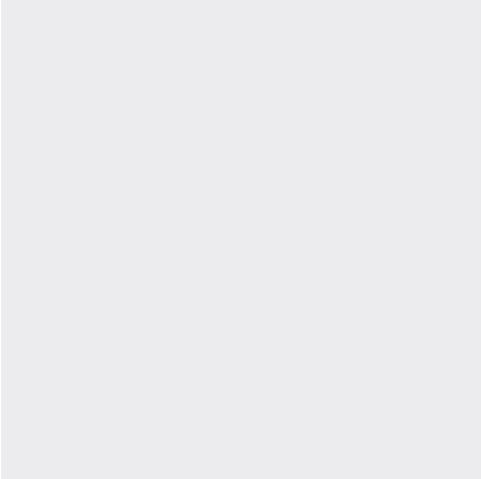


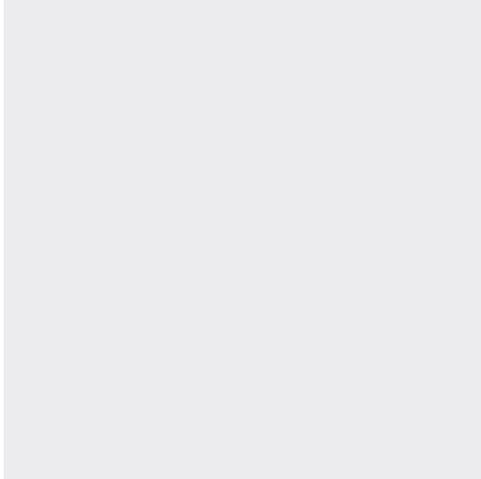
RESEARCH IMPACTS

2017

Better



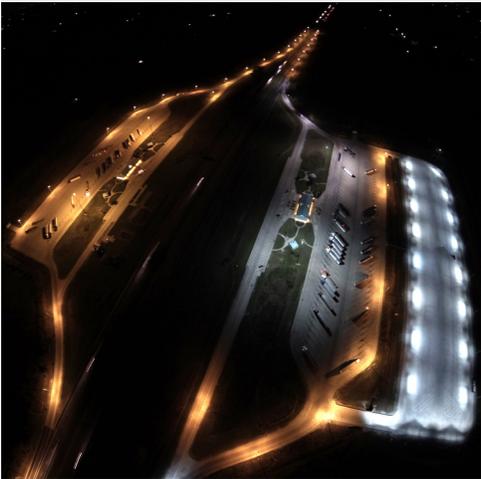
Faster



AMERICAN ASSOCIATION OF
STATE HIGHWAY AND
TRANSPORTATION OFFICIALS

AASHTO
THE VOICE OF TRANSPORTATION

SCOR  RAC



Cheaper

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INTRODUCTION

Research Impacts 2017: Better—Faster—Cheaper

This publication is the latest annual compilation of high value research results submitted by state departments of transportation (DOTs). The research summaries are solicited and published every year by the Value of Research Task Force of the American Association of State Highway and Transportation Officials (AASHTO) Research Advisory Committee (RAC). State DOTs are encouraged to submit innovative projects that impact transportation agencies' practices and policies and that benefit the traveling public.

Award-Winning “Sweet Sixteen” Projects

From among all the submissions in this volume, each of the four RAC geographic regions voted to select its top four research projects (no more than one project per state) to form the AASHTO Research “Sweet Sixteen” Awards.

- These projects will be showcased during the AASHTO RAC and Transportation Research Board (TRB) State Representatives summer meeting and at a poster session during the 2018 TRB Annual Meeting
- Project awards will be presented to CEOs at the AASHTO Annual Meeting and to Research Managers at the AASHTO RAC and TRB State Representative summer meeting.
- The projects are highlighted in the four-page AASHTO brochure, “Research Makes the Difference 2017.”

In this document, the Sweet Sixteen projects are indicated in **red text** in the table of contents and with a winner ribbon on the project page.

Region 1

<i>Connecticut DOT</i>	<i>A Reduction in Nonfatal-Injury Motor Vehicle Crashes with Anti-icing Technology</i>
<i>Maine DOT</i>	<i>Rivet Testing of Rivets Taken from Maine Truss Bridge</i>
<i>New York State DOT</i>	<i>Analysis of Energy Efficient Highway Lighting Retrofits</i>
<i>Pennsylvania DOT</i>	<i>Bridge Deck Cracking: Effects on In-Service Performance, Prevention, and Remediation</i>

Region 2

<i>Arkansas SHTD</i>	<i>Alternative Uses for Ground Penetrating Radar (GPR) in Highway Construction in Arkansas</i>
<i>Georgia DOT</i>	<i>Implementation of Automatic Sign Inventory and Pavement Condition Evaluation on Georgia's Interstate Highways</i>
<i>Louisiana DOTD</i>	<i>Roller Compacted Concrete over Soil Cement under Accelerated Loading</i>
<i>Virginia DOT</i>	<i>Structural Study of Cold Central Plant Recycling</i>

