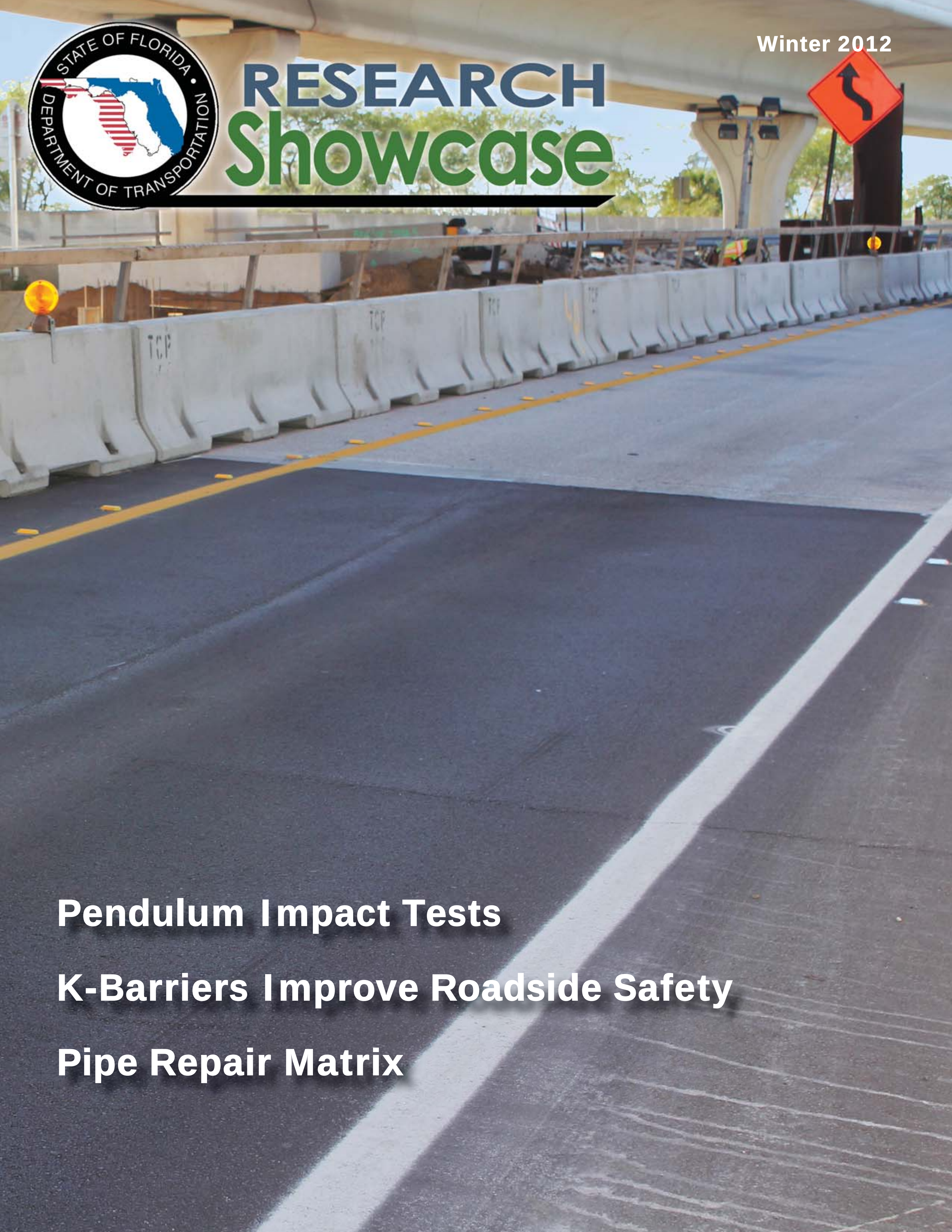


Winter 2012

State of Florida Department of Transportation

RESEARCH Showcase

Pendulum Impact Tests

K-Barriers Improve Roadside Safety

Pipe Repair Matrix

Research Showcase

Winter 2012

The Florida Department of Transportation (FDOT) Research Showcase is published to provide information regarding the benefits of FDOT-funded research.

Managing Editor
Darryll Dockstader

Editor / Writer
Vicki Morrison
Charles Brown

Graphic Design
Vicki Morrison
Charles Brown

Printer
FDOT Reprographics Office

Front and Back Cover: K-Barriers in use along the I-4 to Selman Expressway project

Governor
Rick Scott

Secretary of Transportation
Ananth Prasad

Contact
FDOT Research Center
605 Suwannee Street, MS 30
Tallahassee, FL 32399-0450
Phone (850) 414-4615
http://www.dot.state.fl.us/research-center/

In This Issue

One way we can measure the success of research is to look at how innovative technologies developed through research have made our transportation network safer and more cost efficient. This issue of Research Showcase features three such technologies.

Roadside signs are supported with posts that break away upon impact. However, hurricane force winds caused many signs to fail during the 2004-05 hurricane seasons. Researchers at FDOT's Marcus H. Ansley Structures Research Center are developing a new breakaway connection designed to withstand hurricane-force winds while breaking away safely if struck by a vehicle. The connection is being tested using FDOT's new impact pendulum. The pendulum will enable FDOT researchers to conduct a wide range of future impact tests with the ultimate goal of increasing public safety and reducing costs.

Researchers at the Midwest Roadside Safety Facility (MwRSF), with funding from FDOT and other transportation entities through the Federal Highway Administration's (FHWA) pooled fund program, have developed a modified safety barrier called the K-barrier that can be attached to roadway surfaces. K-barriers deflect significantly less than freestanding barriers, thereby increasing the amount of space available in construction zones, reducing the necessity of closing lanes, and ensuring the safe and cost-efficient mobility of people and goods. Florida is among several states that now specify the use of K-barriers.

