Spring/Summer 2011

RESEARCH Showcase

Pavement Evaluation Tools

Embedded Data Collectors

Key Royale Bridge Test Site

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

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Back Cover: Key Royale Bridge at Anna Maria Sound

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FDOT Research Showcase

In This Issue

FDOT's research program benefits the agency and its customers by developing knowledge and products that are used to enhance safety, reduce costs, improve system performance, and otherwise aid FDOT in effectively carrying out its mission and objectives. This issue of *Research Showcase* highlights several successful research products that not only have been implemented, but nationally recognized.

The first article recognizes the work of the State Materials Office for developing pavement testing and analysis tools that promote safety, improve system performance, create process efficiencies, and generate cost savings. Currently used in Florida, the four tools were selected by the American Association of State Highway and Transportation Officials (AASHTO) Technology Implementation Group (TIG) as focus technologies worthy of adoption nationwide.

The embedded data collector (EDC) system presented in the second article is a technology that was developed and refined through a series of research projects. Also recognized by TIG as a valuable technology, the system is used to monitor piles during installation and has other potential applications, such as health monitoring. It has been used successfully on many bridge projects in Florida and elsewhere in the nation. In the Key Royale Bridge article that follows, the EDC appears again, this time as a tool to study the performance of several test concrete mixes installed during bridge replacement. The Key Royale Bridge project received a Federal Highway Administration (FHWA) Innovative Bridge Research and Construction program award of $400,000 to perform the research.

Please take time to read these and the other articles in this issue, which present many additional beneficial studies along with key players who make the projects and their implementation possible.

Darryll Dockstader, Manager

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AASHTO Showcases FDOT Pavement Evaluation Tools

The Technology Implementation Group (TIG) is a committee of the American Association of State Highway and Transportation Officials (AASHTO) that champions the implementation of technology among AASHTO member agencies, local agencies, and their industry partners to improve the nation's transportation system. Each year, TIG solicits nominations of high-payoff, ready-to-use, and innovative technologies that recently have been adopted by one or more AASHTO member states and found to be highly beneficial. TIG evaluates these nominations and normally selects three that offer particular promise to benefit other transportation agencies. The selected nominations become TIG focus technologies for that year, and a plan is developed to carry out marketing and implementation support activities.

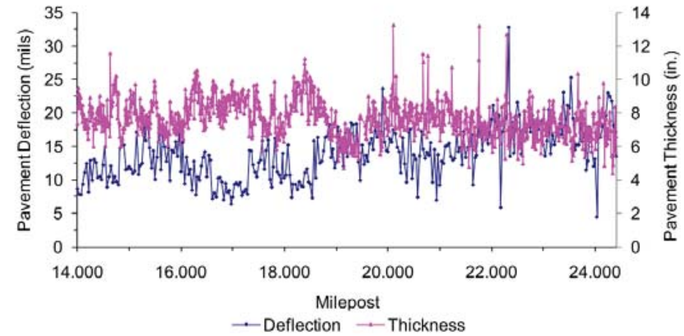
In 2008, TIG selected as a focus technology the FDOT-developed surface resistivity test, a non-destructive, electrically based method for estimating hardened concrete permeability. TIG also selected low profile barriers and embedded data collectors in 2007 to promote as "additionally selected technologies" (ASTs). ASTs are promoted as stand-out technologies, but with limited funding and marketing activities.

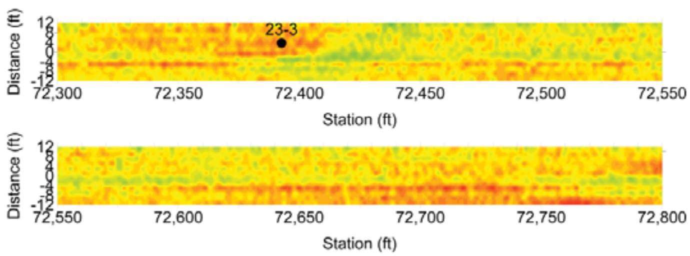
FDOT is pleased to announce that in 2010, TIG selected four FDOT pavement-related technologies to promote as a group. Developed through research and testing conducted and/or managed by the State Materials Office in Gainesville, Florida, these technologies are described below.

Enhanced Pavement Surveys Using Nondestructive Survey Equipment

Engineers have used destructive tests to evaluate the condition of roadway surfaces for nearly a century. Destructive testing often results in the disruption of traffic to obtain structural samples for analysis. However, both on-site sampling and laboratory testing are time consuming and labor intensive.

To overcome the disadvantages of destructive testing, various nondestructive testing (NDT) methods have been developed and implemented worldwide to evaluate transportation infrastructure. Two NDT methods frequently employ ground penetrating radar (GPR), a geophysical method that uses radar pulses to obtain images of the subsurface, and the falling weight deflectometer (FWD), a machine designed to impart a load pulse to the pavement surface to simulate the load produced by a rolling truck wheel.





Above: A scatter plot typically used to present NDT survey data.