Region 3

<i>Indiana DOT</i>	<i>Site Selection for New Lighting Technologies</i>
<i>Minnesota DOT</i>	<i>Hydraulics Inspection Vehicle Explorer (HIVE) Enhances Culvert Inspections</i>
<i>Missouri DOT</i>	<i>Using Online Surveys and Facebook Ads to Solicit Customer Feedback</i>
<i>Wisconsin DOT</i>	<i>Recycled Materials Resource Center – Third Generation</i>

Region 4

Idaho DOT

Texas DOT

Utah DOT

Washington State DOT

State of Idaho Port of Entry Study

Proactive Traffic Signal Timing and Coordination for Congestion Mitigation on Arterial Roads

Improving Cold In-Place Recycling of Asphalt Pavements Using Solventless Emulsion

Earthquake Safety: Building a Flexible Bridge

High Value Research in Safety and Maintenance

Additionally, AASHTO publishes two topic-specific brochures each year to highlight key research areas. The topics for 2017 are safety and maintenance, and each of the RAC regions voted to select two additional projects for each brochure. The 2017 brochures highlight the projects below. These featured safety and maintenance projects are also noted in the table of contents.

Safety

Region 1

Maryland DOT

Massachusetts DOT

Intelligent Dilemma Zone Protection System at High-Speed Intersections

Mitigation Techniques to Modify Driver Performance to Improve Fuel Economy, Reduce Emissions and Improve Safety

Region 2

Florida DOT

North Carolina DOT

Validation and Implementation of Bridge Design Specifications for Barge Impact Loading

Performance Evaluation of Strong Post Double-faced W-beam Guardrail and Strong Post Double-faced Thrie-Beam Guardrail at MASH Test Level 4 (TL-4) and Test Level 5 (TL-5) Conditions

Region 3

Illinois DOT

Indiana DOT

Effects of Intersection Right-Turn Lane Design & Skew on Safety & Operations

T-Scan: Stationary LiDAR for Traffic and Safety Studies - Object Detection and Tracking

Region 4

Montana DOT

Wyoming DOT

Speed Limits Set Lower Than Engineering Recommendation

Planning Support for Mitigation of Wildlife Vehicle Collisions and Highway Impacts on Migration Routes in Wyoming

Maintenance

Region 1

New Jersey DOT

Vermont AOT

Optimizing Work Zone Lighting

Cost-Effective and Rapid Concrete Repair Techniques

Region 2

Alabama DOT
Mississippi DOT

Comparative Evaluation of Concrete Bridge Deck Sealers
Investigation of MDOT's Full-Depth Reclamation and Cold In-Place Recycling Projects—State Study 250

Region 3

Ohio DOT
Wisconsin DOT

Alternative Stream Channel Maintenance at Bridge Crossings
Evaluation of Thin Polymer Deck Overlays and Deck Sealers

Region 4

South Dakota DOT
Texas DOT

Reuse of Aqueous Waste Streams in Transportation Applications
Mitigation of High Sulfate Soils in Texas

Learn More

The electronic version of this document, as well as the brochures “Research Makes the Difference 2017,” “Safety Research 2017,” and “Maintenance Research 2017,” may be found on AASHTO’s research website, research.transportation.org.

Acknowledgments

Cover image sources (top to bottom): Louisiana Department of Transportation and Development, Washington State Department of Transportation, and Indiana Department of Transportation.

Comparative Evaluation of Concrete Bridge Deck Sealers	
<i>Project ID</i>	930-861
<i>Cost</i>	\$87,795
<i>Duration</i>	13 months
<i>Submitter</i>	Alabama Department of Transportation Michelle Owens 1409 Coliseum Boulevard Montgomery, Alabama 36109 334-353-6940
<i>Links</i>	

Project Summary and Benefits

The research consisted of a comparative evaluation of the effectiveness of three bridge deck sealers to resist the intrusion of moisture and waterborne chemicals into concrete bridge decks. The Maintenance Bureau of ALDOT currently relies on a penetrating epoxy sealer (Spec-Seal) that is manufactured solely for ALDOT. It is critical to identify a potential replacement product of equal or greater effectiveness should production of the currently-used sealer be discontinued.

The researchers compared the effectiveness of Spec-Seal against that of two potential replacement products, including a new, penetrating silicate-based sealer called Deep Seal, currently of interest to ALDOT's Maintenance Bureau, as well as untreated concrete. Additionally, the depth of penetration of the each product was evaluated.

Evaluation of In-Place Concrete Strength by Core Testing

<i>Project ID</i>	930-828
<i>Cost</i>	\$282,700
<i>Duration</i>	40 months
<i>Submitter</i>	Alabama Department of Transportation Michelle Owens 1409 Coliseum Boulevard Montgomery, Alabama 36109 334-353-6940
<i>Links</i>	

Project Summary and Benefits

When the average compressive strength of molded cylinder specimens do not meet the minimum required strength for a batch of concrete, the strength of cores are used to assess the in-place compressive strength of the structural member for acceptance and payment.

The overall objective was to develop an ALDOT procedure to evaluate core strength results obtained under various conditions. Since there are many factors that influence the apparent strength of cores, strength correction factors must be applied to core strengths in order to convert them to a standard which can be compared with specified 28-day design strength.