Ensuring a safe and cost-efficient transportation system also is the goal of FDOT's new pipe repair matrix. Repairing damage to underground pipes can be difficult, disruptive, and expensive. FDOT's pipe repair matrix will help to ensure that engineers select the best method to repair underground drainage pipes with the goal of reducing the number of road closures, increasing the safety of the traveling public, and saving taxpayer money.

I invite you to read the following articles to learn more about the benefits of transportation research.

Darryll Dockstader, Manager

Contents

Pendulum Impact Tests Lead to Safer Road Signs

Rigid objects along roadways can become dangerous hazards if struck by a vehicle. This is true even of relatively small road sign supports if they are not designed to break away properly upon impact by an errant vehicle. To reduce potential injuries to vehicle occupants, American Association of State Highway and Transportation Officials' (AASHTO) specifications require that the base of any multi-post roadside ground sign located adjacent to a roadway be connected to its foundation using a connection that will break away upon vehicle impact. It is a significant engineering challenge to design large roadside sign structures with base connections that are both weak enough to properly break away under vehicle impact load and strong enough to resist wind loads. In Florida, where roadside signs may be subjected to hurricane-force winds, the challenge is even greater.

Existing breakaway connections employed by the Florida Department of Transportation (FDOT) meet AASHTO criteria, but the performance of these systems has been undesirably sensitive to installation and maintenance procedures. Roadway technicians may inadvertently apply excessive torque to bolts during installation or maintenance. Excessive bolt torque, in conjunction with friction between different parts of the connection, can prevent the connection from properly breaking upon vehicle impact, thus potentially endangering vehicle occupants.

In 2006, FDOT initiated a research project to develop a new multi-post ground-sign base connection system capable of resisting hurricane-force wind loads and flexible enough to break away safely if impacted by a vehicle. Researchers at the University of Florida's (UF) Department of Civil and Coastal Engineering designed a new breakaway base connection for use in Florida and a pendulum impact apparatus to evaluate the new connection. The pendulum also can be used to conduct future impact load experiments.

The pendulum impact apparatus located at FDOT's Marcus H. Ansley Structures Research Center in Tallahassee, Florida, consists of three 50-foot towers arranged in a triangular configuration and an impact block. An electric winch hoists the impact block to the desired height. The pendulum is capable of swinging a block weighing up to 9,000 pounds (the weight of two full-size pickup trucks). Upon release, the block can drop through a maximum height of 35 feet and accelerate to a maximum speed of 32 mph at the bottom of the swing.

At the beginning of the research project, the FDOT project manager, the late Marcus H. Ansley, and UF researcher Gary Consolazio conducted a site visit to the pendulum impact facility at the Federal Outdoor Impact Laboratory (FOIL) in McLean, Virginia. They had the opportunity to discuss pendulum design, operation, and safety with Federal Highway Administration (FHWA) and National Crash Analysis Center (NCAC) researchers, gaining valuable insights in establishing design objectives for the new FDOT impact pendulum.

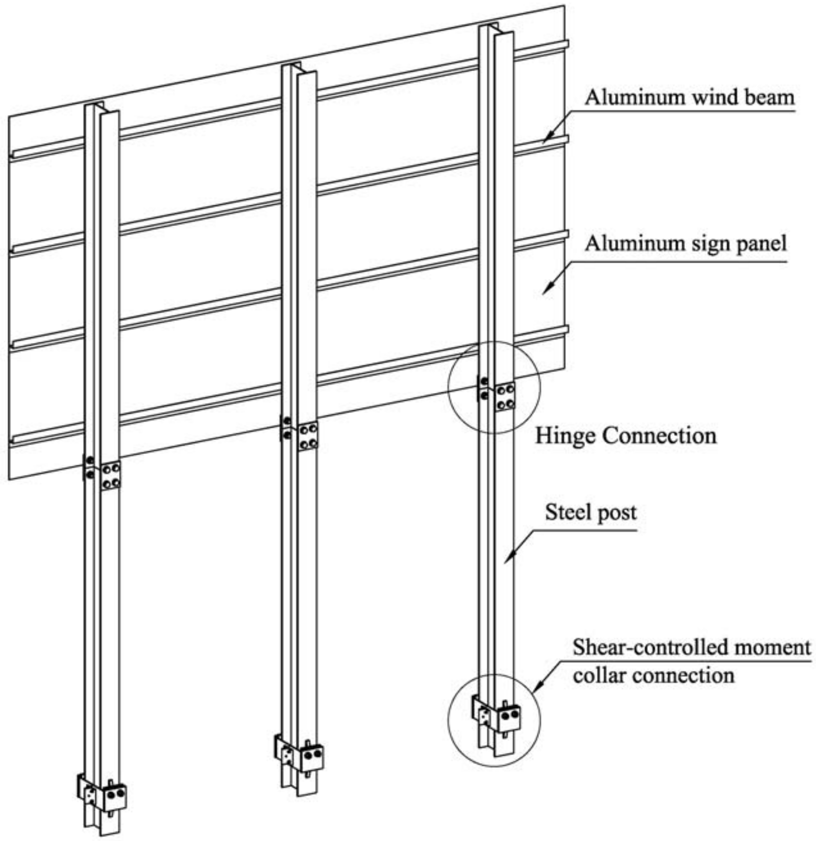
Construction of the pendulum—designed by UF researchers and fabricated at FDOT's Marcus H. Ansley Structures Research Center in Tallahassee, Florida—was completed in 2010, and testing began in 2011. The pendulum consists of three 50-foot-tall steel towers arranged in a triangular configuration. The pendulum is capable of swinging an impact block weighing up to 9,000 pounds (the weight of two full-size pickup trucks). Its triangular configuration enables the provision of three distinct test-article installation areas: a rigid concrete foundation, a strong-soil installation pit, and a weak-soil installation pit. In each swing direction, two of the three towers support the impact block using four steel cables, while the third tower uses a pull-back cable and an electric winch to hoist the block to the desired height. Upon release, the block can drop through a maximum height of 35 feet and accelerate to a maximum speed of 32 mph at the bottom of the swing. Impact blocks of varying weights can be fitted with either rigid or crushable impact noses, depending on the nature of the test.