Below: A contour plot of pavement density generated with GPR data. The black dot represents a selected location for destructive testing.

In general, the advantages of NDT methods are that they are rapid, collect more data, do not damage the roadway surface, and reduce destructive testing. However, as the amount of collected NDT data increases, so does the need for a strategy to summarize the data more efficiently.

The conventional method for presenting NDT survey data is through a two-dimensional scatter plot. Scatter plots provide a simple and useful method for viewing data for a given survey path, but they can be difficult to interpret as the number of survey lines increases, which makes the selection of sites for follow-up destructive testing inexact.

In 2008, FDOT engineers adopted the use of contour plots of nondestructive data necessary to represent the entire survey area. A contour plot is a two-dimensional representation of three-dimensional data that allows multiple two-dimensional plots to be merged into one. Contour plots can be generated from data obtained using a variety of survey equipment. For example, contour plots can depict pavement stiffness using FWD data and can depict pavement density using GPR data.

A falling weight deflectometer (FWD), shown above being towed behind an FDOT survey vehicle, is a nondestructive testing device used to evaluate the physical properties of pavement.

Although it still may be necessary to obtain field samples and conduct laboratory destructive tests to validate or improve upon the results from nondestructive tests, combining the NDT method with contour plotting allows for an efficient presentation of a large amount of NDT data and provides an improved methodology for selecting the most critical areas for limited destructive testing. FDOT estimates that the number of destructive tests has been reduced by 50 percent, saving approximately $73,000 per year.

Identifying Vibration-Sensitive Work Zones Based on FWD Data

FDOT has developed an analysis software algorithm and methodology for estimating the effects of vibrations on adjacent structures and the environment caused by asphalt compacting equipment. The use of large vibratory rollers to compact asphalt during repaving results in greater asphalt density than static rolling and increases pavement life; however, the resulting vibrations may be disruptive to business and residential areas and are suspected of causing damage to nearby structures.

The software uses FWD data to predict ground motion induced by vibrations. It scales the FWD data based on the operating frequency and amplitude of the vibratory compactor to be used. The software helps engineers derive the adequate vibration level in order to predict the appropriate distance restrictions from the roller's edge to nearby structures. Identifying more accurately the distance necessary to avoid adverse impacts allows engineers to determine where vibratory rollers can be used, decreasing the likelihood of damage claims and annoyance complaints.

A vibratory roller compacts fresh asphalt.

Automated Faulting Method

"Faulting" refers to the difference in elevation across a pavement joint or crack. Faulting has a direct impact on roadway lifecycle and vehicle operation costs. FDOT typically has measured faulting with a manual faultmeter. However, this method is slow and labor intensive, disrupts traffic, and presents safety hazards. Collecting fault data with an automated high-speed profiler (HSP) mounted on a survey van provides a more efficient and cost-effective alternative.

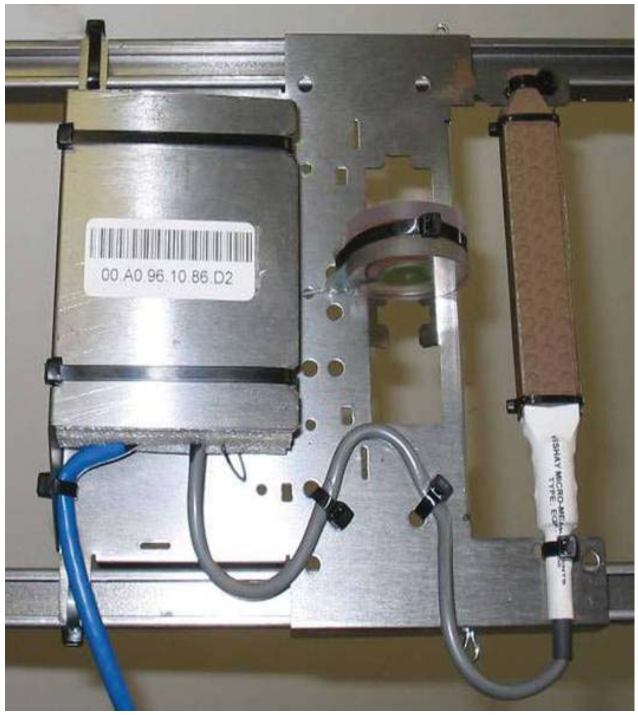
The HSP collects longitudinal profile data in both wheel paths, which is used to derive pavement surface characteristics such as rut depth, smoothness, and texture. Use of the HSP also eliminates traffic disruption and worker exposure to traffic.

FDOT recently developed an algorithm to detect the location of joints and transverse cracks in concrete pavements and to estimate faulting at these locations. The algorithm identifies spikes in the longitudinal profile data for locating joints and transverse cracks. It also emulates AASHTO standard practices for estimating faulting at these locations. The technique for locating joints and cracks has been incorporated into the Automated Faulting Measurement module of the engineering software application, Profile Viewing and Analysis Software (ProVAL), available online free of charge and used by engineers to view and analyze pavement profiles.