The following major factors affect the relationship between the in-place strength and the strength of molded cylinders that were assessed in this project: concrete age, concrete strength level, coarse aggregate type, degree of microcracking, and difference in strength gain due to using using different cementitious materials in the concrete mixture. Eight full-scae slabs were cast.

Investigation of Pile Setup In Alabama, Development of a Setup Prediction Method and Implementation into LRFD Driven Pile Design

<i>Project ID</i>	930-839R
<i>Cost</i>	\$809,855
<i>Duration</i>	28 months
<i>Submitter</i>	Alabama Department of Transportation Michelle Owens 1409 Coliseum Boulevard Montgomery, Alabama 36109 334-353-6940
<i>Links</i>	https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwiO0srhuYLVAhUP1GMKHcReDDUQFggmMAA&url=https%3A%2F%2Fntl.bts.gov%2Flib%2F56000%2F56700%2F56743%2FPile_Setup_930-839R_Research_Final_Report_100515.pdf&usg=AFQjCNHggCUIIH91XFJ1Yae5BktrQ8viAg&cad=rja

Project Summary and Benefits

This funded research is tasked with three main topics of investigation. The first is to identify the pile setup potential of the driven piles installed within the soils of the state of Alabama. This task requires the organization and analysis of historical records of design and installed pile load tests. The second task is to incorporate these historical records into the calibration of statistically determined resistance factors for LRFD design methods. The third task is to install four typical driven pile types into the soil of a planned bridge location to investigate the amount of pile setup as well as the propagation of vibrations to surrounding locations during the installation of the piles. The third task was added as an addendum to the project. The vibration report was completed and attached to the end of the report.

The experimental data shows that the largest vibrations occurred during the installation of the 36-inch concrete pile, which was recorded as 0.82 inches per second. According to the research presented in Table 2 (Hendriks 2002), a vibration level of 0.82 inches per second has the potential to cause structural damage to an adjacent structure. However, this vibration was recorded at a distance of 50 feet from the pile; the vibration level at 100 feet from the pile was reduced to 0.275 inches per second. This vibration level could cause potential architectural damage to buildings constructed with plaster, but would not likely cause structural damage. At 150 feet the vibration levels were reduced to 0.15 inches per second, a level that would have little to no risk of damage to adjacent structures.

Based on the experimental data and a thorough review of the literature, it is recommended that a maximum vibration level of 0.5 inches per second for modern structures and 0.1 inches per second for potentially sensitive

structures be allowed for construction activity at or near the location of the project site. These vibration levels are the allowable levels at the location of the structure. To determine if any structures should be surveyed and monitored for potential vibration damage, a survey distance of 150 feet for modern structures and 250 feet for potentially sensitive structures should be established. The monitoring distances should be measured from the source of the vibration. The ground vibration prediction equation that was developed would estimate at a peak particle velocity of 0.15 inches per second at 150 feet and 0.07 inches per second at 250 feet. The survey distances are well beyond the distance where the prediction equation would estimate vibration levels of 0.5 and 0.1 inches per second and therefore would represent conservative survey distances to ensure adjacent structures are not damaged.

Hydro Acoustic (Underwater) Pile Driving Noise Study	
<i>Project ID</i>	4000 (135)
<i>Cost</i>	\$240,000
<i>Duration</i>	26 months
<i>Submitter</i>	Alaska Department of Transportation Carolyn Morehouse 3132 Channel Drive Juneau, Alaska 99801 907-465-8140
<i>Links</i>	http://www.dot.state.ak.us/stwddes/research/assets/pdf/4000-135.pdf

Project Summary and Benefits

Alaska Marine infrastructure impacts to marine mammals was not quantified on typical projects. The goal of the projects was to quantify marine pile driving activities, characterize sound transmission loss, and calculate distances to marine mammal injury and disturbance thresholds. After JASCO completed the hydroacoustic monitoring, the National Marine Fisheries Service (NMFS) finalized new rules for marine mammal injury thresholds. Thus, threshold ranges in this report reflect previous and current (new) guidance.

Alternative Uses for Ground Penetrating Radar (GPR) in Highway Construction in Arkansas

<i>Project ID</i>	TRC1504
<i>Cost</i>	\$286,341
<i>Duration</i>	22 months
<i>Submitter</i>	Arkansas State Highway and Transportation Department Elisha Wright-Kehner 10324 Interstate 30 Little Rock, Arkansas 72002 501-569-2074
<i>Links</i>	



Project Summary and Benefits

Ground Penetrating Radar (GPR) has long been known to be a good non-destructive method for collecting pavement data. Arkansas State Highway and Transportation Department (AHTD) is currently using GPR to evaluate pavement thickness on Arkansas highways. However, the possibility to utilize GPR for other types of evaluations is needed. Some of these uses include detecting and locating underground utilities, unmarked graves, soil anomalies, and the inspection of highway infrastructure projects such as bridges, bridge decks, and tunnels.

AHTD's current GPR system utilizes two airborne, 2 GHz antennas. Other low frequency GPR systems may be more effective for meeting AHTD's needs. Being able to locate these targets will significantly increase the productivity of design for AHTD and potentially saving the department millions of dollars.