The pendulum impact block fitted with a rigid nose and equipped with tape switches to record the instant of impact. The pendulum supports impact blocks of varying weights, which can be fitted with either rigid or crushable impact noses, depending on the nature of the test.

The pendulum is the optimal tool for evaluating sign structures. The signpost breakaway system now being tested consists of several structural steel components, including lower, middle, and upper post segments, a moment-collar, and fuse- and hinge-plates. The lower post segment consists of a short steel stub beam anchored in a concrete foundation and extending four inches above ground level. At the top of the stub is a thick steel flange plate. The middle post segment consists of a steel beam with a bottom flange plate that bears against the lower stub. A multi-part shear-controlled moment-collar wraps around and joins the flange plates of the lower and middle post segments. Finally, an upper post segment, to which the sign panel is attached, connects to the middle segment with fuse- and hinge-plates (see images and schematic, page 6). In total, the complete system extends approximately 23 feet above ground elevation.

A key innovation in this system involves a newly developed breakaway moment collar that connects the lower and middle post segments. Researchers focused on meeting three primary design objectives in developing the moment-collar connection: 1) to maximize bending strength of the connection, 2) to minimize impact strength of the connection, and 3) to minimize the influence of frictional effects on connection performance. By maximizing bending strength, the new connection system enables a sign structure to withstand winds of up to 150 mph without breaking. However, by simultaneously minimizing impact strength, when an errant vehicle impacts the sign post, the two collar halves break apart cleanly, and the middle segment of the post accelerates away from and in the same direction as the vehicle. Also upon impact, the fuse-plate that connects the middle and upper post segments breaks, further enabling the middle post segment to swing away from and in the same direction as the vehicle without falling to the ground. Minimizing impact strength reduces the force of impact and potential injury to vehicle occupants. Finally, by using two separate load paths to provide bending strength and impact strength, and by using low-friction sheets of polytetrafluoroethylene (PTFE or "Teflon") within the connection, the performance of the system is rendered relatively insensitive to installation and maintenance procedures (e.g., torquing of connector bolts).

Consolazio's team developed and analyzed computer models of the breakaway system prior to conducting physical tests with the pendulum. Once numerical analysis results indicated that the connection was ready for testing, the researchers prepared the pendulum by installing an array of different sensors. Researchers mounted accelerometers on the 2,400-pound (weight of a small car) impact block to monitor deceleration levels during impact. Researchers used infrared break-beams to quantify the speed of the block just prior to the instant of collision with the signpost. They attached tape switches to the face of the block and to the face of the signpost to record the instant of impact. They installed force-measuring load-washers and strain gauges on the test signpost to aid in comparing experimental data to analysis results. Finally, they used two high-speed cameras, each capable of recording 1,000 images per second, to record the response of the breakaway system when impacted by the block. One camera captured vertical wide-angle footage, while the other captured close-ups of the impact zone. Combined, the collected data enabled the researchers to experimentally confirm that the breakaway connection functioned properly and as expected, based on previously conducted numerical analyses.



Schematic of the desired sign structure identifying key compontents.

In the future, researchers plan to use the pendulum to develop hybrid breakaway signpost systems constructed of both steel and fiber-reinforced polymer (FRP) materials, and to measure—at reduced scale—dynamic vessel impact loads that are exerted on bridge structures during vessel collision events.

"This newly constructed impact pendulum—which was born directly out of Marc Ansley's forward-looking research vision—will enable FDOT to conduct a wide range of impact testing programs in the future, all with the ultimate goal of increasing safety along Florida's highways," notes Consolazio. "The pendulum will serve FDOT, and thereby the traveling public, for many years to come." ⬣

The lower portion of a steel sign post, or stub, extends four inches above the ground. The flange plate at the bottom of the middle post segment rests on the stub flange plate. A multi-part shear-controlled moment collar wraps around and joins the flange plates of the stub and middle post.

After the impact test, the front half of the moment collar lies on the ground, bottom right; the back half of the collar traveled several feet in the direction of impact as anticipated.

K-Barriers Increase Roadside Safety

The Federal Highway Administration's (FHWA) Transportation Pooled Fund (TPF) Program has existed for more than 20 years. It is a popular means for transportation agencies, commercial entities, and the FHWA to combine resources to achieve common research goals. Pooling resources allows the funding of costly research at a reduced rate for each contributor.

To qualify as a pooled fund study, more than one state transportation agency, federal agency, municipality, metropolitan planning organization, college, university, or private company must commit funds or other resources to conduct the research. In the past 15 years, FDOT has participated with other transportation entities to complete 74 pooled fund studies, and currently is a contributor in 35 ongoing studies. One of the more successful studies in which FDOT participated was the development of the temporary roadside safety barrier called the K-barrier.

The Midwest Roadside Safety Facility (MwRSF) conducts numerous research projects using pooled fund resources. Housed at the University of Nebraska-Lincoln, MwRSF is one of the premier research crash test facilities in the country. MwRSF researches all aspects of highway design and safety. Its mission is to improve the safety of public roadways through the design and testing of roadside hardware. MwRSF evaluates roadside safety features, performs computer simulation of vehicle impacts with roadside hardware designs, and develops and crash tests roadside hardware. MwRSF also conducts safety performance evaluations of various roadside appurtenances, developing new and innovative design concepts and technologies in the area of highway safety. MwRSF has studied the design and performance of temporary concrete safety barriers for many years. Safety barriers are one of the most common types of roadside hardware found on the nation's highways.

