IDEA

Innovations Deserving
Exploratory Analysis Programs

NCHRP IDEA Program

Products with an Impact or Potential Impact on Current Highway Practice

Notable Examples

March 2015

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

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TRANSPORTATION RESEARCH BOARD
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March 27, 2015

Dear Transportation Professional:

Over the course of the past twelve years, I have had the opportunity to serve as a member and chair of this innovative program within the National Cooperative Highway Research Program (NCHRP). I have found this particular program to be quite unique among all other transportation research programs and know that it is resulting in many implementable products that are solving some of our challenging highway transportation problems. The NCHRP Innovations Deserving Exploratory Analysis (IDEA) program is making a difference in the transportation world around us, and I have found my participation to be very rewarding. This report tells a powerful story about successful and innovative solutions to our pressing transportation problems.

The IDEA projects are solicited from anyone with an innovative idea, which may result in an implementable product that will solve a highway transportation problem. All of the funded projects must meet the criteria of being high risk, and having a high payoff, if successful. This initial funding provides seed money to explore cutting edge concepts in the broad area of highway transportation. The products described in this report have also been identified by type, so you can read about the specific products of most interest to you.

This is the second time the NCHRP IDEA staff have investigated and reported on the products funded by the program since its beginning twenty-two years ago. The first report resulted in a finding of roughly 30% of the products being commercialized or with a high potential for implementation or commercialization. This initial finding pleasantly surprised many of us working with the program, since by its very nature the investments are for higher risk, unproven technologies. This second report has resulted in a finding of about 40% of the products having been commercialized or showing a high potential for commercialization. I am amazed at the impact some of the products have made, which were funded years ago. It seems that many of these products take time to mature and enter the marketplace, but once they do, their use grows. It just takes time.

The American Association of State Highway and Transportation Officials (AASHTO) Standing Committee on Research (SCOR) should be very proud of what this program has accomplished over the years, and should be congratulated for its support and faith in this unique research program.

Sincerely,

Sandra Q. Larson, P.E.
Iowa DOT Systems Operations Bureau Director
Past Vice Chair and Member, AASHTO Standing Committee on Research
Past Chair and Member, AASHTO Research Advisory Committee
Chair and Member, NCHRP IDEA Program Committee

Foreword

The NCHRP IDEA program was my first exposure to the NCHRP program and to TRB. As I became involved with the different programs and categories of funding, I learned very quickly that there is a high competition for funding to meet an even higher demand of research needs. The states and their transportation partners are always looking to push the envelope to help resources go farther. The IDEA program, however, always made sense to me. I believe without question the program should be a high priority. This is important research and should be prioritized to respond to the issues of the day. In my experiences holding various leadership positons within the TRB and AASHTO communities, I have seen many instances where research projects tend to be reactive. But research should also be proactive and look for views and opinions outside of the normal ways of doing business. The NCHRP IDEA program does this. It supports out-of-the-box thinkers. The program helps states and others explore risky concepts that they are not able to do themselves. In having the opportunity to be on the NCHRP IDEA program committee for many years, it was a meeting that excited the group. The discussions and brainstorming that occurred during the selection process made us all better as we finished the meetings and went back to our daily obligations. There was opportunity to touch the world of what could be.

The job of Standing Committee on Research (SCOR) and Research Advisory Committee (RAC) members is not easy. I applaud the members through the years who have spent time and shown passion into making sure the investments are wise. Those investment decisions can always be second guessed, but as a past SCOR member and leader of a state DOT, investing in ideas for the future that may be a little unconventional now, but offer opportunity to do something easier, cheaper, faster, and with more quality later, is sound use of our limited resources.

Susan Martinovich, P.E. March 2015

Former Director, Nevada DOT
Past President, AASHTO
Past Chair and Member, AASHTO Standing Committee on Research
Past Member, TRB Executive Committee
Past Member, NCHRP IDEA Program Committee

Acknowledgements

The information presented in this report would not have been possible without the help of a great many individuals. First and foremost, the IDEA researchers were most helpful in furnishing updated information on their IDEA products. The list is long but not acknowledging them by name would be a grave injustice, for they were the most important, and in many instances the only, source of information on their IDEA products. They are: Bassem Andrawes, Neal Berke, Stan Birchfield, Jean-Louis Briaud, Michel Bruneau, William Buttlar, Leonardo Caseres, Warren Chesner, Madhav Chitturi, Yong Cho, Richard Christenson, Barry Dempsey, Shane Farritor, Maria Feng, Elham Fini, Paul Fuchs, Thomas Hay, Simon Hesp, John Hewitt, Christopher Higgins, John Hillman, Mara Johnson, Vineet Kamat, Neeraj Kanhere, Wesley Keller, John Kemeny, Sang-soo Kim, Jialiang Le, Terry Lee, Guoqiang Li, Michael Lusher, King Mak, Mihai Marasteanu, Louis Marcil, Douglas Meegan, Michael Mooney, Larry Olson, Didem Ozevin, David Noyce, Jamie Padgett, Tongyan Pan, Stephen Pessiki, Deems Pfaff, Therese Pflaum, Jerry Plunkett, John Popovics, Anand Puppala, Kyle Rollins, Alberto Sagues, Sanjay Sampath, Paul Santi, Wayne Sarasua, David Savage, Xianming Shi, Roger Simpson, John Stormont, Douglas Thomson, Yajai Tinkay, Kim Tremaine, Yichang (James) Tsai, Julie Vandenbossche, Semyon Vaynman, Linbing Wang, Glenn Washer, Rusty Weiss, David White, Xiong (Bill) Yu, and Karl Zimmerman.

Many state and federal department of transportation (DOT) officials were also more than willing to share their experiences with the IDEA products that they had evaluated or implemented. Special mention must be made of David Owens, Ivan Lasa and David Horhota (Florida DOT), David Meggers (Kansas DOT), Gloria Burke (Maryland DOT), James Garrard, Jr. (Oregon DOT), Stephen Sharp and Daniel Roosevelt (Virginia DOT), Mark Dunn and Norman McDonald (Iowa DOT), John Wenzlick (Missouri DOT), and Richard Meininger and Julie Zirlin (FHWA).

Finally, several NCHRP IDEA program committee members, past and present, volunteered with helpful information on the implementation of IDEA products that they were aware of. They are: Sandra Larson, Michael Sprinkel, James Sime, David Kuehn, Joe Mahoney, and Tommy Nantung.

The NCHRP IDEA program is deeply indebted to all these IDEA researchers, DOT officials, and committee members for their help in making this report possible.

Special thanks are also due to Ms. Sandra Larson, chair of the NCHRP IDEA program committee, and Ms. Susan Martinovich, a past president of the AASHTO and a past member of the NCHRP IDEA program committee, who kindly wrote an introductory letter and the foreword, respectively, for this report.

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Introduction

This report presents a summary of some of the successful projects from the NCHRP IDEA program, a special project (SP 20-30) of the National Cooperative Highway Research Program, from its inception in 1993 until present (2015).

IDEA (**I**nnovations **D**eserving **E**xploratory **A**nalysis) is a unique concept for transportation research that originated in the first Strategic Highway Research Program (SHRP) and has continued at the Transportation Research Board as the NCHRP IDEA program after the completion of the SHRP in 1993. The program owes its existence and sustenance to three visionaries of the transportation community of their time – Mr. Frank Francoise, the-then Executive Director of AASHTO, Dr. Thomas Larson, the-then Secretary of Pennsylvania DOT and later the FHWA Administrator, and Mr. Dean Carlson, the-then FHWA Executive Director and later the Secretary of Kansas DOT and President of AASHTO – who foresaw the need for such a program seeking innovative, out-of-the-box solutions to pressing highway infrastructure problems. Unlike most transportation research solicitations where competitive proposals are requested on a specific objective with specific tasks, the NCHRP IDEA program seeks out proposals from entrepreneurs, inventors, forward thinkers, and problem solvers – anyone who has a possible solution to any vexing highway transportation problem.

The NCHRP IDEA program provides seed money to explore the technical feasibility of innovative, untried concepts for highway transportation applications. Recognizing that product development and implementation is an involved and intensive process, an IDEA project is intended to help initiate this process. Before a product can be implemented, it usually must go through further development, evaluation, commercialization, and marketing. Considering what it takes to do all this, an IDEA project is a very modest investment ($100,000-150,000). There is a high risk associated with untried and unproven approaches; not every IDEA concept is expected to materialize. Still, despite the modest investment of resources and the high risk involved, a number of NCHRP IDEA projects not only have proved the technical feasibility of their innovative concepts but also have led to the development of implementable products.

As of now, 162 NCHRP IDEA projects have been completed. Of these projects, 27 have led to products that are now in the marketplace. This translates into a success rate of about 1 in 6 projects. Another 40 plus completed or active projects have resulted or are expected to result in products with a high implementation potential in the near term, if provided resources for further development. Some of these products are expected to be on the market within the next two to three years.

The two charts at beginning of the report summarize NCHRP IDEA products that have made to the marketplace or show much promise and are followed by some examples in the following categories:

- NCHRP IDEA products commercialized or implemented
- NCHRP IDEA products supported by FHWA's Highways for LIFE Program for further development and commercialization
- NCHRP IDEA products supported by state DOTs through pooled fund studies for further evaluation and implementation
- Promising NCHRP IDEA products with high implementation potential

NCHRP IDEA Products

At a Glance

- Products in the Marketplace
- Promising Products with High Implementation Potential

Products in the Marketplace

Note: Products highlighted in blue are described in more detail in pages following the charts.

	Product	Benefits	Implementation/Application
1	Sprayed zinc galvanic anode for corrosion protection of reinforcing steel in marine substructures (Project #3) Funding: $65,000 Completion: 1995	Prevents steel corrosion in marine substructures Far less expensive than impressed current ($15-30/ sq. ft. vs. $400-500/sq. ft.) Lasts 8-12 years; respraying is neither expensive nor labor-intensive	A number of state DOTs have standardized the use of metalized zinc technology for bridge rehabilitation. Florida and Oregon lead the way in implementing the technology on a number of their coastal bridges. Other notable user states include Virginia, Missouri, and Alaska. Also being widely used in non-transportation structures, such as high-rise buildings, parking garages, concrete cooling towers, concrete intake and outfall structures in power plants, and dock facilities.
2	An interlayer stress absorbing composite for pavements (ISAC) (Project #6) Funding: $60,000 Completion: 1995	Minimizes pavement reflection cracking Extends pavement service life; reduces maintenance costs	Approved and used by Illinois DOT on several state roads and airports. Wisconsin, Minnesota, and Nebraska also evaluated ISAC. Also used on Houston's Hobby airport. Cost needs to be competitive for its widespread use. Distributed by Crafco, Inc. (Chandler, Arizona).
3	Admixture for improved corrosion resistance of concrete (Hycrete) (Project #13) Funding: $60,000 Completion: 1995 *'Technology Pioneer Award' at World Economic Forum, Davos, Switzerland (2008)*	Inhibits steel corrosion Waterproofs concrete; protects concrete from frost and moisture damage Extends service life of concrete pavements and structures; reduces maintenance costs	Evaluated by a number of states (New Jersey, New York, Ohio, Virginia, Kansas, and the six New England states) and the U.S. Army Corps of Engineers in various construction projects. Approved for use by Ohio and Virginia DOTs. Being widely used in the private sector for commercial and residential real estate, parking garages, and other structures. Sold by Hycrete Technologies, Inc. (Carlstadt, New Jersey).
4	Automated bridge deck anti- and de-icing system (Project #27) Funding: $70,000 Completion: 1998	Prevents ice formation on bridge decks Reduces snow-related accidents, saves lives, Reduced exposure of highway workers to winter operations hazards	This IDEA project was the first to demonstrate this European technology in the U.S. on a bridge in Utah. Minnesota and Ontario (Canada) lead in implementing the technology, with installations on a number of bridges in their jurisdictions. The technology has also been evaluated or implemented by Colorado, Kansas, Kentucky, New York, North Carolina, Virginia, Maryland, Pennsylvania, Wisconsin, and Washington State. Recent installations include Minnesota's I-35 W Saint Anthony Falls Bridge in Minneapolis and Highway 61 Bridge near Hastings and Nevada's Galena Creek Bridge near Reno.

5	Corrosion-resistant steel for concrete reinforcement (DMF/MMFX steel) (Project #28) Funding: $70,000 Completion: 1997 *Winner of the American Society of Civil Engineers' 'Charles Pankow Award' for innovation (2002)* *Winner of the Construction Innovation Forum's 'NOVA Award' for innovation (2004)*	About five times as corrosion resistant and twice as strong as conventional steel Structures using MMFX steel require 20-40% less steel and incur 20-50% less labor costs	A number of states have evaluated or implemented MMFX steel in their bridge projects. These include: Iowa, Florida, West Virginia, Virginia, Delaware, New Jersey, Louisiana, South Dakota, Michigan, Kentucky, Connecticut, Vermont, Texas, Pennsylvania, New Mexico, and Manitoba, Canada. The U.S. Navy and the U.S. Army Corps of Engineers also used MMFX steel on pier and bridge projects in California and Oklahoma. In use by the private sector across North America in residential and commercial buildings, parking garages, and other structures. Sold by MMFX Steel Corporation (San Diego, California). The company has now extended its operations in the Middle East with a new MMFX steel plant in the United Arab Emirates with an annual production capacity of 100,000 metric tons of MMFX steel.
6	Fiber-reinforced polymer composite bridge deck (Projects #30, 46) Funding: $144,000 Completion: 2000 *Winner of 'Counterpoise Grand Design' and 'Best of Market'* Awards *at the International Composite Expo (1997)* *Winner of the 'R&D 100 Award' of the R & D Magazine for innovation (1997)* *Bridge in Fairfield, Ohio was featured on the National Public Radio (2008)*	Rapid installation saves construction time and labor; reduces traffic delays Reduced dead weight allows carrying more live load Corrosion-free, longer service life	The IDEA-funded No-Name Creek Bridge in Russell, Kansas, was the first all-composite bridge in the U.S. Since then, the technology has been implemented by the IDEA contractor in Kansas, Missouri, Nebraska, Colorado, West Virginia, Ohio, Pennsylvania, and New York. Other composite manufacturers have followed suit and installed composite decks in a number of states (Idaho, California, Ohio, New York, Oregon, Maryland, Iowa, Pennsylvania, Illinois, Delaware, North and South Carolina, Virginia, West Virginia, Washington State, among others). There are now more than 400 fiber-reinforced polymer composite bridge deck installations in North America, and the number continues to grow.
7	Pavement quality indicator (PQI) (Projects #32, 47) Funding: $158,000 Completion: 1998 *Winner of the Construction Innovation Forum's 'NOVA Award' for innovation (2003)*	Non-nuclear device eliminates the hassle and hazards associated with owning or operating a nuclear gauge Costs much less than the nuclear gauge to maintain (about $200 vs. about $3,000) Rapid, takes only a few seconds to measure density during paving operation	The technology has been extensively evaluated by a large number of states including Maryland, Pennsylvania, New York, Idaho, Virginia, Minnesota, Connecticut, Oregon, Delaware, Ohio, Florida, North Carolina, Nebraska, Iowa, Illinois, Kentucky, Texas, Wisconsin, and Arkansas. Recommended as a quality control tool but not for quality assurance. Several states (Maryland, Pennsylvania, New York, and Idaho) allow its use for quality control purpose. Many paving contractors now routinely use the PQI for quality control in accordance with AASHTO's specifications for non-nuclear gauges.

8	Hybrid composite beam for bridges (HCB) (Project #60) Funding: $150,000 Completion: 2007 *American Council of Engineering Companies' 'National Grand Award' for the Lockport Bridge in Illinois (2009)* *Engineering News Record's 'Award of Excellence' to IDEA inventor (2010)* *Construction Innovation Forum's 'NOVA Award' for innovation (2010)* *American Society of Civil Engineers' 'Charles Pankow Award' for Innovation (2013)* *IDEA inventor recognized by the White House as one of twelve 'Transportation Champions of Change' (2013)*	High performance, corrosion-resistant, lightweight beam (only about one-tenth the weight of precast concrete beam and one-third the weight of steel beam for the same size bridge) Easier and less costly to ship and erect a bridge with HCB than with conventional material beams, saving time and money Estimated service life of more than 100 years	HCB was successfully tested on a railroad test track in Pueblo, Colorado. Since then, the beams have been installed in 17 highway bridges in nine states (Colorado, Illinois, Kentucky, New Jersey, Maine, Maryland, Missouri, Virginia, and West Virginia) and the province of British Columbia, Canada). At least seven more HCB projects are under consideration for construction in Maine, New Jersey, Washington State, and the provinces of British Columbia, Ontario, and Saskatchewan. The U.S. Army Corp of Engineers used HCB on a bridge in Kentucky. The IDEA inventor has signed licensing agreements with companies in the European Union, Russia, Kuwait, and Brazil. The AASHTO's Technology Implementation Group selected HCB as a focus technology for implementation in 2011.
9	Horizontal wick drains (Projects #57, 76) Funding: $124,000 Completion: 2003	Prevents highway landslides (facilitates drainage to lower the water table) Inexpensive, rapidly installed by crew with minimal training and equipment Resistant to rupturing and clogging better than PVC or steel pipe drains	Technique was successfully demonstrated in Missouri, Colorado, and Indiana. Continues to be used by private manufactures, geotechnical firms, and local agencies (American Wick Drain Corporation, Nilex Corporation, Gillen Company, Tetratech, Inc., Kleinfelder, Inc., Department of Public Works of Mesa County, Colorado, and Blackhawk Geologic Hazards Abatement District in California).
10	A computer-controlled image analysis system for measuring aggregate shape properties (AIMS) (Projects #77, 114) Funding: $110,000 Completion: 2007 *FHWA's Highways for L IFE Program funded further development*	Automated, rapid, and accurate aggregate characterization without operator's influence and bias; saves time and money Versatile – characterizes aggregates for Superpave sieve sizes from 0.075 mm to 25 mm retained Helps select aggregates with better skid resistance for pavements	An improved version of the instrument, AIMS-2, was recently developed and validated with FHWA's support through an inter-laboratory testing project involving 32 private, state DOT, and university laboratories. Two AASHTO provisional specifications (TP81 and PP64) have been adopted based on AIMS. FHWA is currently using AIMS for demonstration and training purposes in its mobile testing laboratory. Sold by Pine Instruments Company (Grove City, Pennsylvania).

11	Improved asphalt cement specifications test methods (Projects #84, 104) Funding: $161,000 Completion: 2006	Test specifications help eliminate thermal stresses in asphalt pavements to avoid premature failure Help select asphalt cement resistant to cracking at low temperatures	Four test methods (LS-228, 296, 299, and 308) now form part of the Ontario Ministry of Transportation's Laboratory Testing Manual and are in use by a majority of asphalt cement suppliers and testing laboratories in Canada. The Quebec province and several Canadian cities (Ottawa, Edmonton, Muskoka, North Bay, Kingston, and Timmins) are also using the methods to help select better quality asphalt cement. Two test methods (LS-296 and 299) are under consideration by the AASHTO. The Europeans have already standardized the LS-296 Test.
12	DriveCam (Project #ITS 84) Funding: $95,000 Completion: 2001 *Received wide media coverage (ABC's World News Tonight and Good Morning America, CBS's Early Show, NBC's Dateline, CNN, and Wall Street Journal)* *Featured on Discovery Channel's show, 'The Truth about Traffic,' focusing on improving traffic flow and driving habits*	Improves driving behavior; reduces accidents, Helps determine accident liability, saving time and money Recorder, triggered by crash or erratic driving, can also be activated manually to capture road rage, hit-and-run, or other road events	Use of DriveCam by transit agencies and industry continues to increase. Transit agencies using DriveCam include San Francisco, Austin, New Jersey, and Washington, DC. Other government agencies and major private companies using DriveCam on their fleets include Alaska DOT, Orange County (Florida), the U.S. Department of State, the U.S. Marines Corps, Greyhound, Sysco Corporation, U.S. Foods, Linde Gas, Ameri Gas, and TXI (a Dallas-based cement manufacturer), among many others. Maryland and Iowa DOTs used DriveCam for teen drivers' behavior and safety programs. DriveCam has now evolved into a major commercial enterprise (was ranked 67th by the Inc. magazine in its list of 500 fastest-growing companies in America in 2005). Sold worldwide by Lytx, Inc. (formerly DriveCam, Inc.), based in San Diego, California.
13	Self-consolidating concrete (SCC) (Project #89) Funding: $78,000 Completion: 2005	Better consolidation for enhanced durability, no vibration-induced segregation Reduces construction time; saves labor costs Uses less material	This project was among the earlier studies in the U.S. to adapt SCC technology for domestic use. Since then, a number of state DOTs, including Florida, Illinois, Nebraska, New Jersey, Nevada, Ohio, and Virginia, have developed SCC construction specifications. Maine showcased its use on its Ogunquit Beach Bridge. Nebraska used SCC on its Skyline Bridge in Omaha. Virginia used it on its Pamunkey River Bridge on Route 33 near West Point. Minnesota used it in the drilled shafts of its new I-35W St. Anthony Falls Bridge in Minneapolis. Mississippi used SCC in its Biloxi Bay Bridge. Other notable structures in the U.S. built with SCC include the U.S. Mission at the United Nations and the Freedom Tower in New York, the Trump Tower in Chicago, and the Comcast Center in Philadelphia.

14	A vertical composite drain system to mitigate soil liquefaction hazard (EQ Drains) (Projects #94, 103) Funding: $148,000 Completion: 2007	Prevents liquefaction and structure collapse due to earthquake by providing a conduit for rapid pore pressure dissipation Drains installed at a fraction of time and cost of alternative methods and need no post-treatment testing to confirm their effectiveness Can be used in new construction or to upgrade existing foundations	Utah DOT and the British Columbia Ministry of Transportation assisted in evaluating the drain system. EQ Drains have been used by California, South Carolina, and Washington DOTs, the Port and the City of Seattle, the Federal Bureau of Prisons, the General Services Administration, the U.S. Marine Corps, Charleston County School District and Daniel Island (South Carolina), Cape Fear Valley (Fayetteville, North Carolina), Bahia Beach Resort and Punta Santiago (Puerto Rico), California Department of Schools, and several commercial interests in Charleston, South Carolina. Sold by HB Wickdrain, a division of Hayward Baker, Inc. (Centennial, Colorado).
15	Asphalt binder thermal cracking test (ABCD) (Project #99) Funding: $76,000 Completion: 2007 *FHWA's Highways for LIFE Program funded further development*	Simple field-like test accurately predicts cracking temperature in cold climate Helps avoid using binders susceptible to cracking at low temperatures Allows simultaneous testing of multiple samples; saves time and money	Device was tested by more than 30 laboratories from state DOTs, universities, and industry across the U.S. and Canada. The test was also evaluated in Minnesota's MnRoad Project. Recently, New Hampshire and Ohio DOTs used ABCD to evaluate their asphalt mixes. A test procedure (TP92) based on ABCD has been adopted by AASHTO for low temperature evaluation of asphalt binders. The developer has received inquiries from overseas customers in the United Kingdom, China, Russia, and Poland. Sold by EZ Asphalt, Inc. (Athens, Ohio).
16	Impact echo scanner for nondestructive evaluation of grout/voids in post-tensioned bridge ducts and imaging structural concrete defects (Project #102) Funding: $85,000 Completion: 2006	Rapid (about 14 feet per minute) and reliable scanning locates areas of void in need of grouting repair Testing needs access to only one side of the structure Applicable to both steel and plastic post-tensioning ducts	At least eight state DOTs have used or evaluated the scanner technology in their bridge projects. Agencies and institutions that own the system include Virginia DOT and the Metropolitan Water District of Southern California. A number of units have been sold in China, Germany, the United Kingdom, and Saudi Arabia to various agencies and institutions. Sold by Olson Instruments, Inc. (Wheat Ridge, Colorado).
17	A mobile geophysical survey method based on electromagnetic induction technology to detect and identify subsurface objects and features (Project #107) Funding: $90,000 Completion: 2006	Rapid survey and mapping (up to 140 lane-miles per day) Reduces construction delays by detecting unexpected subsurface conditions and objects in advance Helps reduce change orders, construction claims, schedule slippage, and cost overruns	California DOT evaluated the method on two highway projects with satisfactory results. Reclamation districts in the Sacramento-San Joaquin Delta also used the technology in their projects. Technology was fully utilized for levees work by several California water resources divisions. Also used for detecting buried archeological artifacts in Egypt and Mexico. The mobile system is available for consulting from Argus Technologies, Inc. (Western Sacramento, California).