Objectives of this research project were to evaluate the possibility of using the current AHTD GPR system, and find/recommend possible alternative GPR systems to be used in AHTD activities with high accuracy. Specific objectives to be studied were to evaluate different GPR systems for their accuracy, given the system frequency, site conditions, soil types, depth of ground water table, required depth of penetration, and lateral and vertical resolutions. Possible changes in GPR readings could be due to seasonal variations, such as large changes in temperature and different levels of water saturations in soil, pavement, and construction materials.

Multiple site visits were conducted to perform GPR surveys to evaluate the efficiency of GPR systems in locating underground utilities. Potential challenges that minimize the accuracy of the GPR and represent a major obstacle to accurate readings are heavy vegetation and rough ground surface. Heavy vegetation acted as a signal impeding medium, while terrain surface resulted in a high artificial noise. High moisture content in soil layers and the presence of shallow water table result in signal attenuation. Hence, pipes and other underground utilities are impossible to locate in such situations.

Concrete (and non-metallic) utilities are harder to locate and detect as compared to DIPs. The research team repeated the surveys using both 200 and 400 MHz antennas during periods of less vegetation and cold dry weather. The purpose of repeating the surveys was to determine the optimum site condition, moisture content, and ground vegetation for obtaining the most accurate results.

A comprehensive GPR survey of this caliber which comprised of several different phases such as planning, collecting, processing, analyzing, interpreting, and reporting would cost somewhere in the range of \$65,000 to \$75,000 due to the complexity, the personnel involved, and the 2 month span of this investigation. The price estimates are only from a NDT stand point and the other techniques that might be used in this project might be more expensive, risky and might also be destructive. Additionally, there may be contractors out there who may offer more competitive prices however, it is not certain how detailed and the reliable the outcome would be. In addition to the financial gains, the knowledge and the experience gained from the project was priceless in regards to minimizing AHTD's dependence on contractors which are not always equipped with the latest technology or may not have the staff for a well-quality analysis.

A complex geology is often hard to interpret if there is lack of experience even in simple cases like utility detection where the contrast between the pipes and the surrounding soil is well defined. EMI methods to detect underground utilities are limited in terms of locating the utilities. GPR provides 2D and 3D images of near subsurface which provide a significantly better outcome when the data analyst has substantial experience and a strong background in GPR theory. This minimizes the risk of being entitled to subpar results. In addition to the reduced risks, in house capabilities will also yield to better management of resources and time if and when project revisits are required in the future. However, in all cases GPR failed to detect and locate the concrete pipes and sewer lines deeper than the reach of the most capable GPR antenna in terms of depth of penetration. The presence of the clay and high moisture content of subsurface is the major limitation of the GPR method. Therefore choosing the right time to do the survey becomes the most important factor for clayey soils.

AHTD utilized the GPR equipment on five sites during this project. The Broadway Bridge Accelerated Bridge Construction project yielded the largest return on investment for AHTD. The team was able to identify undocumented utilities that without this identification would have cost the Department over one million dollars in change orders and time on the project. AHTD has implemented the GPR processes within AHTD's current operating procedures, and eight projects have utilized the new equipment. Seven of the eight projects were to locate underground utilities by means of the ground coupled antennas. The eighth project utilized the ground coupled and air coupled antennas for bridge deck analysis.

The finds from the current implementation has saved AHTD almost a million dollars in time, design work needed, and consultant contracts. AHTD will continue to improve its capabilities through employee training, and equipment and software upgrades as this technology continues to evolve. This technology could ultimately save the department immeasurable time and money over the next five years.

Development of Recommended Guidelines for Preservation Treatments for Bicycle Routes

<i>Project ID</i>	Task #2693
<i>Cost</i>	\$139,000
<i>Duration</i>	48 months
<i>Submitter</i>	Caltrans Nick Burmas 1227 O Street Sacramento, California 95814 916-654-8014
<i>Links</i>	http://www.dot.ca.gov/research/researchreports/reports/2017/4.57_BikePresTrtments_Final_signed_RR-2016-02.pdf

Project Summary and Benefits

California State Route 1 does double duty for the state. It serves as both a connector for communities on much of California’s coast, and acts as an icon of the state’s extraordinary coastline, bringing travelers from around the world—some of whom will drive it and others who will ride their bicycles on it.

In 2012, Caltrans placed a chip seal on SR-1 in San Luis Obispo County from Cambria to the Monterey County line to extend the service life of the existing pavement. However, in January 2013, shortly after the chip seal construction, bicyclists using SLO-1 alerted Caltrans about what they perceived as poor ride quality within the project limits.

In response, Caltrans District 5 Maintenance, the Office of Asphalt Pavement (Maintenance Division) and the Division of Research, Innovation, and System Information worked together with the University of California Pavement Research Center (UCPRC) to respond to this issue, and to extend the results from the SLO-1 study to produce statewide recommendations in 2016 for selection of surface treatment designs that produce acceptable bicycle ride quality. The project required exceptional outreach and interaction by the Caltrans/UCPRC team with the local bicycle club, local government agencies greatly concerned about impacts of the SLO-1 treatment on tourism, and with organized recreational bicycle clubs and the general riding public in urban areas around the state to survey their responses to different pavement surface characteristics.

