IDEA

Innovations Deserving
Exploratory Analysis Programs

NCHRP IDEA Program

Products with an Impact or Potential Impact on Current Highway Practice

Notable Examples

April 2020

The National Academies of
SCIENCES · ENGINEERING · MEDICINE
TRB
TRANSPORTATION RESEARCH BOARD

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Senior Program Assistant, IDEA Programs

March 27, 2020

Dear Transportation Professional:

I had the pleasure of serving as a member and chair of the National Cooperative Highway Research Program's (NCHRP) Innovations Deserving Exploratory Analysis (IDEA) program for twelve years. I found the IDEA program to be unique among all other transportation research programs, and know it continues to result in many implementable products that are solving some of our challenging highway transportation problems. It is making a difference in the transportation world around us, and I have found my participation in IDEA to have been 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 identified in this report have been identified by type, so you can read about the specific products of greatest interest.

This is the third time the NCHRP staff have investigated and reported on the products which were funded by the program, since its beginning twenty-seven years ago. The first report resulted in a finding of roughly 30% of the products being commercialized or soon-to-be commercialized. This initial finding pleasantly surprised many of us working with the program at the time, since by its very nature the investments are for higher risk, unproven technologies. The second report resulted in a finding of 42% of the products being commercialized or poised to be commercialized. This most recent third report has resulted in a finding of 44% of the products either being commercialized or implemented or have a high implementation potential in the near term. I continue to be 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 and patience.

Additionally, I was so pleased to read about the history and contributions of the IDEA program, a recognized and celebrated lasting legacy from the Strategic Highway Research Program, found in TRB's Centennial 1920-2020 book: Transportation Research Board – Everyone Interested Is Invited. If you haven't had a chance yet to read these pages, a section of the book is dedicated to the IDEA program, pages 267-269.

All of us who have worked with the NCHRP IDEA program should be very proud of what this innovative program has accomplished over the years and should be congratulated for the support and faith we have had for decades in this unique research program.

Sincerely,

Sandra Q. Larson
Transportation Innovation Strategies Leader, Stanley Consultants
(formerly, Director, Systems Operations Bureau, Iowa DOT)
Chair, TRB Centennial Task Force
Past Vice Chair and Member, AASHTO Standing Committee on Research (SCOR)
Past Chair and Member, AASHTO Research Advisory Committee (RAC)
Past Chair and Member, NCHRP IDEA Program Committee

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Work Zone Safety

Environmental

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Foreword

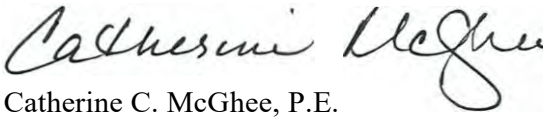
As the current chair of the NCHRP IDEA panel, it is my pleasure to share with you this update on the tremendous contributions that have been made through the IDEA program. The IDEA program serves an important role, bridging the gap between an early-stage concept and initial implementation. The proposals that are received each cycle represent some of the most promising advancements in transportation design, construction, safety, operations, maintenance, and management. We've seen new materials, materials used in ways never previously imagined, new approaches to operations and safety that save lives, and applications of technology that completely change the way we deliver transportation.

Obviously, in a program like IDEA, not every project will lead to successful implementation, and many of those that do will take substantial time to reach full implementation. But as this report will illustrate, there are many success stories to share and much to be proud of. The investment we are making now in helping to nurture these fresh ideas will ensure that our transportation system of tomorrow is the very best that it can be.

I encourage you read this report, share it with others, and help to spread the word about the opportunities available through the IDEA program. We'd love to see proposals from every corner of the country and on every aspect of the transportation industry.

March 30, 2020

Sincerely,



Catherine C. McGhee, P.E.
Director of Research and Innovation
Virginia Transportation Research Council
Virginia Department of Transportation
Chair, 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, Todd Arnold, Neal Berke, Stan Birchfield, Jean-Louis Briaud, Michel Bruneau, William Buttlar, Hongyi Cai, Sam Carpenter, Leonardo Caseres, Cassie Castorena, Warren Chesner, Bhaskar Chittoori, Madhav Chitturi, Yong Cho, Richard Christenson, Barry Dempsey, Shane Farritor, Maria Feng, Elham Fini, Paul Fuchs, Spencer Guthrie, Su Hao, Thomas Hay, Simon Hesp, John Hewitt, Christopher Higgins, John Hillman, Paul Imhoff, Mara Johnson, Vineet Kamat, Neeraj Kanhere, Wesley Keller, John Kemeny, Sang-soo Kim, Josephine Kressner, Jialiang Le, Terry Lee, Tyler Ley, Guoqiang Li, Bret Lingwall, Michael Lusher, Enad Mahmoud, King Mak, Jagannath Mallela, Mihai Marasteanu, Louis Marcil, Brian Mazzeo, Douglas Meegan, Michael Mooney, Antonio Nanni, David Noyce, Larry Olson, Didem Ozevin, Jamie Padgett, Shamim Pakzad, Tongyan Pan, Stephen Pessiki, Deems Pfaff, Therese Pflaum, Jerry Plunkett, John Popovics, Anand Puppala, Chetana Rao, Kyle Rollins, Alberto Sagues, Sanjay Sampath, Paul Santi, Kelvin Santiago, Wayne Sarasua, David Savage, Kevin Schrum, Landolf Rhode-Barbarigos, Rouzbeh Shahsavari, Xianming Shi, Dean Sicking, Roger Simpson, Wil Srubar, John Stormont, Armin Stuedlein, Douglas Thomson, Yajai Tinkay, Kim Tremaine, Yichang (James) Tsai, Julie Vandenbossche, Semyon Vaynman, Linbing Wang, Glenn Washer, Christopher Williams, Rusty Weiss, David White, Xiong (Bill) Yu, Yuanyuan Zhang, Fujie Zhou, 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).

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.

The NCHRP IDEA program is only as good as the innovations it explores for their feasibility and implementation. The innovative projects and the success stories highlighted in this report would not have happened without the proactive involvement of the NCHRP IDEA program committee members who collectively picked these projects and then acted as mentors/advisors to the researchers to ensure their success. The NCHRP IDEA program is heavily in debt to these dedicated individuals for their hard work to make the program a success. Their names and affiliations appear at the end of this report.

Finally, special thanks are due to Ms. Sandra Larson and Ms. Catherine McGhee, the past and present chairs of the NCHRP IDEA program committee, who kindly wrote an introductory letter and the foreword, respectively, for this report.

Introduction

Problems cannot be solved by thinking within the framework in which problems were created.[1]

– Albert Einstein

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 (NCHRP), from its inception in 1993 until present (2020).

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) as the SHRP IDEA program and has continued at the Transportation Research Board as the NCHRP IDEA program after the completion of the SHRP in 1993. For those who became involved in highway infrastructure research and implementation during the past two decades, a brief background information may be useful. The first SHRP was a 5-year, $150-million program mandated by the U.S. Congress for accelerated and innovative research to address the construction and maintenance problems of the nation's highways and bridges. The program, funded in 1987, addressed 6 specific focus areas: asphalt, concrete, corrosion of reinforcing steel, snow and ice control, repair and maintenance of highways, and the long-term pavement performance monitoring. The IDEA program, however, was not in the original plan of the SHRP.

The IDEA program owes its existence and sustenance to three icons of the transportation community of their time who were also serving on the SHRP Executive Committee – Mr. Frank Francoise, the-then Executive Director of the 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 the AASHTO. These visionaries foresaw the need, and provided full support, for a program seeking innovative, out-of-the-box solutions to pressing highway infrastructure problems. This high-risk, high payoff program was named the SHRP IDEA (Innovations Deserving Exploratory Analysis) program, and was allocated 2% of the total SHRP funds.

The first SHRP ended in 1993, but foreseeing the continuing need for a highway infrastructure research activity encouraging innovation and creativity, the SHRP Executive Committee unanimously recommended the continuation of the IDEA program beyond SHRP. So, the program was moved to the TRB as the NCHRP IDEA program and supported jointly by the FHWA and the AASHTO, with two-third of the funds coming from the FHWA and the remaining one-third from the AASHTO through the NCHRP. However, in 1999, the FHWA expressed its inability to further support the program. At that critical juncture, the AASHTO leadership stepped in and took full funding responsibility for the program, which it has continued even to this day.

The NCHRP IDEA program differs from other traditional transportation research programs in a very significant way. Unlike most transportation research solicitations where competitive proposals are requested for achieving a certain specific objective through certain clearly-defined tasks, the NCHRP IDEA program seeks out proposals from entrepreneurs, inventors, forward thinkers, and problem solvers – anyone who has an innovative, out-of-the-box solution to any vexing highway transportation problem, regardless of whether the innovator is a highly qualified academic or a high school drop-out entrepreneur.

[1]https://www.azquotes.com/quote/675568

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 per project). There is also a high risk associated with untried and unproven approaches; not every IDEA concept is expected to materialize into an implementable product. Still, despite the modest investment of resources and the high risk and uncertainty, a number of NCHRP IDEA projects have not only proved the technical feasibility of their innovative concepts but also led to the development of products that have been implemented and made to the marketplace.

As of now, 194 NCHRP IDEA projects have been completed. Of these, around 40 have led to products that have been commercialized or implemented. This translates into a success rate of about 1 in 5 projects. Another 45 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 their further development and evaluation. Also, at least 10 AASHTO and ASTM standard test methods or procedures have resulted from the NCHRP IDEA research and several more are expected in very near future.

The two charts presented at the beginning of the report summarize NCHRP IDEA products that have made to the marketplace or show much promise for their implementation. These charts are followed by a more detailed description of some of the notable products with regard to their benefits and implementation in the following two categories:

- NCHRP IDEA products commercialized or implemented
- 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) for pavement (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 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	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).
9	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 Burlington Northern and Santa Fe Railroad installed a 42-ft. span bridge on a revenue service line in Las Aminas, Colorado. In addition to domestic applications, a single span bridge was fabricated and installed in New Castle, Australia. An HCB Railroad bridge was delivered and installed in Fernie, British Columbia. Discussion have been held with a Canadian company to develop a rapidly deployable all-composite bridge system for mining facilities in the Northern Territories. The IDEA inventor also signed licensing agreements with companies in the European Union, Russia, Kuwait, and Brazil.
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 developed and validated with FHWA's support through an inter-laboratory testing. Two AASHTO provisional specifications (TP81 and PP64) have been adopted based on AIMS. States using the instrument include Illinois, Ohio, Texas, Maryland, and Florida. A number of universities across the U.S. are also using the instrument for research purpose. AIMS units have also been sold in Brazil, China, Hong Kong, and Trinidad and Tobago. FHWA uses AIMS for demonstration and training purposes in its mobile testing laboratory.

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. Both LS-299 and LS-308 tests have been voted by AASHTO's Technical Committee 2b to be adopted as provisional standards while the Europeans have 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. Recently, the patent for liquefaction mitigation using pre-fabricated drains expired. Since then, several companies are marketing the treatment method making it more available and economical for use throughout the U.S.
15	Asphalt binder thermal cracking test (ABCD) (Project #99) Funding: $76,000 Completion: 2007 *FHWA's Highways for LIFE Program funded further development and implementation.*	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 evaluated 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. New Hampshire and Ohio DOTs have used ABCD to evaluate their asphalt mixes. In 2019, the ABCD test was approved as a full AASHTO Standard T387-19: *Standard Method of Test for Determining the Cracking Temperature of Asphalt Binder Cracking Device (ABCD)*. During 2018-19, several private and government agencies in Russia acquired ABCD units to evaluate their asphalt binders. 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. Olson Engineering, Inc. continues to use the scanner system on projects in the U.S. and abroad on consulting basis. 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). The device is expected to have widespread use once specifications requiring modulus-based compaction are developed and relevant AASHTO and ASTM standards become available. Device is commercially available from Roctest, Inc. (Montreal, Canada).
20	3-D 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	The developed Split-FX system was field tested and validated at a number of field sites in Arizona, Colorado, and Utah. Further evaluation aimed at implementing the technology was done through a pooled-fund study involving 8 states (Arizona, California, Colorado, New York, New Hampshire, Pennsylvania, Texas, and Tennessee) while Alaska tested it separately. An NSF/SBIR project extended the system to continuously monitor sites for changes, particularly for highways, bridges, dams, foundations, and tunnels. In 2019, Split Engineering, Inc. merged with Hexagonal Mining, and in 2020 the Split-FX software will be integrated with the Hexagonal's MinePlan software, which should result in its more widespread use.
21	A software system for automatic processing and extraction of roadway sign information from video log images (Project #121) Funding: $100,000 Completion: 2009 *This project formed the basis of a Georgia DOT's Sweet Sixteen project in 2017 on automatic sign inventory and pavement condition evaluation.*	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 now available to transportation agencies for cost effectively inventorying their sign assets to assist them in their asset management activities.

22	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 lightning strikes	California DOT evaluated the device on several bridge sites in California. Tokyo Sokushin, Ltd., a Japanese manufacturer of vibration sensors, has used it for deep ground motion monitoring in Japan. Also used to monitor a 500-meter commercial/retail building in Nanjing, China. Available from Newport Sensors, Inc., (Irvine, California).
23	Virtual assembly system to aid in steel bridge fabrication System (BRIDGE VAS) (Project #127) Funding: $140,000 Completion: 2009 *Several states funded further evaluation and implementation 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 for implementation. A bridge fabricator, Hirschfeld Industries (San Angelo, Texas) also helped in the product evaluation. The system was successfully implemented on a bridge production job in Tennessee. The system is available on a consulting basis from Fuchs Consulting, Inc. (Leesburg, Virginia).
24	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 number of states (Colorado, California, Virginia, Kansas, Nevada and Wyoming) and FHWA evaluated the scanner on their bridge projects. The National Center of Asphalt Technology used it to determine debonding between asphalt pavement layers. Olson Engineering also demonstrated the technology to New Mexico, Texas and Kentucky DOTs as part of SHRP-2 implementation assistance program. The system has tested more than 50 bridges. Recently, Iowa and Indiana DOTs used it on project level deck condition assessment. The system is commercially available from Olson Engineering, Inc. as Sonic Surface Scanner.
25	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 is using the test methods as part of its routine asphalt mixture testing. A number of contractors and laboratories in the U.S. and abroad are already using the test methods for low-temperature performance prediction of asphalt mixtures. In 2016, the AASHTO adopted the creep test as a provisional standard: *TP 125-16, Determining the Flexural Creep Stiffness of Asphalt Mixtures Using the Bending Beam Rheometer (BBR)*. Another draft test method for low temperature bending strength for asphalt binders and mixtures using the modified BBR is currently under development.

26	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).
27	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, New York, and Maryland DOTs. The commercialized system has been demonstrated or used by several state DOTs and public agencies, including Missouri, Ohio, and South Carolina, Texas, Utah and Florida. The system was also evaluated for traffic data collection and incident detection as part of the FHWA's ENTERPRISE pooled-fund study. Transportation agencies with paid system deployment include Colorado, Georgia, Kansas, New Mexico, Indiana and Pennsylvania. The system was also used in Ottawa, Canada and in Italy on a tunnel. Academic institutions using the system include Texas Transportation Institute, Texas Southern University and Wayne State University.
28	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 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. The system has been commercialized with some modifications by Valmont Industries, a U.S. traffic signal pole manufacturer.
29	A mobile system for measuring retroreflectivity of pavement markings (Project #146) Funding: $140,000 Completion: 2011 *The 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	The system was further developed with support from FHWA's Highway for LIFE Program and the Connecticut DOT. An extensive evaluation of the system was conducted in 2014 by FHWA and Florida DOT with a successful outcome. A production version of the system was developed with additional support from FHWA in 2016 and independently evaluated by the Texas Transportation Institute. This evaluation also verified that the system performs as is intended and even better than some other current technologies. The system is now commercially available.

30	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 device were conducted for field validation and to gain industry acceptance. . Nebraska Department of Roads (NDOR) evaluated the device in all of its 8 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 and was shown to rout cracks better than the conventional blower. Considering NDOR's interest in routing cracks, a heavy-duty crack routing device was developed for their use. Indiana DOT has procured several units of the device for their use.
31	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 obtain information that was previously 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 ability to measure this structure without targets, or any other direct contact with the beam surfaces, allowed very spatially-dense measurements that revealed an unexpected behavior of the structure, which is currently not considered in design and analysis. The system is available for consulting from Fuchs Consulting, Inc. (Leesburg, Virginia).
32	Automated asphalt pavement raveling detection system using 3-line laser imaging data (Project #163) Funding: $100,000 Completion: 2015 *Sweet Sixteen: This project formed the basis of a Georgia DOT's Sweet Sixteen project in 2017 on automatic sign inventory and pavement condition evaluation.*	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	Georgia DOT sponsored a project for field validation and implementation of the IDEA-developed system to automatically detect and classify raveling on all interstate highways in Georgia. The detected and classified raveling outcomes were successfully fed into the Georgia DOT's existing pavement management database (COPASES) in support of the DOT's interstate highway maintenance and rehabilitation planning.

33	Augmented reality visualization for excavation safety (SmartDig) (Project #167) Funding: $125,000 Completion: 2016	Improves productivity and safety of operation by introducing significant automation and information support into the traditional process Transforms excavator operation from a skill-based to a knowledge-based process to help prevent future accidents.	A patent on the technology has been received by the University of Michigan. Several versions of the prototype system were built for deployment and testing by actual excavators working in the field. The test results were determined to be within acceptable limits by expert excavator operators. A start-up company, Perception Analytics and Robotics, LLC., was founded to commercialize the invention. Collaboration with Michigan Infrastructure and Transportation Association's member companies was sought and key partnership were established with Walbridge Construction and Eagle Excavation. While the start-up company has yet to commercialize, the technology is available for licensing by other companies.
34	A software system for automated turning movement counts at signalized intersections for shared lanes (Projects #177, 198) Funding: $178,097 Completion: 2018	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	The industry partner, MsSedco, has developed a data collection system to implement the IDEA-developed algorithm software and obtain turning movement counts as well as other performance measures from signalized intersections. MsSedco plans to release an initial version of the system in very near future and has already conducted test deployments in three cities (Appleton, Wisconsin, Bloomington, Illinois, and Ames, Iowa). The commercialization partner will integrate a streamlined version of the classification algorithm into its system, once a licensing agreement is signed with the University of Wisconsin-Madison.
35	A portable total stress measuring instrument for steel bridges (Project #179) Funding: $125,000 Completion: 2017	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	The technique was successfully tested on a steel truss bridge in Missouri. Applications of the technology include truss bridges and gusset plates, skewed and integral abutment bridges, connections, hangers, and bridges damaged by impact, fire, or extreme events. The technique can be used for practical assessment of bridge safety, such as the safety assessment of the Liberty Bridge in Pennsylvania (fire-damaged deck truss) and the Jefferson Barracks Bridge in Missouri (cracks from fabrication stresses). The technology is available for implementation. The research team is working to introduce the technology to the bridge engineering community through demonstrations and additional field testing.

36	Drained timber piles to mitigate soil liquefaction hazard (Project #180) Funding: $147,000 Completion: 2015	Low-cost, renewable, hybrid ground improvement and stabilization using conventional equipment Improves a structure's seismic resilience Helps accelerate construction	This product is freely available for implementation to public or private agencies or entities. Use of timber pile for ground improvement is being implemented in the U.S. and Canada. A hotel in Mt. Pleasant, South Carolina, was constructed over soil mass densified with timber piles. The Knight Bridge over Fraser River in Vancouver, British Columbia, used timber piles to mitigate liquefaction. The inventor has established strong partnership with the Driving Contractors Association, which should help facilitate the product implementation.
37	Small specimen geometries for asphalt mixture performance testing (AMPT) and AASHTO standard procedures for small specimen testing of laboratory and field core samples (Project #181) Funding: $99,998 Completion: 2017	Improves the efficiency and versatility of uniaxial asphalt mixture testing, which is a key input to mechanistic-empirical design framework, including the ME Pavement Design	The IDEA research has resulted in the development and adoption of three AASHTO provisional standards for the fabrication and testing of small specimens: PP 99 (for preparing specimen for AMPT), TP 132 (for determining the dynamic modulus), and TP 133 (for determining the damage characteristic curve and failure criterion). Further inter-laboratory evaluation is ongoing in an FHWA-sponsored project to advance these provisional standards to full standards. The small specimen geometry is being utilized in FHWA-supported Performance-Related Specifications shadow projects being carried out at Maine, Maryland and Missouri DOTs, Ontario Ministry of Transportation, and Western Federal Lands.
38	Web-based software (CityCast) to enable data-driven planning and project prioritization (Project #184) Funding: $100,000 Completion: 2017	Provides engineers and planners a new way to investigate travel behavior. Enables transportation agencies to better plan new modes of transportation such as e-bikes, ridesharing, demand-responsive transit, autonomous vehicles, etc. Saves time and money to transportation agencies in its planning activities in data collection and procurement, travel demand modeling, project evaluation, scenario planning, before-and-after studies, congestion mitigation and management, and tolling studies.	CityCast was used in planning projects in Montgomery County, Maryland (redesigning bus service to and around a new commuter bus rapid transit service) and Norfolk, Virginia (redesigning Hampton Roads Transit's bus network, including evaluating zone-based, last-mile microtransit). The Atlanta Regional Commission used CityCast to study the interaction of freight and residential traffic near the I-85 and I-285 interchange near Atlanta and also to help Cobb County develop its multimodal transportation plan. Several other metropolitan planning organizations and municipalities across the U.S. are evaluating CityCast for a variety of projects and applications

39	An asphalt cracking test (IDEAL-CT) for asphalt mixture quality (Project #195) Funding: $137,000 Completion: 2018	Simple, requires minimal training, needs no instrumentation, cutting, gluing, or notching Test completed within 1 minute Repeatable; coefficient of variation less than 20% Sensitive to mix factors (recycled materials, aggregates, binder, aging, etc.) Good correlation with field performance Affordable – costs less than $10,000	To facilitate implementation, an NCHRP implementation project has been sponsored to train DOT personnel in performing and interpreting the test through hands-on workshops, webinars, and training videos. Six states (Kentucky, Maine, Minnesota, Oklahoma, Texas, and Virginia are participating in this training. The states of Texas and Virginia have already adopted the test for state-wide implementation. The test has now been adopted as an ASTM standard, D8225-19: *Standard Test Method for Determination of Cracking Tolerance Index of Asphalt Mixture Using the Indirect Tensile Cracking Test at Intermediate Temperature*.
40	Vertical Electrical Impedance (VEI) scanner for concrete bridge corrosion assessment without direct rebar attachment (Project #202) Funding: $99,900 Completion: 2019	Provides cost-effective non-destructive evaluation of concrete bridge deck covers; can be used on bare or overlaid bridge decks Fast; scanning rates exceed 1500ft^2 per minute Scans without the need for a direct electrical tap to the steel reinforcement for measurements Requires minimal or no traffic control	Utah DOT and Nebraska DOR evaluated the VEI scanner extensively on bare and overlaid concrete bridge decks in their respective states. The technology is ready for commercial use and has been licensed to Advanced Bridge Inspections, LLC, based in Pleasant Grove, Utah, for commercial evaluation of bridge dicks for corrosion.

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	Duomorph asphalt rheology tester (Project #17, 41, 193) Funding:$225,000 Completion: 2018	Enables larger sampling rates and faster testing of asphalt binders in production facilities or district laboratories Requires minimal operator time or skills -- a significant advantage over the conventional AASHTO procedure.	Work on DART involved working extensively with asphalt binder suppliers, producers and state DOTs to prove its capabilities; however, actual implementation of the device in practice still awaits. Still, work done so far does make a case before all stakeholders to move forward with implementation, considering that the DART has developed a standardized testing method for sample compliance checks in the field and district laboratories, agency verification at hot-mix asphalt production plants, and consistency checks along the supply chain.
2	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.
3	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 planned but 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.

4	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.
5	'Road Recycler' – A mechanical system based on anvil and hammer concept for crushing and recycling concrete pavement (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. The developer needs substantial additional resources to bring a mobile unit to the market.
6	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. If resources are made available, a field implementable safety marker system should be feasible in near future by taking advantage of recent advances in electronics and sensor technology.
7	3-D bridge information modeling system (BIM) (Project #108) Funding: $85,000 Completion: 2006	Streamlines the bridge design and construction process; enables better, faster, and more economical delivery of steel and concrete bridges Provides a single repository for all shared project data; all design and construction documentation is managed coherently under one umbrella.	This IDEA project was one of the earliest, if not the earliest, work on streamlining the design and delivery of highway bridges through 3-D model-centric processes. It led to increased interest and further exploration of the 3-D modeling concept and forms the basis of a currently ongoing pooled fund study on BIM involving 20 states (California, Delaware, Florida, Georgia, Iowa, Illinois, Kansas, Michigan, Minnesota, Mississippi, North Carolina, New Jersey, New York, Ohio, Oklahoma, Pennsylvania, Alabama, Texas, Utah, Vermont, and Wisconsin), in addition to the FHWA.

8	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 available for implementation.
9	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. The device needs to be further refined and extensively evaluated for field implementation.
10	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. More recently the concept was refined into a version to monitor underwater noise in lakes and oceans. This floating noise monitor was used to monitor noise in Chatfield lake (Chatfield State Park, Littleton, Colorado). As part of this refinement, the electronics and packaging were redone using the latest available technologies. The system is available for sublicensing to manufacturers of sound level meters for commercialization and implementation.
11	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. The U.S. Army Corps of Engineers also supported a joint study to test this technology under earthquake loading using large scale shake-table tests. The IDEA researcher, in collaboration with an SMA manufacturer has developed and characterized a new cost-effective SMA that is more suitable for civil engineering applications. The researcher also participated in a project on SMA technology in China and explored the commercialization of the technology with several bridge companies there.

12	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 in actual work zones on I-95 and controlled zones at the Georgia Institute of Technology'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. Additional DOT projects are needed to fully evaluate and establish the developed technology for implementation.
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 showed interest in implementation and commercialization of the IDEA-developed sealant but no firm commitment has been made yet. .
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	The applicability of AEA was demonstrated on a number of projects. Collaboration with the Asphalt Institute and Road Science, LLC, an asphalt paving company, has helped 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. AEA was used for the Illinois Tollway for analyzing field cores from rubber modified, stone mastic asphalt mixtures. More recently, AEA was used in a project sponsored by the Missouri DOT and the Midwest Transportation Center.
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, if interested, may want to pursue its commercialization.

16	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. Further work was conducted with support from the U.S. National Science Foundation and the Korean National Research Foundation to explore other applications of the system developed in this project for integration into bridge joints or other bridge systems. Need to engage Watson Bowman Acme to explore opportunities for further refinement, evaluation, and commercialization.
17	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 was developed with rigid foundation conditions. The system could not be crash tested as the industrial partner withdrew its support. If successfully crash tested and approved by the FHWA, the design can be used by transportation agencies for actual field implementation.
18	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	Work on evaluation and implementation of the IDEA product has progressed through two successive transportation pooled-fund studies (TPF 5-278 with Kansas, New York, Ohio, Oklahoma, and Pennsylvania) and TFP5-364 with Kansas, New York, New Mexico, Maryland, Ohio, and Oklahoma). In the first study, a total of 113 aggregates supplied by the participating states were laser scanned using the developed field prototype. In the second study, the aggregated analysis was performed using a scaled-up field prototype. Upon successful completion of this study, field installation will be considered in selected state laboratories.
19	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 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.

20	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 was pursued, and the New York State DOT proposed a potential demonstration on a bridge structure in Long Island. However, finding for this demonstration project has not materialized so far. The concept seems to be maturing from the commercial transition point of view for the general application of sustainable metal remanufacturing via spray cladding to rebuild worn metals in machine elements in the same manner as was proposed in this IDEA project. The IDEA researcher is exploring other opportunities for technology implementation, including the U.S. Navy, U.S. Army Corps of Engineers, and a Japanese group.
21	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. Further work was done with the National Science Foundation's support, which helped determine a more effective way to couple transducers, extract time of flight more accurately, and determine the acoustoelastic coefficients for normal, transverse, and angled directions. This modified approach now needs to be verified and validated in the field. The IDEA researcher is exploring opportunities for field testing and validation.
22	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 AASHTO standards. Also, welding consumables for these steels should be identified or new consumables developed. The IDEA researcher needs the involvement of steel manufacturers, welding consumable producers, bridge fabricators, FHWA and state DOT's to make this product commercialized and implemented.

23	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	The applicability of the developed device for use in the field was successfully demonstrated. However, plans by Oregon DOT to use it on an existing truss bridge did not materialize as the DOT decided to replace the bridge rather than do an advanced evaluation. State DOTs need to be made aware of the developed device, and a demonstration project should help facilitate implementation of the device in the field. After further field validation, the device should be ready for commercialization.
24	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 showed interest in evaluating the prototype products by installing them on its westbound bridge on US Route 360 over the Appomattox River but funds to implement them have yet to be materialized. The IDEA researcher has held discussions with several other state DOTs and railroads for implementation. The website www.noscour.com and advertisements provide more details.
25	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 were held with a private sector bridge inspection company to adapt the technology for commercial inspection operations but not much further progress has been reported. The technology has potential application in profiling both coatings and concrete bridge decks.
26	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. This often prevents the use of recycled water with higher concentrations of recycled fines and, in some cases, allows the use of recycled water that can result in reduced concrete strength.	Work was 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" were tested and the strength test results successfully compared with predictions from the IDEA-developed models. Results have been presented nationally and internationally and have been discussed with the Seattle and Washington State DOTs. Discussions continue with respect to various paths to implement the recommendations.