18	A microwave imaging device for the nondestructive evaluation of fiber-reinforced plastic composite-wrapped concrete bridge members (Project #109) Funding: $79,000 Completion: 2007	The only available nondestructive method to detect debonding of FRP composite wraps in concrete bridge components Rapid, real-time damage detection allows timely repair to extend bridge's service life	California and New York State DOTs evaluated the device on their bridge projects. Conclinic (a subsidiary of Fyfe Company, a leading manufacturer of FRP products for structural repairs) used it on a bridge in Seoul, South Korea. Obayashi Corporation, a leading construction firm in Japan used the device for real-time concrete tunnel inspection. Device available from Newport Sensors, Inc. (Irvine, California).
19	A soil compaction control measurement device (Project #118) Funding: $95,000 Completion: 2009	Helps ensure proper soil compaction in highway construction projects The only portable device for measuring soil modulus both in the laboratory and the field Rapid test, takes only a few seconds	Florida DOT evaluated the device for field use. A New Mexico DOT project also used it for soil modulus measurements. Other user agencies and institutions include Geotechnics, Inc. (a geotechnical firm in New Zealand), the Missouri University of Science and Technology, the University of New Mexico, and the University of Sherbrook (Canada). FHWA plans to acquire several units for evaluation. Efforts are underway to develop an ASTM standard for this new compaction test. Device commercially available from Roctest, Inc. (Montreal, Canada) with sales offices also in California and Pennsylvania.
20	Three-dimensional digital imaging for management of unstable highway slopes (Split-FX) (Project #119) Funding: $99,500 Completion: 2008 *The NSF/SBIR Program and several states further funded the development and evaluation of the software product through a pooled-fund study*	Eliminates safety hazards associated with traditional geotechnical surveying Allows rapid and accurate analysis of highway slopes using ground-based LIDAR scanning from distances as far as two kilometers	A pooled-fund study involving eight states (Arizona, California, Colorado, New York, New Hampshire, Pennsylvania, Texas, and Tennessee) evaluated the product for implementation while Alaska tested it separately. An NSF/SBIR project further explored the system for monitoring changes at a variety of infrastructure sites (highways, bridges, dams, foundations, and tunnels). The system has also been used by the U.S. Bureau of Reclamation and the British Geological Survey. The software is commercially available from Split Engineering, Inc. (Tucson, Arizona).
21	A fiber optic accelerometer system to assess structural integrity of bridges under traffic, earthquakes, and other dynamic loads (Project #124) Funding: $130,000 Completion: 2009	Cost effective real-time bridge inspection and early warning for structural damage during seismic events and under other dynamic loads Easy to install, needs no cables or electricity Immune to electromagnetic interference and lightening strikes	California DOT evaluated the device on several bridge sites in California. Tokyo Sokushin, Ltd., a Japanese manufacturer of vibration sensors, is using it for deep ground motion monitoring in Japan. Also being used to monitor a 500-meter commercial/retail building in Nanjing, China. Available from Newport Sensors, Inc., (Irvine, California).

22	Instrumentation to aid in steel bridge fabrication – Bridge Virtual Assembly System (BRIDGE VAS) (Project #127) Funding: $140,000 Completion: 2009 *Several states funded further evaluation through a pooled-fund study*	Automated accurate measurements of all aspects of bridge components Minimizes or eliminates the need for shop fit-up and assembly Identifies mismatch at the shop, allowing corrective actions prior to painting and shipment to the job site; helps avoid costly errors before it is too late Allows use of complex steel bridge designs in situations previously considered impractical	The IDEA product was evaluated with assistance from FHWA and two private steel bridge fabricators from Pennsylvania and South Dakota. A pooled-fund project involving several states (Virginia, New York, Iowa, and Texas) and FHWA further evaluated the system. A bridge fabricator, Hirschfeld Industries (San Angelo, Texas) also helped in the product evaluation. The system was successfully implemented on the first-ever bridge production job in Tennessee. A second bridge production job has been planned in Virginia. The system is available for consulting from Fuchs Consulting, Inc. (Leesburg, Virginia).
23	Bridge deck scanner (Project #132) Funding: $100,000 Completion: 2009	Rapid monitoring of bridge decks for delamination; saves time and money Reduces exposure of highway workers to highway traffic hazards	A prototype system was successfully tested on two bridges in Wyoming. The states of Colorado, California, Virginia, Kansas, and Nevada and FHWA also evaluated the scanner on their bridge projects. The National Center of Asphalt Technology used the scanner to determine condition of hot mix asphalt pavements for debonding between pavement layers. The scanner system is available for consulting from Olson Engineering, Inc. (Wheat Bridge, Colorado).
24	Simple tests for low-temperature properties of asphalt binders and mixtures (Projects #133, 151) Funding: $210,000 Completion: 2012	Provides critical parameters for the current AASHTO's MEPDG specifications Helps select asphalt mixtures with superior low-temperature performance Tests use existing bending beam rheometer (BBR) – require no additional equipment	Utah DOT assisted in evaluating the test methods and has implemented them as part of its routine asphalt mixture testing. The methods are already in use by a number of contractors and laboratories, both in the U.S. and abroad, for low-temperature performance prediction of asphalt mixtures. A draft test method for asphalt binder and mixture creep was presented to the asphalt expert task group for adoption as an AASHTO standard. Another draft test method for low temperature bending strength for asphalt binders and mixtures using the modified BBR is currently under development.
25	A software system for a baseline-free methodology for real-time structural health monitoring and post-event damage assessment of highway bridges (Bridge Doctor) (Project #137) Funding: $129,000 Completion: 2010	Timely detection and location of structural damage in real time, as opposed to current periodic visual inspections Allows remote assessment of post-event bridge damage for timely response/repair	California DOT evaluated the system on Jamboree Overcrossing in Irvine, California. The software system (Bridge Doctor) is commercially available from the developers, Newport Sensors, Inc. (Irvine, California).

26	Computer vision traffic sensor for fixed and pan-tilt-zoom cameras (Traffic Vision) (Project #140) Funding: $135,000 Completion: 2010	Cost effective, real-time traffic data collection and incident detection without having to install additional hardware Collects data in all types of conditions (day, night, rain, fog, snow, congestion, and other scenarios)	The sensor was evaluated in partnership with South Carolina, Maryland, and New York State DOTs. The commercialized system (TrafficVision) is being evaluated, or in use, by several state DOTs and public agencies, including Missouri, Ohio, and South Carolina. Recently, TrafficVision was evaluated for traffic data collection and incident detection capabilities as part of the FHWA's ENTERPRISE pooled-fund study. TrafficVision is also being used as a research tool by institutions, such as Wayne State University, Texas Southern University, and the Texas Transportation Institute.
27	Bridge retrofit laser system (BRIDGE RLS) (Project #153) Funding: $139,000 Completion: 2012	Streamlines bridge retrofit steps; saves time and costs Measures with full 3D accuracy in the 1/1000 of an inch; field measurements can be used to produce CAD drawings automatically Makes direct measurements on a specimen surface *without* requiring a special target Capable of measuring on steel, concrete, and even timber and without having to first access the bridge Minimal impact at the bridge site, including traffic and difficult access conditions	The IDEA product is being used by several state DOTs to provide information that is not possible with other measurement systems. Maryland State Highway Administration recently successfully used the system to measure an adjacent box beam bridge that was over water and presented very difficult measurement conditions. The system is available for consulting from Fuchs Consulting, Inc. (Leesburg, Virginia).

Promising Products with High Implementation Potential

Note: Products highlighted in blue are described in more detail in pages following the charts.

	Product	Benefits	Implementation/Application
1	Basalt fibers and basalt fiber composite rebars for use in concrete (Projects #25, 45, 86) Funding: $137,000 Completion: 2003	Corrosion-free material with superior mechanical performance (Basalt rebar exhibit tensile strength three times that of steel rebar) Much less expensive than steel fibers and rebars	Feasibility of using local basalt mineral (from northern Wisconsin and Minnesota) for making basalt fiber products was demonstrated. Mechanical performance as concrete reinforcement (using surface-modified or twisted rebars) was also established as comparable to steel reinforcement. Developers need to set up a basalt fiber plant using domestic basalt mineral to facilitate implementation of the basalt fiber composite technology in the U.S.
2	A fiber-reinforced composite sidewalk (Project #67) Funding: $75,000 Completion: 2001 *The I-beam developed in the IDEA project was exhibited as one of the 'Highly Engineered Materials Designed for Ultimate Performance in Extreme Conditions' at the Smithsonian Cooper-Hewitt National Design Museum in New York City in 2005*	Lightweight, high-strength, and easily installed where concrete or steel would be too heavy for the existing bridge Allows widening of the road within an existing bridge envelope by moving sidewalk outboard	Demonstration of the sidewalk on a bridge in Vermont was postponed at the final stage due to budgetary problems. Plans to install the sidewalks in New York, New Hampshire, and Massachusetts also did not materialize. However, the I-beam developed in the IDEA project with carbon fabric and epoxy resin has found use in the construction industry.
3	A geocomposite layer system for pavement subsurface drainage (Projects #68, 113) Funding: $150,000 Completion: 2009	Prevents pavement damage due to base/subbase moisture; extends pavement's service life	Project received substantial support from several state DOTs (New Hampshire, Vermont, Maine, and New York) and the U.S. Army Corps of Engineers. The geocomposite layer system was successfully tested in MnRoad Project. The test section with the geocomposite layer system had a considerably drier base and subbase than the control section. Product is available for licensing. Availability of a better and less expensive geotextile for transport layer will help facilitate implementation of the technology.

4	A mechanical system based on anvil and hammer concept for crushing and recycling concrete pavement (Road Recycler) (Projects #79, 95) Funding: $120,000 Completion: 2003 *The USDOT/SBIR Program funded further development*	Saves labor and time for removing, fragmenting, and recycling concrete pavement (machine can lift a 12 feet wide and one foot deep section of concrete pavement, pulverize it into reusable aggregates, and separate and cut steel rebar, leaving behind a roadway ready for paving)	Kansas and Iowa DOTs assisted in testing the prototype. A stationary version of the machine was fabricated for a private highway contractor. The machine is now in Minnesota for continued testing and demonstration. Developer needs substantial additional resources to bring a mobile unit to the market.
5	A robotic safety marker system for highway work zone (Project #90) Funding: $87,000 Completion: 2005 *Reported on the CNN and the BBC. The Discovery Channel featured the markers in its movie, 'Future Cars'*	Minimizes exposure of highway workers to work zone safety hazards Robotic barrels could self-deploy and retrieve and be located accurately up to 80 meters away Rapid deployment (in tests, the barrels took less than two minutes to deploy)	Tests showed good agreement between the desired and actual path for each robotic marker in a realistic environment. A field implementable safety marker system should be feasible in near future by taking advantage of recent advances in electronics and sensor technology.
6	An improved detection control system (D-CS) for high-speed signalized intersections (Project #115) Funding: $75,000 Completion: 2007	Drivers approaching a traffic signal with yellow indication at high speed must decide whether or not to stop. The D-SC helps reduce the likelihood of vehicles being in the dilemma zone	The IDEA work was continued in association with a private company (Intelligent Automation, Inc., Rockville, Maryland) through a USDOT/SBIR project that also incorporated driver warning, in addition to signal control, into the system. A dilemma zone protection system with on-board warning devices was developed and tested at the FHWA's Highway Research Center. The improved system is now available for implementation.
7	A software system for automatic processing and extraction of roadway sign information from video log images (Project #121) Funding: $100,000 Completion: 2009	Replaces current manual practice that is time-consuming, costly, and exposes workers to safety hazards	Several state DOTs (Connecticut, Georgia, Florida, and Louisiana) and the City of Nashville tested the method. The U.S. DOT Research Innovative Technology Administration further funded to improve the automatic sign data collection by using both digital video log images and mobile LIDAR data. Georgia DOT also sponsored a project to test the system on an actual highway (a complete sign inventory data on I-285 in Atlanta, Georgia, was provided). The algorithms were also used to develop an application for streamlining the current sign inventory and condition assessment. The system is available to transportation agencies for cost effectively inventorying their sign assets in support of their asset management activities.

8	A field instrument for automated rapid measurement of air permeability of pavement base or subbase (Project #130) Funding: $100,000 Completion: 2009	Rapid test (takes less than 30 seconds) In-situ permeability measurement allows greater precision in the design, construction, and QC/QA of pavement base/subbase	The prototype instrument was tested in several new road construction projects in Iowa, Pennsylvania, and Michigan, and the results were verified with laboratory measurements.
9	A low-cost wireless sensor system for autonomous monitoring and reporting of highway traffic noise data (Project #131) Funding: $125,000 Completion: 2009	Automated traffic noise monitoring Eliminates expensive hardware and the need for an on-site worker Inexpensive wireless sensors can be mounted inconspicuously and left alone while data is transmitted and accessed over the internet	The system was evaluated by Ohio and California DOTs for noise barrier testing and community and wayside highway noise measurements. The U.S. National Park Service used it for monitoring noise in remote national park locations. The system is available for sublicensing to manufacturers of sound level meters for commercialization and implementation.
10	An "active confinement" bridge rehabilitation technique using shape memory alloy (SMA) reinforcement to retrofit concrete columns (Project #135) Funding: $124,800 Completion: 2010	Active confinement using SMAs improves ductility of bridge columns and helps mitigate damage under excessive seismic loading Saves repair costs while improving a bridge's seismic performance	The technique was further improved and evaluated in a National Science Foundation project. Collaboration with SMA manufacturers is planned for commercializing the technology. There is also an agreement with the Illinois DOT to evaluate the technology on some of its bridges to determine the long-term behavior of the SMA-based reinforcement under various climate conditions.
11	A methodology using vision-based vehicle detection and tracking and decision support algorithms to detect intruding vehicle hazards (Project #139) Funding: $100,000 Completion: 2012	Helps improve work zone safety and reduce fatalities/injuries caused by intruding vehicles or missing traffic control devices The developed mobile work zone traffic data collection/monitoring tower also helps collect data for quantitative evaluation of the performance of work zone traffic control devices, work zone configurations, and driver behavior	The developed algorithms were successfully tested on actual work zones on I-95 and controlled zones on Georgia Tech's Savannah campus. The developed mobile tower was successfully used to collect work zone traffic data in an actual resurfacing work zone on I-95 near Savannah, Georgia. This data also helped study driver merge behavior in work zones affected by different roadway geometries and vehicle types. Discussions with state DOTs are underway to initiate projects for the evaluation and implementation of the developed methodology.

12	Signal head vibration absorber for traffic signal support structures (SHVA) (Project #141) Funding: $135,000 Completion: 2011	Inexpensive and low-maintenance system produces significant vibration damping and reduces fatigue damage Can be used in new signals or retrofitted to existing problem poles Readily field installable, needs no modification of standard signal heads or mounting hardware	System was successfully demonstrated in full-scale laboratory tests. A redesigned unit was tested for over a year in Manchester, Connecticut and was found to be robust to the elements with no loss in performance. The system was also tested at the Texas Tech University's National Wind Institute where the performance results showed a reduction of the vortex-induced vibrations of the mast arm by approximately 90%, which decreased the stress range at critical components of the signal support structure and increased the safe life. Discussions are underway with industry for collaboration on developing a commercially-viable device.
13	A shape memory polymer-based sealant for sealing expansion joints in bridge deck or concrete pavement (Project #142) Funding: $135,000 Completion: 2012	Eliminates sealant squeeze-out from the joints – a typical failure mode for sealing materials such as silicon rubber and rubber-modified asphalt sealants	The sealant was applied to two bridge joints in 2012, which continue to be monitored. The performance so far at both joints has been satisfactory. Louisiana DOTD and two private sealant manufacturers are interested in implementation and commercialization of the IDEA-developed sealant.
14	Asphalt embrittlement Analyzer (AEA) (Projects #144, 170) Funding: $260,000 Completion: 2015	Characterizes asphalt material embrittlement temperature threshold at various pavement depths Determines embrittlement temperature of binders and mixtures for quality control purposes Helps assess and monitor pavement condition and select appropriate maintenance strategies for restoring crack resistance	To facilitate commercialization, collaboration has been maintained throughout the project with Troxler, Inc., a leading manufacturer of asphalt quality control and design equipment with extensive experience in commercializing, distributing, and supporting asphalt testing equipment. Also, collaboration with the Asphalt Institute and a private asphalt paving mix company, Road Science, LLC., have been maintained to help with technology transfer through validation of the method using materials and performance data from high-visibility field projects such as the Minnesota's MnRoad project.
15	Algorithms to extract layer properties from intelligent compaction data (Project #145) Funding: $140,000 Completion: 2012	Industry needs a way to isolate/extract layer parameters from intelligent compaction data. Pavement system design is based on layer parameters (such as resilient modulus) whereas intelligent compaction data provides a composite stiffness of multiple layers	The algorithm software is available freely to all users. The product was not patented and intellectual property protection not sought so as not to jeopardize its implementation by public or private agencies. The information has been published widely and shared with manufacturers who may want to pursue its commercialization.

16	A mobile system for measuring retroreflectivity of pavement markings (Project #146) Funding: $140,000 Completion: 2011 *FHWA's Highways for L IFE Program funded further development*	Measures at a very fast rate (4500 times/second) One-operator system saves labor costs; simplified operation with features such as auto start, voice recognition for user interface, and auto calibration and verification Highly stable system; makes consistent measurements on curves	Work has continued on further refinement and commercialization of the IDEA product in collaboration with the Connecticut DOT and with partial support from FHWA's Highway for LIFE Program. The refined system now produces reliable and stable results. The FHWA and Florida DOT assisted in an extensive evaluation of the system in 2014. The system is now scheduled for evaluation by an independent contractor (Texas A&M Transportation Institute) in early 2015.
17	Shape memory alloy-enhanced SMART bridge expansion joints (Project #147) Funding: $140,000 Completion: 2013	Reduced joint repair and replacement costs and improved post-event functionality of bridges Joint design preserves existing desirable service load behavior of the joint Cost-effective solution even in regions of moderate seismicity, given the significant reduction in joint failure probability across a range of hazard levels	A full-scale SMART expansion joint was developed and tested in collaboration with a joint manufacturer, Watson Bowman Acme Corporation. Enhanced performance and functionality were afforded without changing the field construction requirements, which should also facilitate technology transfer. Ongoing discussions with Watson Bowman Acme center on opportunities for further refinement, evaluation, and commercialization. Further work has continued with support from the U.S. National Science Foundation and the Korean National Research Foundation to explore other applications of the SMA devices developed in this project for integration into bridge joints or other bridge systems.
18	Cleaning device for removing debris and chemicals for crack/joint sealing (Projects #148, 159) Funding: $116,800 Completion: 2013	Allows thorough cleaning to ensure proper, durable sealing of pavement cracks and joints Reduces repair crew's workload for crack routing process; saves time and labor costs	Several industry demonstrations and field tests of the IDEA product were conducted. Nebraska Department of Roads (NDOR) evaluated the product in all of its eight districts during the 2012-2013 sealing season. Based on field feedback, a rugged, heavy-duty and more powerful routing device was developed. This new version was demonstrated at the District 7 maintenance yard of the Georgia DOT. NDOR is scheduled to field test the new version in the sealing season of 2015.
19	A guardrail post for mow strips and frozen soils without adversely affecting the safety performance of the guardrail system (Project #149) Funding: $100,000 Completion: 2014	Improves guardrail safety performance under frozen soil conditions Redirects errant vehicle independent of foundation conditions; helps save lives Helps reduce cost of installing mow strips around guardrail system	A non-proprietary guardrail system utilizing an energy-absorbing post design has been developed with rigid foundation conditions. The system needs to be crash tested. Upon successful crash testing and approval by FHWA, the design will be available to all transportation agencies for actual field implementation.

20	Automated continuous aggregate sampling and laser targeting system (Projects #150, 168) Funding: $267,000 Completion: 2014 *Several state DOTs funded further evaluation through a pooled-fund study*	Real-time quality control during aggregate quarrying or during cement or asphalt production Takes seconds or minutes to characterize aggregates; no sample preparation needed A single laser scan characterizes multiple aggregate parameters, eliminating the need for multiple tests	The IDEA product is now being evaluated for implementation by state DOTs through a pooled fund study (TPF 5-278) with Kansas DOT as the lead agency. Other participating state DOTs include New York, Oklahoma, Ohio, and Pennsylvania. As part of this evaluation, aggregate samples from each participating agency are being tested and analyzed. The New York State DOT has also initiated its own demonstration program. A major aggregate producer and a cement company are also participating in the demonstration activities.
21	Bridge cable inspection with long-range ultrasound (Project #152) Funding: $100,000 Completion: 2011	Saves bridge inspection time and cost; visual inspection necessary only on cables that exceed the allowance tolerance on ultrasonic data Eliminates subjective and person-dependent visual inspection data Reduces rope access, use of aerial lift device equipment, and labor costs for cable inspection Minimizes traffic control for cable inspection	The technology is currently being applied to bridge cables and suspender ropes, in addition to other industries that use load bearing wire ropes (such as mining, recreation and amusement parks and facilities, and vertical lift devices). The IDEA work provided the confidence and opportunity to introduce the technology to state DOTs, mining and exploration companies, and some of the largest amusement parks and recreational and entertainment facilities in the U.S. The technology is available to state DOTs for implementation.
22	A corrosion resistant, structurally reinforced thermal spray coatings for in-situ repair of load bearing structures (Project #155) Funding: $135,000 Completion: 2012	Allows for in-situ repair to reclaim original load bearing capability; current practice uses costly and time-consuming cutting or dismantling and replacing the corroded bridge sections	Work on the IDEA product has continued with support from the Center for Thermal Spray Research's industrial consortium. Product implementation on a highway bridge is being pursued and discussions were held with New York State DOT personnel for field evaluation and implementation. A potential bridge-level demonstration project on a bridge in Long Island, New York, is under consideration.
23	A polymer-based coating system for corrosion protection of steels in highway structures (Project #157) Funding: $107,500 Completion: Active	Low-cost, sturdy, and environmentally-friendly steel coating system Durable with a longer service life as compared to conventional zinc-rich three-layer coating system commonly used on highway structures	The coating system is scheduled for field testing on highway bridges in Maryland in collaboration with the Maryland State Highway Administration. Plans are also being developed to commercialize the coating system after successful field trials.

24	An ultrasonic hand-held device for measuring cumulative stress at critical bridge components (Project #158) Funding: $91,600 Completion: 2014	Estimates overload acting on complex loaded structural elements such as gusset plates; currently no nondestructive method exists for measuring dead load stress	The IDEA product was tested on a fracture-critical bridge in Chicago over Calumet River and Norris Bridge over Rappahannock River in Lancaster/Middlesex Counties, Virginia. Work has continued with the National Science Foundation's support, and communications have been initiated with a manufacturer of hand-held ultrasonic testing devices. The developed algorithm can be embedded into the integrated circuit FPGA (field-programmable gate array) for automated stress measurement.
25	Super-weathering steel for infrastructure applications (Project #160) Funding: $100,000 Completion: 2014	Superior mechanical, low-temperature fracture, welding, and weathering properties and more durable than common construction steels Requires less maintenance; saves life cycle costs Needs no painting; no volatile organic compounds or paint removal and disposal Produced by simple hot-rolling process; can be manufactured by any steel mill	The steels were evaluated by the Kentucky DOT for corrosion resistance with good results. For implementation, the steel production needs to be scaled up, thoroughly tested, and included in the ASTM and ASHTO standards. Also, welding consumables for these steels should be identified or new consumables should be developed. The developer needs the involvement of steel manufacturers, welding consumable producers, bridge fabricators, FHWA and state DOT's to make this product commercialized and implemented.
26	A hand-held device for nondestructively measuring in-situ yield stress of steel bridge gusset plates (Project #161) Funding: $130,000 Completion: 2014	No other method currently available to establish the in-situ yield stress of bridge steels	Plans are being developed with Oregon DOT to use the device on an existing truss bridge in 2015. Additional development is required to validate the method over a large population of plate materials. After further validation, the device should be ready for commercialization.
27	New scour-vortex preventing products for scour-critical bridges (scAUR and VorGaur) (Project #162) Funding: $140,000 Completion: 2013	Permanent prevention of scour-causing vortical flows on bridge piers and abutments; protected piers and abutments may last for 100 plus years Product designs prevent debris accumulation and protect from impact loads Provide stability to soil and rocks around piers and abutments Cost effective; products cost an order of magnitude less than current scour countermeasures over the lifetime of a bridge	Virginia DOT has committed to seek funds to install prototype products on its westbound bridge on US Route 360 over the Appomattox River. Several other state DOTs and railroads have initiated discussions for implementation. The website www.noscour.com and advertisements provide more details.