Continued on page 15

Embedded Data Collectors (EDC) Monitor Bridge Foundation Health

Hundreds and sometimes thousands of blows are needed to drive prestressed concrete piles down to a stable bearing layer of rock or competent soil. However, sometimes the concrete piles develop cracks or shatter under the applied stresses imposed during installation, resulting in the time-consuming and expensive process of pile replacement.



From left: Electronics module, accelerometer, and strain gauge imbedded in the pile core allow for the calculation of velocity and force, enabling the engineer to monitor pile driving stresses, integrity, and capacity.

Geotechnical engineers around the world use a diagnostic tool called Pile Driving Analyzer® (PDA) to monitor pile driving stresses, load bearing capacity, and integrity during the driving of test piles. PDA uses instrumentation (i.e., strain transducers and accelerometers) attached near the head (top) of the pile at the construction site to collect data and analyze stress wave characteristics in the pile. Engineers monitor the instruments to obtain a continuous record of the range of stresses imparted to the pile and to estimate static capacity and integrity. PDA calculates results from velocity and force signals obtained by the instrumentation and evaluates the stress wave characteristics, enabling engineers to ensure that capacity will be attained.

Typically, 10 percent of piles in Florida are tested with PDA to determine site-specific dynamic soil response variables (i.e., damping and quake), estimate production pile lengths, and develop driving criteria for use when driving non-instrumented production piles.

In the late 1990s, FDOT contracted with the University of Florida's (UF) Department of Civil and Coastal Engineering to develop a method for detecting pile driving characteristics that could be applied to every pile undergoing the driving process to improve overall capacity prediction. By the end of the research project in 2002, UF engineers had created and successfully tested a first generation system for real-time monitoring of pile driving stresses, integrity, and capacity. The Embedded Data Collector (EDC) is an alternative system that in principle works like the PDA to analyze stress waves but also provides specific measurements of tip (bottom) compressive stress and determines the dynamic soil variables of damping and quake values automatically. Systems like PDA that use only top instrumentation require the aid of wave-matching software to determine damping and quake.

The EDC test system included sensors and transmitters embedded in the wet concrete near each end of a pile during casting. The transmitters sent data via wireless signal to a computer at the construction site, where engineers monitored and evaluated the results and, when necessary, modified driving force to prevent damaging the pile. The system offered the advantage of instrumentation embedded at both the head and tip of the pile, enabling the measurement of tip stresses, early detection of potential damage to the pile tip, and real-time calculation of damping and quake (i.e., the temporary dynamic resistance response) for every hammer blow.

A pile damaged during driving.

Both EDC and PDA alert contractors when driving should stop by measuring stress waves. However, EDC is also capable of measuring tip stress and loss of prestress (i.e., the amount of stress applied to the metal strands during fabrication) near the pile tip. Instrumenting piles with EDC during fabrication allows engineers to spend less time installing instruments on piles at the construction site, subsequently reducing construction time and saving both time and money. Real-time data obtained regarding the integrity and capacity of piles, without having to use wave-matching software to determine site-specific damping and quake values, as required by systems using only tip instrumentation, is a significant advantage of the EDC system. In addition, the capability of instrumenting all piles used for a project reduces the level of uncertainty inherent with indirect methods of monitoring pile driving, allowing the use of higher resistance factors in design, and likely resulting in shorter pile lengths and savings in material costs and construction time. The EDC system offers a solid alternative to current methods and has capabilities that make it a powerful tool for dynamic load testing.

UF researchers first field tested EDC on 11 pilings of the new I-95 Trout River Bridge in Jacksonville. The results showed EDC was a viable system for monitoring pile driving. In 2003, the technology was licensed to Smart Structures, Inc., for further development and manufacture under the trademark name SmartPile™.

Smart Structures, Inc., and FDOT have worked to evaluate and refine EDC in coordination with Applied Foundation Testing, Inc., which installs the sensors in the piles. EDC has been used on several FDOT projects and one county project in Florida (see related article, page 8), and also several major bridges in Louisiana, South Carolina, and Virginia.

The software for analyzing EDC data is still in development. The FDOT Structures Office has compared EDC data with PDA data obtained from the same piles and the results indicate that the systems are comparable within acceptable ranges. FDOT has contracted UF to analyze static load tests that will be performed on piles driven with EDC instrumentation. The results will allow researchers to compare EDC predictions of pile resistance and load distribution between the pile sides and the tip with conventional static load test results to further calibrate the system's ability to determine load distribution. The research results will be used to develop a resistance factor for use in Load and Resistance Factor Design (LRFD).

Because EDC sensors also have a sleep mode during which they can power up at intervals to collect data, one possible future use for EDC is to collect load and stress distribution data throughout the lifetime of the bridge, data that has not been available previously. Such information would prove valuable in monitoring a bridge foundation's long-term health. ⬣

Top photo: A computer equipped with an antenna mounted to a portable tripod receives real-time data from accelerometers embedded in concrete piles.

Bottom photo: Field engineers monitor pile driving characteristics at a construction site.