27	Bio-asphalt from swine manure and crumb rubber for highway construction (Project #171) Funding: $125,000 Completion: 2016 *The European Union's Infravation Program funded a demonstration project for this research* *The inventor was one of 8 individuals to receive the American Association for the Advancement of Science's Lemelson Invention Ambassador Award for 2017-18 for her innovation for "bettering our quality of life and building strong economies."*	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, agreed to help with the production of bio-modified rubber (BMR). This collaboration will also facilitate product commercialization. Several states DOTs (North Carolina, Michigan, and Massachusetts) have shown willingness to provide pavement trial sections, if adequate amount of BMR is available and the produced BMR meets their DOT specifications.
28	Buckling-restrained braces for resilient seismic-resistance bridges (Project #172, 215) 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 design guidelines and examples will be 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. California DOT is collaborating on the project and, if successful, will consider implementing the technology on its bridges.
29	Graphene nanoplatelet (GNP)-reinforced asphalt binders and mixtures. (Project #173) Funding: $120,000 Completion: 2016	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	Minnesota DOT has continued to support GNP product development and implementation through several projects. One project focused on pot hole repair, the other on computer modeling of the GNP asphalt mix design, and another on damage sensing and healing capabilities of the GNP asphalt materials. The next step towards implementation is performance field experiments at the MnRoad facility.

30	Thermal zinc diffusion coatings for steel reinforcement in concrete (Project #174) Funding: $100,000 Completion: 2016	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 Coating follows the substrate surface and offers superior adhesion. Can also be used with high strength steel reinforcing bars.	The industry partner, Distek, NA, is seeking partners to license the technology for reinforcing bars and to put into place equipment needed to make bars of longer lengths. At this point, Distek can produce 7-foot long bars for evaluation in test sections. A major steel producer has indicated that they will produce the reinforcing bars if there is a commercial need. Distek has licenses also for other applications, and several of these could process reinforcing bars and wire meshes.
31	An NDT 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: 2017	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 technology was further developed with support from the industrial partner, Thornton Tomasetti (TT) with specific interest in investigating bolt fracture in connections in large span trusses. The work, however, was limited to laboratory testing. TT is interested in the technology for crack detection in the bolts, and so the field work may be performed in the future as part of ongoing work that TT is performing on long span steel trusses.
32	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: 2017	Almost instantaneous measurements Contactless process, requires no previous surface preparation or stabilization Minimizes traffic disruption during data acquisition	Contacts with potential commercial partners were initiated for product commercialization but further evaluation is needed before they could commit. Florida DOT had committed to collaborate in prototype testing on a pier at the Sunshine Skyway Bridge in Tampa Bay. The FHWA's Long Term Infrastructure Performance Program needs to be approached to consider integration of this potential mapping method in its Robotic Assisted Bridge Inspection Tool.
33	Renewable biopolymers for use in asphalt pavements (Project #178) Funding: $125,000 Completion: 2018	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, was set up by Agro Genesis Chemicals/Seneca Petroleum to produce the proposed biopolymers. Product implementation is being initiated through establishing that the developed biopolymers can be used turn-key in asphalt production and construction facilities. This is to be accomplished through paving demonstration projects, such as the Minnesota's MnRoad project and testing at the National Center of Asphalt Technology Test Track.

34	Use of biochar to reduce stormwater runoff and pollutant loading for highway greenways (Projects #182, 211) Funding: $229,665 Completion: 2017	Stormwater treatment without the cost of new infrastructure or purchase of additional right-of-way Promotes greater infiltration and water retention of soils Reduces amount of storm water runoff Allows time for nutrients to be consumed by biological process before they could pollute the nearby waterways	A roadway soil along Delaware 896 highway, amended with 4% biochar and monitored for 18 months, resulted in 88% reduction in stormwater volume. Based on the promising results from this study, California, Delaware, Maryland, and North Carolina DOTs are evaluating biochar amendment to roadway soils in their states to see if similar performance will be achieved in other soils and geographic locations. Biochar amendment to soil adjacent to paved surface was applied in 2019 to increase infiltration in the flood-prone Ellicott City, watershed in Maryland. Maryland Transportation Authority plans to install biochar in soils adjacent to I-95 in 2020.
35	An RFID system for bridge scour detection (Project #183) Funding: $99,998 Completion: 2019	Provides real-time, continuous 24/7 measurement and monitoring of scour evolution Remote and automated scour data collection and transmission; eliminates the need for on-site surveys, sometimes under hazardous conditions, ensuring crew's safety	The system was tested at the Clear Creek, Iowa and the Third Creek, Tennessee. The measured scour depth compared well with physical measurements. Iowa, Tennessee and Washington State DOTs appear interested in testing and implementing the technology. The Hungry Canyon Alliance in western Iowa is interested in using it for monitoring knickpoint advance, which threatens the region's bridge infrastructure of local roads. The Washington State DOT is interested in using the technology to monitor the effectiveness of Engineered Log Jams for river bank stabilization (for example, along the Skajit River).
36	CurvePortal for automated identification and extraction of horizontal curve information (Project #185) Funding: $100,000 Completion: 2018	Allows obtaining highway horizontal curve data using existing resources at minimum cost. Data helps state and local transportation agencies in performing crash analysis and recommending safety treatments	CurvePortal is being used by Iowa and Wisconsin DOTs. Several other states (Delaware, Indiana, Michigan, Minnesota, New Jersey and Washington) also have been approached for using CurvePortal. Contractual negotiation were conducted with Indiana Local Technical Assistance Program for using CurvePortal to extract curve information for all local roads in the state. The CurvePortal is hosted on WisTransPortal, an online transportation data portal at the University of Wisconsin-Madison (www.curveportal.cee.wisc.edu).
37	An electrical jet grout push probe for rapid assessment of jet grout column diameter (Project #186) Funding: $86,517 Completion: 2018	Provide nondestructive assessment of production columns Allows assessment of diameter within 30 minutes of jet grouting instead of days and weeks; allows timely feedback to modify jet grouting parameters Ability to verify diameter immediately and move on to production saves significant time and money	The probe has been implemented on multiple jet grout construction projects, primarily granular soil sites (sands, silty sands). In all cases, the estimated diameter was found to be within 5% of the actual constructed diameter. Commercial implementation should follow the approach used by Osterberg load cell that was licensed to a specific company.

38	A mobile proximity safety alert system for highway work zone (Project #187) Funding: $86,517 Completion: 2017	Low-cost and easy to install Proactive alert system allows pedestrian worker to avoid hazardous proximity situations. Alert information includes time, worker/equipment IDs, and the incoming direction	Georgia DOT plans to implement the proximity warning system in the state and is supporting further development and improvement of the system though a project that aims to improve the performance of the overall system through real-world highway work zone construction projects in the state. The proximity warning system has received significant attention from the construction industry.
39	Novel V-connector joint system for seismic protection and facilitating accelerated bridge construction (Project #188) Funding: $135,000 Completion: 2019	Joint provide better seismic protection than current joint technology Help maintain structural integrity under strong load or impact and restore the structure to its original state after the impact has passed. Facilitate rapid construction of bridges	Work done in the IDEA project validated the V-connectors' capability for seismic isolation with good safety margin. However further development or refinement and testing are needed before the connector system's acceptance for implementation. This further work should include shake-table tests, pushover tests for safety evaluation, design optimization, and design codification. Working with bridge owners is needed to inform them of the benefits of the V-connectors and seek their collaboration for implementing the connectors into their bridge codes. Also necessary will be working with bearing vendors to standardize the connector product and the manufacturing process.
40	Self-deicing LED signals for highway and railroad intersections (Project #190) Funding: $100,000 (jointly with Rail-Safety IDEA Program) Completion: 2020	Prevents snow or ice build-up on signal lens, improves visibility at the intersection to vehicle operators for safety Requires no manual cleaning of snow or ice; saving maintenance costs Signal light easily swappable with existing signal lights, avoiding the high cost of replacing an entire system with new equipment.	The signal system is being evaluated in a pooled fund study involving seven states (Kansas, California, Maryland, Michigan, New Jersey, Pennsylvania and Wisconsin) and the FHWA. These states have installed prototypes on selected highway intersections or rail track sections at sites with exposure to heavy snow and ice in winter for performance evaluation. A start-up company, Solid State Lighting and Heating Technologies, Inc. (SSLaH Tech., Inc.) has been founded for further development and commercialization of self-deicing signals and accessories. The company is working with the pooled-fund states as well as Union Pacific and Burlington Northern Santa Fe Railroad companies on technology implementation.
41	Microbial-facilitated stabilization of expansive soils in pavement subgrades (Project #192) Funding: $138,000 Completion: 2019	Environment-friendly methodology provide a sustainable alternative to expansive soil treatment Applicable to both new pavement construction as well as repair and rehabilitation of distressed pavements	Montana DOT has expressed interest in implementing this technology, and discussion have been held to select suitable test sites to implement this technology. The research team plans to approach other highway agencies with problematic expansive soils. A trial application of the technique on an existing highway section with appropriate instrumentation and field monitoring is the next step to move this technology forward.

42	Nano-based boron nitride-reinforced concrete for transportation infrastructure (Project #197) Funding: $140,000 Completion:2019	Small addition of the nano material was shown to increase compressive and tensile strengths of concrete by more than 100% and durability by about 3%%, allowing "to do more with less" Beneficial environmental impact -- Use of low volume of concrete translates into lower CO_2 emission associated with concrete manufacturing	Texas DOT (Houston district) is providing a small patch job (maintenance) on a road in Harris County to monitor long term performance, durability and stability of the concrete product *in situ*. The concrete formulation easily met the Texas DOT's requirement of a minimum of 1800 psi within around 5 hours for this repair job. Once successfully implemented, other states will also be able to adopt and benefit from this new concrete technology.
43	Use of x-rays to determine concrete permeability (Project #199) Funding: $100,000 Completion: 2019	Inexpensive and power technique to rapidly determine concrete permeability Technique can be used to compare different mix designs and construction practices in the field. Technique can also be used to compare the effectiveness of different repair materials or the use of surface sealers to extend the concrete service life	The concrete permeability results with x-ray prototype were shared with the FHWA mobile concrete laboratory and Oklahoma, Minnesota, and Illinois DOTs. All these organizations are interested in additional case studies to evaluate the performance of the prototype. For a more confident application of the equipment, a wider range of concrete materials and mixes with a variety of cementitious materials and admixtures need to be investigated. The equipment also needs to be made more rugged, practical and user-friendly in order to be easily usable for the DOTs.
44	Highway slope rehabilitation using a combination of microbial induced precipitation and revegetation (Project #200) Funding: 138,000 Completion: 2020	Economically feasible technique, uses readily available material and is easily applied The microbial enrichment solution doubles as a fertilizer to the plants Works on a wide range of highway slope angles or geometries over long distances around any obstruction	Work has been initiated on product commercialization in collaboration with South Dakota DOT. The customer base for the MICP bio-cement for wind and water erosion mitigation of highway slopes is mainly government agencies that own or operate wildlands that may be subject to wild fires and own or operate highways through those wild lands. These include federal agencies (National Parks Service, Western Federal Lands, Forest Service, Bureau of Land Management, and Bureau of Indian Affairs), state highway agencies, state park agencies, and county highway departments.
45	Self-restoring crash cushion for highway safety -- SaferCushion (Project #203) Funding: $100,000 Completion: Active	Well-suited in locations with high traffic volumes and speeds. Eliminates the need to establish and man a work zone while still providing a high performance crash cushion. Maintains system's effectiveness by periodically and automatically checking for proper system tension Equipped with communication technology to help reduce emergency response time while facilitating automated in-service performance evaluation	Commercialization of the SaferCushion is being explored with highway safety manufacturers for mass production and for the rights to produce and sell the device, pending successful MASH testing. The North Texas Tollway Authority has agreed to provide a pilot installation program to evaluate the SaferCushion in the field. The states of Wisconsin and Wyoming have also expressed interest in trying the SaferCushion in their states.

46	Biomimetic antifreeze molecules as an alternative to air-entraining admixtures for freeze thaw resistance of concrete (Project #204) Funding: $140,282 Completion: 2020	Antifreeze molecules have the potential to serve as an alternative to conventional air entraining admixtures. Unlike conventional air entraining admixtures, do not adversely affect concrete's mechanical properties Reduce concrete permeability; enhance durability.	The development is in its early stage. A patent application has been filed with the U.S. Patent Office. Collaborative partnerships with the City of Boulder, the Colorado DOT, and independent concrete testing facilities are being established for pilot-scale demonstrations. A partnership for advanced testing and demonstration activities is being established with the U.S. Army's Cold Regions Research and Engineering Laboratory, which works with a wide variety of admixture technologies to ensure early- and late-age durability of concrete in cold Arctic and Antarctic environments.
47	Glass fiber reinforced polymer (GFRP) strand for mild prestressed concrete (Project #207) Funding: $119,400 Completion: Active *The innovation was recognized by the 2019 JEC Innovation Award in Construction and Infrastructures. JEC Group is the world's leading organization for the promotion of composite materials and technologies.*	Low-maintenance, cost efficient, corrosion-resistant alternative to steel for reinforced concrete; help extend a structure's service life Require no special equipment for prestressing; uses the same equipment as used for steel strands. Easy handling --flexible for coiling and shipping	Florida DOT intends to field test the MILDGLASS in portions of two bridges and one pier to be constructed in south Florida. Florida DOT will also lead the pre-standardization effort of the developed product. The industry partner, SERIG, has developed two separate production lines to manufacture a 7-wire GFRP strand of 0.6 in. diameter and a round solid GFRP bar of 0.5 in. diameter. Both products are coilable and can be used in mild prestressing applications.
48	A machine-learning-based system for automatic collection of pedestrian data from aerial images (Project #209) Funding: $129,954 Completion: Active	Automatic collection of data needed for improving pedestrian safety Reduces the need for labor training, travel, observation, and record digitization required by manual data collection. Needs just one person to input existing aerial images and monitor results More accurate than existing automated methods.	California and Mississippi DOTs have been providing sample aerial images for testing and analysis, and are assisting in modifying the system to interface with state DOT software and data management environments. These states are also providing guidance from the end user's perspective with regard to data format, database structure, and geocoding. After the system is developed, California and Mississippi DOTs plan to test the system on their work sites. As part of the implementation efforts, a user guide, aimed at state DOT audience will be produced to facilitate adoption and usage of the system.
49	Non-gating guardrail terminal (Project #212) Funding: $130,000 Completion: Active	Helps reduce the number of serious injuries and fatal accidents for vehicles gating through that terminal. Can be used in any location. Reduced length of guardrail installation (at least 12ft 6 in., one standard length of W-beam) saves about $180 per installation	Commercialization of the product is being explored with several highway safety manufacturers, pending successful crash testing. Two state DOTs (Wisconsin and Wyoming) have expressed interest in bringing non-gating guardrail terminals to the market in their respective states. Both DOTs are willing to help with pilot installation.

50	SEAHIVE – An ecofriendly seawall structure shoreline protection system (Project #213) Funding: $119,174 Completion: Active	Profile shape and perforation configuration ensures good stability while increasing wave-energy dissipation capability ensures effectiveness at various condition, including high energy tidal flow. Creates an eco-friendly environment for marine life. Requires no special technology -- can be fabricated using traditional concrete pipe fabrication technology.	Although the SEAHIVE system is still under development, the research team has already initiated efforts towards implementation by promoting the system at various relevant professional meetings such as the 2019 Florida Shore and Beach Protection Association's Annual Conference and also the Coastal Structures 2019 – an international conference organized by the American Society of Civil Engineering's Coasts, Oceans, Ports, and Rivers Institute. The research team has already received inquiries from cement and ready-mix concrete producers as well as local stakeholders.

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
University of South Florida

Rodney Powers
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 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, the former State 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. Re-spraying the structure with zinc is neither expensive nor labor- or equipment-intensive. There is now an American Welding Society's standard specification for metalizing on concrete: Standard C2.20, "Specification for Thermal Spraying Zinc Anodes on Steel Reinforced Concrete".

Application/Implementation

The IDEA project successfully field tested the technique in Florida Keys on Highway US 1 at Bahia Honda, Niles Channel, and Seven Miles Bridges. A number of state DOTs have long since standardized the use of the technology for corrosion protection of bridges and other substructures. Florida and Oregon DOTs have led the way in implementing this technology with the largest portfolio of metalized zinc cathodic protection systems installed on a number of 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 DOT 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), SR 520 Bridge over IWW (SR520, Melbourne), Port Bridge over FPL Discharge Canal (SR A1A, Broward County), Bakers Haulover Cut Bridge (SRAIA, Miami) Mickler O'Connell Bridge (SR 312, St Augustine), Thomas B. Shave Jr. Bridge (AIA / SR 200, Fernandina Beach), Ernest Kouwen Hoven Bridge (SR 500, Indialantic), Channel Two Bridge (US1, Florida Keyes) and various D1Pushbutton bridges in 12 southwestern Florida counties. Several of the bridges listed above have also been re-metalized due to zinc depletion over time.

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 installed zinc anode system on a bridge on Tongass Avenue in 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
University of Connecticut

James Mahoney
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 its installation. 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 about 10% through the use of Hycrete.[1]

Application/Implementation

Many state DOTs have experimented with Hycrete for a number of years. These include the DOTs of New Jersey, New York, Ohio, Virginia, Kansas, and the six New England states. The U.S. Army Corps of Engineers tested Hycrete in sea walls, sewerage treatment plants, and underground aircraft hangers in high sulfate soil. 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 monitored for the long-term performance of Hycrete. The Ohio and Virginia DOTs were the first to approve the use of Hycrete in their construction projects. More recently, New Jersey DOT used Hycrete product in the rehabilitation of the Bridge V-39 in Sussex County, New Jersey.

In 2019, the AASHTO approved Hycrete as a Type S admixture under the AASHTO's guidelines for chemical admixtures for concrete. Hycrete met or exceeded all requirements and was fully approved for use on bridge decks and roadway infrastructure. As part of its approval, Hycrete was tested against control mixtures to make sure that Hycrete-treated samples met the requirements of the AASHTO M194 and Table 1 of the ASTM C494 standard specification for chemical admixtures for concrete. Through three rounds of testing, Hycrete-treated concrete exceeded the standards of compressive and flexural strength against the control.

While state DOTs have been rather cautious in their use of Hycrete, it is being increasingly used in the private sector and in non-transportation projects that include parking garages (Seattle and SeaTac, Washington; Brooklyn, New York), medical school laboratories and office buildings (San Diego, California and Seattle, Washington), hospital (Haymarket, Virginia), high schools (Arlington, Virginia and Washington, DC), housing and retail complex (Salt Lake City, Utah), residential complexes (Los Angeles, Santa Ana, and San Jose, California), potable water tanks (South Barrington, Illinois), Washington State Department of Information Services Building (Olympia, Washington), Science Museum Aquarium (Miami, Florida), Whitewater River Park (Oklahoma City, Oklahoma), and the radar cross-section facility at Hill Air Force Base in Utah. Hycrete was also used in the critical water-sensitive portions of the New York City's Freedom Tower that included concrete feeder trenches containing high power electric feeder cables. The Thomas Jefferson Law School in San Diego reported to have saved about $187,000 on construction costs by using Hycrete in its new building.

Hycrete is also finding acceptance in the 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. Other international Hycrete markets include Taiwan, Bahamas, Dominican Republic, and the United Arab Emirates.

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 several 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 the North Dakota DOT at its I-29 Buxton Bridge near Buxton, North Dakota, and I-94 Red River Bridge between Fargo, North Dakota, and Moorhead, Minnesota, fitted with the fixed automated spray technology (FAST) 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 DOTs to operate and maintain it, it does save human lives and avoids or minimizes injuries and property damage.

Application/Implementation

Since the IDEA experiment in Utah in 1997, a number of states and Canadian provinces have used or evaluated the system in their bridge anti-icing projects. These include the states of Alaska, California, Colorado, Illinois, Iowa, Kansas, Kentucky, Maryland, Minnesota, Montana, New Hampshire, New Jersey, New York, North Carolina, North Dakota, Oregon, Pennsylvania, Utah, Vermont, Virginia, Ontario, Wisconsin, and Washington State, and the Canadian provinces of Alberta, Ontario and Saskatchewan. Some of the above-mentioned states have also been using a micro FAST system, which is a patented strip anti-icing spray system developed by Boschung America and, according to the manufacturer, a low-cost, minimum maintenance and easy installation/operation system. In this system, deicing chemicals are applied to the road surface through a fine, invisible and dense stream by the control of the ice early warning system. The micro FAST strips cover up to ½ mile (2 lanes) and allow optional atmospheric and pavement sensors for full automation. States using micro Fast system include Alaska, Montana, New Hampshire, Pennsylvania, and Vermont.

A number of state DOTs, however, have been rather cautious in embracing the automated anti-icing spray technology, presumably because of its cost or the need for its regular maintenance for effective performance. For example, Virginia DOT evaluated the anti-icing technology (along a ramp from Route 7 to Route 66 in Fairfax County in 1998) but decided not to maintain it after two years. Plans to install a system on Buffalo Creek Bridge on I-81 were also not followed through. In 2002, Maryland DOT evaluated the technology on Clarysville Bridge on I-68 in Clarysville, Alleghany County and found it useful but did not pursue it for additional bridges. Initial costs and maintenance expenses appeared to be the main factors affecting the decision. Maintenance is certainly critical for ensuring that the system performs as intended, and typical maintenance should include regular service on system hardware, such as checking for leaks, pressure loss, and plugged nozzles. As per the experience of the DOTs using the technology, the system appeared most effective when the targeted area had frost, ice formation and light snow (< 1 in.), while factors having an adverse effect on the effectiveness included high wind, extreme low temperatures, rapidly falling temperatures, and heavy snow falls.

Minnesota DOT appears to be most receptive of the technology in the U.S., 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 is also equipped with a similar anti-icing spray system.

As noted earlier, North Dakota DOT installed two FAST 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 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 on the bridge surface.

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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.

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 a structure's service life. A 2007 Michigan DOT study estimated a significantly higher service life for a bridge with MMFX steel than that 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 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 the 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 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. The 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 as well as 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.

Examples of the application of MMFX steel in bridge structures in the U.S. and Canada 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), Richmond, Virginia (SR147, Huguenot Bridge over James River), Vian, Oklahoma (State Highway 100 over Illinois River's Tenkiller Spillway), 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), Swan River, Manitoba, Canada (Province Highway over East Favel River), Winnipeg, Manitoba, Canada (Disraeli Freeway Bridge over Red River), Saskatoon, Saskatchewan, Canada (Circle Drive over South Saskatchewan River), Edmonton, Alberta, Canada (47 bridges on Anthony Henday Drive Ring Road) . The entire bridge structure of US 64 over Gobernador Arroyo River in New Mexico also featured MMFX steel, including the deck. MMFX steel was also used in Mexico's La Yesca Hydroelectric Dam in Hostotipaquillo, Jalisco.

The Sacramento Regional Transit Authority in California selected 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.

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).Virginia DOT used MMFX steel in the construction of Route 460 Connector/Coal Fields Expressway in Bristol County.

Marine structures using MMFX steel include the Gulf State Park Fishing Pier (Gulf Shores, Alabama), Bayonne Pier Terminal (Bayonne, New Jersey), Floating Marina Backwater (Port Orchard, Washington), and North Beach Boulevard Seawall (Bay St. Louis, Mississippi). The U.S. Navy used MMFX steel in hybrid modular piers in San Diego, California. Notable marine structures using MMFX steel abroad include Al-Sowwah Island Diaphragm in Abu Dhabi, the United Arab Emirates.

Other notable public and private non-transportation projects using MMFX steel include 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, 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, designed in accordance with the U.S. Highway Bridge Code HS-25, used three fiberglass honeycomb panels, 23 ft. long and 9 ft. wide, with interlocking edges. The bridge installation took only 6 hours. The honeycomb design resulted in about 20% less bridge weight 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, but 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 the 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 due to 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 structural 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), 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'Fallon Park, West of Denver), among others.

The KSCI's success encouraged other composite technology companies (such as Martin Marietta Composites, North Carolina, Hardcore Composite, Delaware, Infrastructure Composites, California, Creative Pultrusions, Pennsylvania, Bedford Reinforced Plastics, Pennsylvania, Fiber-Reinforced Systems, Ohio, Composite Advantage, Ohio, and Strongwell Corporation, Virginia, among others) also to enter the composite bridge business. The technology now appears to have matured and the industry considerably grown, along with the development of newer, better-performing composite materials on the market. Composite bridges now have been installed all across the U.S., including the states of California, Idaho, Ohio, New York, Oregon, Pennsylvania, Illinois, Maryland, Delaware, Iowa, North Carolina, South Carolina, Virginia, West Virginia, Washington State, and Wisconsin. In addition to new installations, old bridges are also being rehabilitated with FRP composites. In 2017, a 143 years old 221-ft. long bridge was rehabilitated with FRP bridge decks in London, Ontario in Canada.

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, 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). A modified version of the PQI device is also available as the soil density gauge for measuring soil density. The technology was also 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. The device 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 for 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 $200 per year as compared to about $3,000 for the nuclear gauge, while a 2007 Iowa study estimated that a non-nuclear device, such as the PQI, could save as much as about $50,000 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, Louisiana, 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 using PQI for quality control purposes. An Ohio DOT evaluation, however, recommended 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. In 2009, the Indian Road Congress accredited PQI as one of the new technologies for highway applications.

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, a compression reinforcement, and a 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 which is much lighter and well suited to accelerated bridge construction. In general, the 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. The 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. The 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. The HCB also enhances a bridge structure's service life, estimated to be more than 100 years.

Presently, on first-cost construction basis, HCB is competitive with conventional systems, 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, HCBs has been installed in 17 highway bridges in 9 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 Canadian 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.

- Maryland – A 30 ft. span bridge was installed in Allegheny County in 2014

- 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 HCB girders was more than 170 percent of the code-specified ultimate capacity.

- Maine – A two-span bridge with spans of 92 ft. was installed in Bangor in 2015.

- Maine – A four-span bridge with typical spans of 70 ft. was installed in Thomaston in 2015.

- Maine – A two-span bridge with typical spans of 80 ft. was installed in Westbrook in 2016.

- Florida – A five-span bridge was installed in Halls River in central Florida in 2018

- 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. HCB bridge was constructed for Virginia DOT in Colonial Beach, Virginia in 2011.

- West Virginia – A 107-ft. HCB 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.

- New Castle, Australia – A single span HCB bridge was fabricated and installed in 2017.

- Northern Territories, Canada – Currently, discussion is ongoing with a Canadian company to develop a rapidly deployable, all-composite bridge system for mining facilities in the Northern Territories.

- 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 installed in Las Animas, Colorado on a BNSF revenue service line in 2015.

- Canadian Pacific Railroad – An HCB railroad bridge was delivered and installed in November 2014 in Fernie, British Columbia. This was the first international installation of an HCB 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)

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

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

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

Inventors/Investigators
Eyad Masad and Enad Mahmoud
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 developed system, 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 the 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 along with improving the speed and accuracy of testing.

Automated image analysis system (AIMS) for aggregate characterization

Benefits

The AIMS method is rapid, accurate, and more convenient than the 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 the 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 the pavement 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 further supported by the FHWA's Highways for LIFE Program for extensive evaluation and commercialization. A large number of state DOTs from across the U.S. and a Canadian province participated in evaluating the system for accuracy and reproducibility along with 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 the Canadian province of Saskatchewan. The Highways for LIFE Program also sponsored an evaluation of the next generation AIMS-2 through an inter-laboratory study involving 32 state highway agency, university, and commercial 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:

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

State DOTS using AIMS for aggregate characterization include Illinois, Ohio, Texas, Maryland, and Florida. The FHWA has two units that are being used for demonstration and training in the mobile testing laboratory. A number of universities across the U.S. have acquired AIMS device for use in their research studies. These include North Carolina State University, Rutgers University, University of Florida, University of Maryland, University of Nebraska, University of Nevada at Reno, University of Texas at Austin, University of Texas at El Paso, Texas A&M University, and Texas Transportation Institute. AIMS has also been acquired overseas by companies or institutions. So far 11 units have been purchased in China/Hong Kong, 3 in Brazil, and 1 each in India and Trinidad and Tobago.

Improved Asphalt Cement Specification Test Methods (Projects #84, 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. Two of these test methods are now also AASHTO provisional standards test methods.

(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 (EBBR) 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 developed in this IDEA research are simple extensions of regular aging, rheological and failure tests, yet the associated acceptance criteria assure a superior level of toughness and durability for 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 the 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 accelerated loading facility experiment at the 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 (EBBR) 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 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 these 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 were conducted with 10-15 asphalt laboratories participating. Since 2009, the acceptance criteria have been implemented on numerous Ontario pavement projects with few, if any, serious problems. Since 2017, the LS-299 DENT and LS-308 EBBR methods have been fully implemented on nearly all projects for road rehabilitation and reconstruction in Ontario. These two test methods have also been adopted by the AASHTO as provisional standards:

AASHTO TP 113-15: *Provisional Standard Method of Test for Determination of Asphalt Binder Resistance to Ductile Failure Using Double-Edge-Notched Tension (DENT) Test*

AASHTO TP 122-16: *Provisional Standard Method of Test for Determination of Performance Grade of Physically Aged Asphalt Binder Using Extended Bending Beam Rheometer (EBBR) Method*

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

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 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 record and 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 that fleets need to monitor fleet performance, prioritize events for coaching, and provide 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 more than 850,000 drivers annually from more than 3,000 commercial and government fleet clients worldwide.