28	Automated asphalt pavement raveling detection system using 3-line laser imaging data (Project #163) Funding: $100,000 Completion: Active	Automatically extracts pavement raveling data; traditional raveling survey method is time consuming, subjective, and poses hazard to highway workers Much reduced time and cost of collecting pavement condition data	A demonstration project by Georgia DOT is being planned for using the IDEA product to automatically detect raveling on I-285 highway. Following this project, further implementation efforts will be directed towards other state, county, and city DOTs. In addition, contact with pavement condition system integrators will be initiated to plan product commercialization.
29	Rapid laser profiling of steel bridge coatings, corrosion, and heavy metals (Project #164) Funding: $137,200 Completion: 2014	Rapid, safe, and field-friendly method saves time and labor costs and not subject to personal judgment or bias Quantifies heavy metals in coating layers as well as the substrate corrosion	The IDEA project established the feasibility of the technique and the requirements for a field prototype. Discussions are underway with a private sector bridge inspection company to adapt the technology for commercial inspection operations. The technology has potential application in profiling both coatings and concrete bridge decks.
30	Guidelines for recycling water and concrete fines from truck wash-out and maintenance operations in producing new concrete (Project #166) Funding: $94,500 Completion: 2014	The water recirculation system and prediction models provide a better ability to predict concrete performance based on ASTM C 1602 criteria for concrete mixing water. Presently, only refractive index is generally used as the quality indicator of recycled mixing water	Work has continued beyond the IDEA project with support from Northwest Regional Transportation Center. Sensors were installed in the recycled water recirculation system at Stoneway Concrete plant in Seattle, Washington. Mixtures with recycled and "city water" are to be tested and strength test results compared with predictions from the IDEA- developed models. Results are to be presented to the Seattle and Washington State DOTs and the Seattle Department of Planning and Development as part of the implementation efforts.
31	A machine control system based on georeferenced augmented reality and emulated proximity monitoring to guide on excavating (SmartDig) (Project #167) Funding: $125,000 Completion: Active	Improves productivity and safety of operation by introducing significant automation and information support into the traditional process	Plans for testing the IDEA product in an actual DOT excavation project are being formulated. The product commercialization will be pursued via a University of Michigan start-up company. Appropriate patent applications have been filed. Interactions have been initiated with contractors who do extensive work for DOTs.

32	A bio-asphalt, based on swine manure and crumb rubber, for highway construction (Project #171) Funding: $125,000 Completion: Active *This IDEA research is a finalist in a research grant program sponsored by Infravation, an infrastructure innovation initiative of the European Union.*	A cost competitive alternative to petroleum-based asphalt Helps with environmental disposal issues for swine manure and scrap rubber tires	Results of the IDEA research have been shared with several asphalt terminals to gauge their interest in the product. An asphalt company, Seaboard Asphalt, Inc., is interested in scaling up the production while Smithfield Food Company, a major U.S. swine producer, will help with the production of bio-modified rubber (BMR). This collaboration will also facilitate product commercialization. Several states DOTs (North Carolina, Michigan, and Massachusetts) are willing to provide pavement trial sections if adequate amount of BMR is available and the BMR meets their DOT specifications.
33	Bi-directional ductile diaphragm design for bridge superstructures for improved resistance to bidirectional earthquake excitations (Project #172) Funding: $125,000 Completion: Active	Overcomes limitations of currently-used ductile diaphragms Applies to both skew and non-skew bridges unlike current design that applies only to non-skew bridges Also applicable to other types of bridges, in addition to steel bridges	Contacts with several DOTs have been maintained during the project to help facilitate the implementation of the new diaphragms. The IDEA product will consist of design guidelines and examples, provided in a language ready for implementation by the AASHTO (viaT-3 seismic design and T-14 steel design committees) and state DOTs. Design engineers and consultants are the primary audience for this product.
34	Graphene nanoplatelet (GNP)-reinforced asphalt binders and mixtures. (Project #173) Funding: $120,000 Completion: Active	Superior mechanical and electrical properties, resulting in more resilient pavement at low temperatures; cost comparable to common polymer modifiers No special mixing procedures needed; no added costs	The University of Minnesota Office of Technology Commercialization will assist in bringing the IDEA product to the market. A patent application has been filed for this GNP-reinforced pavement material. Minnesota DOT has agreed to build a test segment for field testing the material at its MnRoad testing facility.
35	Thermal zinc diffusion coatings for steel reinforcement in concrete (Project #174) Funding: $100,000 Completion: Active	Superior corrosion resistance as compared to hot-dipped galvanized (HDG) or epoxy-coated reinforcement at equivalent to lower cost Lower coating thickness and application temperature vs. HDG, result in improved ductility; Uses less zinc and no chromates unlike HDG Coated surface provides improved morphology for applying epoxy coatings, resulting in further improvement in corrosion prevention performance	Florida DOT evaluated the coatings in salt spray cabinets with performance levels significantly better than those of HDG steel. Product commercialization will be pursued if results continue to be positive. The industry partner, Distek, NA, will seek partners to license the technology for reinforcing bars and to put into place equipment needed to make bars of longer lengths. Distek has licenses also for other applications, and several of these could process reinforcing bars and wire meshes.

36	A nondestructive testing method, based on stress wave interrogation, for fatigue crack detection in steel anchor rods of sign, signal, and luminaire structures (Project #175) Funding: $121,000 Completion: Active	Automated measurement-based crack identification Portable, easy-to-use device rapidly screens steel anchor rods for fatigue cracking More reliable and sensitive than visual inspection and sounding and more efficient and robust than the ultrasonic method	The prototype device is to be commercialized after validation through field trials. Pennsylvania and Delaware DOTs have agreed to support field trials. The initial field trials will not only aid in the final validation of the test method, but will also help identify essential design features for the prototype device. Further field testing of the refined device will help identify and resolve practical issues related to implementation of the test method.
37	A contactless electrode system based on Kelvin Probe to map electric potential to detect steel rebar corrosion in concrete (Project #176) Funding: $100,000 Completion: Active	Almost instantaneous measurements Contactless process, requires no previous surface preparation or stabilization Minimizes traffic disruption during data acquisition	Contacts with potential commercial partners have been initiated for product commercialization, if field tests are successful. Florida DOT has committed to collaborate in prototype testing on a pier at the Sunshine Skyway Bridge in Tampa Bay. Contact with FHWA's Long Term Bridge Performance Program has also been initiated to consider integration of this potential mapping method in its Robotic Assisted Bridge Inspection Tool.
38	A software-based system for obtaining turning movement counts at signalized intersections for shared lanes (Project #177) Funding: $78,000 Completion: Active	Transforms every intersection into an automatic traffic recorder for continuous real-time turning movement data; helps in signal retiming Needs no additional hardware; incorporates readily into existing radar-based vehicle detection systems	Wisconsin DOT and the City of Appleton, Wisconsin are providing access to their signal cabinets at intersections to collect field data. The City of Portland, Oregon, is also interested in testing the system. MS Sedco, a sensor and traffic control system technology company, has expressed interest in product commercialization.. The University of Wisconsin Alumni Research Foundation, a nonprofit patent and licensing organization, may also assist in product commercialization.
39	Renewable biopolymers for use in asphalt pavements (Project #178) Funding: $125,000 Completion: Active	Economical and renewable alternative to butadiene-based polymers for asphalt pavement Also useful in other highway products (sealants, adhesives used in highway markings and signs, plastic barriers, traffic control devices, etc.)	A plant in Boone, Iowa, has been established by Agro Genesis Chemicals/Seneca Petroleum to produce the proposed biopolymers. Product implementation will be initiated through establishing that the developed biopolymers can be used turn-key in asphalt production and construction facilities. This will be achieved through paving demonstration projects, such as the Minnesota's MnRoad project and testing at the National Center of Asphalt Technology Test Track.
40	A portable total stress measuring instrument for steel bridges (Project #179) Funding: $125,000 Completion: Active	Simple push-button field measurement instrument Measures nondestructively both dead and live load forces; no technology presently does this in-situ Provides reliable assessment; stresses measured experimentally and not based on broad assumptions	Missouri DOT has committed to provide a suitable steel truss bridge for testing the IDEA product. Indiana and Ohio DOTs have also showed willingness to evaluate the device on their bridges. The research team has extensive experience working with FHWA and state DOTs, which should help facilitate product implementation.

41	Drained timber piles to mitigate soil liquefaction hazard (Project #180) Funding: $147,000 Completion: Active	Low-cost, renewable, hybrid ground improvement and stabilization using conventional equipment improves a structure's seismic resilience Helps accelerate construction	Drained timber piles are being field evaluated in Charleston, South Carolina. Several state DOTs (Oregon, South Carolina, Missouri, and Washington State) are also interested in using the technology. The researcher has established a strong partnership with the Pile Driving Contractors Association (PDCA), and several pile driving contractors from South Carolina and Oregon have been involved in the project since the beginning. The PDCA will directly assist in product implementation through its large membership.

NCHRP IDEA Products Commercialized or Implemented

Some Examples

Sprayed Zinc Galvanic Anode for Corrosion Protection of Reinforcing Steel in Marine Substructures (Project #3)

Inventors/Investigators
Alberto Sagues and Rodney Powers
University of South Florida and Florida DOT

IDEA Funding
$65,000

Project Completion
1995

Description

Product: A cathodic protection sacrificial anode system using sprayed zinc for protecting reinforcing steel (acting as the cathode) from corrosion in marine bridge substructures

Splash and seawater evaporation above the waterline cause high chloride ion concentrations in concrete that can lead to the corrosion of the reinforcing steel in the bridge substructure. Cathodic protection is the only technology that can directly stop corrosion in reinforced concrete structures. Sacrificial cathodic protection, by means of sprayed zinc galvanic anode, offers a low cost alternative (several times less expensive than the impressed current method) for protecting these substructures from corrosion. Furthermore, the method is applicable to a variety of structural components and can be easily applied with commonly-available metalizing equipment. Sprayed zinc corrosion protection works best in a humid (not wet) environment.

Sprayed Zinc as sacrificial anode for the cathodic protection of steel in bridge substructures

Benefits

Thermally-sprayed zinc anode costs about $15-$30 per square foot whereas impressed current system would

cost about $400 per square foot, not even including the cost of its long-term maintenance, according to Ivan Lasa, a corrosion engineer at Florida DOT. The zinc application lasts for about 5-8 years in tropical climate (as in Florida Keys and south Florida) and about 10-12 years in subtropical climate. Respraying the structure with zinc is neither expensive nor labor- or equipment-intensive.

Application/Implementation

The IDEA project successfully field tested the technique in Florida Keys on Highway US 1 at the Bahia Honda, Niles Channel, and Seven Miles bridges. A number of state DOTs have now standardized the use of the technology for the corrosion protection of bridges and other substructures. Florida and Oregon DOTs lead the way in implementing this technology with the largest portfolio of metalized zinc cathodic protection systems installed on a number of bridges coastal bridges.

Bridges in Florida with sprayed zinc anode system include Verle Allen Pope Bridge (SR 206, Crescent Beach), Niles Channel Bridge (US 1, Florida Keys), Julia Tuttle Relief Bridge (I-195, Miami), Indian Key Bridge (US 1, Florida Keys), Long Key Bridge (US 1, Florida Keys), Seven Mile Bridge (US 1, Florida Keys), Bahia Honda Bridge (US 1, Florida Keys), Howard Frankland Bridge (I-275, Tampa Bay), Bryant Patton Bridge (St. George Island), Sunset Island Bridge (29th Street, Miami), Channel Five Bridge (US 1, Florida Keys), Indian River High Rise Bridge (SR 404, Melbourne), Melbourne Causeway Relief Bridge (SR 192, Melbourne), Skyway Fishing Pier Bridge (US 275, Tampa Bay Entrance), Clapboard Creek Bridge (SR 105, Jacksonville), Julia Tuttle Causeway High Rise Bridge (SR 112, Dade), Anna Maria Bridge (SR 64, Anna Maria), Gandy Bridge (US 92, Tampa Bay), and Boca Ciega Bridge (SR 679, Pinellas).

During the past five years, Florida has treated a number of additional bridges and retreated previously-treated bridges with sprayed zinc for corrosion protection. A majority of these bridges are located in the Tampa area and the Florida Keys. Bridges in the Tampa area include: Gandy Bridge (US 92 / SR 600), Howard Frankland Bridge (I-275 / SR 93), North and South Skyway Fishing Piers, Courtney Campbell Causeway Bridge (SR 60), and Bunces Pass Bridge (I-275 / SR 93). Bridges in Florida Keys include: Boca Chica Channel Bridge (US 1 / SR 5), Toms Harbor Channel Bridge (US 1 / SR 5), Henry H Buckman Bridge (SR 9A), Little Duck Channel Bridge (US 1 / SR 5), Bahia Honda Bridge (US 1 / SR 5), Ohio-Missouri Channel Bridge (US 1 / SR 5), Thompson Creek Bridge Key West (US 1 / SR 5), Toms Harbor Cut (US 1 / SR 5). Bridges treated with sprayed zinc at other Florida locations include: Pinellas Bayway Structure 'E' (SR 679, Tierra Verde), Card Sound Bridge (CR 905A, Key Largo), Wabasso Causeway Bridge (SR 510, Wabasso), Julia Tuttle Causeway (I-195 / SR 112, Miami), SR 404 Bridge (SR 404, Melbourne), FPL Discharge Bridge (SR A1A, Port St Lucie), Mickler O'Connel Bridge (SR 312, St Augustine), Thomas B. Shave Jr. Bridge (AIA / SR 200, Fernandina Beach), Ernest Kouwen Hoven Bridge (SR 500, Indialantic), and various D1Pushbutton bridges in 12 southwestern Florida counties.

Oregon has more than more than 120 concrete bridges near the ocean that need to be protected from corrosion. Notable bridges protected by sprayed zinc technology include Cape Creek Bridge (North of Florence), Depoe Bay Bridge (Depoe), Rocky Creek Bridge (South of Depoe Bay), Yaquina Bay Bridge (Newport), Big Creek Bridge, Cape Perpetua Bridge, Tenmile Creek Bridge, and Cumins Creek Bridge (South of Yachats), Rouge River Bridge (Gold Beach), and Coos Bay Bridge (North Bend).

Among other states, Virginia has used sprayed zinc anode system on several bridges that include bridges on I-64 over Willoughby Bay and East 13th View Street in Norfolk, Route 58 over Leatherwood Creek in Henry, I-95 over James River in Richmond, and Route 15 over Willis River in Albemarle. Missouri has also used sprayed zinc technology on several structures that include a flyover bridge on I-70/270 Interchange and a 9th Street ramp in St. Louis. Alaska DOT recently installed zinc anode system on a bridge on Tongass Avenue in

Ketchikan, Alaska. Another major project in Alaska using sprayed zinc anode technology is the expansion of the Port of Anchorage (Cook Inlet).

In addition to bridge substructures, piles, and columns, the sacrificial sprayed zinc cathodic protection systems have been and continue to be applied to structures such as high-rise buildings, parking garages, concrete cooling towers, concrete intake and outfall structures in power plants, and dock facilities.

Admixture for Improved Corrosion Resistance of Concrete (Hycrete) (Project #13)

Inventors/Investigators
Jack Stephens and James Mahoney
University of Connecticut and Todd Chemical Company, New Haven, Connecticut

IDEA Funding
$60,000

Project Completion
1995

Description

Product: A chemical additive based on highly hydrophobic dipolar alkenyl dicarboxylic acid diammonium salts for corrosion inhibition of reinforcing steel and waterproofing of concrete

Corrosion of reinforcing steel remains a major problem for the durability of concrete structures exposed to deicing chemicals or marine environment. The corrosion-inhibiting hydrophobic IDEA product, developed at the University of Connecticut in collaboration with the Connecticut DOT, was further evaluated by the New England Transportation Consortium, a group of six New England state DOTs, to establish its corrosion inhibiting performance and its effect on concrete properties. The product is now being marketed as a corrosion inhibitor under the name Hycrete by a company with the same name (Hycrete Technologies, Inc.) located in Carlstadt, New Jersey. In fact, the IDEA product forms the basis of what now has become a suite of trademarked 'Hycrete' corrosion inhibiting and waterproofing products.

Waterproofing concrete with Hycrete

Benefits

The chemical admixture greatly reduces the water and chloride ion permeability of concrete and the corrosion of reinforcing steel bars in cracked concrete specimens. Since the hydrophobic nature of the admixture makes concrete waterproof, it eliminates the need for using waterproofing membrane around the concrete and the associated cost of the membrane and the time for installing it. The admixture also exhibited air entraining properties that improved the resistance of concrete to frost damage but was found to decrease the compressive strength by about 10-20%, although still adequate for most construction applications.

Hycrete sells for between $50 and $75 per gallon which is enough for a cubic yard of concrete. This amounts

to about 25-30% increase in cost per cubic yard of concrete. However, the advantages (superior corrosion resistance, less maintenance, and longer service life) outweigh the upfront material cost increase. A life-cycle cost analysis by Stephen Sharp and Celik Ozyildirim of Virginia DOT for the 2007 construction season (with an allocation of about $15 million for new bridge decks) estimated a cost saving of about $1.5 million each year with a service life increase of 10% through the use of Hycrete.[1]

Application/Implementation

Many state DOTs and highway agencies have been experimenting with Hycrete for the past several years. These include the states of New Jersey, New York, Ohio, Virginia, Kansas, and the six New England states. The U.S. Army Corps of Engineers also tested Hycrete in sea walls, sewerage treatment plants, and underground aircraft hangers in high sulfate soil. The Hycrete projects evaluated by the New England Transportation Consortium included major structural components of a ferry terminal in Rockland, Maine, a bridge curb in Hartland, Vermont, I-91 overpass bridge bent columns in Massachusetts, and large precast culverts in New York. Connecticut DOT implemented Hycrete in precast Jersey barriers positioned along the I-84 corridor. Kansas DOT evaluated Hycrete on a Highway 99 bridge, south of Howard in Elk County. All these projects were essentially evaluation studies and are being monitored for the long-term performance of Hycrete. So far, Virginia and Ohio DOTs have approved the use of Hycrete in their construction projects.

While state DOTs have been rather slow or cautious in their acceptance of Hycrete, it is being used increasingly in the private sector and in non-transportation projects that include parking garages (Seattle and SeaTac, Washington), medical school laboratories and office buildings (San Diego, California and Seattle, Washington), a hospital (Haymarket, Virginia), high schools (Arlington, Virginia and Washington, DC), a housing and retail complex (Salt Lake City, Utah), residential complex (Los Angeles, California), Washington State Department of Information Services Building (Olympia, Washington), and the Hill Air Force Base in Utah. Hycrete was also used in the critical water-sensitive portions of New York City's Freedom Tower such as the concrete feeder trenches containing the high power electric feeder cables. The Thomas Jefferson Law School in San Diego reports to have saved about $187,000 on construction costs by using Hycrete in its new building.

Hycrete is also finding interest in overseas markets, particularly in India, where it has been used in more than 60 projects in recent years. One of these projects, the Palais Royale in Mumbai, required 100,000 gallons of the Hycrete product.

Awards/Recognition

Since Hycrete contributes to clean environment by eliminating the need for petroleum-based waterproofing membranes, the company has been recognized as a green company and won many clean environment awards:

The EcoWorld ‘Clean Dozen Companies Award’ (2007)

‘The Technology Pioneer Award’ at the World Economic Forum in Davos, Switzerland where it was recognized as a new game-changing technology (2008)

The CEO of Hycrete, Inc., was among the eight CEOs of clean technology-focused companies invited to the White House for a roundtable on the economic impact of environmentally-friendly technologies (2009)

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[1] Virginia Transportation Research Council Final Report 07-R30 http://www.virginia.dot.org/vtrc/main/online_reports/07-r30.pdf

Automated Bridge Deck Anti- and De-Icing System (Project #27)

Inventor/Investigator
Rand Decker
University of Utah

IDEA Funding
$70,000

Project Completion
1998

Description

Product: A bridge-mounted automated anti-icing spray system to prevent snow and ice on bridge decks

Although automated anti-icing spray technology has been in use in Europe since late 1970s, this IDEA project was the first to introduce this technology in the U.S. by funding an experimental system on a bridge on I-215 near Salt Lake City, Utah, in 1997. The IDEA project used accepted de-icing liquids and conventional spraying techniques coupled with modern roadway weather information system and data communication and process controls to prevent icing on bridge decks. A comparison of accident data for a test section and control before and after the installation of the system showed a 64% reduction in accidents for the test section.

Automated anti-icing spray system for bridge decks

Benefits

While the automated anti-icing system is expensive compared to conventional deicing or anti-icing methods and requires regular maintenance, there are strong safety benefits. For example, the system on the now-collapsed I-35 Bridge over the Mississippi River in Minnesota DOT's St. Paul district cost about $1.2 million to install and used potassium acetate at a cost of about $3 per gallon as compared to less than 50 cents for salt. However, the deicer was sprayed only when needed and, according to the maintenance engineer, Chris Beckwith, crashes were reduced by 60% in one year.[1] Data reported in 2000 by Paul Keranen of Minnesota DOT for three bridge sites showed a drop of snow-related accidents from 22 to 4 in the 24-month period before and after the installation of the system.[2] Use of the system on a 165-meter stretch of Highways 401/416 interchange in Ontario, Canada, resulted in a 100% reduction in weather-related collisions in its first year of

operation in 2001, according to maintenance superintendent Rick Hofstteter.[1] Significant crash reductions were also observed by North Dakota DOT at its two bridges (the I-29 Buxton Bridge near Buxton, North Dakota, and the I-94 Red River Bridge between Fargo, North Dakota, and Moorhead, Minnesota) fitted with the fixed automated spray systems. The Buxton Bridge system provided a total crash reduction of 66%. Crashes related to property damage decreased by 62% and injury-related by 75%. The Red River Bridge also experienced similar crash reductions. The combined crash reductions for the Minnesota and North Dakota systems were more than 50%. So, while the system may not save money to state DOTs to operate and maintain it, it saves human lives and avoids or minimizes injuries and property damage.

Application/Implementation

Since 1997, a number of state DOTs and Canadian provinces have used or evaluated the system in bridge anti-icing projects. These include California, Colorado, Iowa, Kansas, Kentucky, Maryland, Minnesota, Montana, New Jersey, New York, North Carolina, North Dakota, Oregon, Pennsylvania, Wisconsin, Washington State, Virginia, Ontario, and Saskatchewan, among others.

The state DOTs, however, appear rather cautious in embracing the automated anti-icing spray technology, presumably because of the need for frequent, regular maintenance of the spray system for effective performance or the cost. Some states, such as Virginia, evaluated the anti-icing technology (along a ramp from Route 7 to Route 66 in Fairfax County in 1998) but did not maintain it after two years. Plans to install a system on the Buffalo Creek Bridge on I-81 were also not followed through. Other states, such as Maryland, evaluated the technology (Clarysville Bridge on I-68 in Clarysville, Alleghany County in 2002) and found it useful but did not pursue it for additional bridges. Initial costs and maintenance expenses might have been the factors affecting their decisions.

The Minnesota DOT appears to be most receptive of the technology with systems installed on a number of bridges in the Twin Cities, Duluth, Rochester, and Winona and on segments of I-90 at Worthington and Beaver Creek. In recent years, Minnesota DOT installed an anti-icing spray system on I-35 E Lexington Bridge over the Mississippi River in St. Paul. The new $234-million I-35 W Saint Anthony Falls Bridge in Minneapolis that replaced the collapsed I-35W Bridge is also equipped with a state-of-the-art automated anti-icing spray system. Another bridge over the Mississippi River on Highway 61 near Hastings that opened in 2012 is also equipped with a similar anti-icing spray system.

The North Dakota DOT has installed two fixed automated spray technology systems, one on I-29 (Buxton Bridge near Buxton, North Dakota) and the other on I-94 (Red River Bridge between Fargo, North Dakota and Moorhead, Minnesota). Nevada DOT has recently installed automated anti-icing systems on four bridges on I-580 between Reno and Carson City. The most spectacular of these bridges, the Galena Creek Bridge near Reno, is equipped with a $2 million automated anti-icing spray system. When potentially freezing conditions set in, pavement sensors on the bridge activate spray disks embedded within the concrete. These recessed disks spray a potassium acetate anti-icing solution to help prevent or delay formation of ice.

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[1]Engineering News Record http://enrconstruction.com/features/transportation..../070115-2as...
[2]Virginia Transportation Research Council Final Report 04-R26 http://www.virginiadot.org/vtrc/main/online_reports/04-r26.pdf

Corrosion-Resistant Steel for Concrete Reinforcement (DMF/MMFX Steel) (Project #28)

Inventor/Investigator
Gareth Thomas
University of California - Berkeley

IDEA Funding
$70,000

Project Completion
1997

Description

Product: An improved dual phase ferritic martensitic (DFM) reinforcing steel with superior mechanical properties and corrosion resistance

The high strength corrosion-resistant DMF steel is a low-alloy, low-carbon steel produced by quenching the alloy from the two-phase ferrite/austenite field, yielding a mixture of ferrite and martensite. Further work on DMF steel by the IDEA researcher led to the development of MMFX steel that was found to be about five times as corrosion resistant and twice as strong as the conventional steel. To commercialize and market the new steel, the MMFX Steel Corporation of America was founded in 1998 in San Diego, California. The company has now expanded its operations in the Middle East with the establishment in 2012 of an MMFX steel plant in Dubai, the United Arab Emirates, with an estimated annual production of 100,000 metric tons of high quality, hot-rolled stainless steel billets. The IDEA researcher, Dr. Gareth Thomas, and Mr. Howard Yerusalim, a past president of the AASHTO and a former Secretary of Pennsylvania DOT, have served on the corporation's management team.