Key Royale Bridge: Test Site for New Technology

Construction of the new Key Royale Bridge at Anna Maria Island, located just west of Bradenton, Florida, was completed in 2007. It replaced the original bridge built over 50 years ago. Designed to carry 3,200 vehicles each day when completed in 1960, the bridge was serving nearly 4,700 vehicles per day by 2001. Further, the marine environment had caused severe corrosion, and repairs were no longer feasible.

Construction of the replacement bridge was partially funded by the Innovative Bridge Research and Construction program (IBRC), a Federal Highway Administration (FHWA) initiative to encourage the use of innovative construction materials and practices. To meet these objectives, the bridge served as a test site during construction for the collection of pile driving data, and it will continue to provide researchers with data concerning the performance of various concrete mixtures well into the future. FDOT is conducting this research with the goal of extending the service life of bridges to 100 years.

Bridges are some of the costliest projects funded by FDOT. The replacement cost of the Key Royale Bridge, a relatively small project, was approximately $3.4 million. Increasing bridge service life to 100 years would benefit the public by reducing maintenance and replacement costs and disruptions to traffic.

To attain the goal of 100-year service life, particularly for bridges constructed in marine environments, concrete mixtures must be capable of resisting the ingress of chlorides. FDOT constructed the support piles and fender piles of the Key Royale Bridge using six different high-alkalinity concrete test mixtures. Corrosion sensors embedded just above the high tide area of the piles allow FDOT engineers to monitor corrosion and corrosion potential resulting from salt water penetration of each concrete test mixture.

During annual inspections, bridge engineers will gather data from the corrosion sensors and compare the performance of the concrete test mixtures in terms of strength, durability, and resistance to chlorides. Monitoring the concrete test mixtures under real-time exposure conditions allows engineers to compare on-site performance with accelerated corrosion testing in laboratory conditions.

Small, temporary piles called durability segments were constructed to enable the future analysis of the six concrete mixtures. The durability segments were attached to fender piles and are instrumented with corrosion and temperature sensors. Temperature data obtained by monitoring the temperature gradient in the concrete from the outside in, down to the level of the steel, may prove to be important in predicting the durability of the concrete.

In the future, FDOT engineers will remove the durability segments, conduct structural tests, and develop chloride profiles. Fender piles also will be removed in 15-20 years to allow researchers to examine them for structural integrity, chloride penetration, and corrosion damage.

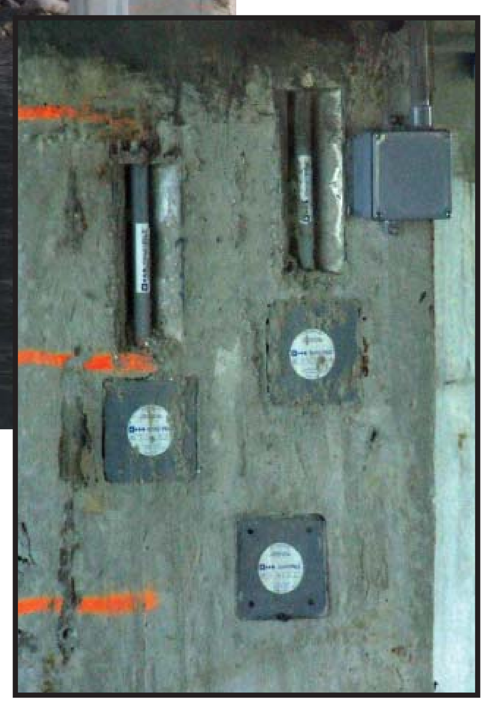
Continuous on-site monitoring and laboratory testing will be useful in identifying where corrosion occurs and which concrete mixtures are most effective at resisting chloride ingress. The data also will help

FDOT to predict when repairs will be needed and to optimize budget expenditures.

At the time of construction, the new Key Royale Bridge also served as a test site for collecting pile driving data. Each pile was equipped with both Pile Driving Analyzer® (PDA) and Electronic Data Collector (EDC) sensors to monitor pile stress, integrity, and capacity during installation. PDA sensors are attached to the outside of piles on the job site, while EDC sensors are cast into each pile. During pile driving, the PDA and EDC sensors sent real-time data via a wireless signal to a computer at the construction site, where engineers evaluated the results. The collected data was used to refine EDC data analysis software.

Piles equipped with the EDC system typically include accelerometers and strain transducers embedded near the pile head and tip to allow for dynamic monitoring of pile driving. For the Key Royale Bridge project, the piles were equipped with two additional sensors embedded in the middle of the piles. The data generated from the middle sensors enabled FDOT engineers to determine how the material properties of the different concrete mixtures affected the dispersal of the loads throughout the piles. In the future, engineers will activate the EDC sensors to test the piles for load and stress distribution.