For the initial response District 5 built test sections with alternative additional treatments to improve bicycle ride quality on a treatment on Monterey 198. The SLO bicycle club and other interested bicycle groups participated in a ride quality survey on Mon-198. The results were used to select a second treatment on SLO-1 that was placed in November 2013. Caltrans districts and local bicycle clubs identified routes with ride quality concerns in San Mateo and Los Angeles Counties that were then included in the surface characteristic

measurement part of the study. Realizing the need for state-wide recommendations for selection of treatments, the UCPRC performed extensive investigations of bicycle/pavement interaction.

These results were combined with a state-wide outreach effort to bicycle clubs to participate in surveys of state and local pavement treatments to calibrate the results. Surveys were conducted in 2014 with 82 riders from road bicycle recreational clubs on 42 sections in Davis, Chico, Santa Rosa, Tahoe and the Silicon Valley on rural roads and highways. Recognizing the need to also consider preservation treatments appropriate for urban routes and a broader range of bicycle riders, a second round of the survey in 2015 involved 155 riders on 67 pavement sections in Davis, Richmond, Sacramento, Chico and Reno. The surveys were coordinated with local government agencies or community groups in each city, and solicited riders from the general public. Students from UC Davis, CSU-Chico and the University of Nevada, Reno helped staff the surveys. The results of the project are guidelines for selection of preservation treatments that meet different levels of bicycle ride quality, and seminal science regarding bicycle/pavement/rider interaction.

Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado

<i>Project ID</i>	2009-5136
<i>Cost</i>	\$250,000
<i>Duration</i>	54 months
<i>Submitter</i>	Colorado Department of Transportation Amanullah Mommandi 4201 E Arkansas Avenue Denver, Colorado 80222 303-757-9044
<i>Links</i>	

Project Summary and Benefits

In Colorado, peak-streamflow equations that are based on peak-streamflow data from selected stations are presented for the 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year instantaneous-peak streamflows. For four of the five hydrologic regions, equations based on daily-mean streamflow data from selected stations are presented for 7-day minimum 2-, 10-, and 50-year streamflows and for 7-day maximum 2-, 10-, and 50-year streamflows. Other equations presented for the same four hydrologic regions include those for estimation of annual- and monthly-mean streamflow and streamflow-duration statistics for exceedances of 10%, 25%, 50%, 75%, and 90%.

A Reduction in Nonfatal-Injury Motor Vehicle Crashes with Anti-icing Technology

<i>Project ID</i>	SPR-2289
<i>Cost</i>	\$200,000
<i>Duration</i>	13 months
<i>Submitter</i>	Connecticut Department of Transportation Flavia Pereira 2800 Berlin Turnpike Newington, Connecticut 06111 860-594-2882
<i>Links</i>	



Project Summary and Benefits

There are several published studies which show that adverse weather conditions contribute to motor vehicle crashes and have an overall negative effect on highway safety. However, there is no published literature demonstrating the positive effects of winter maintenance anti-icing policies on safety for an entire network, such as a state highway system. In 2006/2007, the Connecticut Department of Transportation (CTDOT) converted from deicing (sand-salt (7:2) mix) to anti-icing (salt-only) procedures for state-maintained roadways.

This study analyzed the effects of advances in winter weather maintenance practices and policies have had on road safety in Connecticut. Changing the winter weather maintenance policies from deicing to anti-icing resulted in a significant decline in nonfatal injury crashes. Crashes with nonfatal injuries during winter seasons, in all kinds of weather and road conditions, declined by 19.2 percent between seven winters with sand-salt (7:2) mix (1999/2000-2005/2006) and seven winters of salt-only (2006/2007-2012/2013). Also, the same type of crashes that occurred when roads were covered with snow/slush or ice declined by 33.5 percent.

Furthermore, there was an immediate additional reduction in nonfatal crashes with injuries after CTDOT converted to anti-icing in 2006/2007. Granted that these results cannot be solely attributed to anti-icing procedures alone, but even considering the value of the increase in safety technology employed by modern vehicles, it appears that anti-icing likely reduces the amount of time that roads are slippery, thus prompting a reduction in serious crashes.

Development and Evaluation of a Dual Purpose Bridge Health Monitoring and Weigh-in-Motion System for a Steel Girder Bridge – Phase 2

<i>Project ID</i>	SPR-2271
<i>Cost</i>	\$213,428
<i>Duration</i>	36 months
<i>Submitter</i>	Connecticut Department of Transportation Bradley Overturf 2800 Berlin Turnpike Newington, Connecticut 06111 860-594-2089
<i>Links</i>	http://www.ct.gov/dot/lib/dot/documents/dresearch/BridgeHealthMonitoringandWeigh-in-Motion-PhaseII.pdf

Project Summary and Benefits

This high value research provides a methodology for an existing BWIM system applied to three separate data sets including test trucks, free flowing traffic, and long-term traffic data. This methodology builds on previous BWIM research and includes a new method for calculating vehicle speeds.

A calibrated test truck trials experiment demonstrated that the proposed algorithm can accurately predict vehicle speeds, and that even if the speed is exact other factors can contribute to the inaccuracy of the algorithm. Applying this data to sampled trucks from free flowing traffic has shown that the system can identify vehicle GVWs within a certain confidence interval. Various types of cases are identified for which the methodology cannot function accurately, and a list of error types is developed and described.