MMFX steel deck reinforcement for US 20 Bridge over South Beaver Creek in Gundy County, Iowa

Benefits

MMFX steel is a highly corrosion resistant material with superior mechanical properties. It costs about twice as much as the regular steel. However, according to the manufacturers, by using higher yield strength MMFX steel

of 100 or 120 ksi over conventional Grade 60 steel, construction projects can be completed with 20-50% less steel and up to 60% lower labor costs (for placement and fabrication). In addition, the superior corrosion resistance adds years to the service life of the structure. A 2007 Michigan DOT study estimated a significantly higher service life for a bridge with MMFX steel than with epoxy coated steel and concluded that MMFX steel reinforcement was worth the investment despite an increase in cost of about $12 per square yard over epoxy coated steel reinforcement.[1]

Application/Implementation

A number of state DOTs have evaluated MMFX steel for its mechanical performance and corrosion resistance. These include Iowa, Florida, West Virginia, Virginia, Delaware, New Jersey, Louisiana, South Dakota, and Michigan along with FHWA. In addition, California, Texas, Pennsylvania, and Virginia participated in a round-robin study to evaluate MMFX steel's corrosion resistance. All these studies validated the superior corrosion resistance of MMFX steel. The FHWA's tests, however, indicated that MMFX steel was not as corrosion resistant as stainless steel rebars but still better than epoxy-coated rebars. MMFX steel rebars qualify as ASTM A615 Grade 75, ASTM A1035-04 low-carbon, chromium steel rebars for concrete reinforcement at 100,000 psi, and AASHTO M31 Grade 75. Virginia DOT now allows MMFX steel rebars as an alternative to stainless steel or stainless steel clad rebars for its construction projects.

MMFX steel is now being used across the U.S. and Canada in construction projects on bridges, highways, parking structures, and residential and commercial real estate. According to the manufacturers, MMFX steel has been used by at least 27 state highway agencies and four Canadian provinces in more than 100 bridge projects. The application has been primarily for bridge decks and occasionally in parapets and abutments. A 2010 survey by Pennsylvania DOT indicated no major issues related to the use of MMFX steel although it might have been too early to make a definitive conclusion since the oldest bridge on record was only 8 years old.

Examples of the application of MMFX steel to bridge structures in the U.S. include bridge decks in New Haven, Connecticut (Church St. Extension), New Castle County, Delaware (State Route 82 over Red Clay Creek), Cedar Hill, Grundy County, Iowa (US 20 over South Beaver Creek), Lexington, Scott County, Kentucky (County Road 1218), Jensen Beach, Florida (Causeway Bridge over Intercoastal Waterway), East of Pittsburgh, Pennsylvania (Exit 9 – I-70-76), Derby Township, Vermont (SR105 over Clyde River), Stockton, California (Daggett Road Bridge over Burns Cutoff), Prince Williams County, Virginia (SR123 over Occoquan River), Chesapeake, Virginia (five bridges including the Elizabeth River Bridge, Dominion Boulevard, U.S. Route 17), Spanish Fork, Utah (White River Bridge, Spanish Fork Canyon, near Mile Post 218, U.S. Route 6), Amarillo, Texas (Washington Street Overpass over I-40), Cabo Rojo, Puerto Rico (PR-102 over Laguna Channel), and Swan River, Manitoba, Canada (Province Highway over East Favel River). The entire bridge structure of US 64 over Gobernador Arroyo River in New Mexico also featured MMFX steel, including the deck.

The Sacramento Regional Transit Authority in California chose MMFX steel for its Folsom Light Rail Bridge over Alde Creek for girders, abutments, and columns. The Kitsap Transit Authority used MMFX steel on its intermodal terminal in Port Orchard, Washington on the floating ferry boat dock. The U.S. Army Corps of Engineers used MMFX steel in the entire structure of Lake Tenkiller Spillway Channel Bridge in Sequoya County, Oklahoma, and the U.S. Navy used it in hybrid modular piers in San Diego, California.

MMFX steel has been used in pavements also. The Washington State DOT used MMFX steel dowel bars in several pavement projects (Richland's I-182/SR 240 to Columbia Center interchange, US 395-North Spokane Corridor/US 2 to Wandermere Vicinity, and the Burlington Northern Santa Fe railroad tunnel).

Other notable public and private projects utilizing MMFX steel include the Gulf State Park Fishing Pier (Gulf

Shores, Alabama), Bayonne Pier Terminal (Bayonne, New Jersey), Everglades on the Bay Condominiums (Miami, Florida), California Academy of Sciences Exhibition and Research Center (San Francisco, California), Coastal Residence (Malibu, California), Northern Expansion at Port Fourchon (Grand Isle, Louisiana), Escala Condominiums (Seattle Washington), the National Oceanic and Atmospheric Administration Research Center (Juneau, Alaska), and the Spanish Peaks Lodge and Resort (Big Sky, Montana).

Awards/Recognition

Winner of the American Society of Civil Engineers' 'Charles Pankow Award' for innovation in design and construction (2002)

Winner of the 'NOVA Award' for innovations by the Construction Innovation Forum, an international non-profit organization that recognizes innovations that help improve construction quality and reduce costs (2004)

Winner of the 2004 'Experts' Choice Award' at the World of Concrete Exposition (2004)

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[1]Michigan Department of Transportation Research Report R-1499 http://www.michigan.gov/.../ MDOT_Research_Report_R1499_209781_7.pdf

Fiber-Reinforced Polymer Composite Bridge Deck (Projects #30 and 46)

Inventor/Investigator
Jerry Plunkett
Kansas Structural Composite, Inc., Russell, Kansas

IDEA Funding
$144,000

Project Completion
2000

Description

Product: Lightweight composite bridge made of fiberglass-reinforced polymer (FRP) honeycomb structural panels

The IDEA-funded No-Name Creek Bridge, installed in November 1996 in Russell, Kansas, was the first all-composite highway bridge built in the U.S. The bridge was designed in accordance with the U.S. Highway Bridge Code HS-25 and used three fiberglass honeycomb panels (23 feet long and 9 feet wide) with interlocking edges. The installation of the bridge took only 6 hours. The honeycomb design resulted in about 20% less weight of the bridge and almost 50% less cost than other composite bridges meeting the same AASHTO requirements.

No-Name Creek Bridge in Russell, Kansas, the first all-composite bridge in the U.S., under test

Benefits

The composite decks cost slightly more than the current concrete and steel decks on an initial cost basis. However, they save time and labor in installation, are corrosion-free, require less maintenance over time, and are expected to have a longer service life than a concrete bridge.

The composite bridge technology allows rapid construction or reconstruction of bridges, saving time and reducing traffic delays. The composite bridge decks are strong enough for vehicular traffic but light enough to allow major sections to be factory-built and shipped to the site on a flatbed trailer. Installation is similar to that of prestressed concrete panels but, being lightweight, the bridge is quicker and easier to install using smaller cranes. The decks can be installed in hours or days instead of weeks or months it takes for a traditional bridge on site. Furthermore, the reduced deck weight (dead weight) allows the bridge to carry an increased traffic load. The composite decks are also free from corrosion by winter salt, thereby significantly increasing their service life. The technology also permits the removal and replacement of damaged bridge decks as well as the removal and replacement of decks from bridges that are no longer in service or need to be upgraded.

Application/Implementation

The No-Name Creek Bridge, opened to traffic in December 1996, is still performing well and, according to David Meggers of Kansas DOT, routine inspections have revealed no problems so far. The IDEA support was also used to build two additional bridges, each 32 feet wide and 45 feet long, in Crawford County, Kansas, that also are still performing well.

Following the success of the IDEA project, the IDEA contractor, Kansas Structural Composite, Inc. (KSCI) has installed composite decks on a number of bridges in the states of Kansas (Kansas Detour Bridges #1 and 2 and Crawford County Bridges #1 and 2), Missouri (St. John Street Bridge, Jay Street Bridge, and St. Francis Street Bridge), West Virginia (West Buckeye Bridge, Hanover Bridge, and Goat Farm Bridge), Ohio (Salem Avenue Bridge near Dayton and Ridge Road Bridge near Fairfield), New York (NY 36 over Tributary to Troups Creek and County Route 52 over Conesus Lake Outlet), Pennsylvania (T 565 over Dunning Creek), and Colorado (O'Fallen Park, West of Denver).

KSCI's success encouraged other composite technology companies (Martin Marietta Composites, North Carolina, Hardcore Composite, Delaware, Infrastructure Composites, California, Creative Pultrusions, Pennsylvania, Bedford Reinforced Plastics, Pennsylvania, Fiber-Reinforced Systems, Ohio, and Strongwell Corporation, Virginia, among others) also to enter the composite bridge business, and these companies have installed composite bridges in a number of states across the U.S., including California, Idaho, Ohio, New York, Oregon, Pennsylvania, Illinois, Maryland, Delaware, Iowa, North and South Carolina, Virginia, West Virginia, Washington State, and Wisconsin. There are now more than 400 FRP composite bridge deck installations in North America, and this number continues to grow.

Awards/Recognition

Winner of the 'Best of the Market' and the 'Counterpoise Grand Design Award' from the International Composite Expo. The IDEA contractor, KSCI, Inc., is the smallest-ever company to receive this prestigious design award that has generally gone to major auto and aircraft companies such as General Motors, Chrysler, Boeing, and Lockheed Martin (1997)

Winner of the 'R&D 100 Award,' sponsored by the Research & Development magazine, for being judged as one of the most important innovative developments of the year (1997)

The composite bridge built by KSCI, Inc. in Fairfield, Ohio was featured on the National Public Radio (2008)

Pavement Quality Indicator (Projects #32 and 47)

Inventor/Investigator
Harry Apkarian
TransTech System, Inc., Schenectady, New York

IDEA Funding
$158,000

Project Completion
1998

Description

Product: A non-nuclear asphalt pavement density measuring device based on capacitance energy dissipation

The pavement quality indicator (PQI) estimates density by measuring change in electromagnetic field when an electrical current is transmitted through an asphalt pavement. The impedance or resistance to electrical flow depends on the dielectric constant of the conducting material while the overall dielectric constant of an asphalt pavement is directly related to its density. Changes in the dielectric constant, therefore, can be correlated to changes in the density of asphalt pavement during compaction. Developed with funding from the NCHRP IDEA program and the New York State Energy Research and Development Authority, the device continues to be upgraded and, currently, a fourth generation Model 380 is available with features such as GPS status display, ability to download files to/from the PQI via USB drive, and a new data management system.

The device is being marketed domestically and internationally by TransTech Systems, Inc. (Schenectady, New York). TransTech Systems reports selling about 30 units a month, mostly to private contractors, DOTs, and international transportation agencies. A modified version of the PQI device is also available as the soil density gauge for measuring soil density. In addition, the technology is also being developed for use on rollers for on-the-run, continuous, and real-time density/segregation measurements.

Pavement quality indicator (Model 380)

Benefits

The PQI offers a rapid, convenient, and safe alternative to the nuclear gauge for measuring asphalt pavement density. The PQI, unlike the nuclear gauge, does not expose the operator to harmful radioactive isotopes with ionizing radiation that can penetrate human skin and concrete. It requires no extensive training, no radiation

badges, no badge service and licensing fees, no constant radiation exposure monitoring of personnel, no testing for radiation leaks, no special storage or transportation needs, no disposal hassles, and no accident, security, or terrorism concerns. It is much more rapid than the nuclear gauge, taking only about three seconds to take a density measurement. This allows the PQI to get on the mat, do the test, and get out of the way of the roller for the next pass. The nuclear gauge takes about a minute for a density reading.

The PQI and the standard nuclear gauge cost about the same (about $9,000). However, the PQI provides recurring savings, year after year, compared to the standard nuclear gauge. A 2005 Ohio DOT study estimated the operating cost for the PQI to be about $210 per year as compared to about $3,075 for the nuclear gauge while a 2007 Iowa study estimated that a non-nuclear device such as the PQI could save as much as $50,318 over a period of 5 years.[1]

Application/Implementation

The PQI has been extensively evaluated by a large number of state DOTs, including Maryland, Pennsylvania, New York, Idaho, Minnesota, Connecticut, Oregon, Virginia, Delaware, Ohio, Florida, North Carolina, Nebraska, Iowa, Illinois, Kentucky, Texas, Wisconsin, and Arkansas, among others. These studies recommend the PQI as a useful quality control tool but not for quality assurance. Consequently, several states (New York, Idaho, Maryland, and Pennsylvania) allow the use of PQI for quality control purposes. An Ohio DOT evaluation recommended the PQI for both quality control and quality assurance purposes, provided it is calibrated daily by applying a mix-specific offset. Many paving contractors now use PQI in their paving operations for quality control purpose in accordance with the AASHTO T343 specifications for non-nuclear gauges for density measurements.

Awards/Recognition

PQI 380 – Winner of the ‘Top 30 Products Award’ by Asphalt Contractor Magazine (2014)

PQI 301 – Winner of the ‘Top Rollout Award’ by Better Roads Magazine (2005)

PQI 301 – Winner of the ‘NOVA Award’ for innovation by the Construction Innovation Forum, an international non-profit organization that recognizes innovations that help improve construction quality and reduce costs (2003)

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[1]Mack-Blackwell Transportation Center-University of Arkansas Final Report No. 2075 http://ww2.mackblackwell.org/...williams/MBTC%202075%20-%20FINAL%20REPORT.pdf

Hybrid Composite Beam for Bridges (Project #60)

Inventor/Investigator
John Hillman
Teng and Associates, Inc., Chicago, Illinois

IDEA Funding (joint funding by NCHRP and High-Speed Rail IDEA programs)
$150,000

Project Completion
2007

Description

Product: A high-strength, lightweight, corrosion-resistant hybrid composite beam for highway and railroad bridge construction

The hybrid-composite beam (HCB) consists of three main subcomponents – a shell, compression reinforcement, and tension reinforcement. The shell is made of fiber-reinforced polymer (FRP) composite. The compression reinforcement consists of self-consolidating concrete that is pumped into a profiled conduit within the beam shell. The tension reinforcement is provided by strands of galvanized prestressing steel which run along the bottom flanges of the beam.

The strength and stiffness of the HCB comes from a more efficient use of materials that are well suited to purely axial tension or compression. The classical arch shape of the compression reinforcement dramatically reduces the shear carried by the FRP webs. The low density of the FRP material and the ability to place the compression reinforcement in-situ results is an economical structural member that can be used in the framing system of a bridge structure in the same manner as a steel or prestressed concrete beam, but is much lighter and well suited to accelerated bridge construction. In general, HCB is suitable for 50-120 ft. span bridges for highways and for 30-45 ft. span bridges for rail.

Hybrid composite beam (HCB) being installed on High Road Bridge in Lockport Township, Illinois

Benefits

The HCB weighs approximately one-tenth of what a typical precast concrete beam weighs for the same span length. This lighter weight also reduces shipping and erection costs – shipping and erection weight is 10% of the concrete beam and 33% of the steel beam. HCB improves the speed of construction and is well suited for modular bridge installation (accelerated bridge construction). The beam does not suffer from cracking, spalling, and rusting, and never needs painting. HCB also has a reduced carbon footprint as it uses 80% less cement, reduces the number of delivery trucks, and allows for smaller cranes than those required for precast concrete beams. HCB also enhances a bridge's service life, estimated to be more than 100 years.

Presently, on first-cost construction basis, HCB is competitive with conventional system, such as pre-stressed concrete beam, for many applications. The cost competitiveness will improve as demand for HCBs increases, due to scale economies. For life-cycle costs, HCB is superior to conventional systems because of longer service life.

Application/Implementation

To date, HCB has been installed in 17 highway bridges in nine states (Colorado, Illinois, Kentucky, New Jersey, Maine, Maryland, Missouri, Virginia, and West Virginia) and the province of British Columbia. At least 7 more projects are under consideration in the states of Maine, New Jersey, and Washington, and the provinces of British Columbia, Ontario, and Saskatchewan. The bridges, completed so far, or soon to be completed, include:

Illinois – Lockport Township High Road Bridge over Long Run Creek (2009): The superstructure for this 57-foot, single-span bridge comprises six 42-inch deep HCBs supporting a conventional 8-inch thick reinforced concrete deck. The bridge was finished under budget and ahead of schedule, prompting Ralph Anderson, Illinois State Bridge Engineer, to remark: "I expect this technology will provide an economical option that will greatly benefit the citizens of Illinois."[1]

New Jersey – Route 23 Bridge over Peckman's Brook in Cedar Grove (2009): a single-span bridge with a span of 31 feet and a total deck width of 60 feet.

Maine – Knickerbocker Bridge over Back River in Boothbay (2011): This 540-foot long, 8-span bridge is the longest HCB bridge in the world. The HCB resulted in a framing system that was one-tenth the weight of precast concrete, required no deck forming, and provided a corrosion resistant FRP outer shell to protect from the bay's salt water. Tests conducted prior to construction validated that the load carrying capacity of the HCB girders was more than 170 percent of the code-specified ultimate capacity.

Missouri – Three HCB bridges were constructed as part of the Safe & Sound Project in Missouri with a grant from FHWA's Highways for LIFE Program. These bridges included a three-span bridge with typical spans of 60 ft., a two-span bridge with spans of 50 ft., and a single-span bridge with a span of over 106 ft.

Virginia – A 45-ft. bridge was constructed for Virginia DOT in Colonial Beach, Virginia in 2011.

West Virginia – A 107-ft. bridge was constructed in Charleston, West Virginia in 2013.

The U.S. Army Corps of Engineers installed a 39 ft. HCB bridge at Fort Knox, Kentucky in 2012.

[1]Concrete Construction http://www.concreteconstruction.net/industry-news.asp?sectionID=718&articleID=800467&artnum=2

Burlington Northern and Santa Fe Railroad (BNSF) – The first live load test of a full-scale HCB railroad bridge was conducted at the Transportation Technology Center, Inc. (TTCI) near Pueblo, Colorado, in 2007. A 30-ft. span was subjected to 237 million gross tons. Further endurance testing at TTCI was conducted for a 42-ft. span. The 42-ft. span was removed from the TTCI test track in 2012 and is currently awaiting installation on a BNSF revenue service line in Colorado.

Canadian Pacific Railroad – An HCB railroad bridge was delivered in 2014 for installation in Fernie, British Columbia. This is the first international installation of an HCB Bridge.

Currently four additional HCB bridges are in various states of fabrication for projects in Maine (three bridges) and Maryland (one bridge).

Awards/Recognition

American Council of Engineering Companies' 'National Grand Award' for the Lockport Township High Road Bridge in Illinois (2009)

Engineering News Record's 'Award of Excellence' (2010)

Construction Innovation Forum's 'NOVA Award' for innovation (2010)

The AASHTO's Technology Implementation Group selected HCB as a focus technology for implementation (2011)

American Society of Civil Engineers' 'Charles Pankow Award' for Innovation (2013)

The inventor, John Hillman, was recognized by the White House as one of twelve 'Transportation Champions of Change' (2013).

Improved Asphalt Cement Specification Test Methods (Projects #84 and 104)

Inventor/Investigator
Simon Hesp
Queen's University, Kingston, Ontario

IDEA Funding
$158,000

Project Completion
2005

Description

Product: Test methods based on fracture mechanics for predicting asphalt binder performance at low temperatures

Four standard test methods, as published in the *Ontario Ministry of Transportation Laboratory Testing Manual*, provide user agencies with a significantly improved ability to specify asphalt cements of high quality and durability:

(1) **Laboratory Standard 228 –** *Accelerated Aging of Asphalt Cement Using Modified Pressure Aging Vessel Protocols*
(2) **Laboratory Standard 296 –** *Fracture Performance Grading of Asphalt Cement*
(3) **Laboratory Standard 299 –** *Determination of Asphalt Cement's Resistance to Ductile Failure Using Double-Edge-Notched Tension Test (DENT)*
(4) **Laboratory Standard 308 –** *Determination of Performance Grade of Physically Aged Asphalt Cement Using Extended Bending Beam Rheometer (BBR) Method*

Benefits

In 1997, Ontario was one of the first North American jurisdictions to implement the Superpave performance graded asphalt cement (PGAC) specification. In response, a wide range of new additives and technologies entered the asphalt cement market, not all of which provided superior performance. Early PGAC experiences pointed towards the need for measures of toughness and durability, in addition to quality based solely on low strain rheological measurements.

The four test methods are simple extensions of regular aging, rheological and failure tests, yet the associated acceptance criteria assure a superior level of toughness and durability for the asphalt cement in service:

(1) LS-228 – *Accelerated Aging of Asphalt Cements Using Modified Pressure Aging Vessel Protocols* exposes asphalt cements to high temperatures and air pressures for longer times and in thinner films compared to regular Superpave methodology to assess resistance to oxidative hardening.

(2) LS-296 – *Fracture Performance Grading of Asphalt Binders* provides a measure of asphalt cement toughness in the brittle state in the presence of a sharp notch under severe tensile constraint.

(3) LS-299 – *Determination of Asphalt Cement's Resistance to Ductile Failure Using Double-Edge-Notched Tension Test (DENT)* measures the failure strain in a tiny fiber (fibril) of asphalt cement, a

property that is proven best at ranking asphalt cements in terms of their susceptibility to fatigue cracking in the latest accelerated loading facility experiment at FHWA's Turner-Fairbank Highway Research Center (*Gibson et al., Publication No. FHWA-HRT-11-045, November 2012*).

(4) LS-308 – *Method of Test for Determination of Performance Grade of Physically Aged Asphalt Cement Using Extended Bending Beam Rheometer (BBR) Method* assesses the tendency of asphalt cements to physically harden during cold conditioning. Grade losses due to physical hardening have shown a strong correlation with the susceptibility to oxidative hardening in LS-228, and as such they are able to predict long-term field performance with a high degree of accuracy.

In combination, the acceptance criteria associated with the four test methods will largely leave the grades of superior asphalt cements unchanged while materials of lesser toughness and durability will be downgraded.

Application/Implementation

Over the last 10-12 years, a large-scale collaborative effort among researchers in academia, government, and industry has led to the development, validation, and implementation of the above-noted test methods. In support of this effort, as many as 27 new pavement test sections, each 500 m in length, were constructed around the province of Ontario with nearly all types of modification technologies (air blown, PET and PP fibers, PPA, RET, SBS, etc.) on both low-volume roads in northeastern Ontario (AADT = 1,500) and Canada's second busiest divided freeway connecting Pearson International Airport to downtown Toronto in southern Ontario (AADT = 350,000) (www.hespresearchgroup.ca/pavement-trials.html).

Round-robin evaluations of LS-299 and LS-308 have been ongoing since 2006, with 10-15 asphalt laboratories participating. Since 2009, acceptance criteria have been implemented on numerous Ontario pavement projects with few, if any, serious problems.

The DENT test has recently been voted on by the AASHTO Technical Committee 2b to move it forward as a provisional standard.

The LS-296 test method has so far found little traction in Ontario but a similar protocol has recently been published in Europe as CEN/TS 15963:2010, where it has successfully gone through several rigorous round-robin evaluations.

A slightly-modified fracture protocol, adopted by the University of Wisconsin researchers, has also been voted on by the AASHTO Technical Committee 2b to get it published as a provisional standard.

DriveCam (Project ITS #84)

Inventor/Investigator
Gary Rayner
DriveCam, Inc. (now Lytx, Inc.), San Diego, California

IDEA Funding (funded through the ITS-IDEA program)
$95,000

Project Completion
2001

Description

Product: A palm-sized video event data recorder mounted behind a vehicle's rearview mirror to monitor driving activity by continuously recording video of the roadway, audio, and acceleration/deceleration forces into a digital looping memory

The DriveCam now comes as the DriveCam Program package that includes a palm-sized digital video recording device mounted in the vehicle, wireless upload process, web-based review system, and driver coaching. The program is designed to capture 12 seconds of video and audio inside and outside of the vehicle when activated by a risky driving event, such as hard braking, sudden acceleration, swerving, excessive speed, or other potentially unsafe actions that could lead to a collision. The device can also be activated manually to capture road rage events, hit-and-run accidents, or other road hazards. The video event recorder provides real-time feedback to the driver through the use of LED lights that flash when it has been activated to save an event.