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 of vehicles over a 17-week period as a result of using DriveCam.[2] By helping to improve driver behavior, DriveCam also results in fuel savings of up to 12%.[3]

The information captured by DriveCam is also invaluable for legal defense and insurance purposes. According to the company, the use of the device 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. At the start of 2018, the company announced that more than 3,000 commercial and government fleets with more than 850,000 drivers have deployed the DriveCam Program in their vehicles. These fleets 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. In 2018, Nationwide partnered with the company to add the DriveCam safety program to its long-haul trucking fleet. Other fleets using the DriveCam Program include the Alaska DOT, the City of Mobile, Alabama, the Concho Valley Transit District in Western Texas, 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), Murphy-Hoffman Distribution Company, Dart Transit Company, Southern Maryland Oil, JBS Carriers, Liquid Environmental Solutions, and Cargo Transporters, 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, for example) also now offer the program to their fleet policy holders.

Awards/Recognition

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, SCC 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, 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, since 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 constructions as well as for repairing and retrofitting existing ones. SCC is also being used in repairing concrete members with limited access for conventional placement and vibration techniques.

To help implement the SCC technology, the FHWA has continued to work with state DOTs, researchers, concrete industry, admixture suppliers, and other partners through research and development, deployment, and construction projects. It has sponsored a number of SCC projects nationwide 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 has also offered courses 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 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.

Major overseas highway infrastructure using SCC include the Akashi Kaikyo Bridge in Japan, the world longest suspension bridge (almost 4 km) linking the city of Kobe on the mainland of Honshu to Iwaya on the Awaji Island., the Ohmi-Odori Bridge in in Arahari Ritto in Japan, and the Sweden's largest

infrastructure development – the Sondra Lanken roadway project linking East and West Stockholm that included 6 km of four-lane highway and bridges and 16 km concrete lined rock tunneling and earth retention walls.

SCC is also being used extensively worldwide in non-transportation construction projects, such as residential and commercial buildings and industrial plants and facilities. 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), South Tower in New York City (10 Hudson Yards, a 52-story office building), a 60-story Market Street building in San Francisco, 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.

Notable non-transportation overseas projects include the Burj Khalifa in Dubai, United Arab Emirates, the 166-story world's tallest building that used SCC throughout its structure, Jin Mao Building in Shanghai, China, the world's fifth tallest building, the 101-story Mori Tower in Shanghai, China, the 44-floor Beijing Television Center in Beijing, China, the 74-story Yokohama Landmark Tower in Yokohama, Japan, and the La Maladiere Football Stadium in Neuchatel, Switzerland.

Asphalt Binder Thermal Cracking Test (Project #99)

Inventor/Investigator
Sang-soo Kim
Ohio University

IDEA Funding
$76,000

Project Completion
2007

The FHWA's Highways for LIFE Program supported further evaluation and commercialization and implementation of this IDEA product.

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 allowed accurate measurement of asphalt strength at low temperatures that until then 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.

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 the 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. Participating state DOTs and Canadian provinces that evaluated 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 the FHWA and the Minnesota's MnRoad project. Several private companies such as Exxon Mobil, Mathy Technology & Engineering, and the Hudson Company also participated in this evaluation.

New Hampshire and Ohio DOTs used ABCD in evaluating the low temperature properties of their asphalt binders. The latter used it to evaluate virgin binders, recovered binders from recycled asphalt pavement (RAP), and recycled asphalt shingles (RAS) and their blends as well as extracted binders from asphalt mixes that contained RAP and RAS for test sections in northeastern Ohio. The Ohio DOT found the device easy to set up and operate while providing meaningful results.

A number of academic institutions [Western Research Institute (WRI), Michigan Technological University, Ohio University, and Texas Transportation Institute] have been using ABCD in their asphalt binder studies. WRI has conducted several major research projects involving ABCD and gained significant experience on testing with the device. For example, it used ABCD in the NCHRP Project 09-60 to evaluate at least 50 binders that represented most of the problematic binder compositions as well as some SHRP reference binders. The ABCD test was able to account for strength changes brought in by various modification systems and was considered capable of differentiating modified binders with similar BBR ranking. WRI is also using ABCD in RILEM TGI activities comparing various test procedures for asphalt binders as well as in industry projects under the Asphalt Industry Research Consortium where the device is now a part of the consortium's experimental plan.

During 2018 and 2019, several Russian private and government laboratories acquired ABCD units to evaluate Russian asphalt binders. Additional data and experience in Russia should further facilitate adoption of the ABCD in the US. and elsewhere.

In January 2019, the AASHTO's Technical Subcommittee 2b on Liquid Asphalts approved the ABCD test method as a full standard (AASHTO T 387). This change is to be reflected in the next edition of the AASHTO Book of Standards and Specifications:

> AASHTO T387-19 – *Standard Method of Test for Determining the Cracking Temperature of Asphalt Binder Using the Asphalt Binder Cracking Device (ABCD)*

Impact Echo Scanner for Nondestructive Evaluation of Grouts/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

Product: A hand-held impact echo scanner (IES) 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 presently costs $25,000 while a more economical version with the NDE360 platform costs $17,500.

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 voids in need of grouting repair for both new and old bridges. Scan rates are rapid, on the order of 14 ft. per minute, detecting voids both in steel and plastic post-tensioning ducts. The scanning is near-continuous (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 using 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 that the DOT has used it for.

Other agencies and institutions that have purchased the IES 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 30 units have been sold to various agencies and institutions.

Olson Engineering, Inc., the sister company of Olson Instruments, Inc., continues to consult and employ the IES system on projects with concerns about concrete integrity and grout/void evaluations for post-tensioned ducts and bridges. It recently used the IES system for evaluating serious cracking damage in a post-tensioned bridge in Canada, and the predicted damage was confirmed with destructive examination. IES scanning was subsequently conducted on the bridge to check for any damage to concrete after post tensioning and grouting of the ducts was done and to confirm good grouting of the ducts.

Olson Engineering also participated in the NCHRP Research Project 14-28 conducted by Texas A&M University Transportation Institute on Inspection Guidelines for Bridge Post-Tensioning and Stay Cable Systems Using NDE Methods. The IES system was found to compare well with ultrasonic pulse echo for detecting voids in the grouts. The system was adapted to the curved shape of an external duct and worked extremely well to detect voids in that duct.

"Nondestructive Evaluation of Grout Defects in Internal Tendons of Post-Tensioned Girders," Tevfik Terzioglu, Madhu M. Karthik, Stefan Hurlebaus, Mary Beth D. Hueste, Virginia Foster, Stefan Maack, Jens Wostmann, Herbert Wiggenhauser, Martin Krause, Patrick K. Miller and Larry D. Olson, NDT&E International 99, May 2018.

A Soil Compaction Control Measurement Instrument (Project #118)

Inventors/Investigators
Jean-Louis Briaud
Texas A&M University

Louis Marcil
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 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 moduli. The device is commercially available from Roctest, Inc., based in Montreal, Canada. 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 a user 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 the 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 on 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 evaluated the BCD in several construction projects. The evaluation indicated consistent and reproducible results even when used by different operators. However, when compared with results obtained by standard test methods, the BCD shows weak to moderate correlations. The correlations therefore need further improvement.

Other agencies and institutions that have used 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). The BCD was also used in a demonstration project in New York. 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.

3-D Digital Imaging for Management of Unstable Highway Slopes (Project #119)

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

IDEA Funding
$99,500

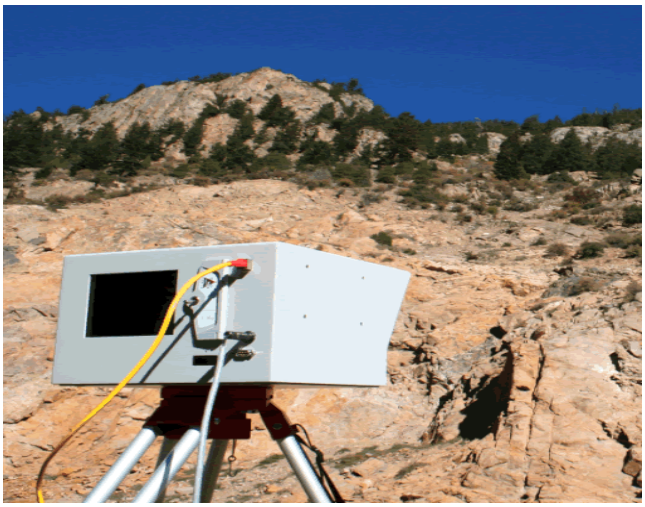
Project Completion
2008

A pooled-fund study, TPF 5-166, involving the states of Arizona, California, Colorado, New York, New Hampshire, Pennsylvania, Tennessee, and Texas and the FHWA, supported further evaluation and implementation of this IDEA product.

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 orientations, stereonet plotting), determining rockfall hazard ratings (slope and highway geometries, geotechnical factors, and human exposure factors), and detecting ground movement between successive scans. Ground-based 3-D light detection and ranging (LIDAR) scanning data is analyzed by Split-FX software for characterizing highway slopes.



Ground-based 3-D 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 2 kilometers.

Application/Implementation

The developed Split-FX 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 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 8 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 highway construction and maintenance activities. Scanning of sites in each of the 8 states was conducted, which included a slope along I-40 near Flagstaff, Arizona and several slopes along Highway 375 near El Paso, Texas. A major deliverable of this work was a draft 'Recommended Practice' for AASHTO's consideration.

The IDEA-developed Split-FX software was 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.

In 2019, Split Engineering was acquired by Hexagon Mining, based in Tucson, Arizona. Hexagon Mining is one of the world's leading companies in mining technology, both in software and hardware. The software products from Split Engineering (Split-Desktop, Split-Online, Split-FX) compliment very well the Hexagon product line, and in 2020, the Split-FX software is to be integrated into the Hexagon's MinePlan software. This is expected to significantly increase the number of users of the Split-FX software. Currently the Split-FX software is available from Hexagon at a cost of about $10,000, including all the accessories. Split-FX is also available to academic institutions at a much reduced cost.

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

Sweet Sixteen: For implementing this IDEA product, a Georgia DOT Research Project 15-11: Implementation of Automatic Sign Inventory and Pavement Condition Evaluation on Georgia's Interstate Highways" received the 2017 AASHTO Sweet Sixteen High Value Research (HVR) Award.

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 allow automating the traffic sign inventory through 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 all state DOTs invest in. These signs provide vital guidance to road users regarding traffic regulations, road hazard warnings, destinations 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 these algorithms lies in their capability to significantly reduce the time and cost for obtaining traffic sign inventory data using video log images. Initial 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 were tested on 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 inventory their sign assets cost-effectively in support of their asset management activities. Based on successful test results, Georgia DOT sponsored an implementation project to collect all traffic signs on all interstate highways in Georgia.

Awards/Recognition

Sweet Sixteen: A Georgia DOT Research Project 15-11: Implementation of Automatic Sign Inventory and Pavement Condition Evaluation on Georgia's Interstate Highways" that implemented the product of this IDEA project was selected as one of the 2017 AASHTO Sweet Sixteen High Value Research (HVR) Projects (https://research.transportation.org/sweet-sixteen-2017/) and (https://ce.gatech.edu/news/national-group-honors-research-using-lasers-and-ai-automatically-assess-health-highway-pavement).

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

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

IDEA Funding
$140,000

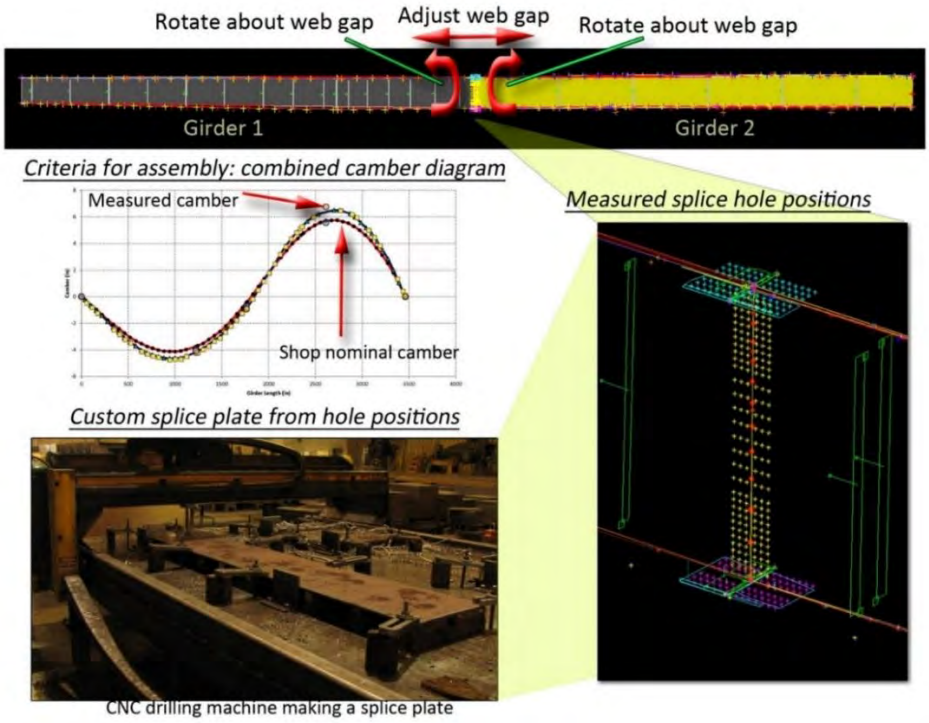
Project Completion
2009

A pooled-fund study, TPF 5-226, involving the states of New York, Iowa, Texas, and Virginia and the FHWA supported further evaluation and implementation of this IDEA product.

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.



BRIDGE VAS concept for virtual assembly and custom splice plate fabrication

The system 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).

Benefits

There are many documented cases of steel bridge erection problems, particularly for complex structures, such as curved girders and box structures, resulting 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 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 can also eliminate 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 in the 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.

The BRIDGE VAS replaces subjective, limited-accuracy conventional measurement methods with a full digital record and provides full documentation of what is fabricated. 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.

BRIDGE VAS measuring a girder in a fabrication shop

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) and the FHWA. Virginia was the lead state for this study. A leading private bridge fabricator, Hirschfeld Industries (San Angelo, Texas), also collaborated in this evaluation.

Under the pooled-fund study, the BRIDGE VAS was successfully implemented on the first-ever production bridge job on a structure for Tennessee DOT. The project illustrated the limitations of conventional measurement methods in a fabrication shop. For example, it was shown that conventional measurements with tape measures always resulted in a girder that was fabricated too short. Virtual assembly systems can help improve steel bridge fabrication processes by providing greater detail and more accurate documentation of exactly what has been fabricated, compared to conventional methods. Also, virtual assembly systems can capture and perform types of measurements that are not currently possible with conventional methods. Virtual assembly processes, such as creation of custom splice plates from measurements, are now being implemented by steel bridge fabricators.

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

Prototype of Three pairs of rolling transducer wheels

The system utilizes the combination 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 deck (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 concrete decks, whether bare or asphalt overlaid. 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 the FHWA have evaluated the bridge deck scanner on their bridge projects. The National Center for Asphalt Technology (NCAT) also evaluated the technology for detecting debonding between layers of hot-mixed asphalt pavements. The use of scanning impact echo and surface waves was able to detect, to a high level of accuracy, debonded asphalt conditions in the SHRP-2 HMAC Pavement Delamination Project (R-06D). Olson Engineering, Inc. further demonstrated this technology to New Mexico, Texas and Kentucky DOTs as part of SHRP 2 R-06D Implementation Assistance Program.

Olson Instruments, Inc. has commercialized the technology and sold, as what is now called a Sonic Surface Scanner (S^3 -- www.olsonengineering.com/wp-content/uploads/S3-Brochure-6.2017.pdf), to Iowa and Indiana DOTs. Both DOTs have used the Sonic Surface Scanner on project level deck condition assessments, with Indiana DOT having tested more than 100 concrete bridge decks. A photo of the system is shown below with a sunlight readable notebook.

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

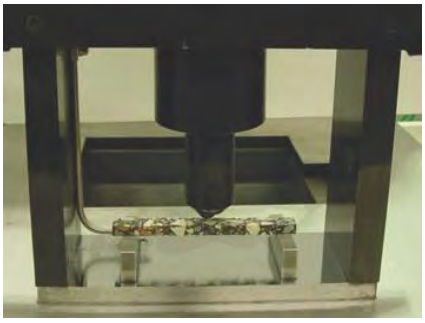
Description

Product: Simple test methods for 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 NCHRP IDEA Project 133, 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 an AASHTO procedure.

I DT and BBR test specimens



BBR with small scale beam of asphalt mixture

Creep compliance of asphalt binders and mixtures, however, 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-on IDEA Project 153. Due to different loading patterns and higher loads required for strength test, a modified BRR (called BBR-Pro)

was developed by Canon Instrument Company for strength testing. 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 having to make any modifications to it. For strength tests, only the loading frame has to be upgraded, while the rest of the apparatus and the calibration procedure remain the same. The preparation of small beams of mixture is very simple and allows testing a large number of specimens, which facilitates routine mixture QC/QA testing. 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

In 2016, the AASHTO adopted the IDEA creep test for asphalt mixtures as a provisional standard:

> AASHTO TP 125-16: *Determining the Flexural Creep Stiffness of Asphalt Mixtures Using the Bending Beam Rheometer (BBR).*

Utah DOT has been using the test method for more than 3 years as part of its routine mixture testing and has recently improved correlations between BBR mixture properties and field performance by using both the creep stiffness and the m-value parameters. A number of research laboratories in the U.S. and Europe are also using this new approach to investigate its applicability to material selection and for research purpose. The research team continues to refine the creep and strength test methods for asphalt binders and mixtures and recently published a new testing protocol, in which both creep and strength are obtained in a single test run.

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

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

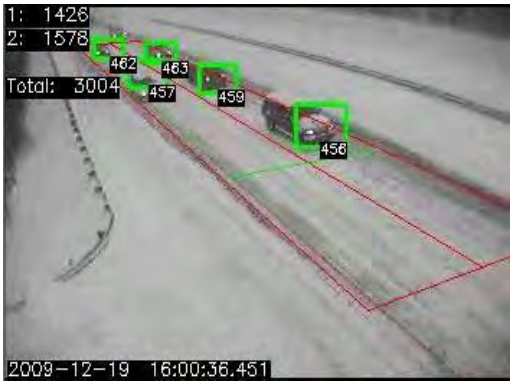
IDEA Funding
$130,000

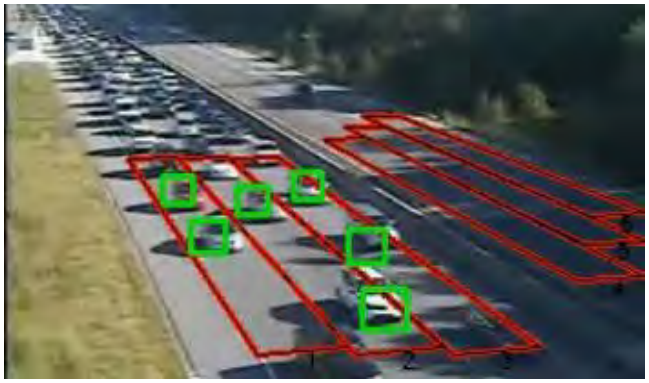
Project Completion
2010

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 vehicle volume, speed, and 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 the 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

The product is a 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 weather or 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.

Application/Implementation

The sensor system was initially evaluated for its traffic data collection capability in partnership with South Carolina, Maryland, and New York State DOTs. The commercialized system (TrafficVision) has been demonstrated to, or evaluated by, many state DOTs and public agencies, including Maryland, Missouri, New York State, Ohio, South Carolina, Tennessee, Texas and Utah DOTs and also on the Florida Turnpike. TrafficVision was also evaluated for its traffic data collection and incident detection capabilities as part of the FHWA's ENTERPRISE pooled-fund study.

Transportation agencies with paid deployment of TrafficVision include Colorado, Georgia, and New Mexico DOTs, Kansas City SCOUT, Indiana Toll Road, and Pennsylvania Turnpike Commission. The system was also used in Ottawa, Canada and on a tunnel in Italy (through Distelco Company). Academic institutions using TrafficVision in their research studies include Wayne State University, Texas Southern University, and the Texas Transportation Institute/Texas A&M University.

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

Inventors/Investigators
Richard Christensen
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 device to reduce 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 using 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.

Laboratory tests of the SHVA were conducted at the University of Connecticut on a traffic signal support structure with a 35 ft. (10.67 m) long mast arm. Free vibration tests showed that the critical damping in the structure increased from 0.2% to 10.1%, which corresponded to a more than 95% reduction in the steady state response of the structure.

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 vibration amplitude, can significantly enhance a structure's fatigue life. 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, 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 an SHVA, by reducing 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

Following the success of the IDEA project, the Center for Science & Technology Commercialization at the University of Connecticut funded a project for 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 ft. (18.29 m) long mast arm in Manchester, Connecticut. The SHVA and its components were shown to be robust to the elements with no loss in performance from the day it was installed to the day it was dismantled.

In 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 ft. (18.29 m) long mast arm at the university's National Wind Institute. During the three months of monitoring, the SHVA was found to reduce vortex-induced vibrations of the mast arm by approximately 90%, which decreased 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 vibrations over the full range of wind speeds collected.

The SHVA was further modified by Valmont Industries, a traffic signal pole manufacturer in the U.S., to make it more marketable. The modified device, Mitigator TR-1, is a stand-alone device that does not utilize the single head itself (http://www.valmontstructures.com/products-solutions/traffic-mass-transit/vibration-damping) and was tested by the IDEA researcher at the University of Connecticut and

several field sites (Hartford, Connecticut and the state of Utah, for example). Test results showed that the device reduced vibrations on most all traffic signal support structures by over 90%. A 90% reduction in response corresponds to a stress-range reduction by a factor of 0.1 and an estimated increase in fatigue life by a factor of 1000.

Results presented at the 2018 ITE Northeastern District Meeting illustrated how the use of the TR-1 damper can result in significantly smaller poles, which serves as a less expensive, more environment-friendly, and safer (smaller poles near the traveling public) alternative to the current designs. For example, typical Connecticut mast arm designs can achieve significant savings in material: a 40-ft. mast arm weight is reduced from 4,009 lbs. to 2,413 lbs. (a 40% reduction) and a 70-ft. mast arm weight is reduced from 7,577 lbs. to 4,682 lbs. (a 38% reduction).

The results of the IDEA project and the consideration that explicit procedures in the AASHTO LRFD SLTS Specifications to identify effective vibration mitigation devices would facilitate a wider adoption of such technologies led the TRB AFF10 (1) Traffic Structures Subcommittee to suggest an NCHRP project to (i) develop test procedures for evaluating the effectiveness of vibration-mitigation devices for structural supports of signs, luminaires, and traffic signals and (ii) propose procedures for considering the effectiveness of these devices in the design process of the structural supports. The IDEA researcher is the principal investigator of this NCHRP Project 12-111, with Texas Tech University, the US Army Corps of Engineers Engineering Research and Design Center, and Modjeski and Masters as partners. The project is currently in progress.

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

The FHWA's Highways for LIFE Program and the Connecticut DOT supported further evaluation and commercialization of this IDEA product.

Description

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

To meet new minimum retroreflectivity standards proposed by the FHWA, state DOTs need to find better and more efficient 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. The system 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 speed. The system is a significant improvement over traditionally-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. However, those markings must be maintained in order to be effective. The Leetron system breaks away from the 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 markings 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 per second), and the measurement capability can be doubled by utilizing two systems to simultaneously measure both the driver- and the passenger-side markings. The system also makes consistent measurements on the curves. Being a one-operator system, it also saves labor costs; the operation is simplified with features such as auto start, voice recognition for user interface, and autocalibration/verification.

Application/Implementation

Work on the IDEA-developed prototype continued for product commercialization in collaboration with the Connecticut DOT and with partial support from the FHWA's Highway for LIFE Program. After further refinement, the system produced reliable and stable results. An extensive evaluation of the system was successfully conducted in 2014 with collaboration from FHWA and Florida DOT. A production version of the system was developed with additional funding from the Highways for LIFE program in 2016 and was independently evaluated by Texas Transportation Institute. The independent evaluation indicated that the technology achieved its design goal and performed as was intended and even better than some other technologies.[1]

While the Leetron device is available for use, the company lacks resources for marketing the product, as it takes substantial efforts and capital to transition from a new product to a market-acceptable product. Still, efforts continue to bring the product to the market.

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[1]https://www.fhwa.dot.gov/hfl/partnerships/pdfs/leetron_2017_finalreport.pdf

Cleaning Device for Removing Debris and Chemicals for Crack/Joint Sealing (Project #148, 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 pavement cracks. 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, particularly 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 Nebraska DOR provided multiple CCD units to all of its 8 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. The 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 showed more interest in routing rather than cleaning the cracks; therefore a heavy-duty crack routing device (CRD) was developed and provided to the NDOR for their use.

Bridge Retrofit Laser System (Project #153)

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

IDEA Funding
$139,000

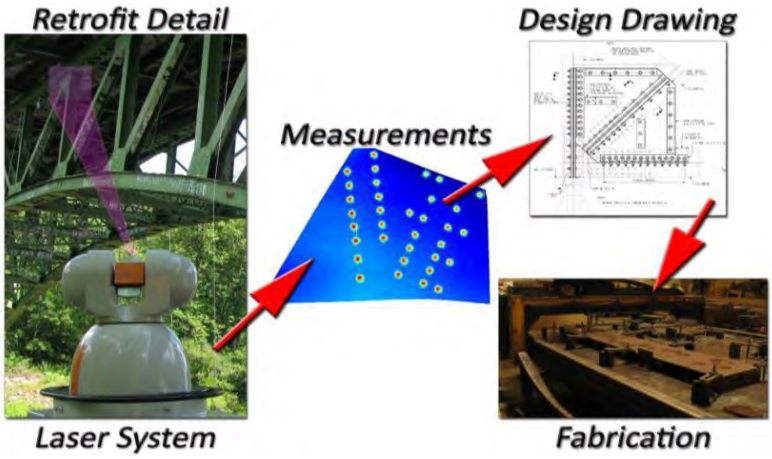
Project Completion
2012

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. Those measurements are then 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 3-D measurements of the 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

BRIDGE RLS measuring steel bridge girders over live traffic

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 how long a bridge is out-of-service or eliminating lane closure can save DOTs substantial costs and is also 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 timber. This is an important attribute as it allows measurements to be made on a bridge without having to first access the bridge in any manner. Measurements are made with full 3-D accuracy in the thousandths of an inch over the working volume [50 m (164 ft.) range] of the instrument. The system makes those measurements with minimal impact at the bridge site, 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 complex movements of adjacent box girders over water

Application/Implementation

The BRIDGE RLS is being used to provide DOTs information that is not possible with other measurement systems. The unique measurement capabilities of the system were highlighted on an adjacent box beam bridge for Maryland State Highway Administration. This particular bridge 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.

Automated Asphalt Pavement Raveling Detection Using 3-D Laser Technology and Macrotexture Analysis (Project #163)

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

IDEA Funding
$100,000

Project Completion
2015

Sweet Sixteen: For implementing this IDEA product, a Georgia DOT Research Project 15-11: Implementation of Automatic Sign Inventory and Pavement Condition Evaluation on Georgia's Interstate Highways" received the 2017 AASHTO Sweet Sixteen High Value Research (HVR) Award.

Description

Product: A method to automatically detect asphalt pavement raveling using 3-D line laser imaging data

The developed reveling detection method involves four major steps. The first step is data pre-processing. This data pre-processing removes data outliers, detects pavement markings and edge drop-off, and extracts the candidate pavement portion for raveling detection. The second step is calculating the feature vectors. Each 3-D line laser image data file covers a pavement section that is 5 meters long in the driving direction and divided into 6 sub-sections (3 sub-sections in each wheel path). Raveling detection is initially performed on each sub-section. Raveling characteristics are represented by 10 features, including mean texture depth, standard deviation, maximum and minimum, and RMS for each sub-section in each wheel path. These 10 features form a feature vector. The third step is detecting raveling. A supervised leaning technique, the Support Vector Machine (SVM), was employed to classify pavement (raveling or non-raveling) based on known learning samples. For selected sample data, visual inspection is needed to determine the existence of raveling in each sub-section in each 3-D line laser imaging data file, which is the ground truth for training the SVM models. Based on the trained SVM models, new data can be classified in accordance with its own features. The fourth and final step is aggregating the sub-section-based raveling. The results from the sub-section-based raveling classification are aggregated based on highway agencies' survey practices.

(a) Severity Level 1 (b) Severity Level 2 (c) Severity Level 3

Raveling classification at Georgia DOT

Benefits

Raveling is one of the most common asphalt pavement distresses in the U.S. Raveling increases pavement roughness, which results in poor ride quality and road/tire noise. Besides safety concerns (such as loose stones that may break windshield glass and can cause hydroplaning), raveling also shortens pavement service life. However, the traditional raveling survey method is time consuming, subjective, and hazardous to highway workers. The IDEA-developed method provides a cost-effective and reliable means to automatically extract pavement raveling data, which was not achieved before. The required algorithm is built based upon the commonly-used 3-D pavement surface data, collected using line laser imaging technology (3-D laser technology) generally used for rutting and cracking data collection. Using the same data for raveling detection will save time and money to state DOTs and pavement industry.