Four years after the bridge was completed, FDOT is poised to begin research that will establish a baseline of concrete mixture performance to which future measurements of chloride penetration can be compared. As part of the research project, FDOT will remove and analyze core samples from the fender piles for chloride penetration, calibrate the corrosion sensors, and develop a long-term testing protocol and instructions. The information gathered from this research will ensure that FDOT applies the most effective concrete mixtures for projects constructed in the marine environment to achieve maximum bridge service life. ⬣



Above: Embedded data collectors, sensor battery packs, and electrical connection boxes are visible on piles and durability segments attached to fender piles of the Key Royale Bridge.

Right: Close-up view of instrumentation on a pile. From top left, two antennas (cylindrical objects) transmit signals to nearby computers; an electrical connection box (far upper right) houses wiring from temperature and corrosion sensors located in each pile bent; two translators/processors (middle) receive voltage from an accelerometer; a removable battery pack (bottom square object) allows the replacement of batteries to activate sensors.

Our Research Partner: University of North Florida (UNF)

The University of North Florida (UNF) School of Engineering in Jacksonville offers education and research programs in the fields of computing, engineering, and construction. UNF is a relatively new university, established in 1969. Currently, UNF has a student enrollment of 16,000 and 500 full-time faculty.

Engineering first appeared at UNF in 1987, with the campus hosting a branch of the University of Florida's Electrical Engineering Department and offering a Bachelor of Science degree in Electrical Engineering. In 1992, UNF paired the program with Computer and Information Sciences, becoming the College of Computing Sciences and Engineering, later renamed the College of Computing, Engineering and Construction in 2004. In 2006, the Division of Engineering was renamed the School of Engineering, in recognition of its growing reputation and importance to the educational and research missions at UNF.

FDOT has contracted with the UNF School of Engineering since 2002 to conduct research projects in the areas of materials, roadway design, and structures. Led by Dr. Mike Jackson, P.E., Associate Professor of Civil Engineering, UNF conducted three projects during the past decade that examined friction course characteristics and other roadway surface factors that contribute to safe driving conditions on Florida's roads. Friction courses comprise the top layer of material placed on roadways and are designed to improve safety. They are built using high quality, polish-resistant aggregates and have an outstanding capacity for providing and maintaining friction between tires and pavement. Their macrotexture allows water to drain rapidly from the pavement surface, improving tire contact with the pavement and reducing the potential for hydroplaning. Florida has used both the open-graded FC-5 course mixture on high-speed, multi-lane roadways and the more dense FC-6 course mixtures on other state-owned urban roadways since the mid-1990s.

Although pavement surfaces are designed and constructed in accordance with FDOT specifications, sometimes the desired frictional properties may not be obtained due to variations in the mix or because of pavement wear. In 2002-03, UNF researchers documented the measures taken in prior years to ensure that friction courses placed on Florida's roadways would meet or exceed expectations and examined whether surface textures varied among applications. This information would help researchers better define and quantify performance.

They recommended that a database management system be developed to monitor and track the durability and performance of both FC-5 and FC-6 course mixes throughout Florida. Since then, researchers have developed software applications to monitor friction number, macrotexture, mix type, traffic, and mix designs to further evaluate the durability and performance of friction course materials. They anticipate developing additional applications to cross-reference other databases in the future.

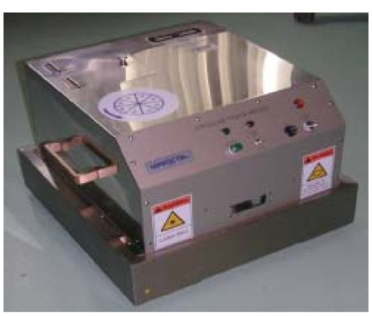
A friction trailer measures friction resistance from the force induced when the wheel is locked for three seconds over a wetted pavement surface. FDOT conducts friction tests on all newly constructed pavement surfaces, overlays, locations identified as having an unusual number of wet weather accidents, research test sections, milled surfaces, bridge decks, and other special request projects.

A subsequent UNF research project studied whether technological advances would allow pavement friction to be measured at speeds higher than previously thought feasible. Historically, the most commonly used method for measuring friction resistance in the U.S. has been with a friction trailer traveling at 40 mph, often 15-20 mph less than posted speeds. Friction measurements are obtained from the force induced on a locked wheel of the friction trailer as it is dragged for three seconds over a wetted pavement surface. However, even though the tests are conducted on weekdays and at night, the slow testing speed creates safety concerns for roadway workers and the traveling public.

As a complement to friction trailers, UNF researchers studied the feasibility of using high-speed, laser-based sensors to measure friction course macrotexture and to predict friction characteristics of pavements. UNF researchers conducted tests in collaboration with the FDOT State Materials Office in Gainesville, Florida, on five sections each of both open-graded and dense-graded friction courses. They found that the 64 kHz non-contact laser provided a quick, repeatable, and accurate measure of surface macrotexture in terms of mean profile depth. As a result of the research, FDOT has deployed high-speed, laser-based sensors to measure friction characteristics of new construction and overlay projects, thus increasing worker safety and providing an accurate and more efficient method to collect friction course data.