DriveCam video event recorder

The DriveCam Program combines data and video analytics with real-time driver feedback and coaching. Powered by the patented Lytx Engine, the program captures, scores, prioritizes, and tracks the results of driving behavior to identify improvement opportunities for increased safety and efficiency. In-vehicle video captures driving behavior which is reviewed and scored within hours by certified professionals and then

passed on to the fleet safety or operations manager to coach driver improvement. Fleets manage the DriveCam Program through DriveCam Online, a web-based online portal. With 24/7 secure access, DriveCam Online provides important information fleets need to monitor fleet performance, prioritize events for coaching, and provide the tools needed to improve driver behavior.

The DriveCam device continues to be upgraded and is sold worldwide by Lytx, Inc., (formerly DriveCam, Inc. founded in 1998) based in San Diego, California. The IDEA product has now evolved into a major business enterprise that protects drivers from more than 950 commercial and government fleet clients worldwide who drive more than 20 billion miles annually. The company was ranked 67th in the Inc. magazine's list of 500 fastest growing companies in 2005.

Benefits

DriveCam has resulted in enhanced safety on the road by improving driver behavior through greater driver accountability and saved time and money by helping determine liability in collisions. Fleets that regularly review the DriveCam's event recording as part of a driving feedback system with their drivers typically report a 40-70% reduction in incidents.[1] A Federal Motor Carrier Safety Administration-sponsored study at the Virginia Tech involving 100 trucks found that risky driving incidents fell by 52% in the first fleet and by 37% in the second fleet for vehicles over a 17-week period as a result of using DriveCam.[2] By helping to improve driver behavior, the DriveCam also results in fuel savings of up to 12%.[3]

The information captured by the DriveCam is also invaluable for legal defense and insurance purposes. According to the company, the use of the device has reduced vehicle damages, workers' compensation, and personal injury costs by more than 50% in over 130,000 commercial, government, and consumer vehicles.[4]

Application/Implementation

The use of the DriveCam Program by industries and government agencies in their fleets continues to increase. Currently, more than 950 commercial and government fleets have deployed the DriveCam Program in their vehicles. These include all types of businesses, such as waste management and sanitation, construction, transit, paratransit, motor coach, utilities, telecom, goods distribution and logistics, trucking, services, and government and municipality entities. For example, in 2010, Sysco Corporation (a major supplier of food products) installed the DriveCam Program on its entire fleet of 9000 vehicles. In 2013, Waste Management installed the program on its entire fleet of 18,000 vehicles and, in 2014, Conway Freight deployed the program across its entire fleet. As for public agencies, the DriveCam Program is already being used by transit agencies in San Francisco, Austin, Orange County (Florida), and New Jersey. In 2010, the Washington Metropolitan Area Transit Authority installed the program on all of its 1500 buses. Other fleets using the DriveCam Program include Alaska DOT, the U.S. Department of State, the U.S. Marines Corps, Greyhound, U.S. Foods, Linde Gas, AmeriGas, and TXI (a cement producer based in Dallas, Texas), among many others.

The Maryland State Highway Administration's Highway Safety Office initiated a 'DriveCam for Families' program in 2008 to help newly-licensed teens become safe and competent drivers. The Iowa DOT, in collaboration with the University of Iowa, also used DriveCam in a similar study in 2010 on teen drivers' behavior.

Insurance companies have also taken notice of the DriveCam Program's impact. In 2008, the American Family Insurance teamed up with Lytx in creating the 'Teen Safe Driver Program' to help reduce risks presented by teen drivers by providing the program to its policy holders. Several other insurance companies (Crum & Forster, Sentry, and ARI Insurance) also now offer the program to their fleet policy holders.

Recognition/Awards

Frost & Sullivan's 'Customer Value Enhancement Award' for continuous improvement in DriveCam's driver safety value proposition to current and future clients, as well as for consistently elevating the safety of drivers and vehicles, resulting in reduced operating costs for its clients (2013)

Featured on ABC's World News Tonight and Good Morning America, CBS's Early Show, NBC's Dateline and Today shows, BBC, and CNN in recent years. Major publications, such as the Wall Street Journal, the Dallas Morning News, and the Forbes magazine have also carried stories on the DriveCam Program

Featured on the Discovery Channel's show, 'The Truth about Traffic' that focused on improving traffic flow and driving habits

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[1] Ignition, Interview with DriveCam inventor Gary Raynor http://www.trb.org/publications/ignition/ignition_2.pdf
[2] DriveCam Newsletter http://www.drivecam.com/News_and_Events/DriveCam_in_the_News.aspx
[3] Lytx Fleet Management Solutions http://www.lytx.com/our-solutions
[4] DriveCam Fleet Risk Management http://www.drivecam.com/Fleet-Risk-Management-Solutions.aspx

Self-Consolidating Concrete (Project #89)

Inventor/Investigator
Andrzej Nowak
University of Michigan

IDEA Funding
$78,000

Project Completion
2003

Description

Product: The adaptation of self-consolidating or self-compacting concrete (SCC) technology for the U.S. market using domestic materials and practice for highway infrastructure construction

Although SCC has been in use in Japan and Europe since the 1980s, this IDEA project was among the first studies in the U.S. supported by the state DOTs that helped establish the feasibility of producing and using SCC with locally available materials. SCC exhibits high deformability in the fresh state while maintaining resistance to segregation and flows easily into tight and constricted spaces filling all voids without requiring vibration and without causing aggregate segregation. To achieve the required fluidity, the SCC mixture uses polycarboxylate-based superplasticizers along with larger contents of cement (or cementitious materials) and fine aggregates and a smaller amount of coarse aggregates as compared to conventional concrete. In some cases, a viscosity-modifying admixture may be used instead of, or in combination with, higher cement and fine aggregate contents to stabilize the SCC mixture.

SCC being poured on the deck of 24th Street Bridge over Interstate 80/29 near Council Bluffs, Iowa

Benefits

SCC produces a durable structure that exhibits low air- and water-permeability and is free from voids or honeycombs generally found around reinforcements when using conventional concrete. There is no risk of aggregate segregation since, unlike conventional concrete, SCC requires no vibration for consolidation. Also, the higher cement content allows it to provide higher strength. Since SCC flows easily, self-compacts, and self-levels, placement is rapid and easy, saving time, labor, and equipment wear and tear. In fact, with SCC,

placement efficiencies can be increased by as much as 300 percent and labor costs reduced by 70 percent. Furthermore, SCC's superior rheology allows for the design and construction of complex shapes with congested reinforcements, and its non-segregating qualities are important for deep-section or long-span applications. Also, the use of SCC results in fewer safety and noise concerns since there are no vibrator operators up on the forms or dragging hoses and cords around the site.

On an initial cost basis, SCC can be about 40-60 percent more expensive than the conventional concrete but other factors (faster construction time, reduction in site manpower, reduced energy consumption, thinner concrete sections, increased durability, and reduced repair and patching problems, etc.) should more than offset the high initial cost.

Application/Implementation

Since this IDEA work, interest in SCC among state DOTs has continued to grow. In 2004, the state DOTs sponsored an NCHRP project 18-12 to develop guidelines for the use of SCC in bridge construction. The U.S. construction industry also took notice of the SCC technology, and technical organizations, such as the Precast/Prestressed Concrete Institute, the American Concrete Institute, and the American Society for Testing and Materials have developed guidelines and standards for using SCC in construction projects.

While SCC is being applied in almost every type of construction projects, it has found extensive use in the precast concrete industry that manufactures concrete structures at a plant for installation on a job site. SCC has also found use as architectural concrete because it produces smooth exposed surfaces that are virtually defect-free and allows innovative options for color and texture of the exposed surfaces. The high deformability and self-compactibility of SCC make it a very desirable material for bridge construction. It can be used for precast elements as well as for pouring concrete on the site both for new construction and for repairing and retrofitting existing ones. To help implement the technology, the FHWA has sponsored a number of SCC projects nationwide through its Innovative Bridge Research and Deployment and Highways for LIFE programs covering a range of applications, including beams and girders, bridge piers and piles caps, columns, abutment and retaining walls, drilled shafts, traffic barriers, bridge rails, and prefabricated elements and systems. The FHWA also offers a one-day course on SCC technology for state DOTs.

Many state DOTs, including Florida, Illinois, Nebraska, New Jersey, Nevada, Ohio, and Virginia, among others, have developed SCC construction specifications that allow SCC as an option to contractors. The state of Maine showcased the use of SCC on its Ogunquit Beach Bridge. Nebraska used SCC in the construction of its Skyline Bridge over Skyline Drive in Omaha as well as on a single-span bridge near Crofton in Knox County. Virginia DOT used SCC in the construction of the Pamunkey River Bridge on Route 33 near West Point. Minnesota used SCC in the drilled shafts of its new I-35W St. Anthony Falls Bridge over the Mississippi River in Minneapolis, and Mississippi used SCC in its Biloxi Bay Bridge project undertaken in the aftermath of the damage caused by the Hurricane Katrina.

SCC is also being used extensively in non-transportation construction projects, such as residential and commercial buildings and industrial plants and facilities. Some notable structures built with SCC in the U.S. include the U.S. Mission at the United Nations, the Freedom Tower (One World Trade Center), and the Columbia University Medical Center in New York City, the Wharton Center for Performing Arts and the Eli and Edythe Board Art Museum at the Michigan State University, the Trump Tower in Chicago (a 92-story reinforced concrete building), the Comcast Center in Philadelphia (the tallest 57-story building in the city), liquefied natural gas storage tanks in Freeport, Texas, and a 50-ft-wide slab under No. 1 subway line that runs the entire length of the World Trade Center in New York City.

Impact Echo Scanner for Nondestructive Evaluation of Grout/Voids in Post-Tensioned Bridge Ducts and Imaging Structural Concrete Defects (Project #102)

Inventors/Investigators
Larry Olson and Yajai Tinkey
Olson Instruments, Inc., Wheat Ridge, Colorado

IDEA Funding
$85,000

Project Completion
2008

Description

Product: A hand-held impact echo scanner for nondestructive evaluation of grout/void in post-tensioned bridge ducts for tendon corrosion and to image void, honeycomb, thickness, and cracking damage in structural concrete

The device uses stress wave technique of the impact echo to capture the compression waves with the scanning technology to produce an internal image of the grout conditions inside post-tensioned ducts. The upgraded IDEA product is commercially available from Olson Instruments, Inc. (Wheat Ridge, Colorado). Two data acquisition platforms are currently supporting the impact echo scanner. The scanner system with the Freedom Data PC platform currently costs $23,000 while a more economical version with the NDE360 platform costs $16,600.

Impact echo scanner

Benefits

Highway agencies can mitigate the risk of corrosion of post-tensioning strands by using impact echo scanning to locate areas of void in need of grouting repair for both new and old bridges. Scan rates are rapid, on the order of 14 feet per minute, detecting voids both in steel and plastic post-tensioning ducts. The impact echo scanning is performed on a near-continuous basis (every inch along the scan line). Another significant advantage of the impact echo scanning is that only one side of the structure needs to be accessible for testing.

Application/Implementation

At least eight state DOTs, including Colorado, California, and Nebraska, have evaluated the scanner technology in their bridge projects. Virginia DOT has purchased the device and is evaluating it for various applications. For example, it has used the device to locate distress/delaminations in box beams and also to locate poorly-consolidated concrete in a parapet and other applications. The device has performed well in all the applications the DOT has used it for.

Other agencies and institutions that have purchased the scanner system include Metropolitan Water District of Southern California, Pennsylvania State University, BAM Federal Institute for Materials Research and Testing (Berlin, Germany), and King Abdul Aziz Center for Science and Technology (Riyadh, Saudi Arabia). China has been the biggest overseas customer of the IDEA product where more than 20 units have been sold to various agencies and institutions.

A Soil Compaction Control Measurement Instrument (Project #118)

Inventors/Investigators
Jean-Louis Briaud and Louis Marcil
Texas A&M University and Roctest, Inc. Montreal, Canada

IDEA Funding
$95,000

Project Completion
2009

Description

Product: A portable laboratory and field equipment using a bending plate for a rapid measurement of soil modulus both in the laboratory and the field to verify attainment of proper soil compaction

The Briaud compaction device (BCD) is a simple, small-strain nondestructive testing apparatus that works by applying a small repeatable load to a thin steel plate in contact with the compacted soil. The resulting deflection of the plate is measured with strain gages mounted on the plate. The BCD modulus is then calculated using an equation derived by calibrating the BCD plate against polyurethane cylinders of known modulii. The device is commercially available from Roctest, Inc., based in Montreal, Canada, with sales offices in Pennsylvania and California. The latest version of the device costs about $10,000.

Briaud compaction device (BCD)

Benefits

Controlling soil compaction for projects such as building roadway bases and backfilling retaining walls is essential to limit the extent to which soil will deform under stress. Highway agencies need modulus measurement because the trend is towards controlling compaction on the basis of modulus rather than dry density. The BCD allows an engineer to determine the target modulus value in the laboratory, write it in the specifications, and verify that proper compaction has been achieved by using the device in the field. Since modulus is very sensitive to how it is measured, it is critical to measure it in the same way both in the laboratory and the field. The BCD is the only tool currently in the market that allows doing this. Furthermore, being rapid and easy to use, the BCD allows controlling extended surfaces and makes testing possible in locations not readily accessible.

Comparative tests have shown that BCD modulus can be compared with parameters obtained from established test methods (listed below). The BCD test, being generally faster and more economical, has the potential to become an alternative to these tests. However, users may need to run a few tests in parallel to establish a local correlation prior to using the BCD more extensively.

- Rigid Plate Modulus (E_{v2}) or Modulus of Subgrade Reaction (k)
- Modulus from the LWD (E_{vd}):
- Resilient Modulus (E_{res})
- Dynamic modulus determined from ultrasonic pulse velocity testing
- California Bearing Ratio (CBR) and the Resistance Value (R-Value)

Application/Implementation

Florida DOT is evaluating the BCD in its various construction projects. The evaluation so far indicates that the device yields consistent and reproducible results even when used by different operators. However, when compared with results obtained by standard methods, the BCD shows weak to moderate correlations that need to be improved. The IDEA researcher is working on improving the correlations.

Other agencies and institutions that have used the BCD include Geotechnics, Inc. (a geotechnical firm in New Zealand), the Missouri University of Science and Technology, the University of New Mexico (on a New Mexico DOT project), and the University of Sherbrook (Canada). Following a demonstration project in New York, FHWA also expressed interest in acquiring several units for evaluation but has not done yet for budgetary reasons. The instrument is expected to have a widespread use once specifications requiring modulus-based compaction are developed and relevant AASHTO and American Society for Testing and Materials (ASTM) standards become available.

Roctest, Inc., the industrial partner and manufacturer of the instrument, is working to have an AASHTO or ASTM standard adopted for this new compaction test. This is a long process but, when completed, will represent a major advancement for measuring soil modulus for highway projects.

Bridge Deck Scanner (Project # 132)

Inventors/Investigators
Larry Olson and Yajai Tinkey
Olson Engineering, Inc., Wheat Ridge, Colorado

IDEA Funding
$100,000

Project Completion
2011

Description

Product: A vehicle-mounted scanner system for the nondestructive evaluation of concrete bridge decks

The scanner system consists of a pair of rolling transducer wheels that evaluate the internal condition (including the top and bottom concrete delamination at the reinforcement layers and other mode of concrete deteriorations) of bare and asphalt overlaid concrete bridge decks. The transducer wheels are designed to be flexible with the mounting and can be connected to either a rolling cart or the hitch of a vehicle.

A pair of rolling transducer wheels connecting to a rolling cart

Three pairs of rolling transducer wheels connecting to a hitch of a truck

The system utilizes the combinations of stress wave techniques of the impact echo method and spectral analysis of surface waves to capture the surface and compression waves with the scanning technology to produce an image of the internal conditions of the concrete decks (with or without an asphalt overlay).

Benefits

Highway agencies can accurately detect the top and bottom concrete delamination (and/or general concrete deterioration) by using the bridge deck scanner on either bare or asphalt overlaid concrete decks. Although the scanning rate is currently limited to a fast walking speed, the use of multiple pairs of transducer wheels allows simultaneous scans of multiple scan lines, reducing the active testing time on the bridge.

Application/Implementation

A number of state DOTs (Colorado, Wyoming, California, Virginia, Kansas, and Nevada) and FHWA have evaluated the bridge deck scanner on their bridge projects. The technology was also evaluated by the National Center of Asphalt Technology (NCAT). The purpose of NCAT's use of the scanner system was to help detect debonding between layers of hot-mixed asphalt pavements. The system is currently available for consulting from Olson Engineering, Inc. (Wheat Ridge, Colorado).

Simple Tests for Low Temperature Properties of Asphalt Mixtures and Binders (Projects #133 and 151)

Inventor/Investigator
Mihai Marasteanu
University of Minnesota

IDEA Funding
$209,612

Project Completion
2012

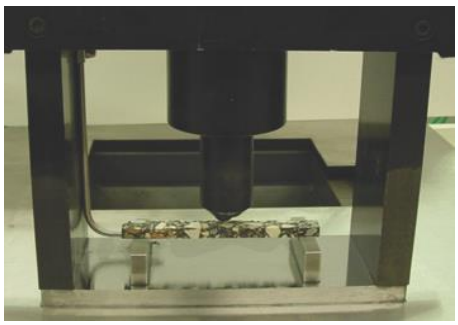
Description

Product: Simple test methods to obtain the low-temperature creep and strength of asphalt binders and mixtures using small-scale specimens on bending beam rheometer (BBR)

Selecting asphalt materials with good low-temperature fracture properties is critical for building asphalt pavements with increased durability. For asphalt binders and mixtures, the indirect tension tester is currently used to perform creep and strength tests on cylindrical specimens loaded in compression along the diameter according to the AASHTO T322-07 Standard. This method requires large loading frames and expensive extensometers.

In the first NCHRP IDEA project, a simple bending creep test on small-scale beams of asphalt binders and mixtures was developed using the BBR, currently used to test asphalt binders and mixtures as part of the AASHTO's performance grading system. A detailed beam preparation procedure for both laboratory compacted and field cores and a detailed loading procedure were developed and incorporated into a draft AASHTO procedure.

IDT and BBR test specimens



BBR with small scale beam of asphalt mixture

However, creep compliance of asphalt binders and mixtures represents only one of two parameters required to predict low-temperature performance. Strength is the other critical input parameter for the AASHTO's pavement design guide algorithm. To meet this requirement, a strength test on small-scale beams was developed for asphalt binders and mixtures in the follow-up IDEA project. Due to different loading patterns and higher loads required for strength tests, a modified BRR (called BBR-Pro) was developed by Canon

Instrument Company for strength tests. Air cooling was found to be the best option for storing and testing both binders and mixtures.

BBR-Pro device

Benefits

Performing creep and strength tests on asphalt binders and mixtures using the BBR at low temperatures has many advantages over the current test methods. Most asphalt testing laboratories have the BRR and can perform creep tests without making any changes. For strength tests, only the loading frame has to be upgraded, while the rest of the apparatus and the simple calibration procedure remain the same. The preparation of small beams of mixture is very simple and allows testing a large number of specimens, similar to asphalt binder testing, which makes routine mixture QC/QA testing possible. In addition, the use of small-scale specimens makes these test methods ideal for investigating aging effects in the structure of real pavements and quantifying the properties of thin and ultra-thin layers made with premium materials, a technology that has seen considerable growth in recent years. The simple three-point bending configuration also allows for extrapolation of strength results to larger structures and different stress fields, providing a better linkage between laboratory results and large pavement structures. Finally, the BBR creep and strength of asphalt binders and mixtures can be used in the mechanistic empirical pavement design algorithm to predict low-temperature performance of asphalt pavements.

Application/Implementation

A draft AASHTO method for the asphalt mixture creep test was developed and presented at the asphalt expert task group (ETG) meeting for further action towards adoption as an AASHTO standard. The method has already been used by many laboratories, both in the U.S. and abroad, as well as an investigative tool in research projects by many researchers. The Utah DOT has implemented the method as a part of its routine mixture testing and has recently completed a study in which significant correlations were found between the BBR mixture properties and field performance. A draft testing method for determining the low-temperature bending strength of asphalt binders and mixtures using the BBR-Pro device is being finalized for consideration by the asphalt ETG and the AASHTO.

Computer Vision Traffic Sensor for Fixed and Pan-Tilt-Zoom Cameras (Project #140)

Inventors/Investigators
Stanley Birchfield, Wayne Sarasua, and Neeraj Kanhere
Clemson University

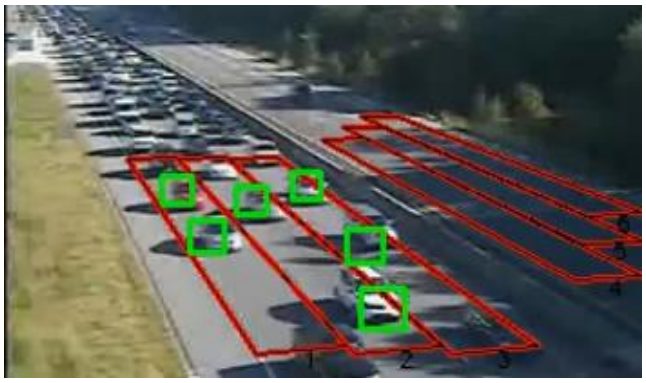
IDEA Funding
$130,000

Project Completion
2010

Description

Product: A traffic sensor based on computer vision technology for use on fixed and pan-tilt-zoom cameras for collecting traffic parameters (TrafficVision)

The computer vision sensor system is capable of collecting volume, speed, and vehicle classification on a per-lane basis. Computer vision tracking helps minimize problems caused by occlusion, spillover, rain, snow, fog, glare, and other environmental conditions. A novel aspect of the system is its ability to work with existing pan-tilt-zoom (PTZ) cameras and automatically calibrate cameras if they are panned or tilted. Autocalibration is accomplished by tracking vehicles through the video sequence to detect changes in the camera's parameters. Traffic Vision (U.S. Patent No. 8,379,926) is commercially available from Omnibond Systems, LLC., based in Clemson, South Carolina.



TrafficVision

In addition to traffic data collection, TrafficVision is capable of automatic incident detection, including identifying stopped vehicles, slow-moving traffic, wrong-way maneuvers, debris, and pedestrian intrusions. There are two typical system installation scenarios. One version, TrafficVision TMC, requires a high-powered server running in a traffic management center to process up to 24 video feeds simultaneously in real time. The other version, TrafficVision Edge/Remote, processes up to 4 video feeds at the site. Both the centralized and decentralized versions have been tested in a variety of city, county, and state locations and installations. Overall, the system can typically collect per-lane counts with less than 5% error, average speeds with less than 1 mph error, and classification errors less than 3% for 4 different vehicle classes (motorcycles, cars, and single- and multi-unit trucks). For incidents, manual inspection revealed a false positive rate of 0.22 false alarms per day per camera.

Benefits

Cost effective, non-intrusive, real-time traffic data collection and incident detection system that works with both fixed and PTZ cameras and without having to install additional hardware. The robust tracking overcomes the limitations of machine vision technologies that rely on virtual detection and are prone to errors due to occlusion, spillover, rain, snow, fog, glare, and other environmental conditions. The autocalibration capability allows the system to work with existing PTZ cameras which are widely deployed along most urban freeways for manual surveillance purposes.

A**pplication/Implementation**

The sensor system was initially evaluated in terms of its traffic data collection capability in partnership with South Carolina, Maryland, and New York State DOTs. The commercialized system (TrafficVision) is being evaluated or is in use by many state DOTs and public agencies, including Missouri, Ohio, and South Carolina DOTs and several others. TrafficVision was also recently evaluated for its traffic data collection and incident detection capabilities as part of the FHWA's ENTERPRISE pooled-fund study. The sensor system is also being used for research purposes by Wayne State University, Texas Southern University, and Texas Transportation Institute.

Bridge Retrofit Laser System (Project #153)

Inventor/Investigator
Paul Fuchs
Fuchs Consulting, Inc., Leesburg, Virginia

IDEA Funding
$139,000

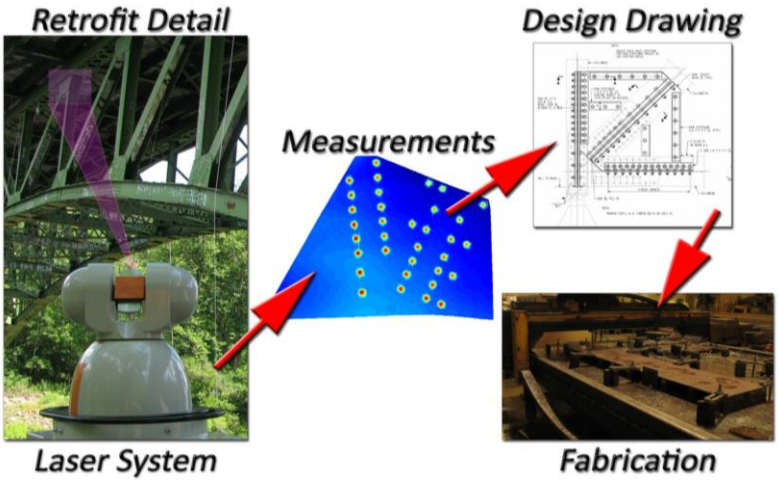
Project Completion
2012

Description

Product: An advanced laser measurement system to accelerate the bridge retrofit process, reducing the time between identifying repair needs and resuming service on a bridge

The bridge retrofit laser system (BRIDGE RLS) precisely measures sections of a bridge structure involved in a retrofit process. Measurements are processed to produce computer-aided design (CAD) drawings of needed retrofit parts that can be sent automatically to a fabricator. The laser measurement system has features not found in other commercially-available equipment, which allow the system to provide data much more accurately than the conventional methods as well as collect totally new types of information.