Application/Implementation

The developed algorithm was successfully used to automatically detect and classify raveling. As a result, Georgia DOT sponsored an implementation project to detect and classify raveling on all interstate highways in Georgia. The detected and classified raveling outcomes were successfully fed into Georgia DOT's existing pavement management database (COPACES) in support of the DOT's interstate highway maintenance and rehabilitation planning.

Awards/Recognition

Sweet Sixteen: A Georgia DOT Research Project 15-11: *Implementation of Automatic Sign Inventory and Pavement Condition Evaluation on Georgia's Interstate Highway*" that implemented the product of this IDEA project was selected as one of the 2017 AASHTO Sweet Sixteen High Value Research (HVR) Projects (https://research.transportation.org/sweet-sixteen-2017/**)** and (https://ce.gatech.edu/news/national-group-honors-research-using-lasers-and-ai-automatically-assess-health-highway-pavement).

Augmented Reality Visualization of Right-of-Way Excavation Safety (Project #167)

Inventor/Investigator
Vineet Kamat
University of Michigan

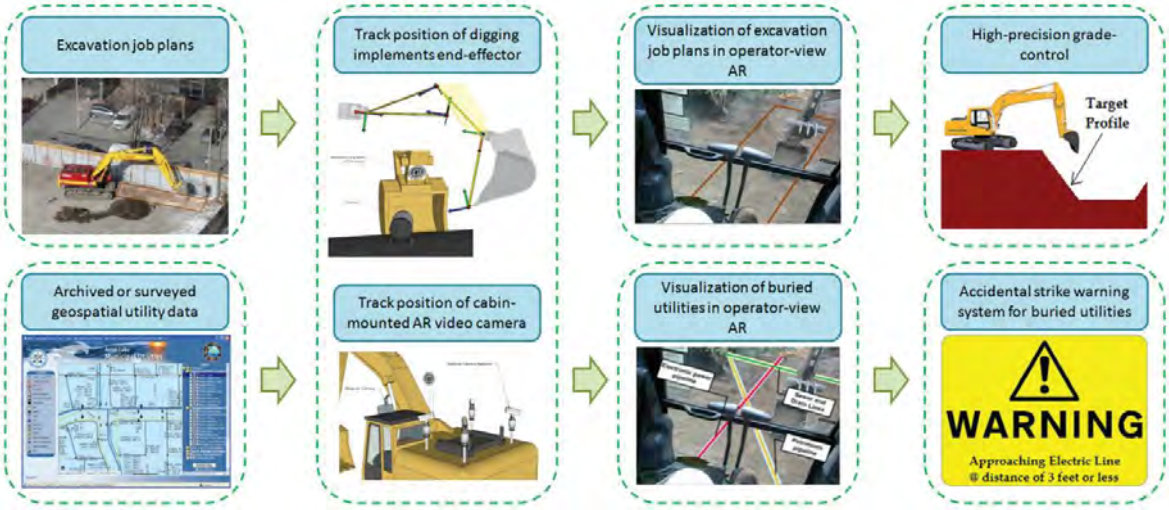
Funding
$125,000

Completion
2016

Description

Product: A machine control system based on georeferenced augmented reality and emulated proximity monitoring to guide on excavating (SmartDig)

An excavator unintentionally hits a buried utility every 60 seconds in the U.S., causing billions of dollars in damage each year. Most of these accidents occur along public rights-of-way (ROWs), typically because excavator operators do not know where utilities are buried (inaccurate or missing utility location data) or cannot perceive where the utilities are relative to the digging excavator (inaccurate spatial perception). This project attempted to address these problems by exploring new methods to communicate "quality-aware" utility location data to equipment operators during excavation. The work focused on creating and evaluating two key capabilities: (i) persistent visualization of assets buried in an excavator's vicinity using a georeferenced augmented reality (AR) approach and (ii) real-time monitoring of an excavator's proximity to underground utilities using a graphical emulation approach. These capabilities enable an operator to be visually aware of the buried assets in a machine's vicinity and provide a real-time quantitative measure of a machine's distance to nearby obstructions, significantly reducing the occurrence of buried utility strikes in a ROW excavation.



Augmented reality visualization of geospatial utility data; precise grade-control (*above*) and utility avoidance (*below*)

Benefits

The developed methodology helps improve productivity and safety of excavation operations by introducing significant automation and information support into the traditional process. Accidents resulting from excavator hits to utilities are a long-standing and significant societal problem that leads to unacceptable fatalities, injuries, property damage, and other costs each year. Inadvertent utility strikes disrupt life and commerce and pose physical danger to workers, bystanders, and the general public. The innovation explored in this IDEA project can potentially transform excavator operation from a skill-based to a knowledge-based process so that future accidents are prevented.

Application/Implementation

The University of Michigan has obtained a patent on the developed technology. The commercialization of the technology was aggressively pursued by the IDEA inventor. Several versions of the prototype were built for deployment and testing on actual excavators working in the field. A start-up company named, Perception Analytics and Robotics, LLC (PeARL), was also founded to commercialize the invention. Collaboration was sought from member companies of the Michigan Infrastructure & Transportation Association (MITA), and key partnerships were established with Walbridge Construction and Eagle Excavation. The prototypes were tested in the field on actual projects, and the results were determined to be within acceptable limits by expert excavator operators. An issue to overcome was to keep the cost of the system down, as compared to the competing products. This issue has been largely overcome with the development of the new versions of the prototype. While the start-up company has yet to commercialize the technology, it is available for licensing by other companies.

A Software System for Automated Turning Movement Counts on Shared Lanes (Projects #177, 198)

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

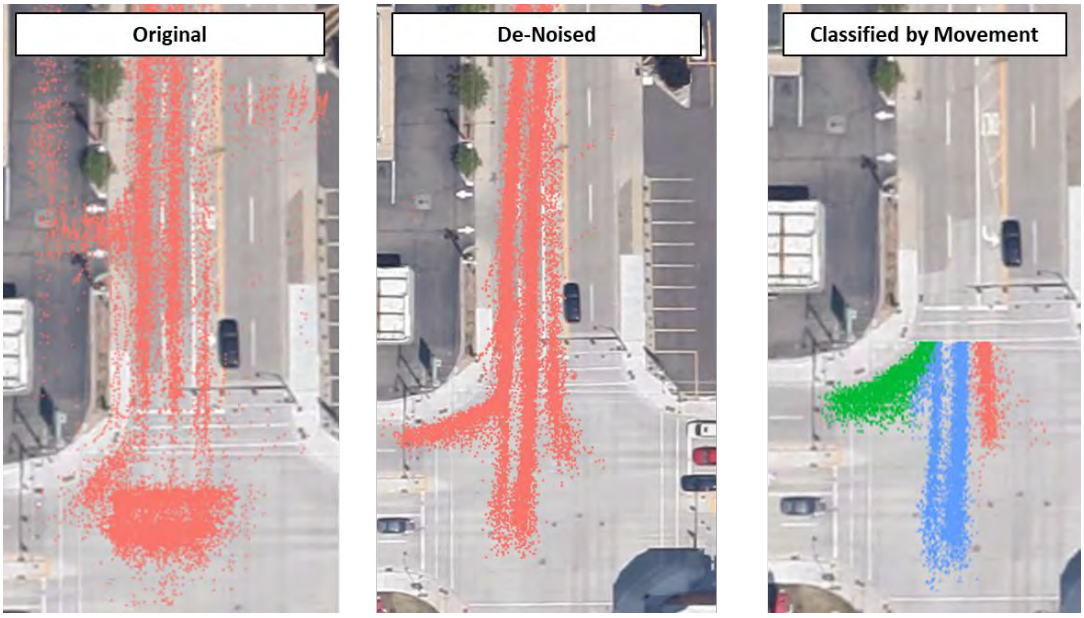
IDEA Funding
$178,097

Project Completion
2019

Description

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

Radar-based vehicle detection systems used as alternatives for loop detectors can continuously monitor the position of multiple vehicles at signalized intersections. However, the data is often used only to detect the presence of vehicles within a zone that emulates an inductive loop detector. A supplemental data collection system installed inside a signal cabinet can log the underlying vehicle trajectory data from the radar-based vehicle detection system without interfering with the system's detection function. An algorithm was developed to improve the quality of the underlying trajectory dataset (vehicle position, length, speed, and time) and to classify vehicle trajectories into corresponding turning movements, thus allowing to break down vehicle volumes by movement, regardless of the lane configuration. This particular feature of the IDEA-developed software system is not offered by any of the existing detection systems currently on the market.



Evolution of trajectory dataset: Original to classified by movement

Benefits

This IDEA innovation has the potential to transform every intersection into an automatic traffic recorder by making continuous turning movement data available for analysis. Turning movement data will have the most direct effect on signal retiming, while also enabling additional applications in the transportation operations, planning, and safety domains.

Traffic signal retiming is one of the most cost-effective methods to improve traffic flow and mitigate congestion. Unfortunately, one of the bottlenecks for implementing a proactive signal retiming program in any jurisdiction is the limited turning movement data available to transportation engineers. The developed system will help address this limitation by providing them turning movement counts continuously year-round and has the potential to make a transformative shift in how frequently transportation agencies can optimize the timing of traffic signals by readily providing the required data. The continuous, high resolution data provided by this system can be used to develop sophisticated safety models to capture the impacts of variations in traffic across seasons, time of day, etc. Also, this data can be further processed to develop other real-time performance measures, such as red light running instances, cycle failures, delay etc.

Application/Implementation

The industry partner, MsSedco, has developed a data collection system to implement the IDEA-developed algorithms and obtain turning movement counts as well as other performance measures from signalized intersections. The system uses a Raspberry Pi computer as the platform and provides data and configuration options via a web interface. The system implements noise removal techniques and structuring procedures identified as the key during the IDEA research. As a result, adding classification by movement based on the IDEA research can be accomplished via a software update.

The commercialization partner, MsSedco, plans to release an initial version of the data collection and analysis product in very near future. It is currently working on the documentation and has already conducted test deployments in three cities (Appleton, Wisconsin, Bloomington, Illinois, and Ames, Iowa). The commercialization partner will integrate a streamlined version of the classification algorithm into their product once the licensing agreement is signed with the University of Wisconsin-Madison. The figure below shows an example of the data collection system deployed in Appleton, Wisconsin and illustrates how it is possible to connect to the system over a wireless connection, thus eliminating the need for opening the signal cabinet if no remote connectivity to the cabinet exists. However, if remote connectivity to the intersection exists, the device can be accessed over the network by using the assigned IP address.

Test deployment in Appleton, Wisconsin

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

Inventor/Investigator
Glenn Washer
University of Missouri-Columbia

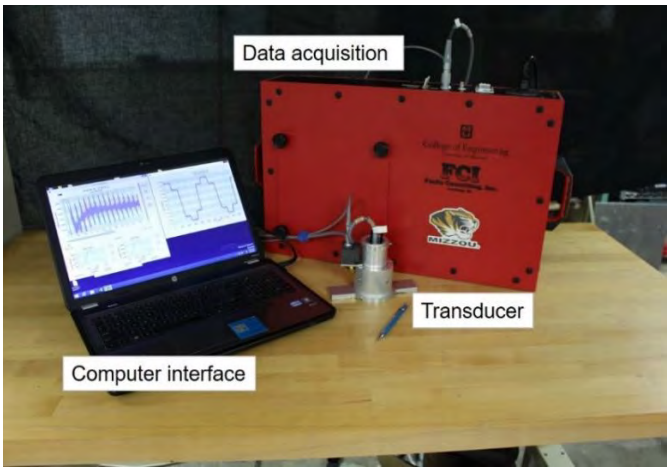
IDEA Funding
$125,000

Project Completion
2017

Description

Product: A portable instrument to nondestructively measure total forces carried by steel bridge members

The instrument developed in this IDEA project uses ultrasonic stress measurement (USM) to determine nondestructively the total stress in steel bridge members. The instrument is unique in that it measures stresses resulting from live and dead loads as well as residual stresses from fabrication. Other technologies, such as strain gages, measure only the live load portion of the stress. As a result, load rating and safety assessments of steel bridges have to rely on assumptions regarding the distribution of forces and residual stresses that may not represent the actual in-situ conditions. Using the USM technology, these stresses can be directly measured in the field to ensure the quality of load ratings and the safety of the bridges.



Ultrasonic stress measurement (USM) system

Benefits

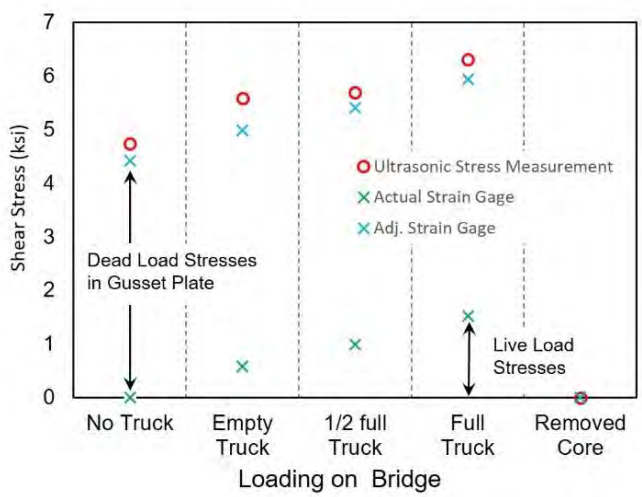
The USM technology introduces a new capability for bridge engineers to quantitatively assess the forces carried in bridge members. Currently no other technology can measure the total in-situ forces carried in bridge members. Dead load stresses, locked-in stresses that may occur during fabrication and construction, unexpected stresses that may occur due to deterioration and damage to the superstructure,

or unanticipated load distributions in a structure, can be assessed using this technology. The tool will facilitate effective safety assessment of bridges and the classification of members that are either under high stress and may not have sufficient capacity to safely carry loads or members that may have significant reserve capacity.

The device is a simple push-button battery-powered portable instrument with a design similar to that of a typical ultrasonic flaw detector and has flexible sensor heads that can accommodate a wide variety of geometries. The sensors are attached magnetically to the specimen and require little or no paint removal, making field application practical and low-cost.

Application/Implementation

Applications of the technology include truss bridges and gusset plates, skewed and integral abutment bridges, connections, hangers, and bridges damaged by impact, fire, or extreme events. A steel truss bridge in Missouri was tested using the USM technology, and it was verified that the technology could accurately measure total shear stress in the gusset plate. Shown below are the field test results comparing the USM measurement of total shear stress with the actual total shear stresses carried by the gusset plate in-situ. The total stresses were verified through destructive testing. High shear stresses are a precursor to gusset plate failure, such as the I35W Bridge collapse in Minneapolis, Minnesota. The USM technology enables the direct assessment of these stresses in-situ to effectively assess the risk of gusset plate failure.



USM measurements of total shear stress in a gusset plate

The technique has a high implementation potential for the practical assessment of bridge safety. Applications such as safety assessment of the Liberty Bridge in Pennsylvania (fire damaged deck truss) or the Jefferson Barracks Bridge in Missouri (cracks resulting from fabrication stresses) could benefit from the application of this innovative technology. The research team has considerable experience working with FHWA and state DOTs, and is currently working to introduce the technology and its new capability to directly measure total stresses in-situ to the bridge engineering community through additional field testing and demonstrations.

Drained Timber Pile Ground Improvement for Liquefaction Mitigation (Project #180)

Investigator/Inventor
Armin Stuedlein
Oregon State University

IDEA Funding
$147,073

Project Completion
2016

Description

Product: Driven timber piles fitted with pre-fabricated drains to improve densification in fine sand and silty sand

Excess pore pressure induced by rapid shearing often leads to liquefaction of granular deposits, resulting in excessive deformation (settlement, lateral spreading) and loss of stability of supported structures. Mitigation techniques attempt to improve the ground so that the soil is densified, reinforced, or drained, lowering the potential for excessive ground deformation. This IDEA research developed a novel drained timber pile technique to mitigate liquefaction, providing a multi-functional ground improvement alternative to conventional techniques. This alternative increases the densification in low-permeability fine sands and silty sands (relative to conventional piles) and provides tensile reinforcement against lateral movements. The drains are readily fixed to the timber piles, and the drain pile is driven using conventional pile driving equipment, eliminating the need for the mobilization of additional heavy equipment.

Drained timber piles (*left*) and installation within a shallow pre-drilled cavity (*right*)

Benefits

The technique uses conventional equipment to provide low-cost, renewable, hybrid ground improvement and stabilization. Drained timber piles can improve a structure's seismic resilience and also accelerate construction. Driving drained, displacement piles into loose, liquefiable soil deposits forces the soil void volume to reduce substantially to accommodate the solid volume of the pile, resulting in a densified soil mass. The degree of densification varies with pile spacing and with the addition of drainage capacity along the side of the pile.

The increased strength derived from densification was demonstrated using a full-scale blast-liquefaction test. The native, unimproved soils were shown to liquefy following detonation of the selected explosive charge weight and sequence, resulting in 8 inches of post-liquefaction settlement as measured at the ground surface. When subjected to the same detonation sequence, the timber pile-improved ground demonstrated lower excess pore pressures and substantially-reduced settlements (generally 1-3 in.). Furthermore, piles driven to a competent bearing layer settled less than an inch, on average. Timber piling can also mitigate challenges associated with poor global stability of embankments, approach fills, and bridge abutments.

Application/Implementation

Use of timber pile to achieve ground improvement is being implemented in the U.S. and Canada. The emergency replacement of the Interstate 26 Four Holes Bridge overpass near Orangeburg, South Carolina required fast construction in an active seismic zone. The new bridge was constructed with two 107 ft. spans with a single central support in the interstate median. The liquefaction hazard to the mechanically-stabilized earth (MSE) wall approach fills and abutments was mitigated using driven displacement piles on a center-to-center spacing of 3.5 ft. (three pile diameters) on the basis of this IDEA research. Each approach fill and abutment subgrade consisted of a footprint extending 80 ft. wide and 40 ft. long, improved with approximately 250 piles 40ft. in length. The same pile driving equipment used to install the substructure-supporting H-piles was used to install the timber piles, leading to significant benefit in the economy of construction. The British Columbia Ministry of Transportation in Canada now regularly approves the use of driven timber piles to buttress existing and new bridges. For example, liquefaction mitigation was accomplished using driven timber displacement piles for the four-lane, 350 ft. long Knight Street Bridge over Fraser River in Vancouver, British Columbia.

As an example of the application of drained timber piles to non-transportation structures, a hotel in Mt. Pleasant, South Carolina, was constructed over a soil mass densified using timber piles.

The IDEA product is openly and freely available for implementation to public agencies and private entities.

Small Specimen Geometries for Asphalt Mixture Performance Testing (Project #181)

Inventor/Investigator
Cassie Castorena
North Carolina State University

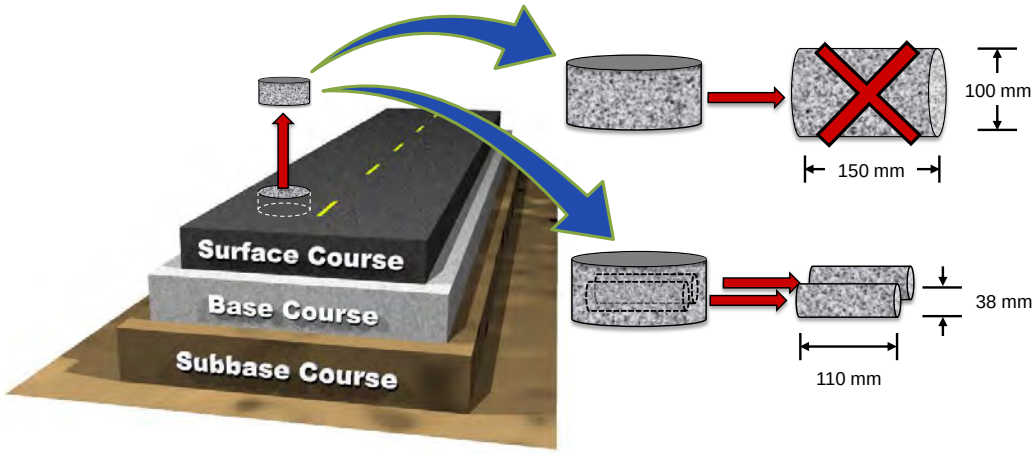
IDEA Funding
$99,998

Project Completion
2017

Description

Product: Equipment to enable small specimen testing in the Asphalt Mixture Performance Tester (AMPT) and AASHTO standard procedures for small specimen testing of laboratory and field core samples.

Small specimen geometries have been gaining attention in recent years for testing of as-built pavement layers. Performance testing of asphalt mixtures allows for evaluation of the material properties, which can be incorporated into pavement performance prediction models. The AMPT allows for routine testing of asphalt mixtures using laboratory-fabricated cylindrical test specimens, 100 mm (4 in) diameter and 150 mm (6 in) high. However, many pavement layers are less than 4 inches thick, which prevents forensic testing of as-built pavement layers. Several researchers have conducted preliminary studies evaluating various small specimen geometries, including 38 mm (1.5 in) and 50 mm (2 in) diameter cylinders and 25 mm by 50 mm (1 in by 2 in) prisms, with heights varying from 100 mm (4 in) to 140 mm (5.5 in).



Small specimen geometry to enable field core testing

Initial experiments in this IDEA project evaluated the effects of specimen geometry on dynamic modulus and fatigue results using plant-produced mixtures that identified the mixtures and test conditions for which small specimen testing could provide representative results of the bulk asphalt mixture behavior. Subsequent experiments evaluated the effect of small specimen coring direction on dynamic modulus and

cyclic fatigue testing results, which led to the optimization of the procedure for laboratory fabrication of small specimens. Dynamic modulus and cyclic fatigue testing evaluated the specimen-to-specimen variability of small specimens prepared by the optimized procedure using four plant-produced mixtures. The equipment needed for the preparation and testing of small specimens was developed with assistance from IPC Global, Controls Group, Instrotek Inc., and the North Carolina State University Precision Machine Shop.

Benefits

The small specimen geometries improve the efficiency and versatility of uniaxial asphalt mixture performance testing. The asphalt mixture performance testing serves as a key input to mechanistic-empirical design frameworks, including the Pavement Mechanistic-Empirical Design. In addition, the performance testing of field cores can be used for performance-based quality acceptance and forensic investigations of asphalt mixture properties of individual pavement layers during a pavement's service life. Standard uniaxial performance testing is conducted using 100-mm diameter specimens, which precludes the forensic testing of thin as-built pavement layers and only allows for the extraction of a single test specimen from a laboratory compacted sample.

This IDEA research suggests that small specimens that are 38-mm in diameter constitute a suitable representative volume element for fatigue characterization. Small specimens can be extracted from as-built pavement layers for forensic investigations. In addition, the small specimen geometry yields four test specimens from a single laboratory compacted sample, offering a means to significantly improve the efficiency of laboratory specimen fabrication.

Application/Implementation

This IDEA research resulted in the development of three provisional AASHTO standards for the fabrication and testing of small asphalt mixture specimens:

AASHTO PP 99: P*reparation of Small Cylindrical Performance Test Specimens Using the Superpave Gyratory Compactor (SGC) and Field Cores*

AASHTO TP 132: *Determining the Dynamic Modulus for Asphalt Mixtures Using Small Specimens in the Asphalt Mixture Performance Tester (AMPT)*

AASHTO TP 133: *Determining the Damage Characteristic Curve and Failure Criterion Using Small Specimens in the Asphalt Mixture Performance Tester (AMPT)*

The FHWA has sponsored a project to conduct a ruggedness study and an inter-laboratory evaluation of the small specimen cyclic fatigue test procedure. Ruggedness and inter-laboratory studies are necessary to advance the provisional standards to full standards and implement them into practice.

The small specimen geometry is being utilized in the FHWA-supported Performance-Related Specification (PRS) shadow projects, being carried out at Maine, Maryland, and Missouri DOTs, Ontario Ministry of Transportation, and Western Federal Lands.

Web-Based Software for Data-Driven Planning and Project Prioritization (Project #184)

Inventor/Investigator
Josephine Kressner
Transport Foundry, Atlanta, Georgia

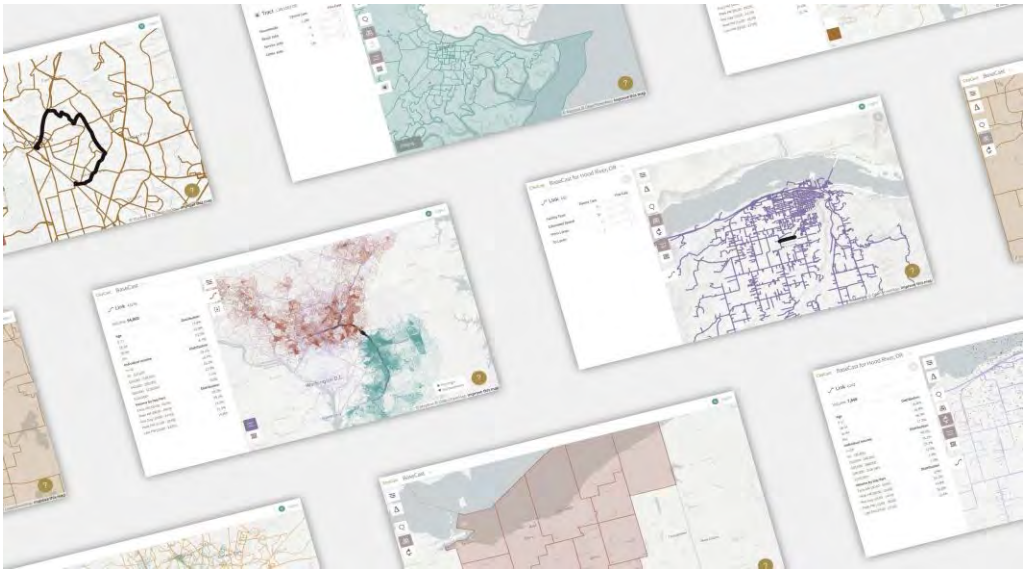
IDEA Funding
$100,000

Project Completion
2017

Description

Product: Web-based software (CityCast) that enables data-driven planning and project prioritization

CityCast is a web-based software system that puts a turnkey, data-driven microsimulation platform in the hands of engineers and planners. The microsimulation platform intelligently merges detailed household and business marketing data with anonymized mobile and vehicle location data to simulate point-to-point, minute-by-minute travel and activities for everyone in a city. Privacy is protected, the whole population is represented, and person-level insights are available.



CityCast

Planners are using CityCast to study transportation alternatives in several cities including the Washington-Baltimore and Atlanta metropolitan areas. CityCast empowers planners to examine current conditions and consider potential impacts of future improvements and policies such as:

- Regional future population and employment forecasts
- Subarea population and employment scenarios like large developments and zoning policies

- Road network scenarios, such as road widening/diets, new roads, new interstate interchanges, limited-access links
- Transit service changes, considering congestion on both the transit and highway networks
- Demand-responsive transit
- Tolling and congestion pricing
- Autonomous vehicle scenarios including mobility as a service scenario and private ownership
- Micromobility (e-scooters, e-bikes)

Benefits

To recommend where roads, transit, buildings, sidewalks, and other infrastructure are needed, planners must understand people, jobs, other destinations, and the movements between them. Traditionally, expensive local surveys and bespoke travel models collect and estimate this information; however, surveys are increasingly biased, expensive, infrequent, and onerous.

CityCast's approach, which builds on up-to-date, passively-collected data that is included in the software, allows engineers and planners to investigate travel behavior in a way that is not feasible presently. The turnkey software saves money and time in data collection/procurement, travel demand modeling, project evaluation, scenario planning, before-and-after studies, congestion mitigation/management studies, and tolling studies. This data-driven approach also enables cities to be smart about new modes of transportation, such as dockless e-scooters and e-bikes, ridesharing, demand-responsive transit, and autonomous vehicles.

Application/Implementation

CityCast was used in planning projects in Montgomery County, Maryland and Norfolk, Virginia. In Montgomery County, CityCast assisted county DOT with redesigning bus services to and around a new commuter bus rapid transit service along US 29. In Norfolk, CityCast was used to assist Hampton Roads Transit with redesigning its complete bus network, including evaluating zone-based, last-mile microtransit (demand responsive minibus vehicles).

Other projects using CityCast include two applications in Atlanta, Georgia. There CityCast is being used to study the interaction of freight and residential traffic near the I-85 and I-285 interchange in a project sponsored by the local metropolitan planning organization (Atlanta Regional Commission) and the Georgia DOT. CityCast is also being used to help Cobb County develop its multimodal transportation plan, which the Atlanta Regional Commission uses as a foundation for its long-range regional planning activities.

Several other metropolitan planning organizations and municipalities across the US are evaluating CityCast for a variety of projects and applications.