Temporary barriers are placed in work zones to protect motorists from hazards such as pavement drop-offs and above-ground hazards. They also protect equipment and roadside workers from errant vehicles.

Typically, safety barriers are segmented units that are attached end-to-end by a load-bearing connection, typically either a JJ hook or a pin and loop assembly (see photos, page 8). The connection system keeps the barriers joined and helps to stop a vehicle upon impact. Their segmentation and portability allows for easy installation, repositioning, and removal.

Since the mid-1950s, the most common temporary barrier used in work zones has been the Jersey barrier. It is 32 inches high, 12 feet long, and 24 inches wide at the bottom, is made of steel-reinforced poured concrete, and weighs approximately three tons. When viewed in profile, the first two inches rise vertically from the pavement, the next 10 inches rise at a 55-degree angle, and the remainder rises at an 84-degree angle. The break in the slope helps to prevent the vehicle from traveling over the top of the barrier and to redirect the vehicle onto the roadway.

In 1997, MwRSF researchers tested and received FHWA approval for a new barrier design called the

Eastbound I-4 at the CSX Railroad overpass. The contractor for the I-4 to Selman Expressway expansion project used K-barriers along the length of the five-mile project. Bolting the barriers to concrete reduces the distance barriers deflect if struck by an errant vehicle and reduces the size of the deflection zone required in work zones.

Above: Test K-barriers at the MwRSF in Lincoln, Nebraska. The barrier bases are attached to the concrete roadway surface by injecting epoxy into a drilled hole, inserting anchor bolts through each toe hole and into the drilled hole, and securing the bolts with a washer and nut above the toe hole.

Below: End view of a K-barrier depicting a pin and loop end connection. Typically, safety barriers are attached end-to-end by a load-bearing connection that keeps the barriers joined and helps to stop a vehicle upon impact.

F-shape barrier. The difference between the Jersey barrier and the F-shape barrier is the distance from the ground to the slope break: 13 inches for Jersey barriers versus 10 inches for F-shape barriers. MwRSF researchers determined that the lower slope-break point of the F-shape barrier is more effective at redirecting vehicles. FHWA called for the phase-out of the Jersey barrier in 2012.

To protect the traveling public and roadway technicians alike, FHWA specifications provide a safety barrier deflection distance of two feet in speed zones of 45 mph or less, and four feet in speed zones of 50 mph or greater. Construction activities are not permitted within this safety deflection zone. However, complying with safety zone requirements affects the amount of space available for construction activities and frequently requires technicians to reduce lane widths or to close lanes entirely. If space is available, it may be possible to construct temporary lanes to compensate for closed lanes; however, this option significantly increases production costs, estimated at $500,000 per mile.

To decrease the distance barriers deflect when impacted and to increase the amount of space available in construction zones, MwRSF researchers studied a method to attach a modified F-shape barrier to roadways. Called the K-barrier, it is identical in shape to the F-shape barrier but cast with six steel-reinforced holes, three per side, in the toe of the barrier. The reinforced holes allow technicians to insert bolts or stakes through the holes and into the roadway surface.

MwRSF researchers published their findings concerning attaching K-barriers to concrete roadway surfaces in the 2003 report entitled *Development and Evaluation of a Tie-Down System for the Redesigned F-Shape Concrete Temporary Barrier*. They constructed a wall of K-barriers, drilled holes into the concrete surface on the traffic side of the barriers, and removed the resulting dust. They injected epoxy into each hole, inserted a 1.25-inch-x-12-inch anchor bolt through each toe hole, and secured each bolt with a washer and nut above the toe hole. Then, they crashed a ¾-ton pickup truck traveling at 62 mph into the barrier at a 25.3-degree angle. The researchers conducted the crash tests according to National Cooperative Highway Research Program (NCHRP) Report 350 evaluation criteria and found that attaching the barriers to the roadway significantly increased the stability of the barriers and reduced deflection. Specifically, they found that upon impact the bolted K-barrier permanently deflected just 3.5 inches from its original line of placement. Compared to the deflection space allowance of four feet for freestanding barriers in a 50 mph or greater speed zone, the safety zone for bolted barriers could decrease by 44.5 inches.

In 2007, MwRSF researchers published *Tie-Downs and Transitions for Temporary Concrete Barriers*. This study included two parts: the development of a method to attach K-barriers to asphalt surfaces, and the development of a transition barrier system. To test the deflection distance of K-barriers attached to asphalt surfaces, researchers constructed a wall of K-barriers and hammered a 40-inch long, 1.5-inch diameter steel stake through each toe hole on the traffic side of the barriers. Then they crashed a ¾-ton pickup truck traveling at 62.5 mph into the barrier at a 25-degree angle, following National Cooperative Highway Research Program (NCHRP) Report 350 evaluation criteria. The researchers found that the staked K-barrier permanently deflected 11.1 inches upon impact from its original line of placement. Compared to the deflection requirements of four feet for freestanding barriers when struck at the same speed, the space required in the safety deflection zone could decrease by almost 37 inches.

FHWA has accepted MwRSF's findings of a 3.5-inch deflection distance for K-barriers bolted to concrete and an 11.1-inch deflection distance for K-barriers staked to asphalt. Florida is among several states that have adopted the K-barrier tie-down systems. Florida specifications allow the outside edge of bolted K-barriers to be placed as close as 1.5 inches from the concrete pavement edge. If impacted, the 24-inch barrier foot will not deflect more than two inches beyond the edge of the roadway surface. FDOT specifications also allow the outside edge of K-barriers staked to asphalt roadway surfaces to be placed as close as 12 inches from the pavement edge so that if impacted, the outside edge of the barrier will deflect to within one inch of the pavement edge.