A unique contribution of this research has been the application of this algorithm to a large continuous traffic data-set consisting of 385 days. Applying the methodology to long-term traffic data has provided much useful information about the type of traffic on the bridge, such as: the average speeds on the bridge; the ADTT for certain months; as well as percentages of errors that occur each month. The type of data collected from long-term BWIM systems can be of extreme value to owners, operators and managers of infrastructure. Information on average speeds as well as the ADTT travelling on the bridge for certain months can be used to improve decisions regarding pavement and bridge design, and load rating analysis of bridges, as the ADTT is directly tied into those fields. The GVW, speed, and time stamp of each identified truck has been saved and loaded to a website that can be accessed by representatives of the Connecticut Department of Transportation. Those reviewing the website are allowed to manipulate the data and draw general conclusions about the traffic pattern on the bridge. This can include identifying times with the heaviest traffic loads or similarly when the overweight vehicles are travelling over the bridge. Through this information improvement in weigh station operational efficiency might be improved.

Future work in BWIM research should continue seeking to identify the limitations of current sensing, acquisition, and algorithm technologies as applied to an increasingly broader type of bridges as well as truck behavior such as multiple vehicles and lane changes occurring on the bridge and offer corresponding solutions to move forward BWIM applications in Connecticut. Specifically, future BWIM research should include the development of a series of interconnected BWIM installations on major routes to monitor truck weights entering and leaving the State.

ConnDOT Specification Requirements for Minimum Asphalt Requirements

<i>Project ID</i>	SPR-2288
<i>Cost</i>	\$37,383
<i>Duration</i>	15 months
<i>Submitter</i>	Connecticut Department of Transportation Bradley Overturf 2800 Berlin Turnpike Newington, Connecticut 06111 860-594-2089
<i>Links</i>	http://www.ct.gov/dot/lib/dot/documents/dresearch/CT-2288-F-16-1.pdf

Project Summary and Benefits

Based upon the literature contained in the reviewed FHWA IC reports, as well as what was found with use of UC equipment on two pilot projects in Connecticut, it is quite clear that IC/UC is capable of collecting many different types of data at a very high rate. This includes roller settings, stiffness, speed, material surface temperature, and ground coverage. These data are displayed real-time, which can be a significant benefit to contractors as informed decisions can be made as to when to start/continue/discontinue compactive effort.

The benefit to agencies (such as Connecticut DOT) is evident from the improvement in density and uniformity of the pavement that was demonstrated on pilot projects on I-84 and I-95 during 2014. Mapping of the data, via Veta software, may prove useful in identifying areas of distress in support layers if the ICMV can eventually be correlated with density and if the mapping itself is improved.

Based upon the research conducted for this study, the research team makes the following recommendations:

- 1) The IC/UC equipment should not be used as an acceptance tool at this time.
- 2) The IC/UC equipment should not be used for identifying areas of distress on HMA surfaces at this time, as there is no conclusive evidence of good correlation between the ICMV values and pavement density.
- 3) The source of the mapping issues identified (superimposed coverage not aligning over the roadway) during this study should be investigated and identified.
- 4) An alternate coordinate system should be trialed in an effort to improve mapping issues as suggested by the FHWA report [3]. UTM is the recommended system and it is stated to use caution when using the State Plane system.

- 5) IC/UC lends itself well as a Quality Control tool and contractors should be encouraged to use the equipment.
- 6) Contractors who choose to employ this technology should take advantage of the ability to develop compaction curves on long term projects that last for multiple days in order to optimize compactive effort and ultimately project density.
- 7) The IC/UC equipment may be useful in identifying problems with support layers if used to map granular bases prior to paving.
- 8) Use of the equipment for UC purposes was successful in improving overall density and uniformity, and should be promoted moving forward.
- 9) When use of UC/IC equipment is required, transfer of the data files should take place daily to ensure continuity of the data. This is the case when only the UC data is required, and also when all IC data is required. The reason for this is the extraordinarily large volume of data.
- 10) Transfer of the UC data files should be managed by uploading to a cloudbased system for easy downloading and to ensure data files are not lost. Email transfer of data files is not recommended.

Preparation of the Implementation Plan of AASHTO Mechanistic-Empirical Pavement Design Guide (M-EPDG) in Connecticut: Phase II – Expanded Sensitivity Analysis and Validation with Pavement Management Data

<i>Project ID</i>	SPR-2293
<i>Cost</i>	\$203,361
<i>Duration</i>	17 months
<i>Submitter</i>	Connecticut Department of Transportation Flavia Pereira 2800 Berlin Turnpike Newington, Connecticut 06111 860-594-2882
<i>Links</i>	http://www.ct.gov/dot/lib/dot/documents/dresearch/CT-2293-F-17-1.pdf

Project Summary and Benefits

The two main objectives of this study were (1) to include flexible and composite pavements on thinner base/subbase with variable quality as well as uncertain distributions of vehicle classes, and (2) ability of Mechanistic-Empirical Pavement Design Guide (M-EPDG) software to predict pavement performance at a higher level of detail (Level 2) using CTDOT Pavement Management Information System (PMIS) inputs.