Awards/Recognition

Grand Prize Winner at the Cameron Rian Hays Competition & Conference for Outside-the-Box Transportation Innovations (2013)

An IDEAL Cracking Test for Asphalt Mix Design, Quality Control, and Quality Assurance (Project #195)

Inventor/Investigator
Fujie Zhou
Texas Transportation Institute/Texas A&M University

IDEA Funding
$137,000

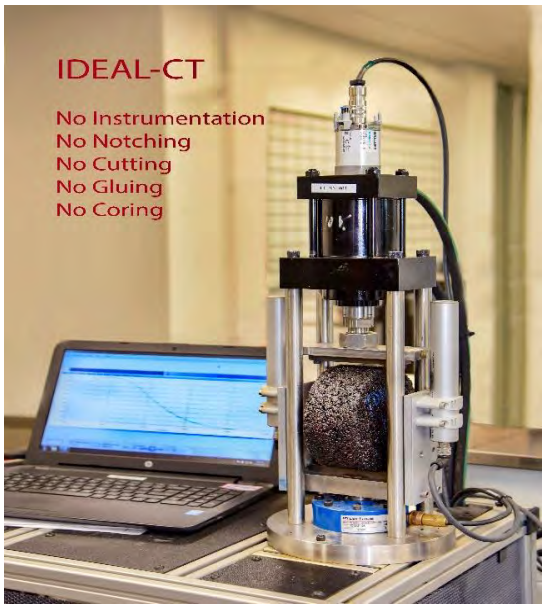
Project Completion
2019

An NCHRP Implementation Project 20-44 (16), involving the states of Kentucky, Maine, Minnesota, Oklahoma, and Texas, is supporting the implementation of this IDEA product.

Description

Product: A simple, repeatable, and performance-related asphalt cracking test (IDEAL-CT) for asphalt mixture quality

Premature cracking of asphalt pavements is a major issue for state DOTs, which can be traced to the use of poor quality asphalt mixtures. There is a need for a practical and reliable cracking test for routine use in the mix design, quality control (QC), and quality assurance (QA) testing of asphalt mixtures. Although various cracking tests have been developed over the years, none is simple enough for routine use, especially for QC/QA testing in the contractors' field laboratories. The IDEA-developed **in**direct t**e**nsile **a**spha**l**t **c**racking **t**est (IDEAL-CT) meets this need.



IDEAL-CT Set-Up

Benefits

In current practice, the cracking resistance of asphalt mixes is not directly evaluated and verified in the process of asphalt mix design and QC/QA testing, although cracking resistance is critical, especially for mixes with high contents of recycled materials. The IDEAL-CT not only fulfills the need of DOTs and asphalt contractors for a simple cracking test, it also enables direct evaluation of the cracking resistance of asphalt mixes in the routine mix design and QC/QA testing.

Compared to current practice, the IDEAL-CT offers the following advantages:

- Simplicity: no instrumentation, cutting, gluing, drilling, or notching required
- Practicality: minimum training needed for routine operation
- Efficiency: test completion within 1 minute
- Affordable test equipment: existing or low cost equipment (< $10,000)
- Repeatability: coefficient of variation less than 20%
- Sensitivity: sensitive to mix factors (recycled materials, aggregates, binder, aging, etc.)
- Good correlation with field cracking performance (validated with field test sections in Texas, LTPP-SPS10 in Oklahoma, and FHWA's Accelerated Loading Facility).

Application/Implementation

The IDEAL-CT was extensively evaluated by a number of research organizations and state DOTs, including Georgia, Kentucky, Minnesota, Maine, Missouri, Ohio, Oklahoma, Virginia, and Texas. To facilitate implementation, an NCHRP implementation project was awarded to the inventor to train DOT personnel on performing and interpreting the test through hands-on workshops, webinars, and training videos. Six states (Kentucky, Maine, Minnesota, Oklahoma, Texas, and Virginia) participated in this implementation project.

The states of Texas and Virginia have already adopted the test for state-wide implementation, and other states are expected to follow suit in near future. Some states intend to use the test for mix design while others for field QC/QA to ensure that good quality mixes are produced and paved on the road.

In 2019, the IDEAL-CT was adopted as an ASTM Standard:

ASTM D8225-19: *Standard Test Method for Determination of Cracking Tolerance Index of Asphalt Mixture Using the Indirect Tensile Cracking Test at Intermediate Temperature*

Awards/Recognition

The IDEA product was featured in the *Roads & Bridges* Magazine (March 2018) and most recently in the *World Highway*s Magazine (March 2019).

Vertical Impedance Scanner for Concrete Bridge Deck Assessment without Direct Rebar Attachment (Project #202)

Inventor/Investigators
Brian Mazzeo and W. Spencer Guthrie
Brigham Young University

IDEA Funding
$99,900

Project Completion
2019

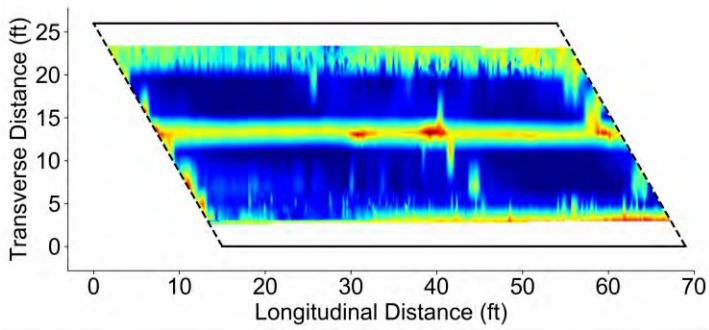
Description

Product: Bridge deck scanner for quantitatively evaluating the steel reinforcement cover protection

Bridge decks in marine areas and cold regions experience rapid and widespread steel corrosion due to the presence of elevated concentrations of salts that are naturally present in the marine environment or deliberately applied in cold regions for traffic safety. Since early intervention, before any concrete cracking could occur, is the most cost-efficient bridge deck management approach, a device for measuring the quality of protection offered to steel reinforcement on bridge decks is very helpful.

To address this need, a multi-channel vertical electrical impedance (VEI) scanner incorporating a large-area electrode (LAE) was developed. This hitch-mounted scanner can be easily transported to bridge decks and quickly deployed on site with minimal or no stationary traffic control. The LAE permits VEI scanning without the need for a direct electrical tap to steel reinforcement. Several previous studies indicate that a low VEI is correlated with compromised cover protection, as evidenced by higher chloride concentrations within the concrete compared to areas with higher VEI.

Vertical electrical impedance scanning



Vertical electrical impedance mapping

Benefits

The VEI scanner provides cost-effective, nondestructive evaluation of concrete bridge deck cover protection. The scanner can be used effectively on both bare and overlaid concrete bridge decks, enabling broad application of the technology. For project-level bridge deck investigations, the device permits mapping of spatial variations in VEI to effectively guide additional, more localized testing, such as chloride concentration determination. In conjunction with other such tests, the VEI scanner provides valuable data to help bridge managers in their decision making regarding preservation, rehabilitation, and replacement options available within their bridge management programs.

Application/Implementation

With support from Utah DOT and Nebraska DOR, the VEI scanner was extensively tested on multiple bare and overlaid concrete bridge decks in Utah and Nebraska in 2018. Field deployment demonstrated that multi-channel measurements could be performed in parallel and that implementation of the LAE successfully eliminated the need for a direct electrical tap to steel reinforcement. The system was able to scan bridge decks at rates exceeding 1500 ft^2/minute.

This technology is now licensed to Advanced Bridge Inspections, LLC, a bridge inspection company based in Pleasant Grove, Utah, for commercial evaluation of concrete bridge decks.

Promising NCHRP IDEA Products with High Implementation Potential

Some Examples

Duomorph Asphalt Rheology Tester (DART) (Projects #17, 41, 193)

Investigators/Inventors
Chetana Rao
Rao Research and Consulting, LLC.

Sam Carpenter and Jagannath Mallela
University of Illinois at Urbana-Champaign

IDEA Funding
$225,000

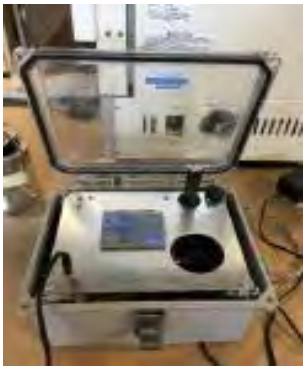
Project Completion
2017

Description

Product: A portable field device for testing rheological properties of asphalt binders for uniformity and consistency

The duomorph is a piezoelectric sensor that can be embedded in a viscoelastic material to determine its modulus and phase angle, the same data required for the Superpave binder grading. The duomorph asphalt rheology tester (DART) system comprises the following main components: (i) a circular piezoelectric bending duomorph sensor (referred to as the DART gage); (ii) an electronic subsystem to electrically actuate the DART gage, measure the resulting gage response, and store the response for further processing; and (iii) software to process the signal and determine the outputs of interest.

The maximum bending strain at the center of the DART gage when driven by an alternating current (AC) signal and the phase lag between the electrical drive signal and the resulting strain response form the basis of the testing and analysis. These parameters are measured at different frequencies both in air and an asphalt binder. The gage is immersed in the asphalt binder to measure its response in the material. The gage's strain and phase lag in the binder relative to its response in air serve as an indicator of the viscoelastic properties of the asphalt binder. Following the test protocol, the gage response data is collected and processed as the binder material cools from about 150ºF to 70°F.



DART electronic subsystem

DART gage embedded in asphalt

Benefits

The DART system can serve as an effective tool for process control of asphalt binders to enable larger sampling rates and faster binder testing in production facilities or district laboratories. It provides a means to verify binder uniformity or to check deviation of a field sample from a certified sample. Testing can be completed in as little as two and a half hours with minimal operator time or skills -- a significant advantage over the conventional AASHTO M 320 procedure. The system, in its current stage of development, can supplement the AASHTO M 320 PG specification testing.

The implementation of the DART device offers several benefits, including (i) simple and quick testing to detect deficiency in quality, (ii) lowered risk of accepting inferior materials by state DOTs/owners, (iii) reduced risk of premature pavement failure, (iv) lowered risk of litigation between suppliers, contractors, and owners, (v) cost savings for suppliers and owners resulting from higher sampling rates when using DART as a screening device, and (vi) generation of data previously unavailable to advance the understanding of the binder science.

Application/Implementation

The DART system addresses the paving industry's need to rapidly, conveniently, and cost-effectively monitor the uniformity and AASHTO M320 specification compliance of an asphalt binder at various points along its journey from the oil refinery to the asphalt mix production plant to the paving job site. It also offers a superior, rheology-based approach to optimize asphalt binder blending operations at a production facility typically performed to achieve the target performance grade.

Work on DART has involved working extensively with asphalt binder suppliers, producers and state DOTs to demonstrate its capabilities. However, while DART was applied on samples provided by highway agencies, actual implementation in practice still awaits. The research performed so far does make a case before all stakeholders to move forward with implementation, considering that the system has developed a standardized testing method for sample compliance checks at field and district laboratories, agency verification at hot-mix asphalt production plants, and consistency checks along the supply chain.

3-D-Centric Modeling for Integrated Design and Construction of Highway Bridges (Project #108)

Inventor/Investigator
Stuart S. Chen
University at Buffalo

IDEA Funding
$85,000

Completion
2006

An ongoing pooled fund study, TPF 5-372: Bridge Information Modeling for Bridges and Structures, involving 20 states and the FHWA has its origins in this early IDEA research on the BIM topic. This pooled fund study is aimed at developing a national standard for an open exchange of modeled bridge and structure data to be used from design to construction and fabrication.

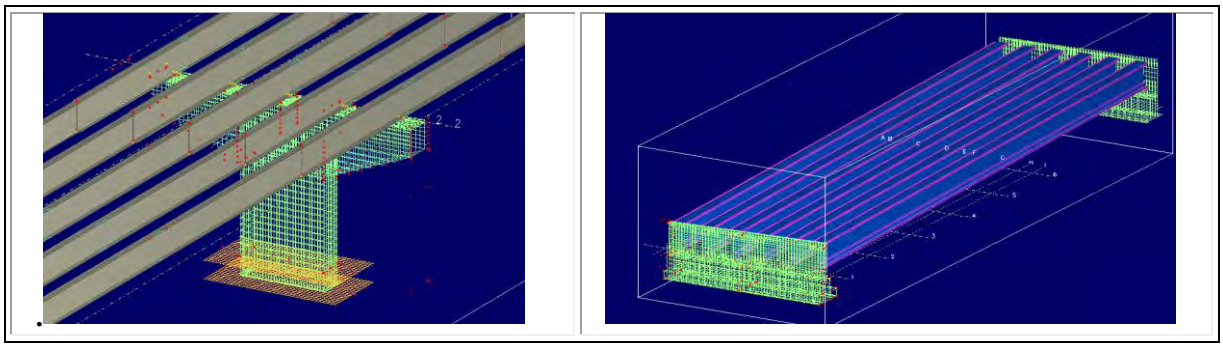
Description

Product: A 3-D-centric model for an integrated design and construction process for highway bridges

This IDEA work was the first study to develop a bridge information modeling (BIM) approach for integrated design and construction of highway bridges and structures. The 2-D drawing process for information transfer during bridge design/fabrication/construction process is inefficient and bogged down by repeated error-prone manual data transcription, time-consuming approvals (e.g., of shop drawings), and inadequate format standardization for electronic data interchange for information transfer. Better, faster, and more economical delivery of steel and concrete bridges requires a more complete integration of 3-D modeling, computer-aided design and engineering, and computer-integrated manufacturing. The key innovation here is that 3-D product models, unlike 2-D drawings, provide a single central repository for all shared project data. If something changes, it changes once in the central 3-D model, and the effects of that change are broadcast automatically to all affected stakeholders ((e.g., owner, designer, contractor, fabricator, detailer, precaster, erector, etc.) with access to that model information. All design and construction documentation is managed coherently under one umbrella. The product from this IDEA investigation is a workable BIM approach, with documented guidelines for a good 3-D-centric practice, to integrated design and construction for improved quality, faster delivery, and more economical bridges. On the next page are a couple of examples of bridge models generated using the BIM approach.

Benefits

The product of this IDEA research has the potential to change the way an entire industry does business. It helps avoid all the bridge design and construction problems associated with 2-D drawings and enables better, faster and economical delivery of steel and concrete bridges. From the single central 3-D model, current project information relevant to any given project stakeholder can be extracted at any given time. Potential cost savings include about 10-15% reduction in field rework, up to 14% reduction in overall project schedule, and up to 40% reduction in fabrication schedule.
http://enr.construction.com/news/buildings/archives /030414. asp



Portions of steel and concrete bridge models generated using BIM approach

Application/Implementation

A pre-stressed concrete bridge provided by Pennsylvania DOT was modeled parametrically in 3-D and evaluated to record lessons learned about how parametric 3-D modeling should be conducted for a real bridge design and construction project. To fully transfer the product application to highway practice, commercial-scale bridge-friendly parametric 3-D-capable software, bridge owners supportive of streamlined business practices, and stakeholders migrating toward 3-D-centric collaborative ways of doing business are necessary. All this seems to be cultivated via a resolution passed by the AASHTO Bridge Committee acknowledging the importance of, and charging one of its technical committees with, coordinating comprehensive integrated bridge project delivery through automation along with the involvement and support of the FHWA and software developers and trial deployment using actual bridge replacement projects.

Interest in BIM has continued to grow since the 3-D model approach was developed in this IDEA research, and state DOTs have come to realize its benefits. In 2017, a pooled fund study, TPF- 5(372): *Bridge Information Modeling for Bridges and Structures*, involving 20 states and the FHWA was initiated with the objective to develop a national standard for an open exchange of modeled bridge and structure data to be used for design to construction and fabrication, with the ultimate goal of updating and using the data throughout the life of the structure. States participating in this study are: California, Delaware, Florida, Georgia, Illinois, Iowa, Kansas, Michigan, Minnesota, Mississippi, North Carolina, New Jersey, New York, Ohio, Oklahoma, Pennsylvania, Texas, Utah, Vermont, and Wisconsin, with Iowa as the lead state. This $1.9 million study, for which HDR Engineering, Inc. is the prime contractor, is scheduled to be completed in 2023 and is expected to play a major role in implementing BIM in the design and construction of bridges.

Asphalt Embrittlement Analyzer (Projects #144, 170)

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

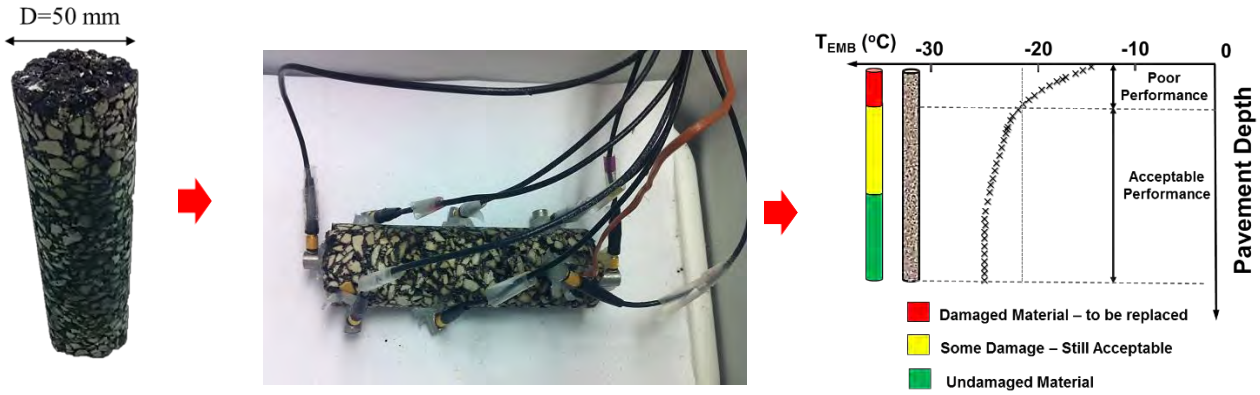
IDEA Funding
$260,000

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 provides highway agencies and pavement evaluation/materials testing laboratories/companies a new tool to help 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, and 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. For lower-volume roadways, airfields, and parking facilities, these maintenance treatments include those 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 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 crack resistance of a pavement surface.

Application/Implementation

The applicability of the AEA was demonstrated across a number of projects. 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. Road Science, LLC. provided access to field-cored materials from asphalt pavements across the U.S. through its National Science Foundation-sponsored collaboration with the University of Illinois at Urbana-Champaign (UIUC). Research conducted at UIUC for the Illinois Tollway featured the AEA in the analysis of field-procured cores from ground tire rubber modified, stone mastic asphalt mixtures. The AEA was also prominently featured in a project co-sponsored by the Missouri DOT and the Midwest Transportation Center, funded through the University Transportation Center program of the US DOT and conducted at the Mizzou Asphalt Pavement and Innovation Laboratory. In this project, the AEA was used to develop and validate advanced cracking tests for the design and control of cracking in modern, recycled asphalt pavements. These modern mixes included varying combinations of reclaimed asphalt pavement, ground tire rubber, reclaimed asphalt shingles, warm-mix asphalt, and rejuvenators.

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

Inventors/Investigators
Jamie Padgett and Emily McCarthy
Rice University

Reginald DesRoches
Georgia Institute of Technology

Paul Bradford
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 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 re-centering and energy dissipating characteristics (which improve a bridge's 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 the existing desirable service load behavior of the commonly-installed joint but can accommodate significant increases in longitudinal displacement under dynamic loads while limiting internal load transfer, which would otherwise lead to the 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. The commercialization of the joint technology requires further refinement and evaluation. Further work was carried out through a joint program supported by 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.

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

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

IDEA Funding
$267,000

Project Completion
2014

Two successive pooled-fund studies, TPF 5-278 (involving the states of Kansas, New York, Oklahoma, Ohio, and Pennsylvania) and TFP 5-364 (involving the states of Kansas, New York, New Mexico, Maryland, Ohio and Oklahoma) supported further development and implementation of this IDEA product.

Description

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

The sampling and laser targeting (SLT) system can be used as a stand-alone unit in a materials laboratory 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 (SLT) 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 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.

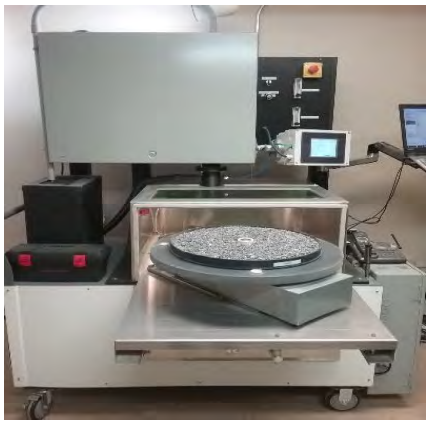
Benefits

For many decades, aggregate users have relied on laboratory-based test methods and specifications compiled by the AASHTO, the ASTM, or the local agencies to define the acceptable quality of aggregates for use in highway construction. Almost all these test methods and their corresponding criteria are empirical in nature and based on studies undertaken over the years defining correlations between 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 are required 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 laser scanning methodology can achieve results within seconds or minutes, providing quality control in real time during aggregate processing or production. It requires no sample preparation, and one laser scan can characterize multiple aggregate quality parameters simultaneously, eliminating the need for multiple tests on each source. It can be used for real-time quality control during aggregate quarrying or during concrete or asphalt mix production to ensure that aggregate quality meets the required specifications.

Application/Implementation

Work on the evaluation and implementation of the IDEA product has progressed through two successive pooled-fund studies, TPF 5-278 involving the states of Kansas, New York, Oklahoma, Ohio, and Pennsylvania and TFP 5-364 involving the states of Kansas, New York, New Mexico, Maryland, Ohio and Oklahoma, with Kansas as the lead state in both studies. In the first pooled-fund study, a total of 113 aggregates supplied by the participating states were laser-scanned using a field prototype system located in a field materials testing laboratory in South Bethlehem, New York. The results showed that laser scanning can successfully predict aggregate properties. Aggregate analysis using laser scanning continues in the second pooled fund study using a scaled-up field prototype. If results of this study are successful, installation of the laser scanning system will be considered in selected state laboratories.



Scaled-up laser scanning prototype

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

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

IDEA Funding
$100,000

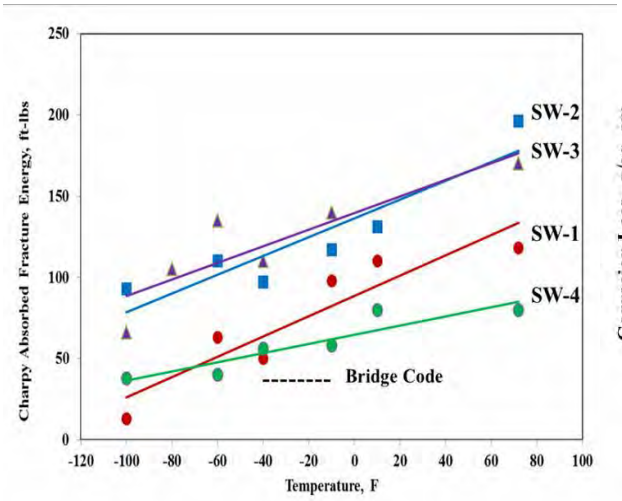
Project Completion
2014

Description

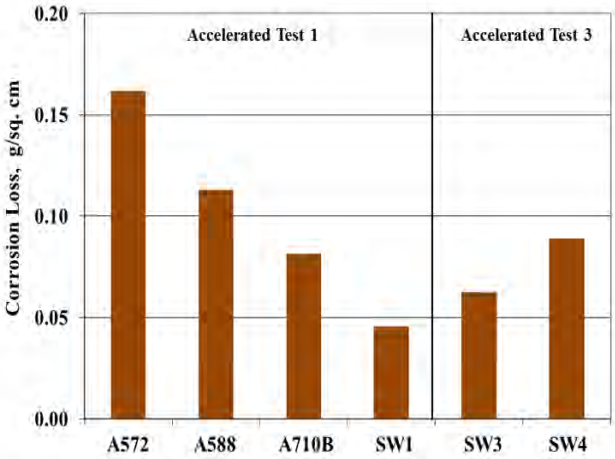
Product: New steels with weathering characteristics superior to weathering steels currently used for bridge construction

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 any special processing or thermal treatment; therefore, any steel manufacturer can produce these steels in any steel-plate size.

Four steels were designed and tested. These new 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.

Also, 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, state DOTs and the FHWA. 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

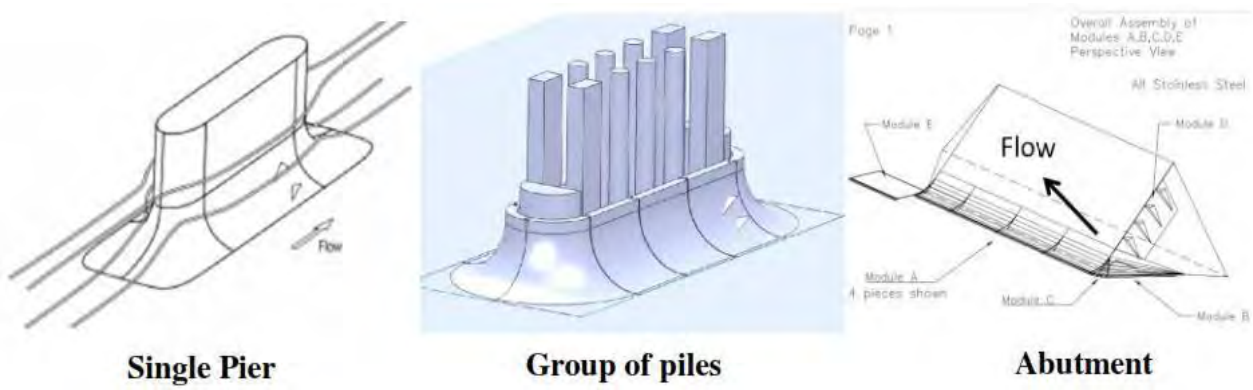
IDEA Funding
$140,000

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 (i) 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 (ii) 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 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 water moves faster around the bridge for any water level or turbulence level).

The scAUR with VorGAUR designs also prevent debris accumulation and protect 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 reducing the downwash from these vortices, and prevent scour on the river bed.

Soil and rocks around 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 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 showed interest in installing the prototype products on the westbound bridge on US Route 360 over the Appomattox River, but this is yet to materialize. Discussion with several other state DOTs and railroads for implementation were also conducted but no further progress occurred. The website www.noscour.com provides more details.

Bio-Asphalt from Swine Manure and Crumb Rubber for Highway Construction (Project #171)

Inventor/Investigator
Elham Fini
North Carolina A&T State University

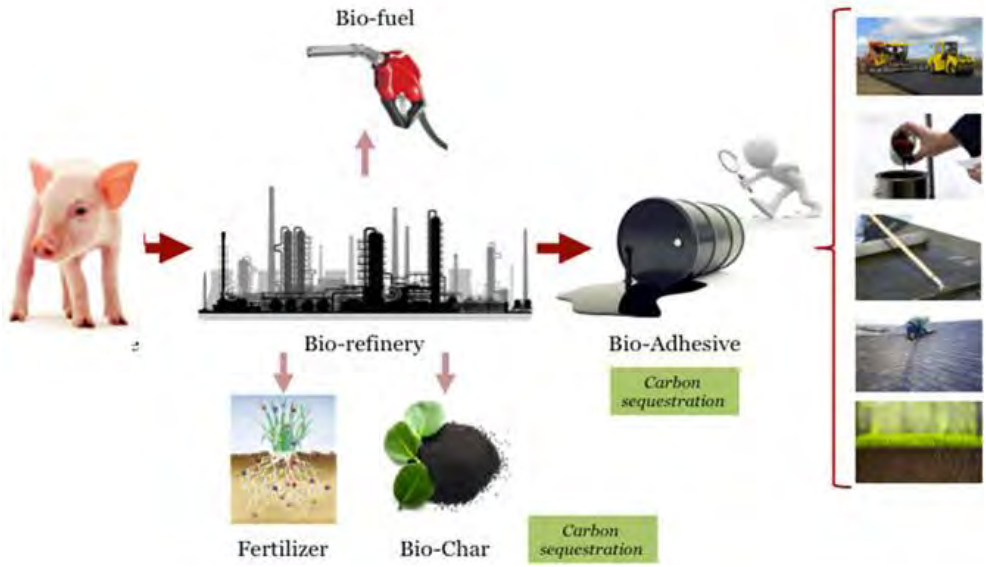
IDEA Funding
$125,000

Project Completion
2016

Description

Product: A bio-adhesive derived from swine manure as an alternative to petroleum-based asphalt product for use in highway construction.

Crumb rubber modified (CRM) asphalt exhibits superior performance in terms of enhanced durability, service life, and reduced noise in paving applications. However, high rubber content in CRM asphalt is problematic due to low workability, rubber-asphalt separation as well as concerns about CRM asphalt's low temperature performance. To alleviate asphalt-rubber segregation and low workability issues, continuous agitation and higher mixing and compaction temperature are employed, which increase the construction cost of rubberized asphalt and also expose the resulting asphalt binder to more oxidative aging due to high mixing and application temperatures (180ºC for rubberized asphalt compared to 150ºC for conventional asphalt). The bio-modifier, produced from the thermochemical liquefaction of swine manure, enhances rubber-asphalt interaction that helps reduce segregation and allows using lower mixing and compaction temperatures. The amide functional groups in the bio-modifier activate the rubber surface to increase this rubber-asphalt interaction.



Bio-refinery and added value products from swine manure

Benefits

The bio-modifier helps produce a better quality rubberized asphalt economically for highway construction. The product also helps address the problem of disposing discarded scrap tires and the swine manure waste.