Florida specifications allow the outside edge of bolted K-barriers to be placed as close as 1.5 inches from the concrete pavement edge.

The decrease in the required size of safety zones has significant ramifications for both traffic engineers and the traveling public. Contractors can apply the space savings gained through the reduction of buffer space in work zones to maintaining lane width and/or by increasing space for roadway workers and equipment. The decrease in required deflection space behind the barrier wall can also help to reduce the necessity of closing lanes or constructing temporary lanes.

One of the first FDOT construction projects that used bolted K-barriers was the expansion of State Road 50 east of Orlando in 2008, which included the widening of the Econlockhatchee River Bridge. By installing K-barriers close to the edge of the bridge, rather than two feet away from the edge as previously specified, the contractor gained valuable space in a constrained area, which eliminated the need to close travel lanes while providing sufficient room to work.

Another early project on which K-barriers were used was the widening of the Dolphin Expressway in Miami-Dade County. The contractor constructed 1.7 miles of K-barrier in the median and reduced lane width from 12 to 11 feet. Because of the use of K-barriers, the contractor gained enough space to construct a new lane without closing existing lanes or constructing temporary lanes.

More recently, the contractor of the I-4 to Selman Expressway project used K-barriers along the five-mile length of the project. The contractor bolted the barriers to the surface of concrete bridges 1.5 inches from the edge, thereby increasing work zone size on the opposite side while not requiring a reduction in traffic speed. In other non-bridge construction zones where there was ample shoulder and deflection space, the contractor connected the barriers end-to-end without staking or bolting. Installing K-barriers throughout the project allowed the contractor to use similar construction equipment to move the barriers and ensured consistent connection methods, thus reducing costs and saving time.

K-barriers developed through pooled fund research have proven to be a safe and cost-effective method for increasing the amount of space available in confined work zones, while simultaneously helping to reduce delays for the traveling public. ⬣

Above: Close-up view of K-barrier damaged in the MwRSF crash test.

Left: K-barriers bolted to a concrete surface at the MwRSF deflected just 3.5 inches when impacted by a vehicle traveling at 62.5 mph.

FDOT's Pipe Repair Matrix: Investing in Florida's Underground Economy

In recent years, events calling attention to the condition of the nation's infrastructure have made national headlines. In the case of structures people see every day, such as roads and bridges, these problems are often obvious – sometimes even dramatic – but under the surface and less apparent are the needs of the vast pipe systems that serve many aspects of everyday life, especially in the area of water management, such as stormwater drainage, freshwater conduits, and wastewater systems.

In August 2008, Tropical Storm Fay dropped 18-24 inches of rain in the Tallahassee, Florida, area. A section of Capital Circle Northeast/U.S. 319 buckled and collapsed when underground drainage pipe failed.

The Florida Department of Transportation (FDOT) constructs, manages, and maintains a significant portion of the stormwater pipe infrastructure in Florida. Investment in pipe is significant. In the last five years, FDOT spent $38 million for new pipe installations. Annual costs for repairing pipe systemwide is approximately $2 million. Pipes are usually located below other infrastructure – in fact, concrete pipe is often part of the support system for roadways – so repair operations tend to be difficult, disruptive, and expensive. Damage to pipe ranges from leaking joints and cracking to punctures resulting from installing guardrail posts or drilling for utility lines.

Finding and implementing the most effective materials and methods for both installation and repair is an important preventive measure and can yield significant savings. Newly installed pipe is expected to last up to 100 years. Where repairs are necessary, they are expected to last for the remaining design life of the pipe, up to 100 years. However, there is relatively little hard data about the durability of specific kinds of repairs.

Over four years, FDOT has been accumulating expertise about pipe repair in the form of a pipe repair matrix. The matrix is a web-based compendium that engineers, FDOT personnel, and contractors can use to identify the best pipe repair method for a specific type of damage and setting. The matrix covers methods for metal, HDPE, PVC, and concrete pipe. Information in the matrix is a compilation of FDOT specifications, design standards, and repair procedures.

The matrix originated when FDOT sought pipe industry specialists' recommendations about pipe repairs. This dialogue continues through FDOT's Pipe Advisory Group and Pipe Installation Task Force, both of which comprise drainage pipe experts and members from the pipe manufacturing, laser profiling, and inspections industries. The matrix is a living document that is continuously enhanced by FDOT experience and research findings, and a guidance document for use by pipe engineers in conjunction with current ASTM and AASHTO documents relating to drainage pipe to provide a series of options for pipe repair. The final decision on any repair is the responsibility of an engineer.

Because the matrix is accessible on a website, contractors, designers, engineers – everyone in the process – is literally working from the same page. Repairs involving a leaking joint or a crack can be resolved with a preferred method like grouting. However, many repairs involve several kinds of damage, and the matrix becomes the basis for the more complex solutions required.

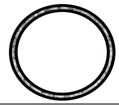
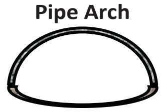
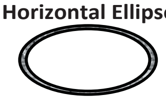
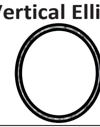
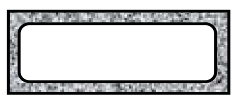
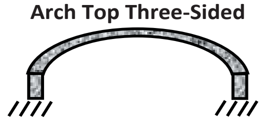
In a recent project to supplement FDOT knowledge about pipe repair, a University of Florida (UF) research team examined a range of repair methods for steel-reinforced concrete pipe. The research team was led by Dr. Fazil Najafi, a civil and transportation engineer, Dr. Willie Harris, an expert in soil chemistry, and Dr. Larry Muszynski, a construction specialist with a research focus on reinforced concrete. The team's goal was to determine how effective specific repairs were in restoring the structural and functional integrity of pipe without reducing required flow characteristics of the overall pipe system.