The overall system concept is remote, non-contact, highly accurate laser-based measurements of a bridge structure undergoing retrofit work. Spatial data is obtained with full three-dimensional measurements of components. The system does not just produce a cloud of points needing extensive post-processing but converts the raw measurements into engineering data that can provide useful information. The engineering data, typically in the form of CAD files, can be sent to a fabricator to make parts for installation on the bridge. The system can also be used for other bridge and civil infrastructure applications that require highly accurate and precise measurements, such as for load testing and other structural analyses.



System concept for laser field bridge retrofit measurements

Benefits

The BRIDGE RLS saves time and money by streamlining measurement steps. The laser field measurements can be used to produce CAD drawings automatically for fabricators. Minimizing the time a bridge is out-of-service or eliminating lane closure can save DOTs substantial costs and is in the best interest of the traveling public.

The laser system makes measurements directly on a specimen surface *without* requiring a special target and can measure on steel, concrete, and even on timber. This is an important attribute as it allows measurements to be made on bridges without having to first access the bridge in any manner. The laser system makes extremely accurate measurements with full three-dimensional accuracy in the thousandths of an inch over the working volume [50 m (164 feet) range] of the instrument.

The system makes measurements with minimal impact at the bridge site and typically without altering traffic under the structure with no lane closure. It can also make measurements over water or other difficult access conditions, such as rail lines.

BRIDGE RLS measuring steel bridge girders over live traffic

Application/Implementation

The BRIDGE RLS is being used to provide DOTs information that is not possible with other measurement systems. For example, the system was recently used to measure an adjacent box beam bridge for the Maryland State Highway Administration that highlighted its unique measurement capabilities. This particular structure is over water and presents very difficult measurement conditions. The BRIDGE RLS was placed on a pile cap and used to measure very low-level deflections and rotations of all beams in two adjacent spans as the bridge was loaded, comparing a nominally intact span and a span with broken tie-rod. Measurement of a very small level of bridge movement would not have been possible without the use of this precise and accurate measurement system. The ability to measure this structure without targets, or any other direct contact with the beam surfaces, allowed very spatially-dense measurements that revealed important behavior of the structure. The unexpected behavior of this bridge observed in the measurements may reveal behavior that is not currently considered in design and analysis.

NCHRP IDEA Products further supported by FHWA's Highways for LIFE Program for Implementation and Commercialization

Some Examples

A Computer-Controlled Image Analysis System for Measuring Aggregate Shape Properties (Projects #77 and 114)

Inventor/Investigator
Eyad Masad
Texas A&M University

IDEA Funding
$110,000

Project Completion
2007

Description

Product: An automated computer-controlled image analysis system (AIMS) for measuring aggregate shape characteristics, such as angularity, form, and texture

The shape characteristics of aggregates used in concrete, asphalt mix, and unbound aggregate pavement layers are known to affect the structural integrity and durability of a pavement as well as its skid resistance. The AIMS automatically determines aggregate shape characteristics by capturing digital images of aggregate samples and comparing them to a reference database to classify the aggregates with a graphical output of aggregate characteristics. The system's software uses a series of analysis algorithms that objectively quantify aggregate properties both on the macro (such as the shape and angularity) and the micro (such as the surface texture) scale. The software also allows characterization of the shape and angularity distribution for correlation with performance in pavement layers.

The IDEA product, further developed and evaluated with support from FHWA's Highways for LIFE Program, is available commercially from Pine Instruments Company (Grove City, Pennsylvania), and units have been sold both in the U.S. and overseas. The earlier system was further refined into a new version, AIMS-2, that combines hardware that captures real-time digital images of paving material samples and a software that analyzes aggregate characteristics affecting pavement quality and improves the speed and accuracy of testing. The latest version with all the accessories costs about $29,000.

Automated image analysis system (AIMS) for aggregate characterization

Benefits

The AIMS method is rapid, accurate, and more convenient than the current manual method that is tedious and time-consuming and often results in inconsistencies in measurement, quality assurance, and mix design. The automated image-based analysis by AIMS is also free from operator's influence and bias and is able to characterize aggregates for Superpave sieve sizes ranging from 0.075 mm to 25 mm retained.

AIMS can also be used to characterize the rate of change of aggregate texture in degradation tests, such as the Micro-Deval test, which can be used to model frictional characteristics of pavements during the mix design process. This is important for the safety of the motorists as there appears to be a strong correlation between aggregate texture and pavement skid resistance.

Application/Implementation

The IDEA product was selected by the FHWA's Highways for LIFE Program for further evaluation and commercialization. A large number of DOTs from across the U.S. and Canada participated in evaluating the system for accuracy and reproducibility along with FHWA and several universities and private laboratories. The participating DOTs included Maine, Vermont, New York, Florida, Mississippi, South Carolina, Alabama, Michigan, Ohio, Indiana, Illinois, New Mexico, Texas, Nebraska, Kansas, Oklahoma, Iowa, Minnesota, North Dakota, South Dakota, Oregon, Washington, Alaska, and Saskatchewan, Canada. The FHWA's Highways for LIFE Program also sponsored an evaluation of the new AIMS-2 through an inter-laboratory study involving 32 university, commercial, and state highway agency laboratories. This evaluation led to the development of procedures and specifications for aggregate shape characterizations using digital imagery, resulting in the adoption of two AASHTO provisional specifications:

> TP81 – *Standard Method of Test for Determining Aggregate Shape Properties by Means of Digital Image Analysis Shape Properties*
>
> PP64 – *Standard Practice for Determining Aggregate Source Shape Values from Digital Image Analysis Shape Properties*

The AIMS is being used by FHWA for demonstration and training in its mobile testing laboratory.

Asphalt Binder Thermal Cracking Test (Project #99)

Inventor/Investigator
Sang-soo Kim
Ohio University

IDEA Funding
$76,000

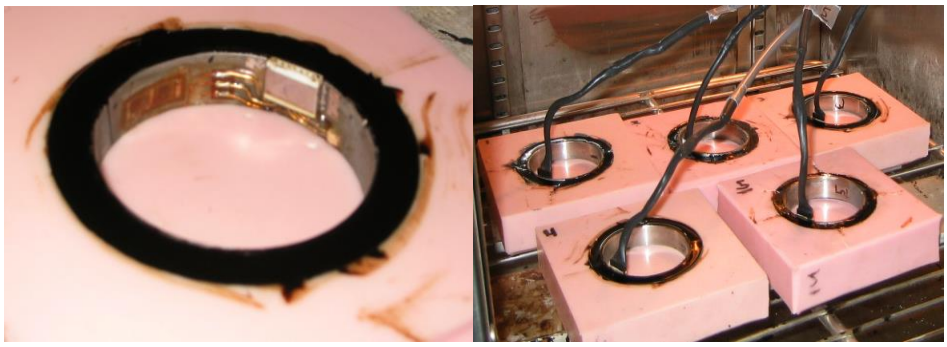
Project Completion
2007

Description

Product: A simple, reliable test for determining low-temperature thermal cracking temperature of asphalt binders

The asphalt binder cracking device (ABCD) is a simple equipment that accurately measures the low temperature thermal cracking potential of modified asphalt binders that AASHTO binder specifications were not able to provide. For ABCD test, a circular asphalt binder specimen is prepared on the outside of a 2-in. diameter Invar ring. Invar is a steel alloy with near-zero coefficient of thermal expansion. As the temperature is lowered, the thermal stress within the asphalt specimen increases until it fractures. The device also allows accurate measurement of asphalt strength at low temperatures that until now had been problematic.

The IDEA product, further developed and evaluated with support from FHWA's Highways for LIFE Program, is commercially available from EZ Asphalt, Inc. based in Athens, Ohio. Due to limited commercial production, it currently costs about $50,000, but the cost is likely to come down when increased usage would require large volume production.



Asphalt binder cracking device (ABCD)

Benefits

Low temperature thermal cracking is a major type of asphalt pavement failure requiring state DOTs to allocate significant financial resources for repairing cracked pavements. To minimize premature failure due to thermal cracking, it is essential to properly grade asphalt binders for the expected climatic environment. The ABCD simulates cracking in the field as it monitors thermal stress induced by a lowering of temperature in an asphalt specimen molded onto an Invar ring. The device directly reads cracking temperature and allows simultaneous testing of multiple specimens (up to 16), saving time and money. It can be used by itself or in conjunction with other test methods to accurately grade asphalt binders for low temperature performance. In field tests, the ABCD

cracking temperatures correlated consistently better with crack severities of the test pavement than AASHTO M320 critical temperatures. The ABCD can also measure polymer modification effects on the low-temperature thermal cracking as well as the fracture strength of asphalt binders at the cracking temperature. The ABCD test has been found to be more accurate than the current bending beam rheometer (BBR) test, and with further validation, may eventually replace the BBR test.

Application/Implementation

The IDEA product was selected by the FHWA's Highways for LIFE Program for further refinement, evaluation, and commercialization. The state DOTs and Canadian provinces that participated in evaluating ABCD for accuracy, reproducibility, and ease of use included Alaska, Florida, Iowa, Kansas, Massachusetts, Minnesota, Montana, New Hampshire, New York, Ohio, Oregon, Texas, Vermont, Virginia, Washington, Wyoming, and Ontario, Canada, along with FHWA. Several private industries such as Exxon Mobil, Mathy Technology & Engineering, and the Hudson Company also participated in this evaluation. The test was also evaluated in the Minnesota's MnRoad project.

Recently, New Hampshire and Ohio DOTs have used ABCD in evaluating their asphalt mixes. The latter used it to evaluate virgin, recycled asphalt pavement (RAP), and recycled asphalt shingles (RAS) binders at different blends as well as to test the extracted binder from an asphalt mix that contained RAP and RAS for a test section in northeastern Ohio. The Ohio DOT found the device easy to set up and run and was quite satisfied with the results.

Research institutions such as the Texas Transportation Research Institute and the Western Research Institute have been using ABCD in their asphalt binder research projects. The developer has also received inquiries from overseas, and contacts have been made with customers in the United Kingdom, China, Russia, and Poland.

The ABCD-based test method was approved by the AASHTO's subcommittee on materials as a provisional standard (TP92) and is included in the AASHTO Book of Standards and Specifications:

> TP 92-14 – *Standard Method of Test for Determining the Cracking Temperature of Asphalt Binder Using the Asphalt Binder Cracking Device (ABCD)*

A Mobile System for Measuring Retroreflectivity of Pavement Markings (Project #146)

Inventor/Investigator
Terry Lee
Leetron, Inc., Concord, New Hampshire

IDEA Funding
$149,000

Project Completion
2011

Description

Product: A laser-based mobile system for rapid and reliable measurement of pavement marking retroreflectivity at highway speeds

To meet the new minimum retroreflectivity standards proposed by the FHWA, state DOTs face a need for better means to manage the maintenance of pavement markings. The Leetron imaging system offers a reliable means to help meet these new standards with fact-based condition data on retroreflectivity while helping reduce the cost of pavement marking maintenance operations. It uses a method of tracking measurements in real time that mitigates the effects of road vibrations and surface roughness. The system aims a laser at the center of the pavement marking and uses a feedback loop to readjust the aim point as the vehicle equipped with the imaging system travels at highway speeds. The system is a significant improvement over currently-used technologies and provides a safe, efficient, accurate, and repeatable method for measuring pavement marking retroreflectivity.

Mobile pavement retroreflectivity measurement system

Benefits

The mobile retroreflectivity measurement helps minimize nighttime driving accidents on the highways. About half of all traffic fatalities occur at night even though only about one-fourth of road travel occurs at night. Retroreflective pavement markings help drivers see the road ahead at night and must be maintained in order to be effective. The Leetron system breaks away from traditional design to a real-time tracking system to counter

motions and environmental effects on mobile data collection and provides a practical, reliable, and efficient means of obtaining retroreflectivity data for pavement marking at highway speeds.

The system is highly stable with stable electronics and optical components in an environmentally-controlled enclosure. Measurements are taken at a very fast rate (4500 times a second), and the measurement capability can be doubled by utilizing two systems to measure both the driver- and passenger-side markings simultaneously. The system also makes consistent measurements on the curves. Being a simple one-operator system, it saves labor costs; the operation is simplified with features such as auto start, voice recognition for user interface, and auto calibration/verification.

Application/Implementation

After the prototype was developed in the IDEA project, work has continued on product commercialization in collaboration with the Connecticut DOT. This work is partly funded by the FHWA's Highway for LIFE Program. After further refinement, the system now produces reliable and stable results. An extensive evaluation of the system was successfully conducted in 2014 with collaboration from FHWA and Florida DOT. The system is now scheduled for further evaluation by an independent contractor (Texas A&M Transportation Institute) in 2015.

NCHRP IDEA Products Supported by State DOTs through Pooled-Fund Studies for further Evaluation and Implementation

Some Examples

Three-Dimensional Digital Imaging for Management of Unstable Highway Slopes (Project #119)

Inventor/Investigator
John Kemeny
Split Engineering, Inc., Tucson, Arizona

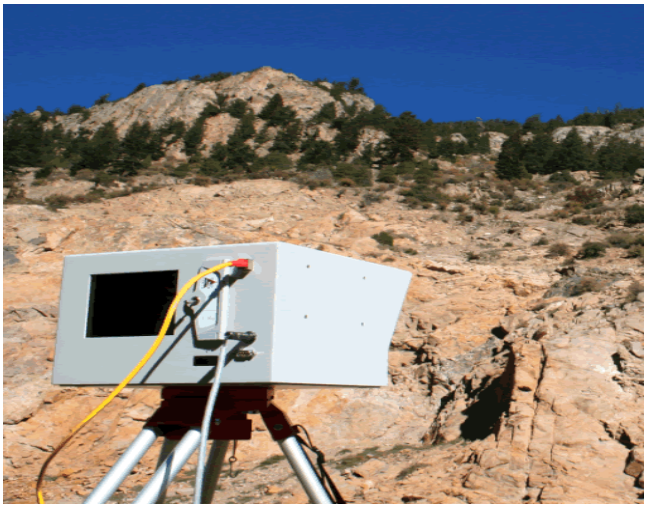
IDEA Funding
$99,500

Project Completion
2008

Description

Product: A software-based system for the identification, evaluation, and management of unstable highway slopes

The software system, Split-FX, includes tools for rock mass characterization (finding discontinuities and their orientation, stereonet plotting), determining rockfall hazard ratings (slope and highway geometries, geotechnical factors, human exposure factors), and detecting ground movement between successive scans. Ground-based three-dimensional light detection and ranging (LIDAR) scanning data is analyzed by Split-FX software for characterizing highway slopes.



Ground-based three-dimensional LIDAR scanning for analysis by Split-FX software

Benefits

There are thousands of miles of potentially unstable highway slopes in the U.S., far too many to analyze using traditional geotechnical techniques. Characterization and categorization of comparatively high-risk slopes remains a labor-intensive task that is further complicated by the broad range of geologic conditions that influence rockfall hazards. The Split-FX software developed in the IDEA project allows highway slopes to be analyzed quickly, accurately, and without many of the safety hazards associated with traditional geotechnical surveying, by processing point clouds from ground-based LIDAR scanning that can be carried out from distances as far as two kilometers.

Application/Implementation

The developed software system was field tested and validated at a number of field sites in Arizona, Colorado, and Utah with assistance from respective DOTs. These sites included Mount Lemmon Highway (Mileposts 2 and 5) and Highway 60 near Globe in Arizona, I-70 near Georgetown, I-70 through Glenwood Canyon, and SR 74 near Morrison in Colorado, and SR 190 at Big Cottonwood Canyon in Utah. Alaska DOT also did its own evaluation of the IDEA product for use on its highway slopes and rockfalls.

Further evaluation with a goal to implement the technology was undertaken through a pooled-fund study (TPF 5-166) involving eight states (Arizona, California, Colorado, New York, New Hampshire, Pennsylvania, Tennessee, and Texas) with Arizona as the lead state. The study focused on the geotechnical evaluation of potentially unstable slopes, including change detection that might affect the construction and maintenance activities of the highways. Scanning of sites in each of the eight states was conducted. These sites included a slope along I-40 near Flagstaff, Arizona and several slopes along Highway 375 near El Paso, Texas. A major deliverable of this study was a draft 'Recommended Practice' for AASHTO's consideration.

The IDEA-developed software is also able to analyze scans taken of the same location but at different times to detect changes due to rock movement and rockfall. This led to funding by the National Science Foundation's Small Business Innovation Research program to further extend the IDEA work to develop a low-cost LIDAR scanner system that could be set up in the field to continuously scan a site and monitor for changes, particularly for highways and other geo-infrastructure sites, such as bridge foundations, tunnels, and dams.

The Split-FX software is available from Split Engineering, Inc. (Tucson, Arizona) at a cost of about $8,000 including all the accessories. It has been purchased by the pooled-fund study participant states and several other domestic and foreign agencies, including the U.S. Bureau of Reclamation and the British Geological Survey.

Instrumentation to Aid in Steel Bridge Fabrication – Virtual Assembly System (Project #127)

Inventor/Investigator
Paul Fuchs
Fuchs Consulting, Inc., Leesburg, Virginia

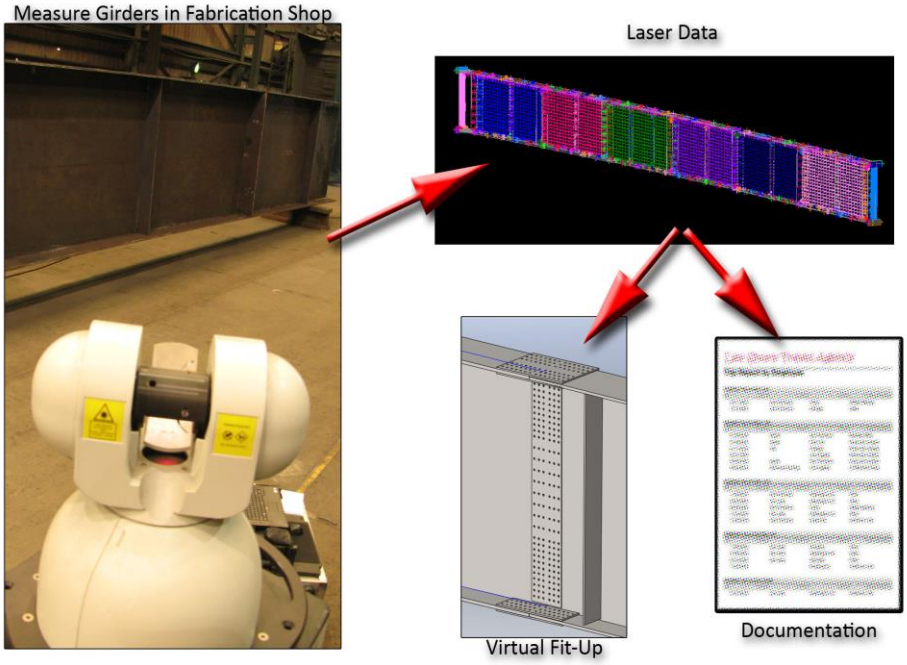
IDEA Funding
$140,000

Project Completion
2009

Description

Product: A laser-based bridge measurement system to precisely measure fabricated components, and a virtual assembly software to take data from measured components and fit them together virtually without physical shop assembly

The bridge virtual assembly system (BRIDGE VAS) improves the manufacturing process and enhances quality control for steel bridge fabrication. The system replaces conventional match-drilling with virtual assembly methods, creating custom-designed splice plates. It measures accurately and precisely all aspects of bridge components, including splice hole locations, camber, sweep, web panel deformations, and end-kick in a nearly fully-automated manner. It can also measure any size or shape girder fabricated in a shop (from simple plate girder to complex tub girder). The system is highly flexible and can work in any clear area of the shop floor, with no special modifications required (such as special lighting, dust-free clean room, vibration limiting, or other highly restricted activities).



System concept for laser measurement of steel bridge girders

Benefits

There are many documented cases of steel bridge erection problems, particularly for complex structures, such as curved girders and box structures. For example, in 2001, the Virginia DOT was faced with a problem for a bridge at Magruder Boulevard over I-64 in Hampton where an incorrectly fabricated girder was not identified until most of the structure was erected and some components did not fit together. This single incident resulted in millions of dollars in legal expenses, re-fabrication costs, and delays in the construction of the bridge. Because of these types of problems, most states now require a steel bridge fabricator to shop assemble some or all parts of a steel bridge to make sure that the structure, primarily the splice plates and cross frames, will fit together at the job site, as designed. However, this shop assembly procedure is labor- and time-intensive and adds significantly to the cost. In addition, quality control data is typically taken by hand with string lines and rulers and recorded manually on paper reports. This process can sometimes introduce errors (such as wrong numbers written down or errors made in measurements) and does not provide a complete permanent record of a fabricated component. The BRIDGE VAS will eliminate or minimize these problems and help improve the quality and reduce the cost of complex bridge fabrication.

The BRIDGE VAS improves the manufacturing process by eliminating some time- consuming steps. By piecing together individually measured girders virtually in the software, the need to physically laydown, align, and match-drill spliced pairs can be eliminated. The match-drilling step is the bottleneck in the overall process and is one of the most, if not the most, time-consuming and expensive tasks in the fabrication of a steel bridge. Some estimates put the cost of this step at 15-20% of the total fabrication cost. The IDEA product can virtually manipulate and align girders and produce a combined camber diagram of a girder pair or multiple girders. Based on a virtual assembly, custom-designed splice plates can be made.

The BRIDGE VAS also eliminates the laydown process. Depending on the shop, the laydown area may require one-third to one-half of the floor space of the entire shop. Girders are laid on their sides and set end-to-end, taking up several hundred feet of space. By using BRIDGE VAS, this laydown area is now freed for use for other purposes, improving efficiency in a shop. By eliminating the laydown process, full-sized holes can be placed at the beginning of the fabrication of a girder using equipment that can drill holes much more efficiently. This would eliminate the need to manually drill hundreds of holes at each splice. All this would result in significant savings on the fabrication of every steel bridge.

BRIDGE VAS measuring a girder in a fabrication shop

The BRIDGE VAS replaces subjective, limited-accuracy conventional measurement methods with a full digital record and provides full documentation of what is fabricated, much beyond what currently exists. This digital record is certifiable, traceable, and can be used to fully document the as-built girder at the fabrication shop. From the digital record, any number or form of customized reports can be automatically generated. The digital record encapsulates all relevant data and the final measurements for a girder and can be used to produce data in standardized formats compatible with commercially available software tools. All key aspects of a girder are measured and documented, including length, camber, sweep, stiffener locations, and web panel deformations. An important quality control feature of the BRIDGE VAS is the ability to get immediate feedback of fabrication errors in real time with actual measurements overlaid with a shop drawing-based model.

Application/Implementation

The FHWA and two private manufacturers (High Steel Structure, Inc., Lancaster, Pennsylvania and Eggers Steel Company, Sioux Falls, South Dakota) collaborated in testing the IDEA product. The system was further developed and evaluated for application to complex bridge structures in a pooled-fund study (TPF 5-226) involving four states (Virginia, New York, Iowa, and Texas) along with FHWA. Virginia was the lead state for this project. A leading private bridge fabricator, Hirschfeld Industries (San Angelo, Texas), also collaborated in this evaluation.

The system was successfully implemented on the first-ever production bridge job on a structure for Tennessee DOT. A second production bridge job has been planned in Virginia.

Automated Continuous Aggregate Sampling and Laser Targeting System
(Projects #150 and 168)

Inventor/Investigator
Warren H. Chesner
Chesner Engineering, PC, Long Beach, New York

IDEA Funding
$267,000

Project Completion
2014

Description

Product: A laser scanning system for continuous or semi-continuous monitoring of aggregate material for highway construction

The system, referred to as a sampling and laser targeting system (SLT), can be used as a stand-alone unit in a materials laboratory, where sample buckets are deposited into the system or deployed adjacent to a moving conveyor line of bulk material, where a subsample of the target material is diverted into the SLT for analysis.