The research approach for this project included:

- 1) sensitivity analysis of M-EPDG inputs with both M-EPDG 1.1 (the last publically available) and Pavement-ME (most recent commercial) software packages,
- 2) evaluation of PMIS inputs to be used for validation of M-EPDG distress predictions, and
- 3) evaluation of accuracy of the Pavement-ME predictions based on PMIS data.

Findings and Conclusions on Sensitivity Analysis of Pavement-ME Inputs

Overall, the new Pavement-ME software allows for faster runs of simulation projects, although having a more complicated structure of the reports. The Pavement-ME sensitivity runs mostly yielded similar rankings of design input importance compared with that of the M-EPDG runs, with the following observations worth noting:

- The Pavement-ME longitudinal cracking model for new AC pavements is much more sensitive to input changes as compared with the M-EPDG software.

- For thicker AC-overlaid AC on PCC pavements, the Pavement-ME analysis yielded on average much lower sensitivity of cracking predictions to all input as compared with M-EPDG software. In addition, for this pavement type, the Pavement-ME analysis yielded larger effects of subgrade and preoverlay pavement surface condition on rutting and IRI as compared with M-EPDG software.
- For AC-overlaid PCC pavements, cracking sensitivity rankings were noticeably different between the Pavement-ME and M-EPDG prediction models. This included finding of zero sensitivity for the transverse (thermal) cracking model and an enormously high (up to 2300%) variation in longitudinal cracking predictions. This does exclude reflective cracking as the Pavement-ME software counts that type of cracking as slab cracking.

Findings and Conclusion about Accuracy of PMIS Performance Data

The analysis of pavement performance data generated by the WiseCraX™ software was complemented by the visual evaluation of distresses directly from the Photolog pavement surface images.

The following are the most significant findings from the analysis:

- It appears that PMIS reports overestimate the extent of linear cracking in all directions, possibly because of built-in settings of the processing algorithms. In particular, the factor of overestimation was slightly larger with respect to longitudinal cracking for data collected with laser cameras used on CTDOT van 8 whereas the strobe system (CTDOT van 7) significantly overestimated transverse cracking.
- The analysis of annual deterioration trends indicated that visual assessment of the images is likely to be closer than the automated method to “ground truth.” Although alligator cracking has never been reported by the WiseCraX™ system, it is deemed feasible and advantageous to develop a transfer function to estimate the alligator cracking in percent area from the total linear cracking length. This is important because the alligator cracking is one of the major distress outputs in Pavement-ME analysis.

Findings and Validation of Accuracy of Pavement-ME Predictions

- Extensive analysis of distributions along with multiple correlation analysis of predicted and reported distress values generally indicated poor accuracy of Pavement-ME predictions regarding cracking with the exception of longitudinal cracking, IRI, and AC layer rutting. This difference was made more evident by the way cracks are categorized in the Pavement-ME software as compared to CTDOT’s Pavement Management software.
- Analysis of the influencing factors on the accuracy of Pavement-ME predictions revealed pavement type having the highest influence on bias in prediction of all distresses, followed by construction type (new or rehabilitation).
- It has been confirmed that an increase in the level of detail for asphalt material properties can lead to an increase in accuracy for longitudinal cracking prediction.

District Mobility Project	
<i>Project ID</i>	2016-Other-01
<i>Cost</i>	\$955,098
<i>Duration</i>	14 months
<i>Submitter</i>	District of Columbia Department of Transportation Stephanie Dock 55 M Street, Suite 500 Washington, D.C. 20003 202-671-1371
<i>Links</i>	https://districtmobility.org

Project Summary and Benefits

The District Mobility website and supporting data are providing benefit to DDOT in several ways. First and most immediately, the performance measures have set a baseline that can be used in other projects within the agency, reducing the need for some initial data collection and setting standard measures across projects. Second and more long term, the project identified focus areas for work going forward, which DDOT will be working to integrate into the project selection process for the STIP. The impact will be that we have a more targeted, data-driven approach to directing funding to areas with identified congestion issues that affect all modes, and therefore can have greater benefit for all travelers.



Validation and Implementation of Bridge Design Specifications for Barge Impact Loading

<i>Project ID</i>	BDK75 977-31
<i>Cost</i>	\$245,855
<i>Duration</i>	27 months
<i>Submitter</i>	Florida Department of Transportation David Sherman 605 Suwannee Street, MS 30 Tallahassee, Florida 32399 850-414-4613
<i>Links</i>	

Project Summary and Benefits

The researchers developed a revised collision risk assessment methodology including various new UF/FDOT analysis procedures. The UF/FDOT and AASHTO procedures were applied to two real-world bridges, Florida’s Bryant Grady Patton Bridge over Apalachicola Bay and Louisiana Highway Bridge 1 over Bayou Lafourche, and the results were compared. UF/FDOT predicted higher risk than AASHTO in these cases. However, terms in the AASHTO annual frequency of collapse expression associated with the probability of an impact event may, in fact, overpredict this probability, thereby inflating risk estimates.