The price of liquid asphalt has increased dramatically within the last decade, from $250 per ton in 2004 to $550 per ton in 2019. Refineries are decreasing asphalt production (from 3.2% of crude oil to less than 2%) by converting their asphalt binder into synthetic fuel using coking technology, resulting in a shortage of asphalt binder and an increase in its price. In this scenario, the bio-modified rubber (BMR) asphalt offers the benefits of lower cost, lower volatile organic content, and higher durability. The BMR asphalt also allows the use of an increased amount of recycled asphalt pavement (RAP). Activated rubber surface in BMR asphalt enables better interaction with the asphalt matrix, including the oxidized asphalt in RAP, that not only reduces asphalt-rubber segregation but also facilitates higher RAP application.

Bio-binder also helps with the disposal of swine manure -- a major environmental and economic problem. An estimated 40.2 million tons of swine manure are produced annually in the U.S., of which more than 90% is stored in lagoons, resulting in serious health and environmental problems. Associated with storage and land application of manure are the possibilities of the outbreak of diseases in livestock and people via bacteria and pathogens. Current manure management practice also raises concerns about surface water and groundwater quality as well as air quality, as affected by odors and gaseous emissions from large-scale swine production operations. Furthermore, excess nutrients in water lead to algal blooms, which results in the depletion of the available oxygen in water, adversely affecting fish life. Scrap tires is another important environmental problem where bio-binder from swine manure is useful. An estimated 3.9 million tons of discarded tire are available annually in the U.S., much of which ends up in landfills. Application of bio-modifier will allow consumption of about 40.2 million tons of swine manure and 3.9 million tons of scrap tires in the U.S. to produce about 32 million tons of BMR asphalt for pavement construction

Application/Implementation

The next step towards implementation and commercialization is to further optimize and scale-up the bio-binder production to enable field evaluation of the BMR asphalt. The scaled-up production cost of the bio-adhesive is estimated to be about $0.54/gallon (in comparison, the cost of asphalt is about $2/gallon), making it an economically viable asphalt modifier. The cost of BMR asphalt is estimated to be around $25/ton as compared to $50/ton for petroleum-based asphalt.

The research team has made contacts with small and large businesses specializing in asphalt binders and paving mixtures. These include Dewitt Products Company, Seaboard Asphalt, Inc., Pavement Technologies International Corporation, PRI Asphalt Technologies, Inc., and Crafco, Inc. The research results have also been shared with several state DOTs that include Connecticut, Missouri, Massachusetts, New Hampshire, New Jersey, New York, North Carolina, and Rhode Island. Furthermore, Smithfield Food Company, a major swine producer in the U.S., has expressed interest in scaled-up production of bio-asphalt.

Awards/Recognition

The IDEA inventor received the **Lemelson Invention Ambassador Award** for 2017-18 from the American Association for the Advancement of Science (AAAS) for her bio-adhesive innovation. She was one of 8 individuals selected in 2017 by the AAAS whose innovative work was judged to be important in "bettering our quality of life and building strong economies."

Buckling-Restrained Braces for Resilient Seismic-Resistant Bridges (Projects #172 and 215)

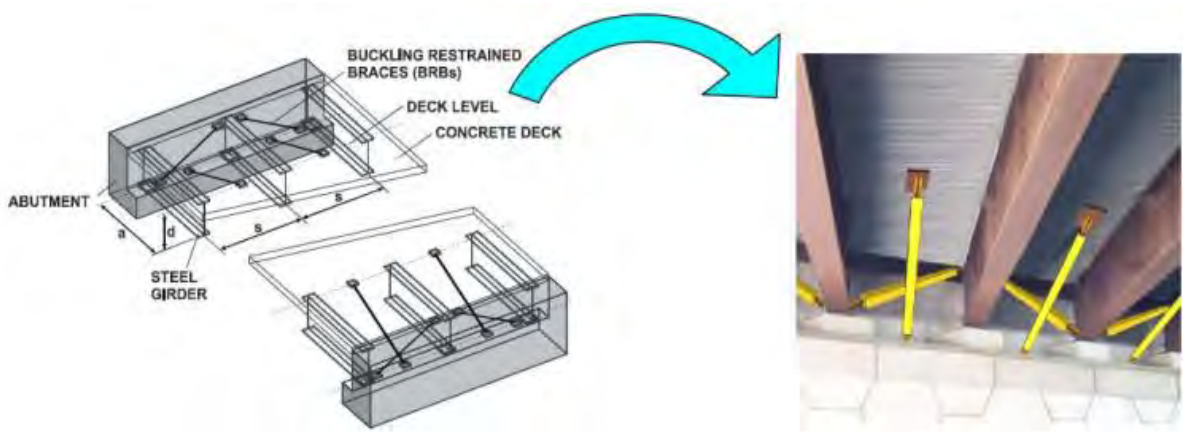
Inventor/Investigator
Michel Bruneau
University at Buffalo

IDEA Funding
$234,997

Project Completion
Active

Description
Product: A bidirectional ductile diaphragms design using buckling-restrained braces for bridges providing improved resistance to bi-directional earthquake excitations and preventing damage to the bridge super- and substructure.

The term "bidirectional ductile diaphragms" is used to emphasize that energy dissipation is achieved at the ends of the spans of the superstructure – in this case, using buckling-restrained braces (BRBs). This innovative approach can be implemented in both concrete and steel bridges. BRBs with stable and high energy dissipation capacity for seismic applications have been implemented in buildings for over 15 years.



Bidirectional ductile diaphragm Concept with BRBs in transverse and longitudinal directions (girders can be steel or concrete)

In a multi-span bridge, BRBs connect floating spans to the abutments and bent caps (in another option, the longitudinal BRBs tie spans together, instead). Connections to the span itself can be to the girders or the underside of the deck.

To make the bidirectional diaphragm concept applicable to multi-span bridges, two issues need to be resolved. First, an analytical understanding must be developed of the behavior of multi-span bridges with simply-supported spans and the BRBs tying the spans to each other or to the column bents, and the findings

must be formulated into a simple design procedure applicable to general multi-span bridges. Second, the BRBs and their end connections must be shown capable of providing their expected ductile behavior while subjected to full 3-D end displacements that are unique to this type of implementation.

Benefits

Current state of practice in seismic design of common multi-span bridges relies on either plastic hinging of columns to dissipate earthquake energy or base isolation. The first approach implies damage to the gravity-carrying columns while the second requires bearings and expansion joints to accommodate displacements that can be extremely large in many cases and also a special design procedure (and sometimes design peer review by other engineers). Application of the bidirectional ductile diaphragm concept with inexpensive BRBs can provide, at low cost, resilient bridges with damage-free columns while minimizing displacement demands to levels that can be easily accommodated.

Application/Implementation

The products of this IDEA work are design guidelines and examples, provided in a language ready for implementation by the state DOTs. Design engineers and consultants are the primary audience. Adoption as a design document would significantly overcome potential impediments to deployment. Towards that goal, the IDEA researcher is working with the California DOT's Structural Steel Committee to inform various design and detailing decisions during the course of this project and to ensure that the knowledge generated is readily implementable by the California and other DOTs.

California DOT is collaborating on this IDEA project and, if proven viable through experimentation and demonstration, will consider implementation of the IDEA product.

Graphene Nano-Platelet (GNP)-Reinforced Asphalt Mixtures ((Project #173)

Inventor/Investigator
Jia-Liang Le
University of Minnesota

IDEA Funding
$119,945

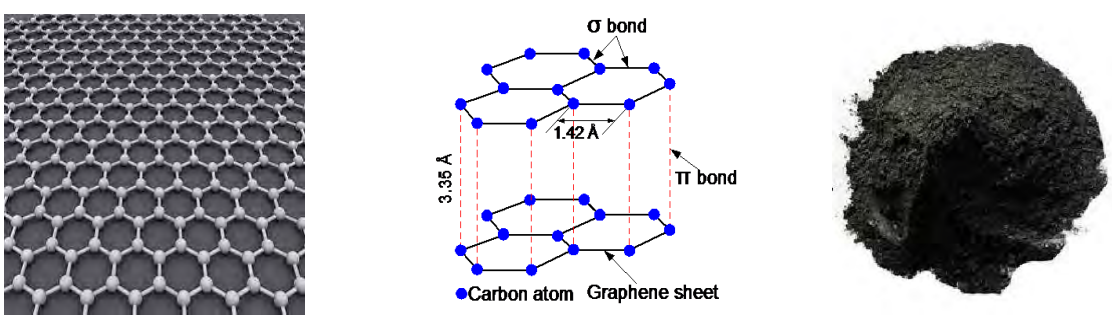
Project Completion
2015

Description

Product: Graphene nanoplatelet (GNP) reinforced asphalt binders and mixtures with superior mechanical and compaction properties.

In recent years, there has been an emerging interest in applying nanotechnology to asphalt pavement materials to potentially improve the sustainability and resilience of the asphalt pavement. A nanoparticle is generally defined as a particle with its least dimension less than 100 nanometers. This IDEA research explored the application of graphene nanoplatelet (GNP) particles to asphalt binders and mixtures.

GNP is made from exfoliated graphene and consists of stacks of graphene sheets that can be characterized as nano-discs with a diameter of sub-micrometer and a thickness on the order of a nanometer. A graphene sheet is a single layer of carbon atoms with a hexagonal arrangement. Graphene material exhibits superior mechanical and electron transport properties. For example, the stiffness of graphene is on the order of 1 TPa, the strength approximately 100 times that of steel, and the electrical conductivity higher than that of copper. Graphene also has an exceptional thermal stability up to at least 2600 K. The aspect ratio of GNP is significantly lower than that of carbon nanotube (CNT), which makes it easier to disperse. Furthermore, since GNP also has a lubricant effect, it is expected to help enhance the compaction process of asphalt mixtures.



Graphene nanoplatelet (GNP) -- graphene sheet (left); atomic structure of GNP (center); as received GNP materials (right)

Benefits

GNP-reinforced asphalt binders and mixtures have the potential for increasing the durability of asphalt

pavements in cold regions by improving the low-temperature strength and fracture properties of asphalt materials. Addition of GNPs has been shown to lead to considerable improvements in low-temperature strength and fracture properties of asphalt binders and mixtures. While the properties of asphalt binders at intermediate temperatures are minimally affected, for some combinations of binders and GNPs, the increase in low-temperature strength is more than 100%. Similarly, for some of the asphalt mixtures tested, the low-temperature asphalt fracture energy was found to almost double as compared to mixtures without the GNPs. Laboratory compaction experiments showed that, by adding a small percentage of GNPs to asphalt binders, the number of gyrations needed to achieve a target density was reduced by as much as 20-30%.

The cost of GNP materials depends on its type and carbon purity. For large-scale applications, the material cost can be as low as $3-$4 per lb., which is significantly lower than that of the multi-wall CNTs. The material cost of GNPs is comparable to some existing asphalt modifiers, such as the styrene butadiene styrene.

Application/Implementation

The Minnesota DOT has continued to support further work on the development and implementation of the GNP-reinforced asphalt binders and mixtures through several projects. One of those projects focused on the pothole repair while another developed a computational model of this new type of asphalt materials to facilitate the mix design. Another ongoing project explores the damage sensing and healing capabilities of GNP-reinforced asphalt materials. Through these projects, a comprehensive investigation of the multi-functionality of the material is being accomplished with very promising laboratory results so far. The next step is to perform field experiments at the MnRoad research facility in collaboration with Minnesota DOT. Upon satisfactory field results, the materials will be promoted with assistance from Minnesota DOT for use by county engineers and asphalt material producers.

Renewable Biopolymers – An Alternative for Petroleum-Based Polymers for Asphalt Pavement (Project 178)

Inventor/Investigator
R. Christopher Williams and Eric W. Cochran
Iowa State University

IDEA Funding
$124,999

Project Completion
2018

Description

Product: Bio-renewable polymers produced from soybean oil for use in asphalt pavements

Considering the economic uncertainty and environmental concerns with traditional petroleum-derived polymers, there is a justifiable need for developing sustainable alternatives to potentially replace petroleum-derived polymers for use in asphalt pavements. The biopolymer developed in this IDEA research was produced from non-food soybean oil through chemical polymerization. The biopolymer modified asphalt binder showed positive stiffening behavior and improved elasticity in comparison to the neat asphalt binder. The biopolymer was demonstrated to be an effective alternative to its commercially available counterparts in modifying asphalt at the same dosage level.

Bio-renewable polymer (*left*) and construction of biopolymer NCAT test track (*right*)

Benefits

The production of the biopolymer proved the feasibility of using non-food source soybean oil as a bio-feedstock to produce polymers. The cost comparisons indicated that the biopolymer would be able to save about $2800 per lane mile in the hot mix asphalt (HMA) than its commercial counterparts. The polymer can be used at the same dosage level with similar or better positive modification effects (such as cost-

effective, environmentally-friendly, and improved sustainability) than petroleum-derived polymers. More importantly, the biopolymer could be produced in a biopolymer pilot plant in large enough quantities for paving demonstration trials.

Application/Implementation

The industry partner, Seneca Petroleum, has set up a pilot plant in Boone, Iowa for large-scale production of the biopolymer for field trials. The plant was able to produce more than 600 gallons of the biopolymer for paving a National Center for Asphalt Technology (NCAT) Test Track section in 2018, with support from the United Soybean Board and Seneca Petroleum. The plant production of the biopolymer demonstrated that the biopolymer polymerization reaction could be scaled up from laboratory to pilot plant scale. The successful biopolymer asphalt mixture paving construction also proved the feasibility of implementing the biopolymer into existing HMA construction practice.

A demonstration paving project is scheduled and will be constructed in Iowa in near future to further evaluate the performance of the biopolymer-modified asphalt binder in HMA mixtures under real environmental and traffic conditions. Additional paving projects will be done in coordination with owner agencies such as Iowa DOT and other regional transportation agencies. The biopolymer formulation will be continuously reviewed and implemented to meet performance requirements for different climate and traffic conditions to help transportation agencies benefit from a sustainable, cost-effective, and environmentally-friendly polymer-modified asphalt binder.

Commercial scale biopolymer pilot plant in Boone, Iowa

Use of Biochar to Reduce Stormwater Runoff and Pollutant Loading for Highway Greenways (Projects #182, #211)

Inventors/Investigators
Paul Imhoff
University of Delaware

Chuck Hegberg
reGENESIS Consulting Services, LLC., Hanover, Pennsylvania

IDEA Funding
$229,665

Project Completion
2020

Description

Product: Use of biochar to amend highway greenway soils to help reduce stormwater flow and pollutants reaching nearby waterways

Stormwater discharge from roadways collects and carries pollutants to waterways and is expensive to control for state DOTs. For example, for Maryland State Highway Administration, costs are projected to exceed $720 million by 2020 to achieve nutrient removal standards using traditional technologies. The addition of biochar to highway greenways has the potential to dramatically increase pollutant removal efficiency while simultaneously reduce stormwater volume and avoid adding new infrastructure. The process involves mixing wood-derived biochar into the top 30 cm (about 12 inches) of soil along highways during construction or maintenance operations.

Application of biochar to a roadway soil along Delaware 896 in New Castle County, Delaware

Benefits

Rather than capturing roadway stormwater for treatment in new treatment systems, "enhancing" existing roadway greenways (filter strips and swales) by amending the top 30 cm of soil with a wood-derived biochar, provides stormwater treatment without the cost of new infrastructure or purchase of additional right-of-way.

As part of construction, a typical highway has final sections that are a mix of cut (subsoil) and fill (compacted soils) generally with compaction readings greater than 93% and a thin layer of a few inches of topsoil stabilized by the application of fertilizer and grass seed. This condition obviously does not create a "natural" soil. As studies have shown, such conditions actually result in high volumes of stormwater runoff with minimal water quality treatment as well as poor water retention and infiltration.

Biochar, produced by the pyrolysis of waste biomass, when added to roadway soils can reduce nutrients and stormwater quantity by promoting greater infiltration and water retention in soil. These are critical benefits, since holding nutrient-laden water in the soil zone provides time for evapotranspiration and biological processes that consume nutrients. The result is significant decreases in runoff volume and nutrient loads to nearby surface waters.

Application/Implementation

A roadway soil along Delaware 896, a four-lane divided highway, was amended with 4% wood-derived biochar by weight to 30-cm depth, with support from the National Fish and Wildlife Foundation and the Delaware DOT. For 84 storm events over 18 months, the average reduction of stormwater runoff volume and peak flow rate because of biochar amendment was 88% and 84%, respectively. In comparison, tillage alone without biochar amendment reduced stormwater runoff volume by an average of 66% and peak runoff flow rate by 59%. Thus, biochar amendment increased the ability of the tilled roadway soil to reduce stormwater runoff volume and peak flow rate by about 40% at this site. The estimated design and construction cost was $31,700 per impervious acre, much less costly than almost any other best management practice (BMP) while utilizing only 0.12 acre to treat 1-acre impervious. A cost analysis comparing biochar-amendment to 23 BMPs showed the biochar to be less expensive than 20 other BMPs – up to about 10 times less.

Based on the promising findings from this IDEA study, California, Delaware, Maryland, and North Carolina DOTs are evaluating biochar amendment to typical roadway soils in their jurisdictions to determine if biochar amendment will show similar performance for other soils and at other geographical locations.

In 2019, Howard EcoWorks, Inc. applied biochar amendment to soils adjacent to paved surfaces to increase stormwater infiltration in the flood-prone Ellicott City watershed in Maryland. The Maryland Transportation Authority plans to install biochar in soils adjacent to Interstate 95 in 2020.

Awards/Recognition

To date, invited articles describing this project were published in ASCE *Civil Engineering*, January 2018, and ASCE Geo Institute's *Geostrata*, September/October 2018.

The project was the focus of a workshop "Biochar Opportunities in Stormwater Management" held at the US Biochar Initiative's Biochar 2018 Meeting (> 350 attendees) in August, 2018.

The project was also the subject of one of three invited plenary presentations at the Biochar Symposium 2019 held at the National Chiao Tung University, Taiwan, in May, 2019.

An RFID Scour Detection System (Project #183)

Inventor/Investigator
Thanos Papanicolaou
University of Tennessee

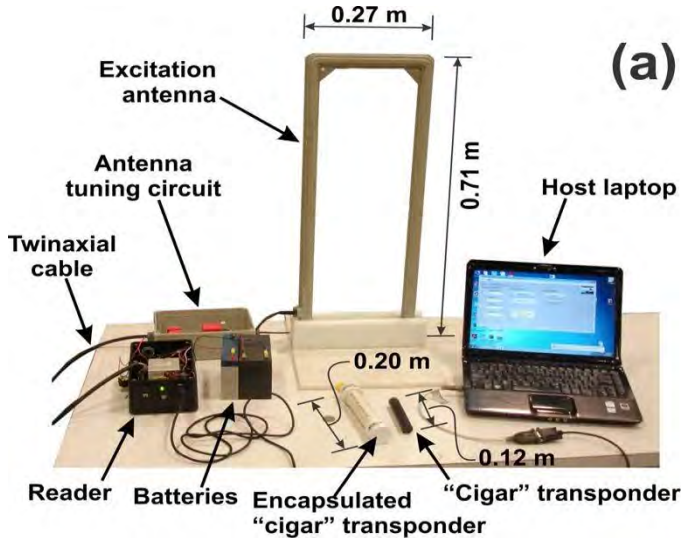
Funding
$99,998

Completion
2019

Description

Product: A Radio Frequency Identification (RFID) Scour Detection System (RSDS) to monitor scour autonomously, continuously, and remotely at bridge piers and abutments.

The RFID technology uses radio waves for non-line-of-sight transfer of information between a base station (i.e., a reader) and sensors (i.e., transponders or tags) through an antenna. Low frequency radio waves can pass through water columns and saturated sediment, making them well-suited for stream scour investigations. Building on this technology, an easy-to-use scour detection system was developed that provided unmanned, real-time 3-D measurements of scour evolution to help assess a hydraulic structure's stability. The development involved enhancing the existing RFID technology to improve its applicability to measuring scour in bridge piers and abutments. The enhancements included (i) adding integrated circuits and inclinometers to improve accuracy and detectability when buried, (ii) adding a wake-up function to provide anti-collision features, (iii) developing triangulation functionality to identify x, y, and z coordinates, and (iv) enabling remote interaction with network capabilities. The developed system provides reliable and repeatable 3-D scour data for both clear water and live-bed scour conditions and was verified through laboratory and field applications.



The RFID scour detection system (RSDS). The system includes a remote base station (i.e., a reader) that communicates with buried sensors (i.e., transponders or tags) through an antenna

Benefits

Excessive scour can expose the foundation of a bridge and compromise its stability. Although the FHWA has identified more than 150,000 bridges in the U.S. vulnerable to scour, it requires assessment of the scour condition of a bridge only on a biannual basis, presumably due to financial and labor constraints.

The developed RSDS provides continuous, real-time measurements to capture modifications to bed shear stress as the scour hole evolves and the resultant effect on the growth rate and the extent of the scour hole. The capability of the RSDS to automate scour data collection and transmission eliminates the need for on-site surveys, which sometimes may have to be done under hazardous conditions (such as floods), thus ensuring personnel safety. It also improves a manager's insight and decision-making by facilitating a shift to condition-based management that helps save costs through timely detection and repair.

Applications/Implementation

For testing the RSDS in the field, two locations were explored -- the Clear Creek site in Iowa (a sand bed river draining 270 km^2 of mostly agricultural land) and the Third Creek site in Tennessee (a gravel bed system draining only 7.5 km^2 of mostly urban areas). During testing, only the Clear Creek site experienced measureable scour. The RSDS measurements estimated a 7.6-cm scour depth which compared well with the physical measurements.

The states of Iowa, Tennessee, and Washington have shown interest in exploring and implementing the RSDS technology for measuring scour depth in bridge infrastructure. The Hungry Canyon Alliance and the Golden Hill RC&D in western Iowa are interested in using the RFID technology for monitoring knickpoint advance, which threatens the bridge infrastructure of the local roads in the region. The Washington State DOT is interested in applying the technology to monitor the effectiveness of the Engineered Log Jams, which it implemented for river bank stabilization (for example, along the Skajit River). Efforts to increase awareness of the developed technology continue.

CurvePortal for Automated Identification and Extraction of Horizontal Curve Information (Project #185)

Inventors/Investigators
David Noyce, Madhav Chitturi, and Andrea R. Bill
University of Wisconsin-Madison

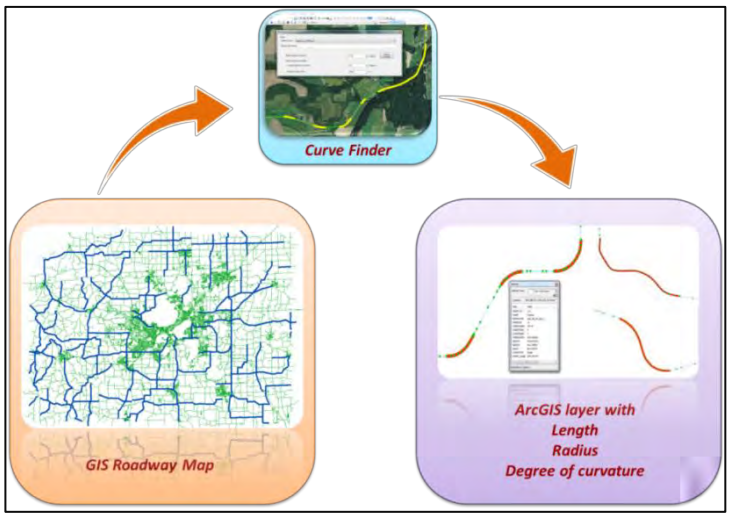
IDEA Funding
$ 100,000

Project Completion
2019

Description

Product: CurvePortal, a web interface for automatic extracting horizontal curve location and geometric information from GIS roadway maps and providing curve data in GIS format for easy integration with existing asset management, roadway inventory, and crash data sets.

Building on their extensive experience with geographic information systems (GIS), data integration, and safety analysis, the IDEA researchers developed CurveFinder, a tool to extract horizontal curve location and geometric information automatically from GIS roadway maps. This IDEA project improved the CurveFinder algorithm to address accuracy issues with low-quality GIS maps and developed a prototype of CurvePortal, which is a web interface for extracting horizontal curve location and geometric information automatically from GIS roadway maps. In addition, the ability to extract curve-related Model Inventory of Roadway Elements (MIRE) was also incorporated into the algorithm.



CurveFinder concept

CurveFinder preparation, calibration, and run for production of final results were streamlined into a five-step process within an ArcMap toolbox containing models which reference internally managed python scripts. This is an improvement over previous approaches as it creates an easy-to-follow process with

reduced need for user documentation to obtain reproducible results. In addition, to improve the accuracy of the CurveFinder for low-quality GIS datasets, two smoothing methods were used to pre-process the data before applying the CurveFinder algorithm. Calibration was performed within desktop GIS software by an iterative process. A total of 231output curve versions were created during this step to identify optimal parameters for the CurveFinder. The application of the pre-processing and calibration steps resulted in a better identification of the curves' start and end points, as demonstrated by the increased coverage of identified curves as compared to ground truth curves.

CurvePortal, is hosted at www.curveportal.cee.wisc.edu. It serves as an intuitive web interface by which users can upload spatial road features as well as optionally define an attribute field on which distinct road segments of a given roadway can be joined. This is commonly the road name or other identifier unique to a route. Additionally, the interface offers the option to upload ground truth features that can be used for calibration and identification of optimal algorithm parameters prior to the final curve identification step.

Benefits

The most significant impact of this innovation is its ability to obtain highway horizontal curve data using existing resources at a minimum cost. Horizontal curves have long been recognized as one of the critical locations with regard to roadway departure crashes. The FHWA reports that horizontal alignment contributes to 76% of single-vehicle run-off-road (ROR) crashes in the U.S., based on the 2007 Fatality Analysis Reporting System data. Previous research also indicated that crash rates on horizontal curves were 1.5 to 4 times higher than those on roadway tangents. A typical safety countermeasure to prevent roadway departure crashes from occurring in horizontal curves is to install warning signs in advance of the curves. The 2009 *Manual on Uniform Traffic Control Devices* (*MUTCD*) mandates horizontal alignment warning signs with advisory speed on roadways with a total daily traffic volume of more than 1,000. In practice, some locations of high crash rates or severe crash levels lack appropriate curve warning signs or the signs are not placed at a proper location. Knowing the locations and geometric characteristics of the curves is essential for improving the curve safety. Many states do not have curve data for non-state trunk roads. Considering that horizontal curves are the major contributing factor to ROR crashes on rural county and local roads, having a horizontal curve database is essential to reach the 'Towards Zero Deaths' goal adopted by the AASHTO. Therefore, a complete set of horizontal curve data for all roadways, including state trunk roads, county roads, local roads, and even unpaved or gravel roads, should benefit the state and local transportation agencies for performing crash analysis, recommending safety treatments, and meeting the *MUTCD* mandate.

Application/Implementation

CurvePortal (www.curveportal.cee.wisc.edu) is hosted on WisTransPortal, an online transportation data portal at the University of Wisconsin–Madison. It is accessible to transportation agencies to upload their GIS roadway map shapefiles to extract the horizontal curve data. Iowa and Wisconsin DOTs used CurveFinder in the past. The research team has reached out to several other state DOTs (e.g., Delaware, Indiana, Michigan, Minnesota, New Jersey, Washington, etc.) across the U.S. for using CurvePortal. Contractual negotiations have been conducted with Indiana Local Technical Assistance Program (LTAP) for using CurvePortal to extract curve information for all local roads in the state.

An Electrical Probe for Rapid Assessment of Ground Improvement (Project #186)

Inventor/Investigator
Mike A. Mooney
Colorado School of Mines

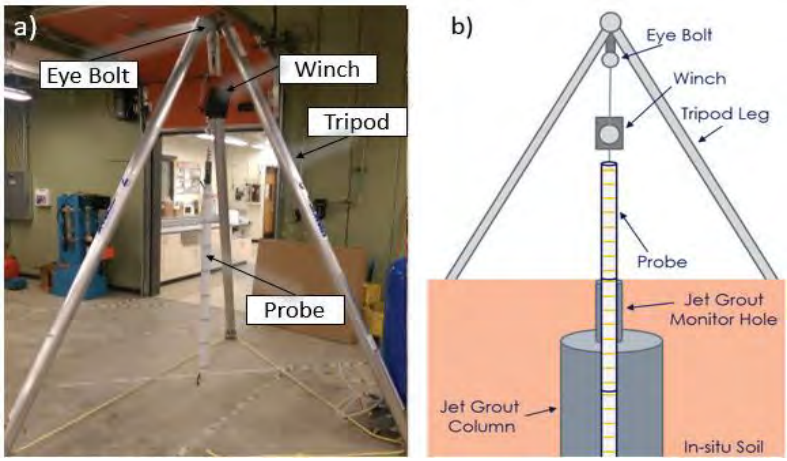
IDEA Funding
$86,517

Project Completion
2018

Description

Product: A jet grout push probe for rapid assessment of jet grout column diameter

Through a combination of finite element modeling, prototype development, and field testing, this IDEA research developed an electrical probe to assess the diameter of freshly mixed jet grout columns. The probe is inserted into a freshly jet grouted column immediately after removing the jet grout monitor. The test requires 20-30 minutes to collect sufficient data to estimate column diameter. The scientific principle of the device is electrical resistivity or conductivity; the probe takes advantage of the higher electrical conductivity of the jet grout and the lower electrical conductivity of the original soil.