Sampling laser and targeting system in a materials laboratory at a quarry site

This new aggregate scanning technology is based on laser-induced breakdown spectroscopy (LIBS) in which a high-powered pulsed laser is used to excite atoms in an aggregate material generating distinct wavelength patterns or spectra unique to the composition of the aggregate constituents (elements and molecules in the aggregate material). The engineering properties and the corresponding quality of aggregate materials are fundamentally related to the composition of the aggregate constituents (elements and molecules in the aggregate material); consequently, aggregate materials exhibiting specific engineering properties can be expected to contain similar elemental and molecular components and similar wavelength patterns or spectra. The LIBS spectral patterns of aggregate materials are quite complex, but using multivariate chemometric statistical techniques, one can analyze the wavelength patterns and differentiate between spectral patterns to

tell the difference between aggregate types and correlate the spectral patterns of the aggregate with its quality and engineering properties. Laser scanning also allows collecting large quantities of spectral data, thus providing sufficiently-sized sample populations to account for the inherent chemical heterogeneity associated with aggregate materials used in highway construction.

Benefits

For the past 75 plus years, aggregate users have relied on laboratory-based test methods and specifications compiled by the AASHTO, the American Society for Testing and Materials (ASTM), or the local agencies to define the acceptable quality of aggregate for use in highway construction. Almost all these test methods and their corresponding criteria are empirical in nature and are based on studies undertaken over the years that have defined correlations between the laboratory test data and field experience. These test methods require sample collection and preparation and can take hours, days, or weeks to complete, and generally separate tests must be performed for each aggregate quality parameter of interest. Finally, difficulty with collecting sufficient number of samples and obtaining a representative sample limits the utility of many test methods to adequately characterize the target sample for many aggregate quality parameters.

The methodology based on laser scanning technology can achieve results within seconds or minutes, providing quality control in real time during aggregate processing or production. The technique requires no sample preparation, and one laser scan can characterize multiple aggregate quality parameters simultaneously, eliminating the need for conducting multiple tests on each source. The technique, therefore, can be used for real-time quality control during aggregate quarrying or during cement or asphalt production to ensure that aggregate quality meets required specifications.

Application/Implementation

The IDEA product is now the focus of a transportation pooled-fund study (TPF 5-278) with Kansas DOT as the lead agency. Other participating states include New York, Oklahoma, Ohio, and Pennsylvania. As part of this pooled-fund study, aggregate samples from each participating agency are being tested and analyzed. The New York State DOT has initiated its own demonstration program. The technology was recently demonstrated at an aggregate quarry near Albany, New York. A major aggregate producer and a cement company are also participating in the demonstration activities.

Promising NCHRP IDEA Products with High Implementation Potential

Some Examples

Image Pattern Recognition Algorithms for Processing Video Log Images to Facilitate Roadway Infrastructure Data Collection (Project #121)

Inventor/Investigator
Yichang (James) Tsai
Georgia Institute of Technology

IDEA Funding
$100,000

Project Completion
2009

Description

Product: Algorithms to automatically detect and recognize roadway traffic signs using image pattern recognition methods and digital video log images

The IDEA product consists of generalized algorithms developed to automatically detect and recognize more than 670 different types of traffic signs specified in the *Manual on Uniform Traffic Control Devices* (MUTCD) by using video log images that are widely available. Instead of manually reviewing millions of images frame by frame, these algorithms provide new capabilities for automating the traffic sign inventory by means of batch processing.

(a) Triangle (b) Rectangle (c) Pentagon (d) Octagon

Traffic Signs with Different Shapes

Benefits

Traffic signs are among the major roadway assets that the state DOTs invest in. These traffic signs provide vital guidance to road users regarding traffic regulations, road hazard warnings, destination and other geographic information, and temporary road conditions. However, the current manual inventory method makes it difficult to comprehensively collect sign data statewide, which, in turn, makes it difficult for an efficient and effective sign management and maintenance. The detection and recognition algorithms developed in this IDEA project show much promise for providing an intelligent sign inventory and

management system. The benefit of the developed algorithms lies in their capability to significantly reduce the time and cost for obtaining traffic sign inventory data using video log images. Preliminary tests showed that 86% of the manual frame-by-frame image review effort could be saved by using the developed algorithms.

Application/Implementation

The IDEA-developed algorithms have been tested by using image data provided by several city and state DOTs, including Georgia, Louisiana, Connecticut, and Nashville, Tennessee. Based on promising results from the IDEA project, the U.S. DOT Research Innovative Technology Administration (now the Office of the Assistant Secretary for Research and Technology) sponsored a follow-on study to further improve the automatic sign data collection by using both digital video log images and mobile LIDAR data. The Georgia DOT also sponsored a project to test the enhanced algorithms for signs on an actual highway. A complete sign inventory data on I-285 in Atlanta, Georgia, was collected and provided to the DOT. An application was also developed for streamlining the current sign inventory and condition assessment using the IDEA-developed algorithms. Efforts continue to implement the developed algorithms to help state, county, and city transportation agencies cost-effectively inventory their sign assets in support of their asset management activities.

Signal Head Vibration Absorber for Traffic Signal Support Structures (Project #141)

Inventor/Investigator
Richard Christenson
University of Connecticut

IDEA Funding
$135,000

Project Completion
2011

Description

Product: A vibration damping system based on magnets to reduce fatigue in traffic signal support structures exposed to excessive wind-induced vibrations

The signal head vibration absorber (SHVA) is a vibration mitigation device to reduce the in-plane wind-induced vibrations and the resulting fatigue of traffic signal support structures. The SHVA is based on a vibration absorber that uses the mass of the traffic signal head along with eddy current dampers utilizing permanent magnets to provide a robust vibration absorber applicable to a wide range of mast arm lengths to reduce or minimize fatigue in signal support structures.

Signal head vibration absorber installation at Texas Tech's wind field station

Benefits

Traffic signal support structures, particularly cantilevered structures, are susceptible to wind-induced vibrations. Various types of wind loading, including galloping, vortex shedding, natural wind gusts, and truck-induced gusts, can cause vibrations in traffic signal support structures that, over time, can result in fatigue and eventually failure. Reducing the effective stress range (the difference between the maximum and the minimum stress in a cycle), by reducing the amplitude of the vibration can significantly increase the fatigue life of the structure. The AASHTO's standard specifications for structural supports for highway signs, luminaires and traffic signals recognize that an effective vibration mitigation device can reduce vibrations and eliminate the need to design for fatigue.

The SHVA is an effective vibration mitigation device that is relatively inexpensive, easy to install, and low-maintenance, and requires no modification of standard signal heads and mounting hardware. It can be readily installed in new traffic signal support structures or retrofitted to existing problem structures.

A unique attribute of the SHVA is that it is robust to mistuning, which means that a single SHVA design can reduce vibrations over a wide range of mast arm lengths and signal structure configurations and designs. The SHVA does not need to be tuned for each structure.

Since SHVA, by reducing the wind-induced vibrations of traffic signal support structures, reduces fatigue and increases the safe life of the structure, fewer resources will need to be allocated for replacing and repairing fatigued structures while contributing to a safer and more efficient surface transportation infrastructure. Since AASHTO specifications specify that, in lieu of designing for galloping and vortex shedding forces, an effective vibration mitigation device may be used to reduce vertical deflections, smaller, less expensive structures can be used when equipped with an SHVA.

Application/Implementation

Laboratory tests of SHVA were conducted at the University of Connecticut on a traffic signal support structure with a 35 feet (10.67 m) long mast arm. Free vibration tests showed that the percent of critical damping in the structure increased from 0.2% to 10.1%, which corresponded to a more than 90% reduction in the steady state response of the structure.

Following the success of the IDEA project, the Center for Science and Technology Commercialization at the University of Connecticut awarded a prototype fund project to conduct field testing of the SHVA. As part of this testing, a redesigned unit was tested for more than a year on a traffic signal support structure with a 60 feet (18.29 m) long mast arm in the town of Manchester, Connecticut. The SHVA and its components were shown to be robust to the elements with no loss in performance between the day it was installed and the day it was dismantled.

In August 2012, the Texas DOT funded a supplement to an ongoing project at Texas Tech University to conduct field testing of the SHVA installed on a traffic signal support structure with a 60 feet (18.29 m) long mast arm at the university's National Wind Institute. The field test results were consistent with prior laboratory testing. During the three months of monitoring, the SHVA was found to reduce vortex-induced vibration of the mast arm by approximately 90%, which reduced the stress range at critical components of the traffic signal support structure and increased the safe life. Further, the one minute modal mast arm displacement at the mast arm tip was effectively reduced to less than 1 inch over the range of wind speeds (from 3 mph to 45 mph). The SHVA performance was independent of the type of wind excitation and was demonstrated to reduce vertical vibration over the full range of wind speeds collected.

Current efforts are focused on identifying a test procedure for traffic structure owners to qualify particular vibration mitigation devices as effective and incorporate the added performance of the selected device into the design of the structure and on working with industry to develop a commercially-viable SHVA.

Asphalt Embrittlement Analyzer (Projects #144 and 170)

Inventor/Investigator
William Buttlar
University of Illinois at Urbana-Champaign

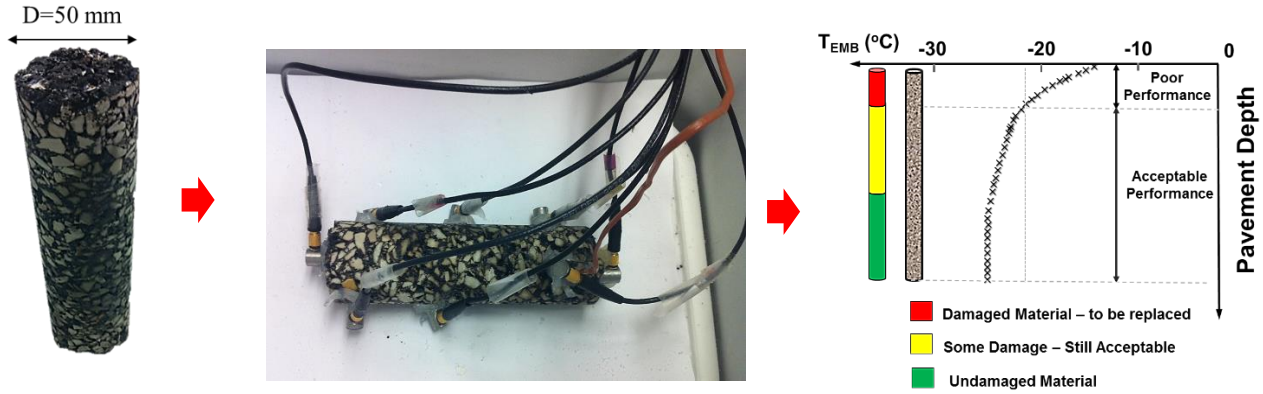
IDEA Funding
$260,000

Project Completion
2015

Description

Product: A multi-sensor, acoustic emission-based asphalt embrittlement temperature detection system at various pavement depths

The asphalt embrittlement temperature detection system, referred to as the asphalt embrittlement analyzer (AEA), provides a means to rapidly and reliably characterize the asphalt material embrittlement threshold at various pavement depths using small-diameter field cores. By cooling a field core sample, acoustic emission sensors can listen for and identify the temperature at which the material reaches a brittle state (the state where macro cracks propagate rapidly). By employing multiple sensors, the location of micro cracks (which emit noise) can be determined (using a technique similar to GPS triangulation). In this manner, a continuous material profile can be generated for the field core, providing a color-coded plot of asphalt embrittlement temperature versus pavement depth from the surface. Crack-prone surface materials can then be removed (milled), treated, and/or surfaced with sufficient material to insulate them from their AEA-determined cracking threshold.



(a) (b) (c)

Continuous embrittlement temperature property characterization of age-graded field core materials, (a) 50 mm diameter field core sample (b) AEA sensing system mounted on mixture sample (c) real-time graphical display of embrittlement temperature profile throughout the pavement thickness

Benefits

The AEA will provide highway agencies and pavement evaluation/materials testing laboratories or companies a new tool to accurately assess and monitor pavement condition and strategically select an appropriate maintenance strategy to restore crack resistance cost-effectively. By avoiding damaging forms of pavement surface cracking (such as top-down fatigue, thermal, and block cracking), pavement structure can be retained, costly rehabilitation delayed, and user costs significantly decreased. In addition, by applying thin maintenance treatments at the right time, significant sustainability benefits can be realized by avoiding or delaying the application of thicker, hot-mixed overlay systems and allowing the use of thinner treatment systems. For lower-volume roadway, airfield, and parking facilities, these include treatments which often involve the use of cold- or warm- applied asphalt binder systems, thereby reducing the use of new materials, fuel usage, and the carbon footprint of the pavement.

The AEA can also be used in the single sensor mode to determine the embrittlement temperature of asphalt binders and mixtures. Using the AEA in this mode can also yield sustainability benefits through optimized mixture designs that maximize the effective usage of recycled asphalt products from pavement and roofing shingles as well as warm mix asphalt products.

The AEA may also be used to assess the effectiveness of rejuvenators in softening and restoring crack-resistance to the pavement surface. Currently, there is no evaluation approach available to accurately and rapidly assess the depth to which rejuvenators are able to penetrate and their actual effectiveness in restoring a pavement's crack resistance. The AEA can be used as an evaluation tool to determine the extent of in-situ pavement embrittlement or embrittlement depth and also as a design tool to assess the effectiveness and proper use of any proposed rejuvenators to restore the pavement surface's crack-resistance.

Application/Implementation

To facilitate commercialization and implementation of the IDEA product, the research team has been working closely since the beginning of the project with Troxler, Inc., a leading manufacturer of asphalt quality control and design equipment with extensive experience in commercializing, distributing, and supporting asphalt testing equipment. Through meetings, site visits, and reviews of interim research results and test designs, Troxler, Inc. is assisting in the development of a viable, industry-friendly testing device. In addition, collaboration with the Asphalt Institute and Road Science, LLC., an asphalt paving mix company based in Tulsa, Oklahoma, has helped to advance technology transfer through validation of the test method using materials and performance data from high-visibility field projects, such as the Minnesota's MnRoad project. The Asphalt Institute, with an asphalt industry membership of more than a hundred, can help communicate the AEA's performance through its online and printed publications. Road Science, LLC. has provided access to field-cored materials from asphalt pavements across the U.S. via its recent National Science Foundation-sponsored collaboration with the University of Illinois. Development of an AASHTO standard test and vetting through the FHWA's asphalt expert task group are now being pursued.

Shape Memory Alloy-Enhanced SMART Bridge Expansion Joints (Projects #147)

Inventors/Investigators
Jamie Padgett, Emily McCarthy, Reginald DesRoches, and Paul Bradford
Rice University, Georgia Institute of Technology, and Watson Bowman Acme Corporation

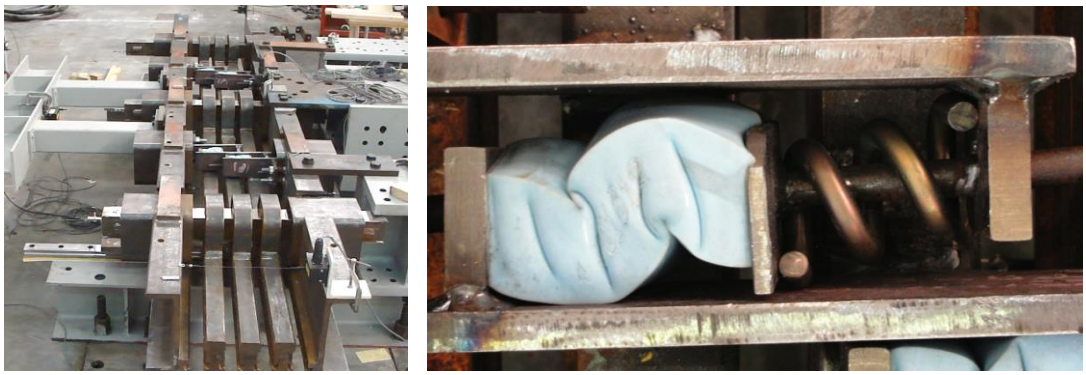
IDEA Funding
$140,000

Project Completion
2013

Description

Product: A new type of bridge expansion joint, based on shape memory alloys (SMAs), to accommodate service loads as well as large displacement demands during extreme events such as earthquakes

The new joint system, referred to as a SMART joint, given its enhancement with SMAs, offers an intermediate alternative between commonly-installed service-level expansion joints and dedicated seismic expansion joints, which, unless explicitly specified, are often avoided due to the added cost and complexity. The SMART expansion joint integrates nickel-titanium SMAs to modify a commonly-installed modular bridge expansion joint. Through strategic placement within the bridge joint, beneficial and unique SMA behaviors are introduced into the expansion system, such as recentering and energy dissipating characteristics (which improve seismic behavior) and corrosion resistance (which alleviates maintenance costs associated with bridge joints). Through limited alteration of the existing joint configuration, up-front costs are minimized and limited to less than 15% increase over a basic service level joint. The resulting system averts the need for post-event joint repair or replacement, thus improving bridge functionality and reducing expected life-cycle costs.



SMART expansion joint and close-up of expansion system incorporating SMA spring

Benefits

The SMART joint design preserves existing desirable service load behavior of the commonly-installed joint but can accommodate significant increases in longitudinal displacement capacity under dynamic loads while limiting internal load transfer that would otherwise lead to failure of the joint components. These improvements translate into reduced joint repair and replacement costs and improved post-event functionality of the bridges, offering systems that are capable of accommodating traffic passage after a hazard event. The

minimal cost increase makes the SMART joint a cost-effective solution even in regions of moderate seismicity, given the significant reduction in joint failure probability across a range of hazard levels. The reduction of expected life-cycle costs and preservation of current field construction requirements should facilitate transfer of the SMART joint technology into practice.

Application/Implementation

The development of the IDEA product involved Rice University, the Georgia Institute of Technology, and a joint manufacturer, Watson Bowman Acme Corporation. The joint's advanced performance and functionality were afforded without changing the field construction requirements in order to provide an easy transfer of the technology into practice. Furthermore, industry-driven cost and manufacturability considerations were at the forefront of this collaborative endeavor, which would also help with product transfer.

Ongoing discussions with the joint manufacturer, Watson Bowman Acme, center on opportunities for further refinement, evaluation, and commercialization to make this technology available to the bridge engineering community in near future. Beyond these direct outcomes, subsequent support was also obtained through a program with the U.S. National Science Foundation and the Korean National Research Foundation to explore other applications of the SMA devices developed and tested in this IDEA project for integration into bridge joints or other bridge systems.

Cleaning Device for Removing Debris and Chemicals for Crack/Joint Sealing (Project #148 and 159)

Inventor/Investigator
Yong K. Cho
University of Nebraska-Lincoln

IDEA Funding
$116,800

Project Completion
2013

Description

Product: A pneumatic cleaning, cutting, and routing device for pavement crack and joint sealing

The crack cleaning device (CCD) is an air-powered rotary attachment system with an onboard air nozzle that blows out material deposited in the pavement crack. The device also allows for a seamless connection with the existing maintenance vehicles' air compressor systems, which reduces the need for further retrofits and eliminates the need to haul flammable liquids.

The innovation incorporates four traditional crack/joint cleaning methods into one device: (i) wire brushing (wire brush), (ii) routing (router), (iii) saw cutting (blade), and (iv) air blasting (air nozzle). The device uses a pneumatically-driven rotary wire brush and a rotary router carbide bit to remove mid- to large- sized debris and vegetation from the cracks. A masonry cutting blade can be attached to create a saw joint on the concrete pavement. An air blasting nozzle, directly behind the rotary attachment, expels fine-grained particulates like concrete dust, fine sand, old sealants, and winter de-icing chemicals from the walls and the surface of the pavement cracks.


Highway pavement crack cleaning and routing using the CCD

Benefits

The IDEA product greatly facilitates pavement crack repair. Compared to the existing routing machine (costing about $12,000), this low-cost versatile device (costing about $3,000) can be used on a greater variety of cracks than existing crack cleaning devices and with better performance. The device helps improve the quality of preventive maintenance and increase the service life of pavements, saving the cost of new construction.

Analytic hierarchy process (AHP) and economic analyses were conducted on the CCD along with three other currently-used crack cleaning devices using the surveyed data from the Nebraska Department of Roads (NDOR) road maintenance crew. The AHP analysis based its evaluation on safety, quality, and productivity and ranked the four devices in the descending order: CCD, air blower, heat lance, and router. The economic analysis ranked the four devices in the descending order: air blower, CCD, heat lancer, and router. Discarding the option of air blower because of the quality issue, the CCD was determined to be the best option, especially far better than the router. In addition, the investment in a CCD was estimated to be paid back in less than a year.

Application/Implementation

For field validation of the CCD and to gain industry acceptance, several industry demonstrations and field tests were conducted. The NDOR provided multiple CCD units to all of its eight districts during the 2012-2013 sealing season. The feedback and analyzed results showed that the CCD was well regarded in terms of improving productivity and safety and reducing maintenance costs. Based on field tests and feedback, a rugged, heavy-duty routing CCD was developed with a much higher pneumatic power and torque. This new generation CCD was field-demonstrated at the Georgia DOT's District 7 maintenance yard. This demonstration also showed the quality of the routed cracks by the CCD to be better than that by the conventional air blower while taking about the same amount of time. The NDOR has scheduled additional field tests of the new routing CCD during the 2015 sealing season.

Bridge Cable Inspection with Long-Range Ultrasound (Project #152)

Inventor/Investigator
Thomas R. Hay
Waves-in-Solids, LLC., State College, Pennsylvania

IDEA Funding
$100,784

Project Completion
2011

Description

Product: A long range ultrasound technology for rapid screening of bridge suspender ropes and stay cables for damage

The technology is employed to screen bridge cables and suspender ropes to assess structural integrity and prompt a more detailed visual inspection, if warranted. The sensor system is retrofitted on to an entire bridge cable system or cables showing advanced corrosion or wire breaks. A trained technician installs the sensor(s) and acquires baseline data. Moving forward, the data is collected on a weekly, monthly, or annual basis to determine if cable damage has been initiated or further advanced. Beyond a certain damage tolerance, a follow-up visual inspection is prompted to ensure continued safe operation of the bridge.

Handheld instrument is used to download data from bridge

Data is uploaded to database for damage tracking

Cable ID	Damage Level
West Side 1	3% CSA at socket
West Side 2	None
West Side 3	25% CSA at socket
West Side 4	None

Suspender rope damage assessment coefficient with increasing % cross section area loss

Benefits

There are several cost benefits of the technology for cable system bridge owners. The technology allows transition from time-based to condition-based visual inspection. Visual inspection is performed only on cables that exceed the tolerance allowance on the ultrasonic data. As a result, significantly less inspection time is required to evaluate the cables over the lifetime of the bridge cable system. The ultrasonic inspection is generally performed at walkways where the sensor is installed and very rarely requires traffic control. The technique also results in a reduction of rope access, aerial lift device equipment, and personnel costs to support cable inspection.

Ultrasonic inspection also eliminates subjective and person-dependent visual inspection data as it provides high-quality engineering data over the entire bridge cable system remotely without any personal bias. The technology also facilitates inspection of hard-to-access cables and suspender ropes as, due to security concerns and surface coatings, cables systems are becoming increasingly difficult to inspect visually. The ultrasonic technology, therefore, is well suited to provide a viable, effective inspection solution for the future bridge cable systems.

Application/Implementation

The technology is available for implementation. The long-range ultrasound technique is currently being applied to bridge cables and suspender ropes regularly, in addition to other industries that use load bearing wire ropes. These include mining, recreation, amusement parks, and vertical lift devices. The IDEA project provided the confidence and opportunity needed to introduce the technology to state DOTs, mining and exploration companies, and some of the largest amusement parks and recreational entertainment facilities in the U.S.