The research team began their efforts by reviewing the research literature and compiling an up-to-date list of pipe repair methods and solutions, with descriptions of their use, longevity, and efficiency. From this information, they selected a number of common repair methods and sites where the repairs had been made. This was a challenging task in itself because records of repairs tended to vary considerably in their level of detail, if they existed at all. In some cases, the memories of long-term workers were the only guide. From the information collected, the team created a database containing pipe repair data covering the past 15 years. The majority of pipe issues requiring repair were leaking joints, joint gaps, spalling, and cracking. They identified in the database repair sites corresponding to major, commercially available repair types.

The team selected 16 sites as good candidates for further study. Repair types included chemical grout, pipe liner, fiberglass liner, joint seal, band seal, and repair sleeve. Wherever possible, researchers selected both closed-circuit television and laser profiling to evaluate the condition of repaired pipes. At the repair sites, researchers collected field data on infiltration of water or sediment, debris accumulations, corrosion of metal pipes and their repairs, staining, cracking or deflection, alignment, seam and joint integrity, pitting, and shape and thickness of repaired pipe. Soil sampling provided data on the influence of surrounding soil properties on both damage and repairs. Soil-specific measurements included identification of soil type, pH, electrical conductivity, and other properties that can contribute to pipe degradation.

The research team summarized their findings in the form of recommendations and in a pipe repair flowchart. Research findings like this will further enhance the pipe repair matrix and ultimately lead to better repairs and prolonged service life of pipe installations. Savings over the service life of many pipe networks can be measured in the millions of dollars.

The research team recommended that guidelines should be developed to formalize systematic tracking and assessment of pipe condition and repair. This project helped to establish a protocol for reporting pipe repairs and a database repository to assist in accumulating and accessing repair information.

SHAPE	RANGE OF SIZES	COMMON USES
Circular 	12 to 180 inches reinforced; 4 to 36 inches non-reinforced	Culverts, storm drains, and sewers.
Pipe Arch 	15 to 132 inches equivalent diameter	Culverts, storm drains, and sewers. Used where head is limited.
Horizontal Ellipse 	Span x rise 18 to 144 inches equivalent diameter	Culverts, storm drains, and sewers. Used where head is limited.
Vertical Ellipse 	Span 36 to 144 inches equivalent diameter	Used where lateral clearance is limited.
Rectangular (box sections) 	Span 36 to 144 inches	Culverts, storm drains, and sewers. Used for wide openings with limited head.
Arch 	Span 24 to 41 feet	Culverts and storm drains. Used for low, wide waterway enclosures.
Flat Top Three-Sided 	Span 14 to 36 feet	Culverts and storm drains. Used for low, wide waterway enclosures.
Arch Top Three-Sided 	Span 16 to 36 feet	Culverts and storm drains. Used for low, wide waterway enclosures.

Standard concrete pipe shapes, ranges of sizes, and common uses (AASHTO 1991).

The research has helped to advance the need for more and better long-term data on the performance of pipe repairs. Consistent and thorough record keeping is critical to infrastructure and repairs that last well beyond a typical career. Better data is the key to further advancing the effectiveness and utility of the pipe repair matrix and assuring that Florida's stormwater infrastructure is maintained at optimum efficiency and economy. ⬣

Meet the Project Manager

Peter Lai, P.E., Assistant State Geotechnical Engineer, FDOT Structures Office

Peter Lai has managed geotechnical research projects for FDOT since 1987. The research projects have led to improved geotechnical engineering practices in the design and construction of deep foundations, enabling FDOT bridge engineers to design safer and more cost-effective bridge foundations.

Lai has been instrumental in calibrating deep foundation resistance factors for load and resistance factor design (LRFD) specific to Florida's geology and design methods. LRFD is a methodology that was adopted in the 1990s by the Federal Highway Administration (FHWA) and the American Association of State Highway and Transportation Officials (AASHTO) to design bridges.

Lai and a team of researchers at the University of Florida (UF) found that the calibrated resistance factors were significantly larger than AASHTO's recommended values. Their findings enabled FDOT to design bridges specific to Florida's geologic conditions and at a lower cost. Because of Lai's leadership, Florida became the first state in the nation to calibrate resistance factors specific to its geology.

Currently, Lai and UF researchers are developing LRFD factors for deep foundation designs that consider highly variable subsurface conditions and employing various resistance factors by bridge site zone for specific subsurface conditions.

Lai also has conducted extensive research to develop innovative deep foundations. In 2001, Lai and University of South Florida researchers began evaluating the effects of post-grouted drilled shaft tips in sand with the goal of shortening drilled shafts constructed in sandy soils. The researchers gathered data from Florida construction sites where post-grouted shafts could be a plausible alternative to driven piles and created a spreadsheet program called Shaft 1-2-3. The program is capable of predicting the capacity of both conventional and post-grouted shafts. The research resulted in a new design rationale and methodology applicable to granular soils, such as sands and gravels.

In 2009, Lai and UF researchers invented a new deep foundation method that uses jetting and pressure grouting to install precast concrete piles. By eliminating the noise and vibration typical of driven pile installation, the method is suitable for urban areas where vibrations can damage infrastructure. Grouting along the pile shaft and tip also improves pile strength. Currently, Lai and UF researchers are developing a new method of drilled shaft installation whereby engineers inject grout at the sides near the tip of drilled shafts prior to tip grouting. Researchers are conducting load tests to validate the design method and also will conduct load tests on the jet-grouted piles in Florida soils. The research will result in the development of a more efficient, cost-effective, and reliable foundation method.

