report	2006	
458	VA	Bridge on Route 712 over Route 29				no report	2009	Technology not reported
459	VT	Bridge 213 carrying VT Rte 100 over Ryder Brook	FRP Rebars and High Performance Concrete in Deck Slab	FRP	Decks	complete	2001	
460	VT	VT Bridge 64, VT 105 over Clyde River	MMFX Rebars	Reinforcing Bars	MMFX	complete	2002	
461	VT	Moretown Bridge, Lovers Lane over Mad River	FRP Deck (to reduce dead load for historic truss)	FRP	Decks	not recommended	2003	No information provided by DOT
462	VT	Bridge #8 FAS 0166 over White River	High Performance Steel in I-Girders	HPS	Beams/Girders	complete	2004	
463	VT	Route 50 over Ottauquechee River	Accelerated Bridge Construction with precast deck elements	ABC	Precast	complete	2005	
464	VT	Bridge 2, Readsboro	Accelerated Bridge Construction with precast box culvert, wings, and headwall	ABC	Precast	complete	2005	
465	WA	SR 20, Twisp River Bridge	High performace concrete in pre-tensioned and post-tensioned girders	HPC	Girders	complete	1999	
466	WA	US Route 2 - Barclay Creek Bridge	High Performance Steel in Plate Girders	HPS	Beams/Girders	complete	2000	
467	WA	Chief Joseph Dam Br. - Pearl Rd. over Foster Creek	FRP Deck Panels	FRP	Decks	complete	2001	
468	WA	Ever's Bridge - Shelton-Matlock Rd over Decker Creek	FRP Bonded Reinforcement	Reinforcing Bars	FRP	complete	2001	
469	WA	Monroe Street Bridge over Spokane River	Precast deck panels with a thin, reinforced high performance concrete overlay	HPC	Decks	complete	2002	
470	WA	Granite Falls Bridge #102 over the South Fork of the Stillaguamish River	FRP Deck Panels	FRP	Decks	complete	2003	
471	WA	William Bugge Bridge, SR 104 across the Hood Canal	High performance steel in truss pipe members	HPS	Beams/Girders	complete	2003	
472	WA	William Bugge Bridge, SR 104 over Hood Canal	Rapid move of new 605-ft long precast concrete superstructure in high seismic	ABC	Precast	complete	2004	
473	WA	SR 20, Fredonia Shaft Test	Self Consolidated Concrete in Piles	SCC	(none)	complete	2005	
474	WA	Congestion Reduction in the Lake Washington Corridor - SR 520 Bridge Replacement and	Design of Toll System and Active Traffic Management Techniques to Rapidly Deploy	Other		complete	2007	
475	WA	US12 over Tieton River	SCC in griders	SCC	(none)	complete	2009	Technology not reported
476	WI	STI 131 Winchel Valley Land Br. Rockton	HPC	HPC		no report	2000	
477	WI	SHT131 New Land Bridge B-62-187	HPS	HPS		no report	2000	
478	WI	STH 172 USH 41, IH43 Ashland Ave. Bridge	Clad Stainless Steel Rebars in Deck Slab	Reinforcing Bars	Stainless	no report	2000	
479	WI	Highway 151 over State Highway 26	FRP Deck Panel	FRP	Decks	complete	2001	

Summary Sheet Tracking						Status		Award	COMMENTS
Completed Contact Report Forms			Technology	Category	Sub-Category	(initiated / needs input / complete)		year	
480	WI	US Highway 151 over De Neveu Creek	FRP grid reinforced concrete deck	FRP	Wraps	complete		2002	
481	WI	IH 39/94 over Door Crk.	Precast full width deck pannel	ABC	Precast	complete		2003	
482	WI	North Bound off ramp from North Bount I-43 to Tory Hill of the Marquette Interchange	Solid Stainless Steel Rebars	Reinforcing Bars	Stainless	no report		2004	
483	WI	USH 12, Coffee Cr Crossing	FRP Deck Panel/ strutted tied deck arch	FRP	Decks	complete		2005	
484	WI	USH 063 USH 63 over Rush River	Accelerateed bridge construction.	ABC	Precast	complete		2005	
485	WV	Market Street Bridge	FRP Deck Panel	FRP	Decks	complete		1999	
486	WV	East Street Viaduct carries CSX RR over WV Alt 14A	FRP Bonded Reinforcement	Reinforcing Bars	FRP	complete		1999	
487	WV	Hanover Bridge	FRP Deck Panel	FRP	Decks	no report		1999	
488	WV	Katy Truss carrying WV 250 / 11	FRP Deck Panel	FRP	Decks	no report		1999	
489	WV	Veterans Hospital; County Road 98	FRP Bonded Reinforcement	Reinforcing Bars	FRP	no report		1999	
490	WV	Big Arch Bridge				no report		2000	Technology not reported
491	WV	CO39 West Buckeye Br./Dunkard CR.09.mi E WV7				no report		2000	Technology not reported
492	WV	CO39 West Buckeye Br./Dunkard CR.09.mi E WV7				no report		2000	Technology not reported
493	WV	Howells Mill Bridge CR 1 over Mud River	FRP Deck Panel	FRP	Decks	complete		2001	
494	WV	Big Arch Bridge	FRP Bonded Reinforcement	Reinforcing Bars	FRP	no report		2001	
495	WV	Cedar Creek Truss on CR 119/13	Steel clad deck reinforcement and high performance steel girders.	Reinforcing Bars	Stainless	no report		2002	
496	WV	Bigley Ave. Interchange Charleston, WV	Very early strength latex modified concrete overlay patching for accelerated	HPC	Overlay	complete		2002	
497	WV	Powell Branch Bridge				no report		2003	Technology not reported
498	WV	Culloden Railroad Overpass Bridge	Use of hybrid steel girders (100 W, 70 W, and 50 W).	HPS	Beams/Girders	complete		2003	
499	WV	Honey Creek Bridge	High Performance Concrete in Deck Slab, High Performance Steel in I-Girders, and Self-consolidating concrete.	HPC	Decks	not recommended		2005	Very little information provided by DOT
500	WV	Stalnakar Run Bridge County Route 219/86 (MP 3.18) over Stalnakar Run		SCC	(none)	complete		2006	
501	WV	Man Bridge in Logan Co	Use of a polmer deck sealant for penetrating cracked bridge decks.	Deck Coatings	Polyester	complete		2007	
502	WY	Statewide Sign Structures	Other - Sign Structures	Other	Sign Structures	complete		1999	
503	WY	Ranch_Rd_Interchange_over_I25	High Performance Steel	HPS	Beams/Girders	complete		2002	

Number of Complete Reports:	289
Number of Projects with "No Report" submitted by State:	115
Projects "Not Recommended" for Summary Report:	100
Total:	504
% Completed	100%