Super-Weathering Steels for Infrastructure Applications (Project #160)

Inventors/Investigators
Semyon Vaynman, Morris Fine, and Yip-Wah Chung
Northwestern University

IDEA Funding
$100,000

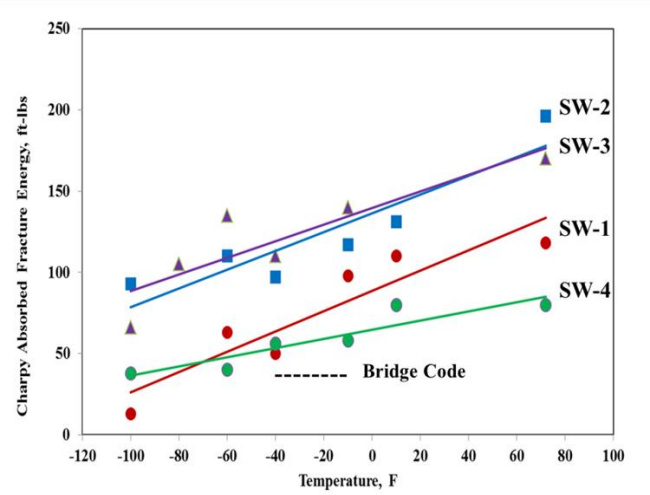
Project Completion
2014

Description

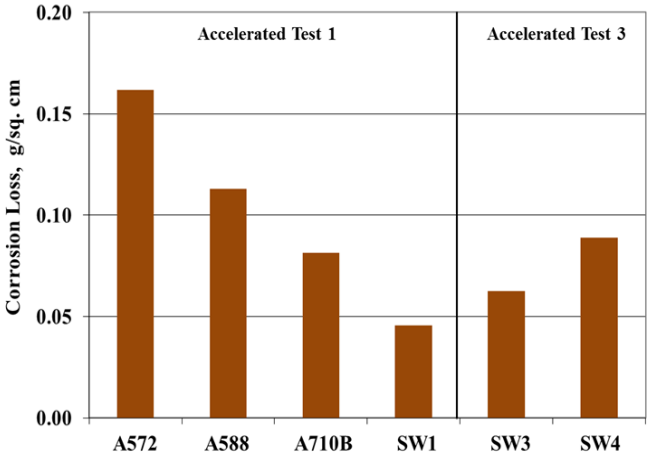
Product: New steels with weathering characteristics superior to weathering steels currently used for bridge construction

A new class of low-cost steels was developed with superior weathering, strength, and low-temperature fracture characteristics. The composition of these steels is based on the copper-precipitation-strengthened A710 Grade B steel developed at Northwestern University in the 1990s and used in bridges in Illinois. A strong weathering-enhancing element, phosphorus, was added to the steel, and embrittlement was mitigated by the addition of specific amounts of titanium to keep phosphorous from migrating to the grain boundaries. The production of these new steels does not require special processing or thermal treatment; therefore, any steel manufacturer can produce these steels in any steel-plate size.

Four steels were designed and tested. The steels were found to be very ductile and fracture-tough to -100°F, significantly outperforming the requirements of the ASTM A709 bridge steel standard. No brittle heat-affected zone was formed in high-power laser welding simulations, indicating that the steels could be easily welded without pre- or post-welding heat treatment. Accelerated weathering studies indicated the new steels to possess significantly better weathering characteristics than the A588 weathering steels currently used in bridge construction.



Charpy absorbed fracture energy of experimental super-weathering steels



Results of accelerated weathering prohesion tests (ASTM G85 annex A)

Benefits

The use of weathering steels in highway infrastructure construction provides cost savings as well as environmental benefits. Initial cost savings of more than 10 percent are realized because the steel is easier to handle and install during construction and needs no painting. Life cycle cost savings are estimated to be more than 30 percent because weathering steels require less maintenance and are more durable than the common construction steels.

Without the need for painting, the new steels provide significant environmental benefits since there is no need to deal with volatile organic compounds from paints and the removal or disposal of contaminated blast paint debris over the life of the structure.

These new steels have a potential to replace currently-used weathering steels because of their superior mechanical, low-temperature fracture, welding, and weathering properties. In addition, since these steels are produced by simple hot-rolling (without special processing or heat treatment), they can be produced at any steel mill in any length at a cost competitive with existing weathering steels.

Application/Implementation

The IDEA project was a successful feasibility study for a new class of weathering steels. To commercialize and implement these steels, the developers need to involve steel manufacturers, welding consumable producers, bridge fabricators, FHWA, and state DOTs. To be accepted for use in infrastructure applications, the steel production needs to be scaled up. After several commercial steel heats are produced and thoroughly tested, they need to be included in the AASHTO and ASTM Standards. Also, welding consumables for these steels need to be identified from those presently available or new consumables may need to be developed specifically for these steels and rigorously tested.

New Scour-Vortex-Preventing Products for Scour-Critical Bridges (Project #162)

Inventor/Investigator
Roger L. Simpson
Applied University Research, Inc., Blacksburg, Virginia

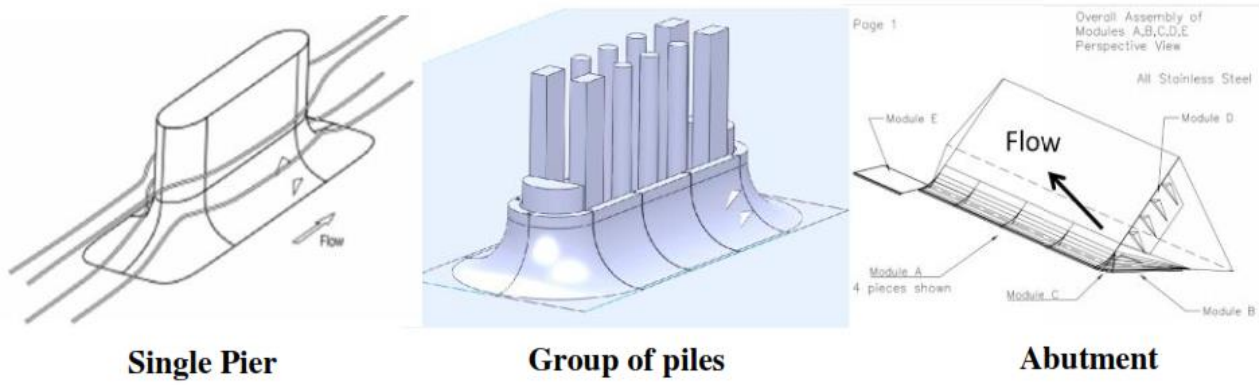
IDEA Funding
$140,000

Project Completion
2013

Description

Product: Scour-vortex-preventing products (scAUR and VorGAUR) for permanent or long-term and cost-effective solution for the bridge pier and abutment local scour problem

The basic concepts of this innovation are that (a) the shape of the scAUR streamlined fairing prevents local scour around bridge piers and abutments by preventing the formation of scouring vortices over and around the fairing and (b) the VorGAUR vortex generators located well above the river bed prevent flow separation and scour on the downstream part of the fairing and cause some near-river-bed flow on the sides of the fairing to move up onto the fairing and prevent scour of the side bed of the pier or abutment.



Left: Flow streamline patterns around the scAUR pier fairing with VorGAUR vortex generators obtained via computation fluid dynamics simulation. Middle: scAUR pier fairing with VorGAUR vortex generators for a group of piles. Right: Spill-through abutment with scAUR fairing with VorGAUR

Local scour of bridge piers and abutments is one of the most common causes of the failure of a highway bridge. All currently-used countermeasures are temporary, expensive, and do not prevent the cause of scour – discrete large-scale vortices formed by flow separation and recirculation from the underwater structures. These large-scale vortices bring higher-velocity water down to the river bed and cause scour. The products scAUR (U.S. Patent No. 8,348,553) and VorGAUR (U.S. Patent No. 8,434,723) prevent the near-free-surface higher-velocity water from going down to the river bottom and cause scour and also keep the lower-velocity water near the river bed, providing practical, long-term, and cost-effective solution to the bridge pier and abutment local scour problem regardless of the type and size of the surrounding soils and rocks.

Benefits

In addition to permanently preventing the formation of local scouring vortical flows, the scAUR with VorGAUR designs are effective for swirling and large angle-of-attack approach flows. There are lower drag forces on the bridge (since no high-speed water is drawn down to the pier or abutment surface), much lower flow blockage (since the water is accelerated around the pier or abutment), much lower water level (since the flow is more accelerated around the pier or abutment), and much lower over-topping frequencies on bridges during flood conditions (because the water moves faster around the bridge for any water level or turbulence level).

The scAUR with VorGAUR designs also prevent debris accumulation and provide protection from impact loads because of the streamlined flow around the pier without a horseshoe vortex, which deflects objects and debris away from the underwater structure. For a piece of debris to remain lodged in front of a pier, it would require perfect balance of the debris weight on both sides of the pier. The scAUR shape with VorGAUR prevents the formation of the pier nose horseshoe vortex, so there is no downflow at the pier that would submerge the floating debris. In reality, the bow wave in front of a pier is unsteady, meaning that the position of an arbitrary piece of debris is unstable due to the asymmetries of the flow. Therefore, the debris would move to one side of the pier or the other and float downstream. The vortex generators are designed so no debris can get caught. The downstream sloping surfaces of the vortex generators have no place to catch the debris. Vortex generators around the nose of the pier or the upstream edge of an abutment create counter-rotating vortices that diffuse the free-surface pier bow or abutment separation vortex, greatly reduce the downwash from these vortices, and prevent scour on the river bed.

Soil and rocks surrounding the piers and abutments are more stable with VorGAUR and a leading edge ramp. Scour generated around a foundation protected by scAUR with VorGAUR always occurs at a significantly higher approach flow speed than a speed that will cause open-bed scour. Huge flow speeds will cause open-bed scour but the curved-top rectangular planform leading edge ramp creates counter-rotating vortices on each side that bring open-bed materials toward the foundation for protection from further scour.

Piers and abutments protected by scAUR with VorGAUR and a curved-top rectangular leading edge foundation ramp are expected to last 100 plus years. Since loose open-bed scoured material will be brought toward the sides of the pier or abutment, the bottom of the foundation will always have material around it, even if an upper portion of the foundation is exposed because of high-speed flood waters.

The present value cost of scAUR and VorGAUR products over the life of a bridge are an order of magnitude less than the current scour countermeasures. However, the lifetimes of scAUR and VorGAUR products will be dictated by the type and design parameters of their construction materials, such as the quality of the concrete and the thickness of the stainless steel for retrofits.

Application/Implementation

The scour-preventing products are ready for implementation. Virginia DOT has committed to seek funds to install prototype products on the westbound bridge on US Route 360 over the Appomattox River. Several other state DOTs and railroads have initiated discussions for implementation. The website www.noscour.com provides more details.

Rapid Laser Profiling of Steel Bridge Coatings, Corrosion, and Heavy Metals (Project #164)

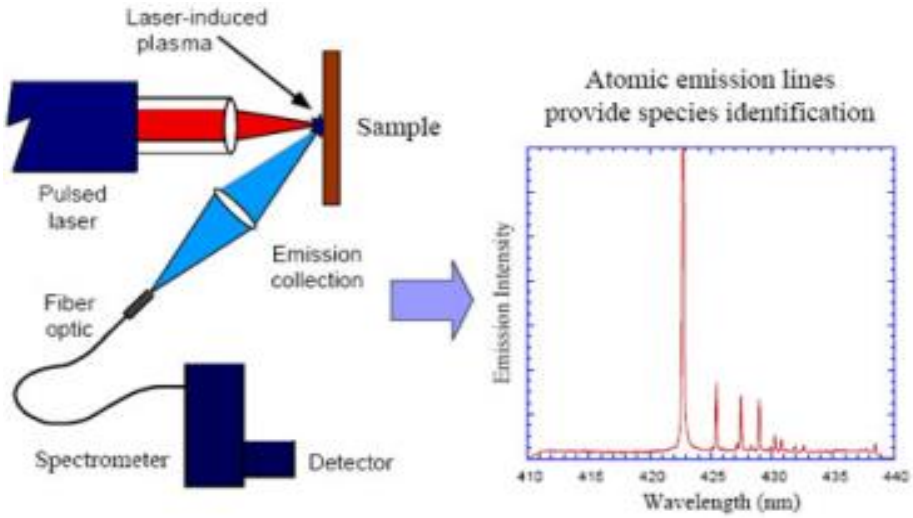
Inventor/Investigator
Warren H. Chesner
Chesner Engineering, PC, Long Beach, New York

IDEA Funding
$137,238

IDEA Project
2014

Description

Product: A laser-drill to rapidly identify and profile the types and layers of coatings on a bridge structure, the presence and severity of subsurface corrosion under the coatings, and the embedded heavy metals



Laser profiling system (LPS) concept

The technology, referred to as the laser profiling system (LPS), is based on laser-induced breakdown spectroscopy (LIBS), which has become increasingly important in a variety of monitoring applications for the chemical and physical characterization of target materials. In LIBS, a high-power pulsed-laser is focused onto the target material and when the laser energy exceeds the material's ablation threshold energy, chemical bonds are broken fracturing the material into energetic fragments that consist of a mixture of neutral atoms, molecules, and ions inducing a plasma. The light emitted by the plasma is characteristic of the chemical make-up of the ablated material. This emitted light can be quantified by collecting the light and generating a spectral image (consisting of the emission wavelengths and their intensities) in a spectrometer. The spectrum is compared to the spectra of known materials to identify the characteristics of the target material.

Benefits

Current characterization methods for bridge coatings and corrosion generally rely on a combination of "hands-on" and "visual" inspection methods. This hands-on inspection includes both physical and chemical measurements to assess the condition of the coating and substructure. Where deterioration is observed, samples

of the coating and the underlying structure are scraped off and tested or examined in the chemical and physical laboratories. Where toxic metals are suspected in the pigments, heavy metal analysis is performed on the scraped samples. All this testing is tedious and time-consuming.

Similarly, visual inspections are generally concerned with general appearance and corrosion and are based on the inspector's interpretation of the reference standards and typical corrosion patterns. Despite the comprehensive criteria established, most of the inspection methods and, particularly, the recorded results are open to personal judgment and biases, depending upon the person's training and experience, and require significant staff training to obtain reliable information.

The LPS device is anticipated to replace many of the above-mentioned tasks with a rapid and field-friendly operation. The device will quantify heavy metals of interest in various coating layers and also the corrosion of the substrate – something only done visually (qualitatively) in the field. Use of the LPS device is expected to enhance field productivity by as much as 50 to 75 percent and shave days from time spent analyzing samples in the laboratory.

Application/Implementation

This IDEA work was intended to establish the feasibility of the laser profiling process and the requirements for a field prototype. The research team is now working with a bridge inspection company to adapt the technology to commercial inspection operations. The technology has potential application in profiling both coatings and concrete bridge decks.

A Software System for Automated Turning Movement Counts on Shared Lanes (Project #177)

Inventors/Investigators
Madhav Chitturi, David A. Noyce, and Kelvin Santiago
University of Wisconsin-Madison

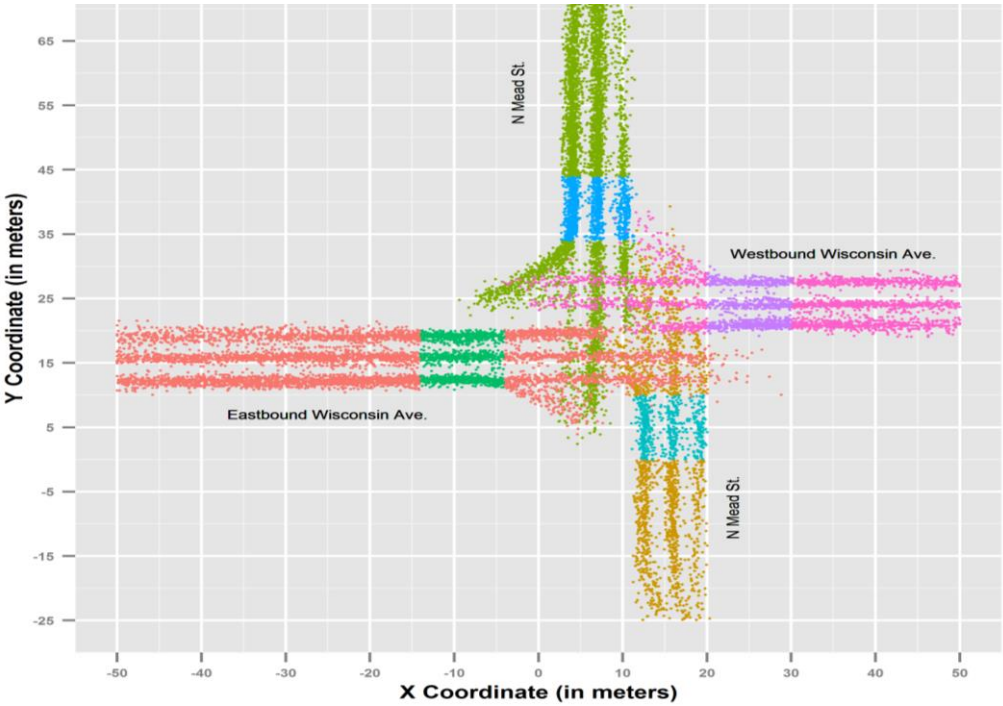
IDEA Funding
$78,097

Project Completion
Active

Description

Product: A software module for automatically producing turning movement counts on shared lanes using existing radar-based detection systems

While existing radar-based vehicle detection systems monitor vehicles approaching an intersection, they are also being used to detect vehicles for traffic signal control. The proposed software-based system harnesses the potential of existing radar detection systems to automatically obtain turning movement counts for shared lanes. Specifically, trajectory (position and time) information of individual vehicles will be tapped to categorize turning movements of the vehicles. Existing radar detection systems in the market do not offer this feature.



Sample vehicle trajectory data at intersection in Appleton, Wisconsin

Benefits

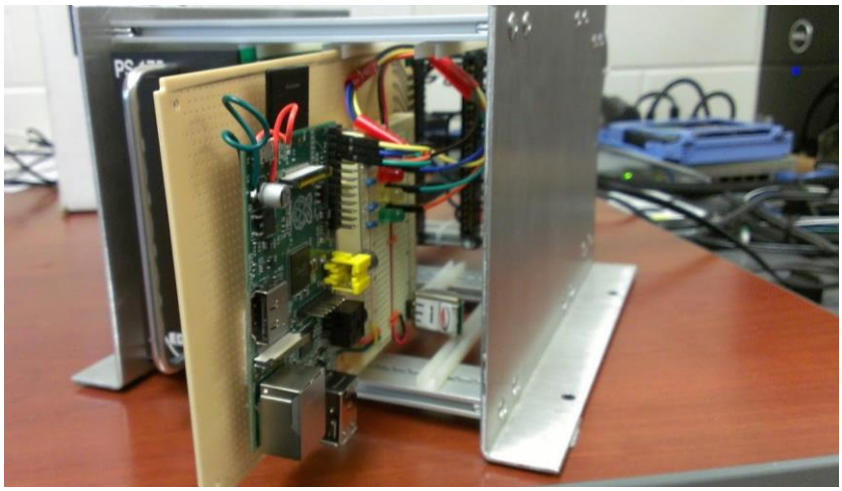
This innovation can potentially transform every intersection into an automatic traffic recorder to continuously

provide turning movement data. Turning movement data will have the most direct effect on signal retiming while enabling multifarious applications in transportation operations, planning, and safety domains.

Traffic signal retiming is one of the most cost effective ways to improve traffic flow and mitigate congestion. One of the bottlenecks for implementing a proactive signal retiming program in any jurisdiction is the unavailability of turning movement data. The IDEA-developed system will help meet this need by providing transportation agencies with turning movement counts continuously throughout the year. The innovation has a potential to make a transformative shift in how frequently transportation agencies can retime traffic signals by readily providing data needed for developing signal timing plans and, perhaps, resulting in an automated methodology for retiming

Application/Implementation

The proposed system does not involve any additional hardware. The innovation is totally software-based and can be readily incorporated into existing radar-based vehicle detection systems at a nominal incremental cost. MsSedco, the manufacturer of the Intersector, a microwave motion sensor system, is keen to incorporate this innovation into its motion sensor system. Another possibility is to move towards the development of a separate new portable product. This may be accomplished with assistance from the University of Wisconsin Alumni Research Foundation, a nonprofit patent and licensing organization. A customized version of such a product that can be placed in the detector rack inside a signal cabinet is shown below.



Potential market deployment option

A Portable Total-Stress Measurement Instrument for Steel Bridges (Project #179)

Inventor/Investigator
Glenn Washer
University of Missouri-Columbia

IDEA Funding
$125,000

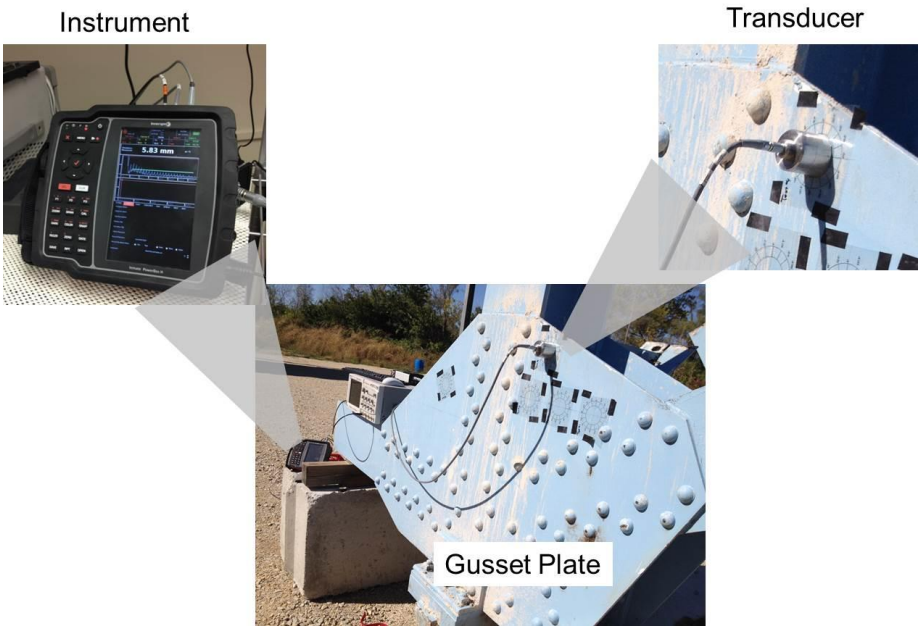
Project Completion
Active

Description

Product: A portable instrument to measure total in-situ stress (both dead and live loads) in steel bridge members

The instrument uses ultrasonic birefringence to measure bulk stress in a steel bridge member. Ultrasonic birefringence is a through-thickness method that produces an assessment of the average stress in the material and is based on the acoustoelastic effect. The acoustoelastic effect is the variation in ultrasonic wave velocity due to the presence of stress.

The instrument is unique in that it measures nondestructively both live and dead load forces in-situ on a bridge member. It can be used in a variety of applications for highway bridges, such as evaluating the stress distribution in gusset plates, evaluating forces in truss members, assessing conditions of a pin and hanger connection, evaluating bearing performance, assessing the extent of damage to steel girders impacted with over-height loads, etc.



System measurement concept on a portion of a truss removed from service

Benefits

The device is a simple push-button battery-powered portable field instrument with a design similar to that of a typical flaw detector with flexible sensor heads to accommodate a wide variety of geometries. The sensors are attached magnetically to the specimen. Measurements require no or minimal paint removal.

The technique provides reliable assessments as stresses are measured experimentally rather than based on some broad assumptions. Current practices for assessing adequate load-carrying capacity rely on idealized assumptions regarding load distribution and in-situ forces carried in bridge members.

Ccurrently no technology measures nondestructively the total in-situ forces carried in bridge members. Technologies such as strain gages are only capable of assessing stresses that occur after the sensor is installed – typically live-loads such as traffic or thermal effects. The IDEA-developed instrument will measure these effects as well as dead load stresses, locked-in stresses that may occur during fabrication and construction, and unexpected stresses that may occur due to locked bearing, deterioration and damage to the superstructure, or unanticipated load distributions in a structure. The tool will facilitate the effective classification of members that are either under high stress, and warrant further investigation to determine if they are structurally adequate, or members that may have significant reserve capacity.

Ultrasonic measurement of stresses in steel bridge members will enable bridge engineers to identify at-risk bridge members in the field. Since both dead and live load stresses are measured, the total applied stress in a member can be determined to improve the reliability of analysis over that performed using assumed forces and force distributions. The device can be used to identify overstressed members in the field during typical inspection activities. For example, the instrument can quantify maximum shear stresses in gusset plates, a key indicator of buckling potential, in-situ and in real time. Currently no other technology is capable of making such measurements.

Application/Implementation

Applications of the technology include truss bridges and gusset plates, skewed and integral abutment bridges, connections, hangers, and other steel bridge components. During this IDEA project, a steel truss bridge in Missouri undergoing replacement will be tested to verify the quality of stress measurements using the developed instrument.

The technique has a high implemental potential as ultrasonic birefringence has been previously applied successfully to assess force distributions in an integral abutment steel bridge in Virginia. Looking forward, the technology is anticipated to be applied to assess the condition of gusset plates and the distribution of loading in truss bridges and for other structural assessments where accurate stress information for bridge members is critical. The research team has considerable experience working with FHWA and state DOTs, which should help facilitate implementation of this IDEA product.

Additional Information Resources

Final reports for all completed NCHRP IDEA projects are available online. To access these reports please go to the following TRB website:

http://www.trb.org/IDEAProgram/NCHRPHighwayIDEACompletedProjects.aspx

Then click on the project of interest to access the report.

Brief summaries of all completed and active NCHRP IDEA projects are also provided in the NCHRP IDEA program's annual progress report, ***New IDEAS for Highway Systems***. The report can be accessed at the following TRB website:

http://onlinepubs.trb.org/onlinepubs/sp/NCHRPIDEAReport.pdf