(a) Tripod deployment system and one probe section assembled in the lab; and (b) illustration of the probe and tripod deployment system placed in a jet grout column

Benefits

The push probe provides a non-destructive assessment of production columns and results in significant time saving. Instead of waiting 7 days after jet grouting to perform coring and another 7-21 days for unconfined compressive strength test results, a contractor can assess the diameter within 30 minutes of jet grouting. This provides immediate actionable feedback to allow the contractor to modify jet grouting parameters as needed within the same work shift. Further, the ability to verify diameter immediately and move on to production can save significant time and money.

Application/Implementation

The probe has been implemented on multiple jet grout construction project sites, primarily the granular soil sites (sands, silty sands). In all cases, the estimated diameter was found to be within 5% of the actual constructed diameter. Extensive computational modeling was performed to provide the basis for the design and for the resistivity methodology used to determine the column diameter.

Commercial implementation should follow the approach used by the Osterberg load cell that was licensed to a specific company (companies). The push probe deployment should involve well-trained field personnel to carry out the tests. This will help develop confidence in the test and build a record of test results that can be used for further interpretation and confidence in the results.

A Low-Cost Mobile Proximity Warning System in Highway Work Zone Safety (Project #187)

Inventor/Investigator
Yong K. Cho
Georgia Institute of Technology

IDEA Funding
$86,517

Project Completion
2017

Description

Product: A mobile proximity safety alert system for highway work zone

The proximity warning system is a proactive alerting system that allows pedestrian workers to avoid hazardous proximity situations. The personal protection unit (PPU) and equipment protection unit (EPU) alert the workers when a hazardous situation appears imminent.

The developed system adopts low-cost Bluetooth beacons for cost-effectiveness and easy installation. The PPUs and EPUs measure the signal strength of the beacons attached to the construction equipment, estimate the distance to the equipment, and alert the workers and the equipment operators with vibration, sound, and direction indicator. When an alert is raised, information including the time, the worker/equipment IDs, and the incoming direction is uploaded to the cloud server. The real-time online monitoring system summarizes and displays the information to a remote project manager/supervisor. An example of field implementation of the system for a paving site is shown below.

Proximity warning system field implementation: *Top:* EPU installed to a compactor; *Bottom:* PPU embedded in workers' safety vests

Benefits

The proximity warning system improves highway work zone safety by detecting the proximity to nearby equipment and alerting workers and equipment operators when an imminent collision is expected to avoid possible injuries and fatalities. A proactive alert in hazardous proximity situations can allow pedestrian workers additional time and capability to escape hazardous situations. Using low-cost Bluetooth technology, the proximity warning system can reduce the cost in highly dynamic work zones, such as the highway work zone where pre-built infrastructure is unavailable.

Application/Implementation

The Georgia DOT intends to implement the proximity warning system in the state and has supported its further development and improvement. This further development and improvement included electronic hardware devices for the system for pedestrian workers and equipment operators as well as a cloud computing-based real-time online monitoring system. Ongoing research focuses on improving accuracy, easy deployment, improved portability, longer battery life, and clearer notifications. The Georgia DOT project aims to improve the performance of the overall system through real-world highway work zone construction projects in the state. The proximity warning system has received significant attention also from the construction industry.

Novel Joints for Seismic Protection and Facilitating Accelerated Bridge Construction (Project #188)

Inventor/Investigator
Su Hao
ACII, Inc., Irvine, California/Wilmette, Illinois

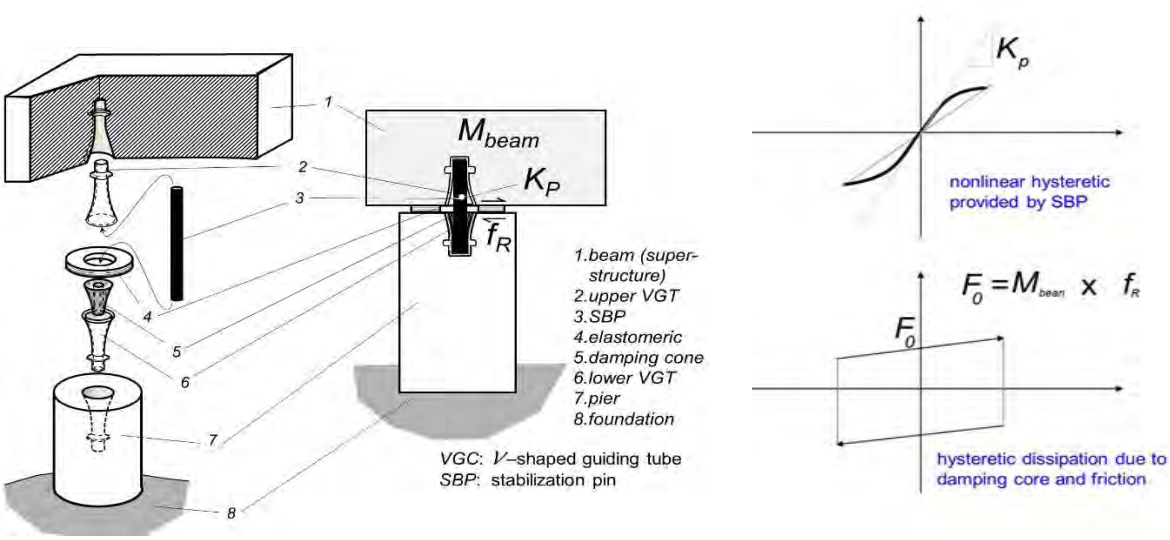
IDEA Funding
$135,000

Project Completion
2018

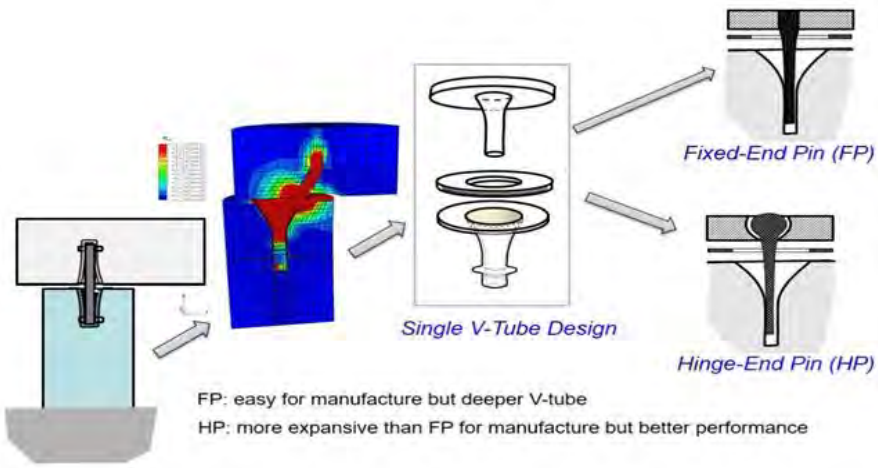
Description

Product: A class of joints, termed V-connectors, for seismic protection and facilitating accelerated construction of bridges

This IDEA research developed a class of innovative V-connectors for use as joints between a bridge pier and superstructure or between a bridge pier and footing, providing robustness for needed seismic resistance and facilitating accelerated bridge construction. The V-connector system comprises five basic elements installed between the two connected parts of a structure – two V-shaped guiding tubes (VGT), a vertical stabilizing pin (SBP) with its two ends inserted into the two VGTs, a damping cone around the pin within the lower VGT, and a washer whose major function is to provide friction-induced energy dissipation when an earthquake strikes a bridge. Two versions of the V-connectors – fixed-end pin (FP) and hinge-end pin (HP) -- were designed and tested at the Pacific Earthquake Engineering Research Center at the University of California at Berkeley and a bridge laboratory in China. The test that involved analytical modeling of the superstructure behavior and experimental testing of the substructure with the V-connector demonstrated that the V-connector does exhibit the hysteresis behavior for seismic isolation and could provide the expected seismic resistance performance for bridge engineering applications.



The V-connector concept



Two subgroup designs of the V-connectors

Benefits

Accelerated bridge construction generally involves stacking one structural part on top of another using gravity to ensure the structure's integrity. However, such "modular bridges" often lack the capacity to sustain extreme loads (such as during earthquakes, hurricanes, barge collisions, etc.). The cast-in-place method makes a bridge strong but requires extra cost for formwork and time for concrete attaining the desired strength. The V-connectors, on the other hand, can facilitate accelerated construction while assuring structural integrity and robustness of a bridge.

The V-connectors have a potential to enhance seismic resistance of a bridge better than presently-used technologies. For example, the seismic resistance of elastomeric bearing (EB) is limited by the capacity of the rubber material and is without energy dissipation. EB with lead-core-rubber improves energy dissipation but the shortcoming of the rubber remains. The friction pendulum bearings require large bearing seat that significantly increases the cost because of increased size of the columns and cantilever abutments. In contrast, the V-connectors provide robustness under normal operating conditions and also possess a better capacity to enable a structure sustain strong dynamic loads, such as an earthquake. The connectors maintain structural integrity by accommodating temporal separation between the two connected parts of a structure under strong load or impact and restoring the structure to its original state after the impact event has passed.

Application/Implementation

The tests performed in this IDEA research appear to have validated the V-connectors' capability for seismic isolation with considerable safety margin. While further research is necessary to explore in depth the underlying physics and develop a more optimized design, the next step of this development will also involve working with bridge owners (states and local transportation agencies) to implement V-connectors into the bridge design and developing codified industrial standard to guide engineering application. Further development/refinement and evaluation is also needed for full implementation of the V-connectors, which should include shake table tests, pushover tests for safety evaluation and design optimization, and design codification. Implementation efforts will involve seeking bridge owners' collaboration for implementing the V-connectors into their bridge codes. Working with bearing vendors to standardize the V-connectors and the manufacturing process will also be necessary.

Self-Deicing LED Signals (Project #190)

Inventors/Investigators
Hongyi Cai, Steven Schrock and Eric Fitzsimmons
University of Kansas

IDEA Funding (joint funding with Rail Safety IDEA Program)
$100,000

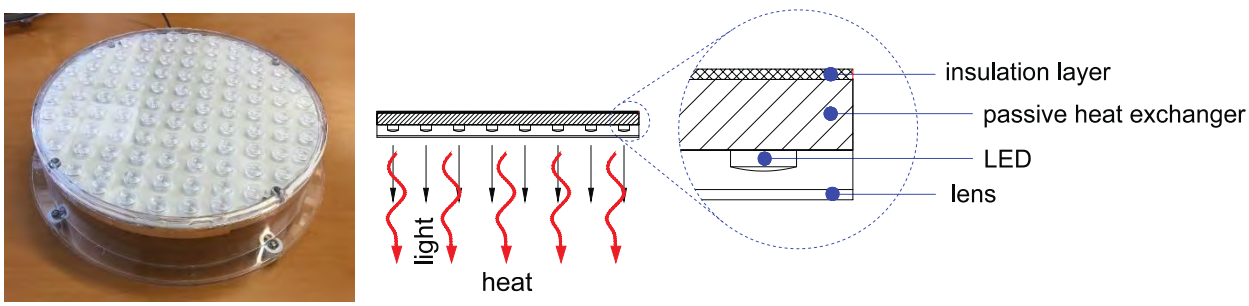
Project Completion
2020

A pooled-fund study, TPF 5-351, Deicing LED Signals, involving the states of California, Kansas, Maryland, Michigan, New Jersey, Pennsylvania, and Wisconsin and the FHWA is supporting further evaluation and implementation of this IDEA product.

Description

Product: A new type of self-deicing LED signals for highway and railroad intersections

Most of the electricity (about 70-80%) consumed by the LEDs is transformed into heat energy. The developed self-deicing LED signals deploy innovative integrative lighting and heating technology to harvest the otherwise wasted heat generated by the signal light LEDs to prevent buildup or accumulation of ice, sleet, or snow on the signal lens without the need for additional heat generators.



Self-deicing LED signal prototype deploying the "Integrated Light and Heat Arrangement of Low Profile Light-Emitting Diode Fixture"

Benefits

The self-deicing LED signal light solves the problem with the existing "cool" LED signal light that does not generate sufficient heat in the forward direction towards the signal lens to melt snow or ice that accumulates on the lens and impairs light visibility to vehicle drivers or locomotive engineers approaching the intersection. This impairment of light visibility adversely impacts the performance of signalized intersections and railroad crossings and can result in collisions during the inclement weather.

The self-deicing LED signal light is swappable with the existing signal light, thus avoiding the high cost of replacing an entire system with a new equipment. No manual labor is required any longer to sweep the snow or ice off the lens or paint chemicals on the lens to prevent snow or ice buildup. Thus, replacing existing signals

with new signals can result in substantial annual overall maintenance cost saving to the transportation agencies. In addition to cost saving, safety, efficiency and environmental sustainability are other significant benefits to the transportation agencies, the railroad companies, and the driving public in snowy regions. Given the potential number of signals that can be swapped with the new signals, the potential payoff is quite significant.

The self-deicing LED signal light is expected to find use in other rail applications (such as commuter or light rail) or other surface transportation applications (such as airport taxiway/apron lighting and seaport installations) in cold weather zones.

Application/Implementation

The IDEA-developed self-deicing LED signals have been tested in a related pooled-fund study, TPF 5(351), involving 7 states (Kansas, California, Michigan, New Jersey, Wisconsin, Pennsylvania, and Maryland) and the FHWA, with Kansas as the lead state. These states participated in field evaluation of the prototypes installed on selected highway intersections or rail track sections at test sites exposed to heavy snow and ice. The field tests were conducted in three successive wintery seasons for further improvements and on-site demonstration of the final product before implementation.

A start-up company, Solid-State Lighting & Heating Technologies. Inc. (SSLaH Tech, Inc.), has been founded for research and development and commercialization of the self-deicing LED signals and supportive accessories. The company has been working with pooled-fund partner states and other interested states in the snow-belt region in the U.S. and Canada as well as the Union Pacific and Burlington Northern and Santa Fe Railroad companies for potential technology transfer and implementation of the IDEA product into practice.

Microbial-Facilitated Stabilization for Sustainable Improvement of Expansive Pavement Subgrades (Project #192)

Inventors/Investigators
Bhaskar Chittoori
Boise State University

Malcolm Burbank
Global Micro Bio Technologies, Pullman, Washington

IDEA Funding
$138,000

Project Completion
2019

Description

Product: A new microbial-facilitated treatment method for stabilizing expansive soils underlying pavement infrastructure

Expansive soils cause significant damage to the highway infrastructure because of their ability to undergo significant volume changes with water content fluctuations. Various ground improvement techniques such as chemical stabilization, deep soil mixing, and moisture barriers have been used to counteract the problem caused by these soils; however, these methods are either expensive or have a negative impact on the environment. A more sustainable and economic solution is the microbiological treatment to stabilize these soils. This IDEA research demonstrated the use of microbial-induced calcite precipitation (MICP) to stabilize and improve the engineering properties of expansive soils using urease-producing bacteria. Calcite precipitation significantly improved strength and reduced swelling of the expansive soils. A field protocol for future field implementation of the method was also developed.

Laboratory treatment of soils

Field treatment of soils

Benefits

MICP can be usefully applied in both new pavement construction as well as repair of distressed pavements in regions with problematic expansive soils. This environment-friendly methodology provides a sustainable alternative for expansive soil treatments. Fewer incidences of pavement cracking would result in lower infrastructure maintenance costs. With further optimization of the bacteria injection technique, the method can potentially be applied also on existing highway pavements that suffer distress due to expansive soils. Treatment of the existing subgrade without having to excavate and completely remove the pavement structure would contribute to a more economical repair and rehabilitation of the existing pavement structures.

Application/Implementation

The implementation of the developed technique will require buy-in from highway agencies as well as contractors. Montana DOT has shown interest in implementing the technology. The project team is working with the DOT to find suitable test sites to apply the technique. The research team also plans to approach other highway agencies experiencing problematic subgrades. A trial application of the technique on an existing highway section with appropriate instrumentation and field monitoring is the next step to move the technology forward for implementation.

Nano-Based Multifunctional Concrete for Transportation Infrastructure (Project # 197)

Inventor/Investigator
Rouzbeh Shahsavari
C-Crete Technologies, LLC, Houston, Texas

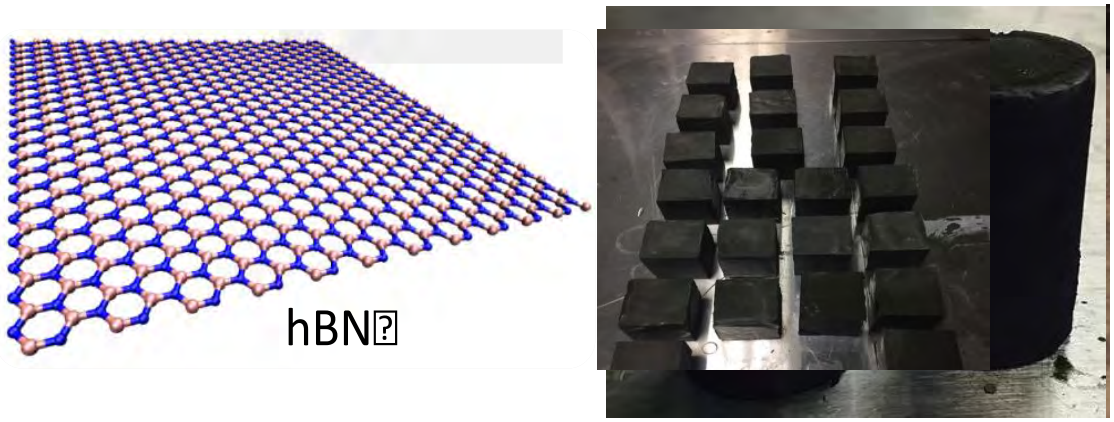
IDEA Funding
140,000

Project Completion
2019

Description

Product: Nano-enabled concrete product with enhanced mechanical and durability properties

The IDEA product is a new class of ultra-high performance, multifunctional concrete for transportation infrastructure applications. The core technology involves exfoliating and mixing emerging two-dimensional (2-D) materials, such as hexagonal boron nitride (hBN) with its exotic properties (ultrahigh surface area, flexibility, chemical inertness, and ultrahigh mechanical properties), in the bulk concrete. Such 2-D materials, ideally only a few atoms thick, can have a profound impact as multifunctional reinforcing agents in concrete. In particular, their 2-D sheet-like nature provides double surface area per mass as compared to fibrous counterparts.



hBN

***Left*: An atomistic image of a mono-layer of hBN. *Right*: Representative coupons of hBN/Concrete**

Benefits

Concrete is the most widely used synthetic material on earth. In the U.S. alone, more than 75% of bridges and over 60% of Interstate highways are made of concrete. There appears to be no other bulk material on the horizon to replace concrete for the purpose it is being used. However, despite decades of extensive research, concrete bridges and highways still suffer from fracture, deterioration, and external chemical attacks resulting in billions of dollars in maintenance costs annually. The 2-D materials when mixed with concrete have the potential to significantly improve the performance and durability of highway pavements

and bridges. For example, the compressive strength of a 4 in x 8 in concrete cylinder can increase up to 130% with only a very small fraction of the 2-D material and the tensile strength by more than100%. The durability of concrete specimens containing 2-D materials has shown approximately 35% increase, as determined by electrical resistivity measurements (AASHTO TP 95-1 standard). Such improved strength and durability allow users to "*do more with less*." A more durable concrete leads to reduced maintenance costs while a higher strength concrete allows using lower volume for construction of transportation infrastructure. In addition to cost savings, lower concrete volume means lower CO_2 emission associated with cement/concrete manufacturing.

Application/Implementation

The promising properties of the developed concrete product have been shared with Texas DOT for evaluation and finding the best path for implementation. For pilot testing, the Houston District of the DOT is providing a small patch job (maintenance) on a road surface in Harris County to monitor the long term performance, stability, and durability of the concrete product *in situ.* In such repair/maintenance jobs, which often occur overnight, a key requirement of the Texas DOT was achieving early strength of more than 1800 psi within approximately 5 hours in order to be able to quickly open the road to traffic. The IDEA researchers have tested and optimized the compatibility of their formulation using common accelerators and confirmed achieving more than 1800 psi in about 5 hours. The location and logistics of the pilot test area are being finalized. Once implemented, other states will also be able to adopt and benefit from this new technology.

Use of X-Rays to Determine Concrete Permeability (Project #199)

Inventor/Investigator
Tyler Ley
Oklahoma State University

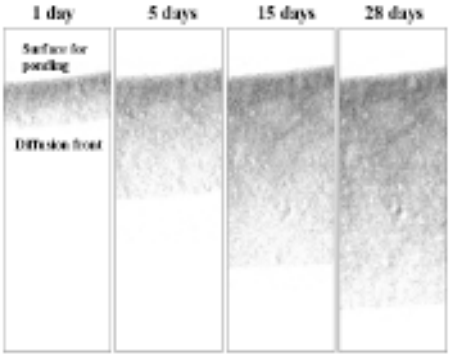
IDEA Funding
$100,000

Project Completion
2019

Description

Product: Equipment based on medical x-ray machine to determine concrete permeability

The service life of concrete is strongly dependent on its durability, which can be defined as its ability to maintain serviceability within a specific environment causing issues such as corrosion, freezing and thawing, sulfate attack, physical abrasion, carbonation, alkali-silica reaction, etc. The mechanism for many of these durability issues involves penetration of fluid into concrete. For example, chloride solution penetrating concrete leads to corrosion of steel reinforcement. Therefore, permeability plays an important role in the durability of concrete. This IDEA project developed a prototype by adapting the dental x-ray machine to observe fluid penetration into cement paste, mortar, and concrete using tracers.



Left: **X-ray prototype;** ***Right:*** **X-ray images of ions penetrating from 1 day to 28 days**

Benefits

The developed x-ray equipment has the potential to provide state DOTs an inexpensive and effective tool to rapidly determine the permeability of concrete in highway infrastructure. The equipment can be used to compare different mixture designs as well as different construction practices in the field. The method can be used on cores from the field after concrete has been placed, consolidated, or cured. The measured permeability values could alert the owner/DOT if there was a problem during the construction process. In addition, the method could be used to compare the effectiveness of different repair materials or the use of surface sealers to prolong the service life of concrete.

Application/Implementation

Concrete permeability results using the x-ray prototype have been shared with the FHWA mobile concrete laboratory and Oklahoma, Minnesota and Illinois DOTs. All these partners are interested in providing additional case studies to further evaluate the performance of the prototype. For these case studies, the research team needs to obtain concrete samples during mixture design, construction, and after placement and curing of concrete. For a more confident application of the equipment for determining concrete permeability, a wider range of concrete materials and concrete mixtures with a variety of cementitious materials and admixtures needs to be investigated. This would also help find and address issues that might arise before a commercialized version of the device is developed.

The present instrument is an initial prototype that was developed to prove the feasibility of using x-rays to determine concrete permeability and durability. While the feasibility of the technique has been shown with excellent results, much still needs to be accomplished to make it a viable equipment that can be commercialized and implemented. The equipment needs to be made more rugged, practical and user-friendly in order to be easily usable by the DOT personnel. The IDEA investigator has applied for a follow-on IDEA project to improve and refine the instrument and for more extensive field evaluation.

Rapid Rehabilitation of Highway Slopes using Seeded Microbial Bio-Cement (Project #200)

Inventor/Investigator
Bret Lingwall
South Dakota School of Mines and Technology

IDEA Funding
$135,000

Project Completion
2019

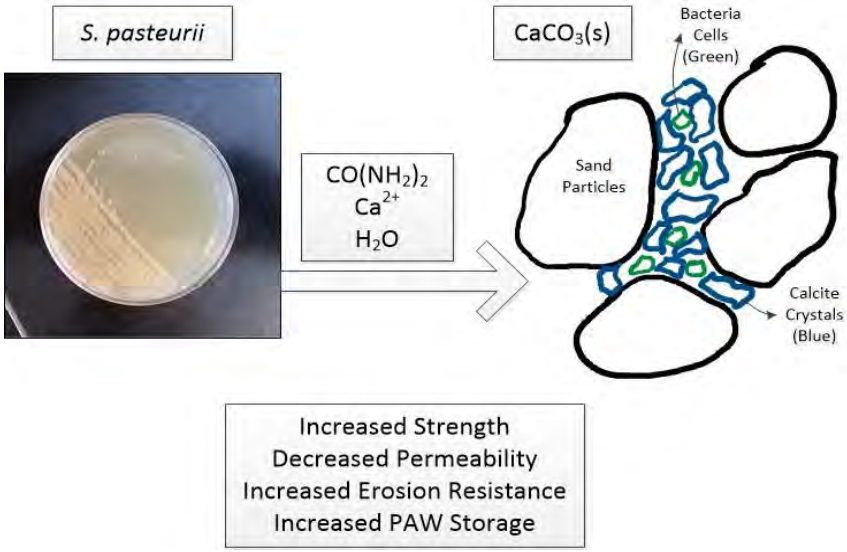
Description

Product: A technique using microbial-induced calcite precipitation (MICP) in combination with revegetation for rapid rehabilitation of eroded highway side slopes after wildfire or construction

Highway slope erosion is a persistent, widespread transportation earthwork problem, which is most pronounced when the slope is denuded of vegetation, such as after construction or intense wildfire. The current practice for mitigating highway slope erosion is to use technologies such as geosynthetics with or without seeding, hydroseeding, straw mats, vegetated compost blankets, or seed application with minor to major mulching (such as newspaper pulp or straw dust). This IDEA research offers a promising alternative – use of bio-cement produced by MICP in combination with revegetation for areas where fire or construction has largely denuded the soil biome. The bio-cement process utilizes ureolytic bacteria to precipitate calcium carbonate polymorphs between soil grains and has been shown to mitigate wind erosion and control fugitive dust. Specifically, the IDEA approach used *Sporosarcina pasteurii* microbes to rapidly induce slope protecting MICP in conjunction with a native grass and plant seed treatment as, after construction or intense wildfire, the bare soil slopes require vegetation for long-term erosion control. The innovation here is a synthesis between MICP for short-term erosion protection and vegetation for long-term protection using a balanced approach, as too much bio-cement application would create a low permeability crust that would slow down infiltration and prevent seed sprouting.

Benefits

The MICP bio-cement can be used on a wide range of highway slope angles or geometries over long distances around any obstructions, encourages long-term natural vegetation growth, and resists wind and water erosion until natural vegetation develops. The microbial enrichment solution also doubles as a liquid fertilizer for plants. Salt and pH-tolerant grass and plant seeds are required for the process. The method is economically feasible as the main components of the treatment solution are water, urea, calcium chloride and soy nutrient broth, all of which are readily available. The main associated costs are in the volume of treatment material required for large areas and upscaling the microbial culture process from laboratory to industrial scale. The limitations of the technique are highly clayey soils, highly compacted soils, and compacted clay soils where infiltration could be too slow, letting the solution to mostly run-off than infiltrate. The treatment can be applied via handheld or backpack sprayer, airplane, drone, helicopter, and tanker truck using conventional equipment in two steps or phases -- a seeding phase and a treating phase. If desired, the technique can be used to supplement, augment, or increase the effectiveness of other slope treatment technologies, such as hydroseeding, compost, straw mats, and geosynthetics.



Overview of microbial biocementation process using ureolytic bacteria

Application/Implementation

Work has continued on product commercialization in collaboration with South Dakota DOT. The customer base for MICP bio-cement for wind and water erosion mitigation of highway slopes are mainly government agencies that own or operate wildlands that may be subject to wildfires or own or operate highways through those wildlands. These agencies include: federal agencies (National Parks Service, Western Federal Lands, Forest Service, Bureau of Land Management, and Bureau of Indian Affairs), state highway departments, state parks agencies, and county highway departments. The customer base for the technology may possibly extend also to the farmers who have wind and water erosion issues after wildfires in their crop or range lands. They could benefit from a seeded application to rapidly restart crop or grazing activities devastated by wildland fires.

SaferCushion (Project #203)

Inventors/Investigators
Dean Sicking, Kevin Schrum, Blake Feltman, Kent Walls, Joseph Schwertz, and Steve Thompson
University of Alabama - Birmingham

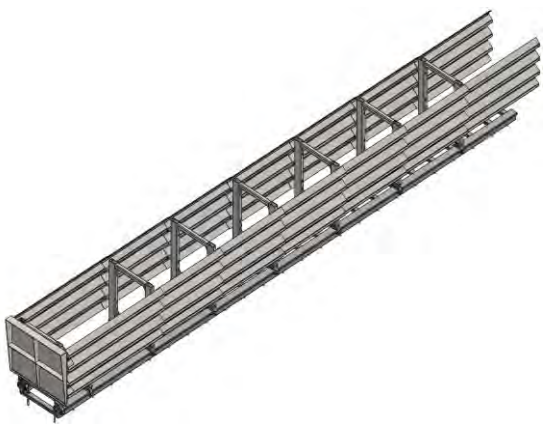
IDEA Funding
$100,000

Project Completion
2019

Description

Product: A self-restoring crash cushion with the capability to run self-diagnostics and communicate a crash event to emergency personnel, DOTs, and the manufacturer.

The SaferCushion comprises a track and diaphragm system. The track is epoxied to a foundation. The diaphragms are constructed from rectangular tubes. At the diaphragm base, steel "feet" are inserted and bolted in place. These feet slide along the track while still being able to transfer load to the track and the ground for high angle or side impacts. Along each side of the SaferCushion, a series of corrugated steel panels are bolted to the diaphragms with special shoulder bolts. In the valleys of these panels, slots are cut that allow the panels to telescope back upon impact with the end.