One of Lai's ongoing projects has been the development of a deep foundation database and its recent conversion to a Web-based platform. In 1987, Lai and UF researchers developed the first driven pile database using Lotus 1-2-3 software, allowing users to analyze bridge designs based on the available data. The database evolved over the years to include data on drilled shafts. In 1999, researchers designed a completely new database that combines the data into a single menu-driven database capable of storing and managing data more efficiently. The Web-based database organizes data by bridge project and allows users to search for data by GPS location. It also allows users to query and analyze data and map results using ArcView software.

After several years of testing and fine-tuning, FDOT expects to publish the Web-based database and offer training later this year. Says Lai, "The extensive amount of information contained in the database will allow geotechnical engineers to design bridges with greater confidence and a smaller margin of error, resulting in more reliable foundation designs."

Lai is proud of the research projects he has managed at FDOT. "I have been able to save the state of Florida millions of dollars in construction costs through the development of better bridge foundation analysis tools. Florida will realize even greater savings from the implementation of the deep foundation database." ⬣

Meet the Principal Investigator

Gary Consolazio, Department of Coastal and Civil Engineering, University of Florida

Dynamic loading conditions, such as collisions, blasts, earthquakes, wind, and waves, all have the potential to damage transportation infrastructure. Gary Consolazio, associate professor at the University of Florida's (UF) Department of Civil and Coastal Engineering and principal investigator for numerous FDOT research projects, has been conducting research on the response of structures to dynamic loads since 1998. His research has focused on the effects of rapidly applied impact loads, such as those generated by vessel or vehicle collisions on structures, including bridge piers, sign support structures, and work zone barriers. By developing a better understanding of how structures respond to impact loads, Consolazio's work is helping engineers to design safer and more efficient systems.

A primary focus of Consolazio's research has been the study of barge impact loading on bridge piers. Because bridges that span navigable waterways are at risk of barge-pier collisions, they must be designed to resist potential impact loads. Bridges in the U.S. are designed to resist vessel collisions according to specifications developed by the American Association of State Highway and Transportation Officials (AASHTO). However, core components of these specifications are based on analysis procedures and experimental data developed over 25 years ago. Since then, advances in computer technology have allowed the ability to conduct quick and cost effective dynamic structural analyses.

In 2001, Consolazio began a multi-year research project funded by FDOT to develop improved bridge design and analysis methodologies. The replacement of the St. George Island causeway bridge provided an opportunity to experimentally measure impact forces and the related structural responses produced during barge collision events. Consolazio and a team of UF structural and geotechnical researchers conducted 15 full-scale experiments in which a 600-ton barge was rammed into instrumented piers of the decommissioned bridge prior to its demolition. Comparison of the experimental test data to results from AASHTO calculations and numerical impact simulations showed that the experimentally measured impact loads were generally smaller than those stipulated by AASHTO, but that the horizontal resistance to movement created by the weight of the bridge roadway caused the pier design forces to be substantially larger than expected.

To further validate several numerical design tools developed through the barge impact research, Consolazio and his research team are preparing to conduct experiments using the impact pendulum at FDOT's Marcus H. Ansley Structures Research Center in Tallahassee, Florida. He anticipates submitting proposed revisions to the barge collision portions of the AASHTO specifications near the end of 2012. Concurrently, Consolazio and his team are also conducting tests with the pendulum to develop a new impact-breakaway, wind-resistant base connection for multi-post ground signs (see related story, page 4).

Previous research concerning the response of structures to dynamic loads includes a 2002 project to design and crash-test a low-profile concrete safety barrier for use in roadside work zones. By limiting the height to only 18 inches, the barrier provides improved visibility for vehicle drivers, thereby improving safety for vehicle occupants and construction workers. Rather than requiring mechanical anchorage to the roadway, the barrier uses mass-related inertial resistance to redirect an impacting vehicle. When struck, the force of the vehicle impact is distributed along the barriers, reducing impact to the vehicle. In a follow-up project, Consolazio's team designed and crash-tested a tapered end treatment for the barrier. Instead of configuring the barriers to curve around corners, the end treatment allows the barriers to end immediately at driveways and cross streets.

"My research team and I have been able to combine numerical simulation with physical testing," says Consolazio. "Simulation using numerical models is a powerful tool for gaining insight into structural behavior and for designing systems to respond, as desired, to different loads. Physical testing permits us to validate the accuracy of numerical models, and helps establish confidence in their predictive capabilities." ⬣

TRB's Annual Field Visit Program

Each year, members of the Transportation Research Board (TRB) meet with staff of state departments of transportation (DOT), universities having transportation activities, and rail, aviation, transit, safety, marine, port, industry, and transportation organizations as part of the annual field visit program. The visits provide an opportunity for TRB state representatives, DOTs, and transportation organizations to exchange information concerning TRB activities and services, research in progress, and problems and issues facing state DOTs and other transportation organizations. The visits help to keep the DOTs up to date on any assistance and information TRB can offer to help address problems. The visits also provide an opportunity for DOTs to suggest problems/ issues TRB should consider addressing, and to recommend activities TRB should consider undertaking to provide the best service to state DOTs and other transportation organizations.

TRB representatives visited the Traffic Engineering Research Laboratory (TERL) during their visit to FDOT in November 2011. Left to right: Dr. Richard F. Pain, Transportation Safety Coordinator; Stephen Andrle, Deputy Director of SHRP2; Mark Wilson, FDOT State Traffic Operations Engineer; Darryll Dockstader, FDOT Research Center Manager; Trey Tillander, Traffic Research Engineering Laboratory Manager.