A follow-up study in 2007 sought to develop a practical methodology to synchronize texture and skid resistance measurements from the standard locked-wheel friction trailer with measurements obtained using portable friction test equipment in areas where high-speed testing is not feasible. Typical equipment used in these situations includes the Circular Track Meter (CTM) and the Dynamic Friction Tester (DFT).

Researchers compared test data collected with the locked-wheel friction trailer traveling at 30, 40, and 50 mph with data collected using the portable equipment traveling at highway speeds. They found that the CTM can provide a repeatable and accurate measure of pavement macrotexture comparable to the truck mounted laser. They also found that the DFT results can be correlated with locked-wheel friction test results. As a result of the research, they developed a methodology to measure friction characteristics at variable speeds and to synchronize the results to the data obtained from standard tests conducted at 40 mph.




Left: A Circular Track Meter (CTM) measures the macrotexture of a road surface.

Right: A Dynamic Friction Tester (DFT) measures the dynamic coefficient of friction under various conditions.

In the area of roadway design, Dr. Tobias Sando, Associate Professor of Civil Engineering, is studying whether significant safety and/or operational benefits are realized in the use of atypical lane width configurations on multi-lane roads by creating wider outside curb lanes for bicyclists. His research will study the effectiveness of installing sharrows on roads with speeds greater than 35 mph and with wider outside lanes to determine the amount of separation drivers give to bicyclists and their willingness to pass bicyclists safely. Another of his studies focuses on the behavior of drivers during encounters with bicyclists in designated bicycle lanes and shared lanes. Both of these projects examine ways for bicycles and automobiles to share roadways safely by utilizing existing roadway space.

Sharrows are makings placed on roadways to indicate that bicycles share the lane with automobiles.

Dr. Adel El-Safty, Associate Professor of Civil Engineering is conducting research to establish recommendations for new sealant materials that will better withstand the movements of bridge deck cracks caused by thermal and shrinkage effects and load combinations. Another structures-related project concerns the feasibility and performance of repairs to damaged bridge girders using carbon fiber reinforced polymer (CFRP) laminates. The goal of both projects is to develop effective methods to extend the service life of Florida’s bridges.

“UNF researchers possess a variety of experience necessary to meet FDOT’s ongoing and diverse research needs,” says Jackson. “We are looking forward to continuing our research partnership with FDOT.” ⬣

Meet the Project Manager

Richard Kerr, P.E., Bridge Management Inspection Engineer
FDOT Maintenance Office

Richard Kerr is considered the driving force behind the success of FDOT's Bridge Management Inspection Program. His office oversees the biennial inspection of Florida's 11,800 bridges and provides overall coordination, training, and guidance for FDOT bridge inspections. Following a recent internal audit of the program by the Office of Inspector General, FDOT recognized Kerr as Employee of the Year for his outstanding work, finding that the Bridge Management Inspection Program was the best run program at FDOT.

The primary purpose of the program is to protect the safety and welfare of motorists and safeguard the public's investment. The program helps identify bridge deficiencies, both critical and non-critical, that can be corrected to lengthen bridge service life, reduce total maintenance costs, and provide the public with a better return on investment.

For the past 21 years, Kerr primarily has been responsible for implementing the Pontis bridge data management software tool for FDOT. Pontis is an application developed by the American Association of State Highway and Transportation Officials (AASHTO) used to manage the bridge maintenance cycle, including bridge inspection and inventory data collection and analysis. It develops recommendations of optimal preservation policy, predicts needs and performance measures for bridges, and identifies projects to include in FDOT's capital budget.

Pontis can be customized to meet specific agency needs and helps FDOT management to arrive at least-cost, long-term preservation and improvement policies. Kerr has been an active participant in the evolution of Pontis at the national level, having served on the Pontis users' group for over 10 years, and is regarded nationally as a bridge preservation expert.

Kerr has managed several FDOT-funded research projects pertaining to bridge management. His previous research has also involved enhancements to Pontis, including the development of project planning models and user cost data.

A recently completed project enhanced Pontis at both project and network levels. The research team developed an improved version of the National Bridge Inventory (NBI) Translator database using two years of bridge inspection data from the Florida bridge inventory. The research developed a stand-alone computer program and a Microsoft Excel spreadsheet version of the Translator program, which was incorporated into the Pontis Project Level Analysis Tool (PLAT). The research team improved deterioration, action effectiveness and cost models for Pontis and PLAT, and developed a new, simplified procedure for estimating one-step models that produce usable results with smaller sample sizes. These research products will improve the efficiency of the bridge maintenance program and more effectively guide FDOT's funding decisions.

Another research project Kerr managed resulted in the development of a network-level analysis tool that compares the tradeoffs between bridge performance and bridge funding. The tool can compile and summarize individual bridge inputs using multi-objective benefit/cost analysis to predict system-wide performance at any funding level. The tool improves programmatic decision making and helps FDOT bridge managers optimize funding allocation. The tool is generic enough to be useful when analyzing a variety of transportation components and helps FDOT achieve compliance with Government Accounting Standards Board requirements for reporting capital assets.