SolidWorks rendering of assembled structure (*left*) and energy absorbing mechanism (*right*)

At the back end of the SaferCushion, a rotatable device is mounted on an axle. This device includes two large diameter drums separated by a spindle. A flat nylon strap wraps around the spindle and then feeds along the length of the SaferCushion. The strap wraps around another stationary spindle and attaches to the bottom of the lead diaphragm. Upon impact, the lead diaphragm gets driven down the track as the strap unspools from the drums at the back end. To resist this unspooling and absorb impact energy, band brakes are mounted to the drums. The drums are integrated with a motor and a programmable logic controller (PLC). This PLC would disengage the band brakes and then lock into the drums. Once in place, the motor will reverse the direction of the drums, effectively re-spooling the nylon strap onto the spindle. Still being

attached to the lead diaphragm, this re-spooling will also pull the telescoped SaferCushion back into position. To assist with this operation, a series of sensors will be used to detect the presence of a vehicle (and, in that case, delay the resetting). Sensors in the motor will be used to run self-diagnostics on the tension in the nylon strap. Finally, using information gathered from the sensors, an impact can be detected. Then, using cellular signals, the impact will be recorded and communicated as needed. This will help facilitate faster emergency response times as well as establish the framework for automated in-service performance evaluation.

Benefits

Approximately 100 highway workers die in work zones each year. Any effort to reduce the need for work zones or the time spent in work zones will help reduce this number. For a large proportion of impacts, the SaferCushion will eliminate the need to establish and man a work zone, while still providing a high-performing crash cushion. While maintenance problems can often render a system ineffective, the SaferCushion periodically and automatically determines proper system tension to maintain its effectiveness. Finally, the communication technology associated with SaferCushion will help reduce emergency response times, while also facilitating automated in-service performance evaluation.

Application/Implementation

Crash cushions generally shield severe locations, such as bridge piers and gore areas, where there is insufficient space to use a guardrail and terminal system. The SaferCushion can be used in any location that meets this standard but is especially well-suited for locations with two or more crashes per year. It is also well suited in locations with high traffic volumes and speeds, which, in fact, are the most dangerous locations to establish a work zone.

Commercialization of the SaferCushion is currently being explored. Highway safety manufacturers are being consulted for a transition into mass production and for rights to produce and sell the safety system, pending successful MASH testing.

The North Texas Tollway Authority is willing to provide a pilot installation program to evaluate the SaferCushion in the field. A member of that organization is on the expert panel advising on this IDEA research. In addition, the states of Wyoming and Wisconsin have expressed interest in utilizing the SaferCushion in their states, and a representative from each of these states is also serving on the IDEA project expert panel.

Biomimetic Antifreeze Molecules – A Novel Alternative to Air-Entraining Admixtures for Freeze-Thaw Resistance of Concrete (Project #204)

Inventor/Investigator
Wil V. Srubar III
University of Colorado - Boulder

IDEA Funding
$140,282

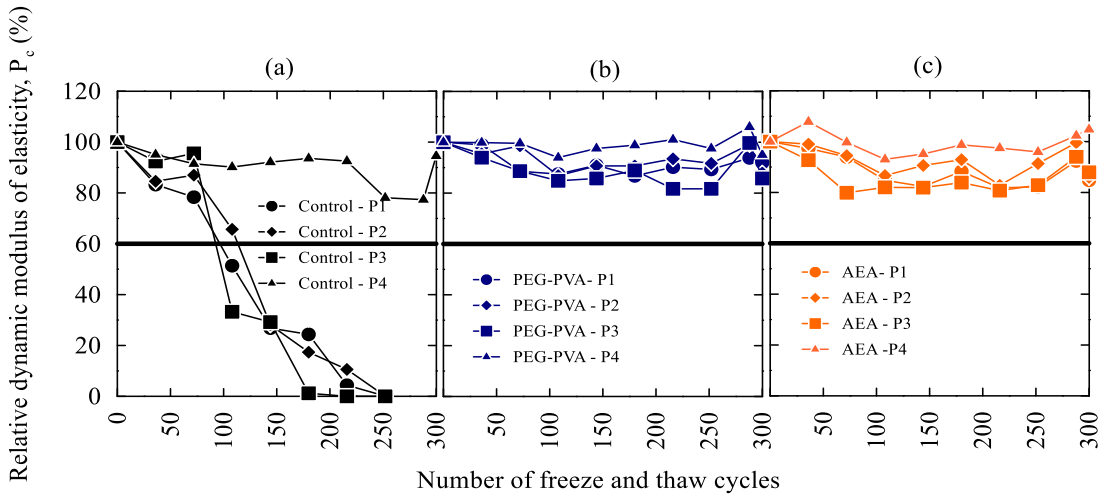
Project Completion
2020

Description

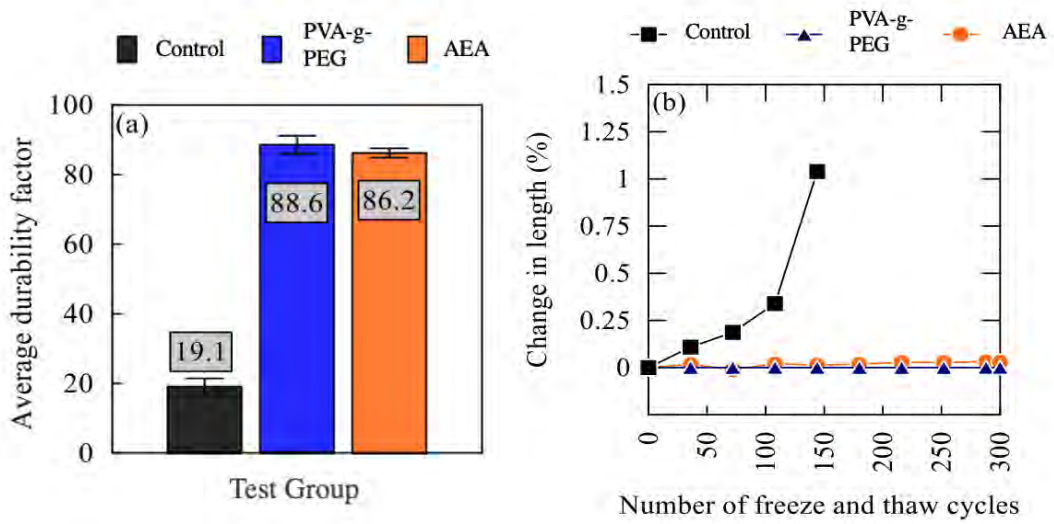
Product: Non-air-entraining small antifreeze molecule additives for freeze-thaw resistance of concrete

Since the 1930s, air-entraining admixtures (AEAs) have been used to enhance resistance of concrete to freeze-thaw damage. Although AEAs enhance the freeze-thaw resistance of concrete, they also have some drawbacks that include: (i) reduction in mechanical strength, which can be as much as 6% per 1% entrained air, (ii) increase in permeability, (iii) set time retardation, and (iv) difficulty in achieving consistent air void systems. Additionally, recent work has shown that once a critical saturation level is met (>85%), proper air entrainment will not prevent freeze-thaw damage.

In this IDEA research, the small poly (ethylene glycol)-graft-poly(vinyl alcohol) (PEG-PVA) molecule that displays ice recrystallization inhibition activity was also discovered to provide freeze-thaw resistance to concrete without the need for entrained air void system. This molecular additive (<1% by weight of cement) inhibits damage due to freezing and thawing *via* a very different mechanism. Instead of air voids releasing the osmotic and hydraulic pressure build-up from growing ice crystals, the new molecular additive prevents nucleated ice crystal growth and coalescence within cement paste and concrete, thereby inhibiting damage due to freeze-thaw cycles.



ASTM C666: (a) control, (b) PEG-PVA, and (c) air-entrained concretes



ASTM C666: Average durability factor and average length change for each test group. Error bars indicate standard deviation for n=3.

Benefits

This new biomimetic approach offers several key advantages over traditional AEAs for concrete. It retains the compressive strength by minimizing entrained air and reduces the overall permeability, which subsequently leads to increased long-term durability, particularly, in chloride-laden environments. In fact, this IDEA work lays the scientific foundation for future research and development related to biomimetic antifreeze admixtures for use in concrete infrastructure for protection from freeze-thaw damage.

Application/Implementation

Since this research is at its most fundamental stage, the application of the technology has been limited to laboratory-scale testing and evaluation. Work continues to identify other cost-effective molecules that will exhibit performance similar to that of the PEG-PVA molecule. In addition, a preliminary patent application has been filed with the US Patent Office. Collaborative partnerships with the City of Boulder, the Colorado DOT, and independent concrete testing facilities are being established for pilot-scale demonstrations. A partnership for advanced testing and demonstration activities is being established with the U.S. Army Corps of Engineers' Cold Regions Research and Engineering Laboratory, which works with a wide variety of admixture technologies to ensure early- and late-age durability of concrete in cold Arctic and Antarctic environments.

MILDGLASS – GFRP Strands for Resilient Mild Prestressed Concrete (Project #207)

Inventors/Investigators
Antonio Nanni[1] and Marco Rossini[1], Giovanni Dotelli[2], and Saverio Spadea[3]
[1]University of Miami, [2]Politecnico di Milano, Milano, Italy, [3]University of Dundee, Dundee, United Kingdom,

IDEA Funding
$119,400

Project Completion
2020

Description

Product: An easy-to-deploy, corrosion-resistant, cost-effective glass fiber reinforced polymer (GFRP) strand for mild prestressed concrete

There is an increasing demand for corrosion-resistant prestressing technologies for use in concrete highway infrastructure but the available options are expensive, complex and sometimes ineffective. These options include: (i) stainless steel strands with brittle behavior and about four times as expensive as steel; (ii) carbon fiber reinforced polymer (CFRP) strands with the same issues as those for stainless steel plus a complex tensioning procedure requiring expensive anchors; and (iii) epoxy-coated steel strands that have been banned in some states because of their poor performance in highly corrosive environments. In comparison, glass fiber reinforced polymer (GFRP) bars provide an effective and cost-effective corrosion-resistant solution for reinforced concrete. However, a GFRP strand for prestressed concrete is not yet available in the marketplace. This IDEA product is aimed at meeting that need

The IDEA product is a GFRP strand prototype for application in mild-prestressed concrete (MPC) elements. Limiting the initial level of prestress addresses constructability issues associated with CFRP and ensures compatibility with traditional steel chucks and conventional tensioning techniques so that the precasters do not experience any difference. The cost of GFRP (about 1.3 times the cost of steel) makes the product a competitive and durable alternative to standard steel strands in applications that require low level of prestress and that are directly exposed to chlorides, such as bearings and sheet piles in coastal areas, seawalls, precast stay-in-place forms and shells, and deck panels exposed to deicing salts.

In partnership with the industry, the developed technology involves corrosion-resistant E-CR glass fibers (from Owens Corning) and a new type of thermoplastic resin (from Arkema) to facilitate manufacturing of a twisted 7-wire strand. The strand is optimized for prestress to reduce shear lag, ensure adequate creep-rupture strength, and allow coilability and steel-like constructability.

Benefits

The GFRP strand does *not* alter the conventional fabrication process at the precast plant. The strand is coilable, shippable and compatible with traditional techniques applied to steel-prestressed concrete (PC) tensioning and construction. Due to low level of tensioning as compared to ultimate strength capacity, no additional efforts or safety precautions are required at the plant, thus removing any barrier to large-scale implementation. Mild prestressing can be attained with conventional steel chucks, and the relatively low-modulus of GFRP will result in elongations or movements of the stressing blocks of the same order of

magnitude as with steel strands. Additionally, the relatively low material cost will make this product an attractive alternative to traditional and non-traditional prestressing technologies. The extended service life and low-maintenance features have positive implications in terms of life cycle costs, with a projected 90% reduction in maintenance costs and a 25% reduction in total life cycle costs.

Prototype thermoplastic GFRP 7-wire strand (*left*) and round solid bar (*right*)

Application/Implementation

The product development, currently underway, shows much promise. Two separate production lines have been developed at Sireg (industry partner) to manufacture a 7-wire thermoplastic GFRP strand of 0.6 in. (15.2 mm) diameter and a round solid thermoplastic GFRP bar of 0.5 in. (12.7 mm) diameter. Both material systems are coilable and can be used in mild prestressing applications.

Florida DOT, a key stakeholder of MILDGLASS, is using GFRP-prestressing in portions of a bridge and appears interested in leading nation-wide pre-standardization of the technology. The bridge is the NE 23rd Avenue Bridge over Ibis Waterway in Broward County. Two GFRP-prestressed piles were cast in February 2020 for installation as soldier piles sustaining the wing walls (figure below). At this field implementation stage, coilable 0.5 in. (12.7 mm) GFRP bars made with vinylester resin were used and coupled with pre-tensioning anchors with polymeric wedges.

Tensioned GFRP tendons ready for casting (*left*) and final member (*right*)

Awards/Recognition

The innovation of using thermoplastic resin in GFRP reinforcement for MILDGLASS was recognized by the **First Place JEC Innovation Award in the Construction and Infrastructures Category** at the JEC Expo in Paris, France in 2019. The JEC Group is the world's largest organization dedicated to the development and promotion of composite materials and technologies worldwide.

An Automated System for Pedestrian Facility Data Collection from Aerial Images (Project #209)

Inventors/Investigators
Yuanyuan Zhang and Chaoyang Zhang
University of Southern Mississippi

IDEA Funding
$129,954

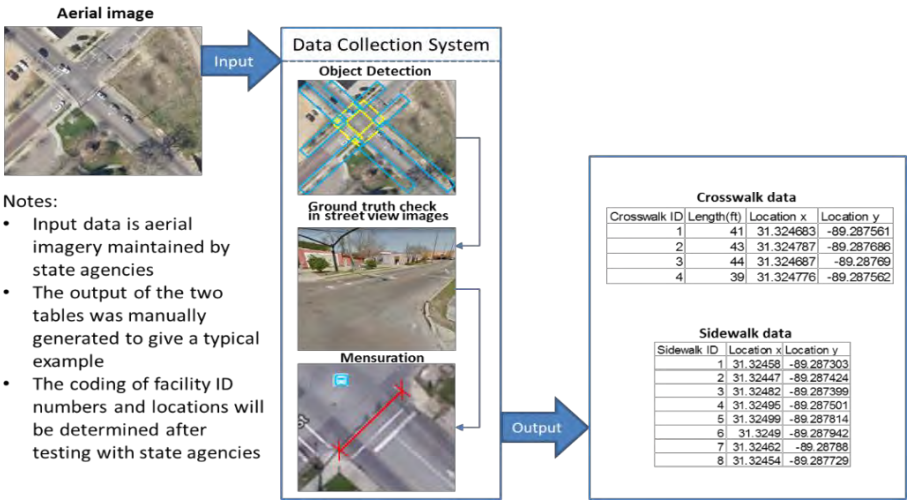
Project Completion
2020

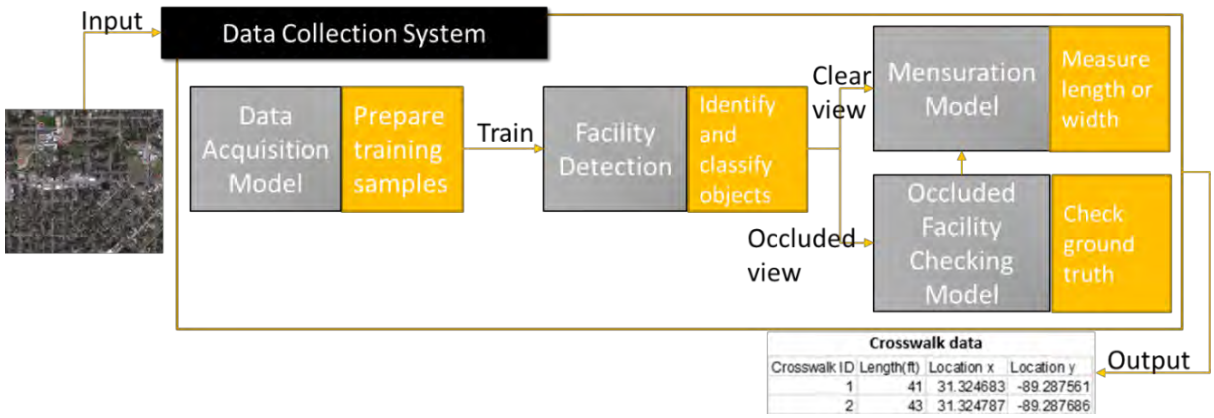
Description

Product: A machine-learning-based system for automatically collecting pedestrian facility data from aerial images

Pedestrian facility data is urgently needed for improving pedestrian safety, and collecting these data has been recognized as a high-priority action item in the state DOTs' strategic highway safety plans. To address this need, a novel data collection system is being developed in this IDEA project to automatically detect, classify, and measure major pedestrian facilities from aerial images owned by state DOTs. The information being collected includes paved sidewalk presence, marked crosswalk presence, and marked crosswalk length. Aerial images will be input into the system where pedestrian facilities will be detected and measured using deep learning methods combined with traditional image processing techniques. The final output will be a database, storing pedestrian facility data for future integration into the existing roadway inventories of state DOTs.

The data collection system comprises four function models: (i) a "Sample Data Acquisition Model" for automatically acquiring labeled aerial images as training samples; (ii) a "Facility Detection Model" based on deep learning methods for detecting and classifying non-occluded facilities; (iii) an "Occluded-Facility-Checking Model" which smartly combines satellite view and street view information to check the ground truth for occluded facilities; and (iv) a "Mensuration Model" to automatically measure the length or width of the target facility.





Top: **Illustration of the data collection system;** ***Bottom:*** **Illustration of the function models**

Benefits

The proposed system has the potential to greatly reduce the costs of collecting pedestrian facility data by minimizing the need for labor training, travel, observation, and record digitization, which manual data collection methods require. The costs associated with the proposed system are much lower since its data sources are free and the training process only needs to be conducted once. Furthermore, using the proposed system requires just one person to input existing aerial images and monitor the results.

The accuracy of the proposed system has the potential to surpass that of existing automation methods for image-based data collection. Many of the related image object detection methods suffer from low accuracy (ranging from 60% to 87%). By combining the power of deep learning methods with smart automated ground truth verification in the proposed system, the prototype convolutional neural network models have been determined to be 98.4% accurate for crosswalk classification and 92.9% accurate for sidewalk classification. The prototype crosswalk mensuration model also uses deep learning (a feature pyramid network) to detect and measure crosswalks in aerial images by identifying the portion of the image containing the crosswalk. The automated data collection system is currently functional and is being optimized to make it more efficient and customized for use in sidewalk and crosswalk prediction.

The developed innovative system pioneers the application of the most advanced machine learning technologies to transportation facility data collection, and it incorporates big data to guarantee higher accuracy and efficiency in large-scale data collection. The system is expected to transform the way state highway agencies collect information not only about major pedestrian facilities but also other safety-related items, such as curb ramps, median refuges, pedestrian signals, etc., with future system enhancements.

Application/Implementation

California and Mississippi DOTs have been providing sample aerial images for testing and analysis and are assisting in modifying the system to interface with their DOT software and data management environments. These DOTs are also providing guidance from the end users' perspective with regard to data format, database structure, and geocoding. After the system is developed, both DOTs will assist in testing it on their work sites. A user guide, oriented towards DOT audience, will also be produced as part of the implementation effort to facilitate adoption and usage of the system.

Non-Gating Guardrail Terminal (Project # 212)

Inventors/Investigators
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Sicking Safety Systems, Indian Springs Village, Alabama

Kevin Schrum, Blake Feltman, Kent Walls, Joseph Schwertz, and Steve Thompson
University of Alabama - Birmingham

IDEA Funding
$130,000

Project Completion
2020

Description

Product: An energy absorbing non-gating guardrail end terminal system designed to redirect a vehicle along its entire length to reduce crash injuries and fatalities

Roadside guardrail terminals can be classified as either gating or non-gating. Gating designs allow vehicles that strike the end of a barrier at an oblique angle to "gate through the barrier" and travel behind the barrier at a high speed. Since a barrier is in place to shield motorists from a hazard behind the barrier, a gating event normally produces more severe outcomes than non-gating events. It is therefore generally accepted that the risks of injury or death can be significantly reduced if a non-gating guardrail terminal can be developed. However, the guardrail terminal technology has not yet progressed to the level of fully non-gating performance. This IDEA research is aimed towards this goal.

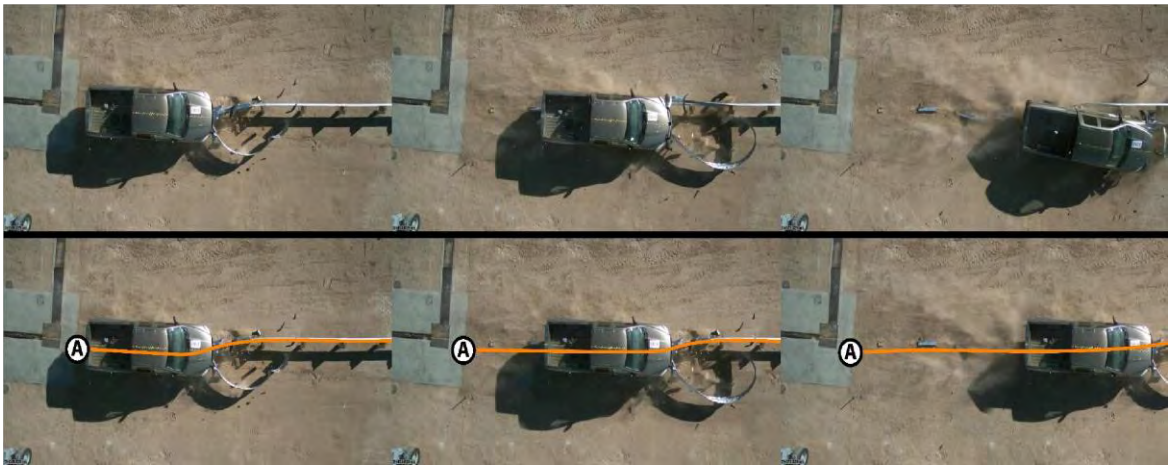
The key component of a non-gating guardrail terminal is the lateral restraint system that must be created and tuned to provide sufficient redirecting capability. Presently, guardrail barriers are intentionally soft in the lateral direction to provide a low-force redirection of the vehicle. However, this relative softness, on the end, leads directly to gating. One mechanism for providing this new redirecting capacity is to connect the impact head to a very tightly stretched wire rope. In this configuration, as the impact head is carried out of line with the guardrail, the wire rope will pull the front of the vehicle back towards the travel way. Lateral resistance provided by the wire rope is a combination of the tension in the cable and the spacing and stiffness of the posts to which the wire rope is attached.

Benefits

The primary benefit of a non-gating guardrail terminal is the reduction in the number of serious injuries and fatal accidents associated with vehicles gating through that terminal. According to Fatal Accident Reporting System between 2014 and 2016, striking a guardrail terminal was classified as the first harmful event in an average 178 fatal crashes per year and striking the terminal as the most harmful event in 91 of those crashes. The remaining 87 crashes that involved a vehicle first striking a guardrail terminal and another event classified as the most harmful event were fatal accidents that could have been avoided by non-gating terminals.

Also, gating terminals require a longer length-of-need (LON) to put the area behind the terminal

sufficiently far from the danger that is being shielded. However, if gating is not possible, then the overall length of guardrail installation would be reduced. This shortening can be at least 12 ft. 6 in. (one standard length of W-beam), saving approximately $180 per installation. This cost saving could offset most, if not all, of the additional costs associated with non-gating designs.



***Top: Gating* -- MASH 3-33 low angle impact sequence of a truck impacting a widely used gating end terminal; *Bottom: Non-Gating* -- Digitally altered sequence of the same impact depicting the vehicle's reaction to a non-gating end terminal. This illustrates a cable being introduced to the system (red line) which is anchored upstream of the impact head to the ground at point A and another point downstream of the length of need on the guardrail**

Application/Implementation

A non-gating guardrail terminal can be used in any location that uses a gating terminal. It may also be applicable to locations where there is insufficient space to install the traditional LON plus a gating terminal.

Commercialization of the product is being explored with several highway safety manufacturers, pending successful crash testing. Two state DOTs (Wyoming and Wisconsin) have expressed interest in bringing non-gating guardrail terminals to the market in their respective states. Both DOTs have representatives serving on this project's expert panel and are willing to help with pilot installations. The principles discovered as part of this project will be distilled in a journal article and made available to anyone interested in developing their own non-gating guardrail terminal.

SEAHIVE – Sustainable Estuarine and Marine Revetment (Project #213)

Inventor/Investigator
Landolf Rhode-Barbarigos
University of Miami

IDEA Funding
$119,174

Project Completion
2020

Description

Product: A novel, cost-effective, efficient and ecofriendly seawall structure shoreline protection system

The impacts of recent hurricanes in the U.S. and elsewhere have brought to the forefront the need to improve protection of the built environment and infrastructure in coastal communities from hurricane winds, waves and storm-surges by designing more efficient and sustainable shoreline protection systems, such as seawalls. This IDEA project develops the design of a novel seawall structure system.

The system, called the SEAHIVE, consists of a series of perforated tube elements that can be installed horizontally or vertically, stacked in a tight configuration or with an offset, allowing the system to be adapted for various applications and topographies. The perforations along the length of the elements allow the wave energy to dissipate within them, thus increasing material efficiency and performance. The SEAHIVE elements are to be fabricated using low-alkali cement with seawater and non-corrosive reinforcement rebars to ensure a good integration with the natural environment. Furthermore, the system elements at higher elevations can be filled with sand and soil to promote coastal vegetation, creating a protective environment for marine life to thrive.

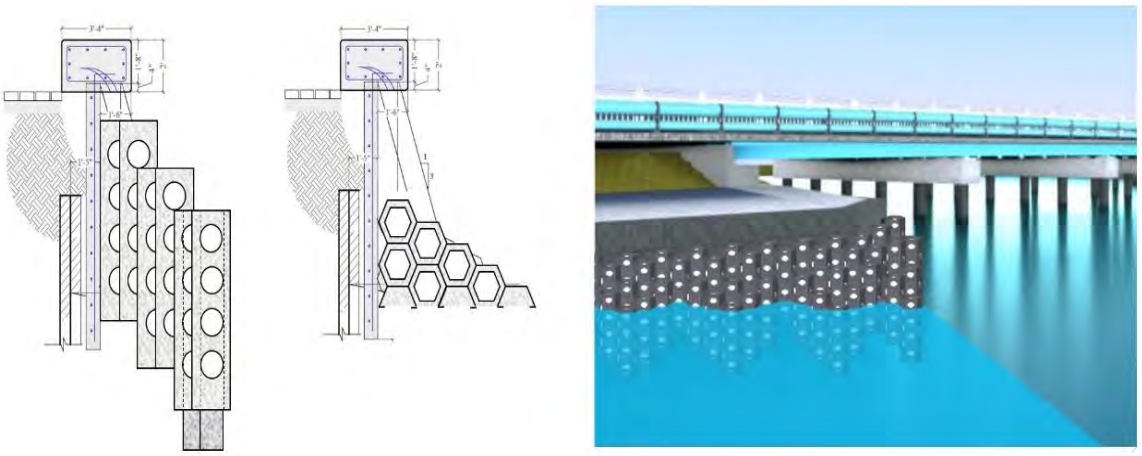


Illustration of SEAHIVE system configurations (*left*); application of the system (*right*)

SEAHIVE is currently under development and testing at the University of Miami's Surge STructure

Atmospheric Interaction (SUSTAIN) Facility – a wind-wave tank that can generate waves by means of a 12-paddle system combined with direct wind forces, simulating hurricane conditions up to Category 5 on the Saffir-Simpson scale. The SUSTAIN allows testing of SEAHIVE elements at near-full-scale conditions as well as scaled system configurations to help validate system's performance under varying wave conditions and water levels as well as extreme tidal conditions.

Benefits

The SEAHIVE system offers an efficient and cost-effective shoreline protection system for locations with high energy tidal flow while creating an ecofriendly environment for marine life. Its adaptive features allow its use for various applications and topographical situations. A profile shape design and perforation configuration provide good stability, while increasing wave-energy dissipation capabilities ensure effectiveness at various conditions, including high tidal flow. Element shape tuning and modularity are expected to allow the system to be used for a wide variety of applications, while material selection and structural complexity can ensure good compatibility with the natural environment. Finally, the system can be constructed economically by employing conventional concrete pipe fabrication technology for element fabrication.

Application/Implementation

Although the SEAHIVE system is currently under development, the research team has already made significant efforts towards implementation by promoting the system and its development process at various professional meetings, such as the 2019 Florida Shore & Beach Preservation Association's Annual Conference and *Coastal Structures 2019*, an international conference organized by the American Society of Civil Engineering's Coasts, Oceans, Ports, and Rivers Institute. The research team has already received inquiries about the SEAHIVE system from cement and ready-mix concrete manufacturers as well as local stakeholders. As part of implementation efforts, a field site was identified in collaboration with North Bay Village where SEAHIVE elements, fabricated with assistance from a local casting company, will be installed as an alternative to riprap and monitored to evaluate their performance. Implementation efforts will continue and are expected to gain pace as the product development nears its final stage.

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

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