TRB's annual visit to FDOT occurred in mid-November 2011. Representatives Dr. Richard F. Pain, Transportation Safety Coordinator, and Mr. Stephen Andrle, Deputy Director of the Second Strategic Highway Research Program (SHRP2), met with FDOT program staff and toured the Traffic Engineering and Research Lab (TERL). Pain and Andrle also provided updates on the status of SHRP2 products and implementation activities.

Congress authorized the highly focused, $218 million SHRP2 research program in 2005, with the overarching theme of providing outstanding customer service for the 21st century. SHRP2 is investigating the underlying causes of highway crashes and congestion. SHRP2 builds on the success of SHRP, a $150-million effort that produced many valuable products for the highway industry, including the widely used Superpave asphalt pavement.

SHRP2 has four focus areas: accelerating the renewal of America's highways, improving highway safety, providing a highway system with reliable travel times, and providing highway capacity in support of the nation's economic, environmental, and social goals. Following a competitive application process, Florida universities/agencies were awarded $6 million to participate in research studies in the safety and capacity focus areas.

Safety: SHRP2's safety objective is to identify countermeasures that will significantly improve highway safety through an understanding of driving behaviors. Driver behavior has been identified as the major factor in about 90 percent of roadway crashes. Data has shown that every one percent reduction in crashes will prevent 330 deaths and about $2 billion annually in medical expenses and other losses. To improve driver safety, SHRP2 has developed a naturalistic driving study focusing on methods to prevent or reduce the severity of highway crashes. The study is the largest coordinated safety program ever undertaken in the U.S. It focuses on the driver's interaction with the vehicle, roadway characteristics, traffic environment, traffic controls, and weather, and seeks to identify the differences in crash risk associated with these interactions. Over 3,000 volunteer drivers in six states, including Tampa, Florida, are participating in the study. The five other locations are Seattle, WA; central Indiana; Erie County, NY; central Pennsylvania; and Durham, NC. The locations were selected to provide a range of demographics, geography, weather, state laws, road types, and road usage.

Researchers with the University of South Florida's (USF) Center for Urban Transportation Research

(CUTR) are coordinating the study being performed in Florida. They have installed on-board data acquisition systems (DAS) in the cars of participating drivers to gather information about what happens when people crash, when they experience a near crash, and when they drive without incident. The cars will be monitored for a two-year period beginning in 2010. The goal is to collect about 3,900 vehicle-years of data in a 28-month period. The resulting data will provide a wealth of information regarding driving behavior, lane departures, and intersection activities, which is anticipated to be of great interest to transportation safety researchers and others for at least 20 years. Researchers also will be developing methods to store, maintain, and analyze the data, and establishing protocols for access to the data.

Capacity: Decision makers often base their decisions about spending public funds for transportation capacity improvements on estimates and forecasts developed with mathematical models. The more closely the models represent reality and include important influencing factors, the more confidence decision makers have when making funding choices. Models that provide a better basis for predicting how highway improvements affect congestion, or that reflect the differences in forecasting freight demand and passenger transportation, for example, provide a more reliable estimate of future needs.

SHRP2 is conducting two projects that will improve modeling and network processes and procedures in order to address policy and investment questions. The projects will produce a transferable product, process, and sample data set that can be adapted for use elsewhere. Project C10A, Partnership to Develop an Integrated, Advanced Travel Demand Model and a Fine-Grained, Time-Sensitive Network, being conducted in Jacksonville, Florida, and Project C10B, Partnership to Develop an Integrated Advanced Travel Demand Model with Mode Choice Capability and Fine-Grained, Time-Sensitive Networks, being conducted in Sacramento, California, both aim to reduce congestion and increase capacity. The projects are examining the nature of demand, mode choice, destination choice, timing, travel route as a response to highway congestion, roadway management strategies, road pricing, transit service, parking, and other public policies.

SHRP2's research team has partnered with the North Florida Transportation Planning Organization, whose region covers the Jacksonville metropolitan area, to conduct project C10A.

SHRP2 has developed a Web portal that organizes planning around key decisions and a case-based tool for estimating the economic impact of proposed highway expansion. Both the C10A and C10B projects are expected to be complete in 2012. More information can be found at www.transportationforcommunities.com.

The methods, guidance, and technologies developed thru SHRP2 research will help transportation agencies make changes necessary to better serve their customers and better manage institutional change. The products of SHRP2 research, if widely implemented, could significantly enhance taxpayers' investments in transportation and improve the daily experience of roadway users. ⬣

For More Information

Pendulum Impact Tests

BDK75 977-40, Pendulum Impact Testing of an Impact-Breakaway, Wind-Resistant Base Connection for Multi-Post Ground Signs
Gary Consolazio, Principal Investigator
Will Potter, Project Manager

BDK75 977-42, Pendulum Impact Testing of Metallic, Non-Metallic, and Hybrid Sign Posts
Gary Consolazio Principal Investigator
Sam Fallaha, Project Manager

BD545-69, Development of an Impact-Breakaway, Wind-Resistant Base Connection for Multi-Post Ground Signs
Gary Consolazio, Principal Investigator
Marcus H. Ansley, Project Manager

Pipe Repair Matrix

BDK75 977-38, Durability of In Situ Pipe Repair
Fazil Najafi, Principal Investigator
Larry Ritchie, Project Manager

Midwest States Regional Pooled Fund Program

TRP-03-180-06, Development of Tie-Down and Transition Systems for Temporary Concrete Barrier on Asphalt Road Surfaces
http://engineering.unl.edu/specialty-units/mwrsf/MwRSF-Downloads/TempBarrier/TRP-03-180-06.pdf

TRP-03-134-03, Development and Evaluation of a Tie-Down System for the Redesigned F-Shape Concrete Temporary Barrier
http://engineering.unl.edu/specialty-units/mwrsf/MwRSF-Downloads/TempBarrier/TRP-03-134-03.pdf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