Currently, Kerr is overseeing research on the development of risk assessment and management models for incorporation into Pontis. The research investigates hard-to-predict events, such as damage from storms or collisions that could adversely impact bridges, and attempts to determine the probability of such events. Kerr is also managing a study on the development of effective strategies for the inspection of steel prestressing/post-tensioning strands for FDOT bridges.

"I'm very proud to be a part of the team that develops and implements meaningful bridge analysis tools," says Kerr. "These tools have saved FDOT millions of dollars by enabling maintenance engineers to make asset management and programming decisions quickly and effectively based on credible information." ⬣

Meet the Principal Investigator

Alberto Sagüés, Ph.D., Department of Civil and Environmental Engineering
University of South Florida

The corrosion of steel rebar reinforcement is the most common source of distress in concrete bridges. Salt water is particularly corrosive. The expansive corrosion properties cause the concrete to spall, requiring costly repairs or early replacement.

Dr. Alberto Sagüés, distinguished professor of Civil and Environmental Engineering at the University of South Florida, and principal investigator for over 30 FDOT-funded research projects, has been studying corrosion and its impact on bridge durability since 1985. FDOT has long recognized the importance of controlling corrosion in order to extend bridge life expectancy and ensure safety.

One of Sagüés' studies in the late 1990s involved the durability of reinforced concrete substructures constructed with different concrete formulations. He evaluated 13 Florida bridges to assess chloride ion penetration and the consequences of preexisting cracks. His research confirmed that the high performance concrete formulation FDOT used pursuant to its specification for building bridges with reinforced concrete represented a dramatic improvement in lowering permeability and susceptibility to corrosion relative to previous alternatives. His research resulted in the development of a comprehensive forecasting model that considers the proportions of the concrete mixture, rebar cover and size, and system geometry, to predict the progression of corrosion damage on marine bridges. The model allows FDOT to forecast bridge durability based on various factors and to select the best design to achieve a 75-year design service life.

Sagüés has also studied the condition of bridges built with epoxy-coated rebar (ECR) to establish a durability prognosis. From the late 1970s until the early 1990s, FDOT constructed approximately 300 bridges using ECR. ECR had been thought to create a barrier between concrete and steel and to prevent corrosion. After premature corrosion was observed in some Florida Keys bridges, FDOT engaged Sagüés to investigate its causes. His research showed that chloride penetrated coating imperfections, resulting in severe localized corrosion. This finding led FDOT to stop using ECR for bridge construction.

Based on field examinations, laboratory tests, and chloride penetration measurements, Sagüés developed a computational model to predict corrosion spall development in ECR structures. In 2004, he conducted a follow-up study to assess the condition of bridges previously studied, update corrosion models, and apply the improved models to project corrosion damage and repair needs. In a related study, he developed a predictive model that may aid in determining the cost effectiveness of alternative corrosion protection methods, such as corrosion resistant rebar.

Sagüés also has studied methods of determining structural strength of external tendons of post-tensioned segments and columns by applying vibrations to the tendons. Tendons are critical structural components of post-tensioned bridges, and sometimes rapid assessment of the tendons in an entire bridge is needed to make important maintenance decisions. The tests consist of lightly impacting the free length of the tendon, recording the resulting vibration frequencies, and applying the value of the frequency, tendon dimensions, and unit mass length to a computational model that calculates the tendon tension. Sagüés has developed advanced data processing methods to quickly evaluate data from thousands of bridge tendons and an inexpensive testing and analysis method that reduces the amount of time necessary to conduct field tests. His research has resulted in a cost-efficient and nondestructive method to measure tendon tension and to assess the structural health of post-tensioned bridges.

Sagüés has conducted numerous other investigations related to corrosion and bridge health. His work to develop long-term durability forecasts of high performance concrete used in Florida's bridges has saved the state millions of dollars and helped FDOT plan for its future needs.

"I have tried to find the right way to look 75, 100, even 150 years into the future, by following up on previous studies and validating predictive models," says Sagüés. "Through research and long-term durability forecasting, I have been able to defend the value of the Department's investments." ⬣

Web-based Inspector Training Improves Graduation Rates, Job Performance

Safety inspectors, formerly with FDOT's Office of Motor Carrier Compliance (OMCC) and now part of the Florida Highway Patrol's Bureau of Commercial Vehicle Enforcement (CVE), assist FDOT in its mission to provide a safe transportation system. Commercial motor carriers must comply with applicable federal and state laws and regulations. As sworn law enforcement officers, safety inspectors examine driver qualifications; hours of service; financial, accident, maintenance, and inspection records, and conduct physical vehicle inspections. Compliance with safety laws and regulations reduces fatalities, injuries, property damage, and hazardous materials incidents. In 2010, safety inspectors conducted over 126,000 inspections.

A safety inspector examines the air braking system of a commercial vehicle.

Safety inspectors must be knowledgeable of regulations established by the Federal Motor Carrier Safety Administration. Candidate safety inspectors attend the Commercial Vehicle Law Enforcement Academy for training and certification. They receive 400 hours of classroom training in advanced law enforcement and commercial vehicle safety enforcement, including two weeks of training on federal regulations and inspection procedures. Upon completion of academy coursework, candidates attend a 14-week Field Training Officer (FTO) program. However, the program had been experiencing failure rates of over 25 percent.

In 2010, OMCC concluded research with the University of Central Florida (UCF) to develop an enhanced safety inspector training and certification program with the goal of improving graduation rates. UCF researchers designed Web-based lessons to supplement classroom instruction that candidates can take at their own pace. Each lesson describes various vehicle components, explains equipment workings, and explains the application of enforcement criteria during inspections. The lessons clarify regulations using plain language and include interactive images, diagrams, flow charts, videos, and safety check quizzes.

The Web-based program features practice scenarios, quick reference aids, and simulated walk-around inspections. The program also includes an online reference library inspectors can use in the field. The reference library helps inspectors locate information and complete inspections quickly and accurately.

During pilot implementation, UCF researchers found that the Web-based lessons improved the graduation rates of safety inspectors and field officers significantly. The failure rate during the training academy phase dropped to zero, and the evaluation scores during the Field Training Officer phase increased dramatically. Since implementation, the program has seen a 98 percent pass rate on the required federal certification test.

CVE continues to maintain and update the reference library and anticipates developing additional training modules to address hazardous materials, cargo tanks, weights, and passenger vehicles. ⬣

A safety inspector examines the wheel of a flat-bed truck.

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The algorithm allows for the accurate measurement of faulting data and helps FDOT to more effectively allocate funds for roadway improvements, thereby improving driver safety and extending pavement life.

Automated Cross-Slope and Drainage Path Evaluation Method

Pavement surfaces deteriorate from their original design due to wear and surface deformation, resulting in areas prone to poor drainage and surface water entrapment. These roadway characteristics can cause hazardous driving conditions that can result in hydroplaning. FDOT has developed a software program for detecting these hazards. A multi-purpose survey vehicle (MPSV) equipped with an electronic data acquisition system captures roadway characteristics at highway speeds. These characteristics include cross-slope (the transverse slope across a lane), vertical roadway grade, smoothness, rut depth, and GPS location.

The software calculates the drainage path length, which is the distance water travels before it leaves the pavement surface, using cross-slope vertical grade pavement width as inputs. The program also generates results in tabular form as well as two- and three-dimensional plots. It identifies areas prone to water retention such as those typically found at the bottom of roadway vertical curves, in and around transition areas where pavement surfaces meet, and areas with inadequate cross-slope. The software also identifies areas prone to slow surface runoff and sheet flow, the condition where the rate of water accumulation exceeds the pavement's surface drainage ability. The software can evaluate the effectiveness of various corrective actions intended to reduce potentially hazardous conditions.

The software can summarize data for any pavement segment and can assist engineers to visualize problem areas and select appropriate solutions. It is also used in the pre-design stage of resurfacing and widening projects and provides engineers with critical information to identify potential safety problems.

While traditional survey methods measure discrete locations, this technology offers practically unlimited survey points without increasing cost. Like the automated faulting method, this tool is operated at highway speed, which reduces worker exposure to highway traffic, eliminates traffic disruption, and is more cost effective. Since 2007, this technology has been used to evaluate over 360 projects and close to 4,500 lane miles. ⬣

For More Information

Pavement Analysis Tools

BDB11, Use of Nondestructive Techniques to Estimate the Allowable Vibratory Compaction Level during Construction
Mike Jackson, Principal Investigator
Charles Holzschuher, Project Manager

BDK05, Using High Speed Ground Penetrating Radar for Evaluation of Asphalt Density Measurements
James Greene, Principal Investigator
Charles Holzschuher, Project Manager

BD544-11, Evaluation and Validation of a High-Speed Multi-Function System for Automated Pavement Condition Survey
Manjriker Gunaratne, Principal Investigator
Abdenour Nazef, Project Manager

Related AASHTO TIG pavement technologies papers are available at: http://www.dot.state.fl.us/research-center/AASHTO_TIG_publications.shtm

Embedded Data Collectors

BD545-87, Analyses of Embedded Data Collector (EDC)
Michael McVay, Principal Investigator
Peter Lai, Project Manager

BB349, Estimating Driven Pile Capacities during Construction
Michael McVay, Principal Investigator
Sastry Putcha, Project Manager

University of North Florida

BDH23, Harmonization of Texture and Skid-Resistance Measurements
Mike Jackson, Principal Investigator
Charles Holzschuher, Project Manager

BD273, Evaluation of Variable Friction Properties of FDOT Friction Courses - Phase I
Mike Jackson, Principal Investigator
Bouzid Choubane, Project Manager

DO2022, Measuring Pavement Friction Characteristics at Variable Speeds for Added Safety
Mike Jackson, Principal Investigator
Bouzid Choubane, Project Manager

Safety Inspector Training

BD548-19, Web-based Safety Inspector Training and Certification Program
Ron Tarr, Principal Investigator
David Binder, Project Manager