This project showed that the procedure for bridge collision analysis and design developed by UF and FDOT are feasible, given modern programming and computing power. The new procedure has many advantages in its relationship to the real-world problem and the number of factors considered. Better procedures will lead to more accurate risk estimates and better bridge designs.



Development of a Smear Proof Horizontal and Vertical Permeability Probe	
<i>Project ID</i>	BDK75 977-35
<i>Cost</i>	\$53,280
<i>Duration</i>	21 months
<i>Submitter</i>	Florida Department of Transportation David Sherman 605 Suwannee Street, MS 30 Tallahassee, Florida 32399 850-414-4613
<i>Links</i>	

Project Summary and Benefits

Through a succession of prototypes, researchers tested a variety of methods to either prevent or resolve clogged ports. Eventually, they arrived at a design in which the probe has a retractable inner core. In the extended position used for pushing the probe into the ground, the core closes the tip of the device and holds 12 keys in place to block the slits in the side of the probe, preventing soil intrusion. When retracted, the end and side ports open, allowing outflow of water for testing. The final design is easy to break down and reassemble, if cleaning is needed in the field.

During the numerous cycles of design, testing, and verification of the probe and its supporting equipment, the researchers worked closely with FDOT to resolve design and operational concerns, which led to numerous improvements found in the final design. For example, the researchers developed a dial that addressed concerns of FDOT workers who wanted to know the probe’s rotation and depth during tests. Testing and data reduction procedures for the final design were documented in a manual included the project’s final report, and a computer program was developed to analyze results.

Implementation of Automatic Sign Inventory and Pavement Condition Evaluation on Georgia's Interstate Highways

<i>Project ID</i>	RP 15-11
<i>Cost</i>	\$73,625
<i>Duration</i>	15 months
<i>Submitter</i>	Georgia Department of Transportation Ernay Robinson 3993 Aviation Circle Atlanta, Georgia 30308 404-631-1389
<i>Links</i>	http://g92018.eos-intl.net/eLibSQL14_G92018_Documents/15-11.pdf



Project Summary and Benefits

FHWA requires all agencies having jurisdiction over a road to establish and implement a sign assessment or management method to maintain minimum levels of sign retroreflectivity. A comprehensive sign inventory and management system is indispensable to support the implementation of a selected plan. However, the number of signs on interstates, state routes, and secondary state routes is large for state DOTs to maintain. For GDOT, an estimated three million traffic signs are to be inventoried, making manual survey extremely difficult.

The objective of this research project was to develop and implement the automatic methods not only for traffic sign inventory, but also for pavement condition data collection using 3D mobile light detection and ranging (LiDAR), digital images, and 3D pavement laser data along with computer vision algorithms. GDOT sought to streamline procedures for sign data collection and pavement condition evaluation to improve the data quality and productivity of the data collection practice while keeping field engineers from being exposed to roadway hazards. The procedures utilized both the available automatic methods and several customized interactive tools for quality control and quality assurance (QC/QA).

The developed methods have been implemented on Georgia's interstate highways. For the first time, GDOT has inventoried a complete 22,344-sign dataset on Georgia's interstate highways with MUTCD codes, classification, overhead sign, and conditions using a streamlined procedure. Also, a complete 1,513-mile survey of asphalt pavement condition (COPACES) data, based on GDOT pavement distress protocol and crack classification, was collected with detailed pavement distresses and ratings to support the Georgia Asset Management System in GDOT. The successful implementation demonstrated that the streamlined procedures provide a consistent, reliable, and cost-effective means for traffic sign inventory and pavement condition evaluation on interstate highways. More importantly, the developed methods eliminate the need for workers' exposure to roadway hazards and dramatically improve safety. The experience of this successful implementation can also be extended to other state DOTs and Public Works agencies nationwide.

Deploying SHRP2 Renewal 10 Guidebook for Project Management Strategies for Complex Projects in the Georgia Department of Transportation

<i>Project ID</i>	RP 15-12
<i>Cost</i>	\$65,000
<i>Duration</i>	15 months
<i>Submitter</i>	Georgia Department of Transportation Darryl VanMeter 600 West Peachtree Atlanta, Georgia 30308 404-631-1703
<i>Links</i>	http://g92018.eos-intl.net/eLibSQL14_G92018_Documents/15-12.pdf

Project Summary and Benefits

Georgia Department of Transportation (GDOT) utilized the Strategic Highway Research Program 2 (SHRP2) to implement a guidebook for “Project Management Strategies for Complex Projects,” SHRP2 Project R10. GDOT wanted to maximize its benefits from the R10 product not only at the project level but also at the program level by enhancing its current project delivery process and development plan for complex projects. GDOT projects are increasingly becoming more complex, per Georgia’s Major Mobility Investments ([hyperlink](#)) initiative over the next 10 years. More than any time in GDOT’s history, the agency is relying on innovative project delivery systems, such as design-build (DB) and public-private partnerships (P3), to deliver complex projects.

In this research, several components of the R10 research product were rigorously evaluated to enable the GDOT Office of Innovative Delivery to enhance its DB manual. Complexity mapping, five-dimensional project management methods, and several tools from the R10 product are incorporated into GDOT’s DB manual to facilitate managing complexity in GDOT DB and P3 projects. GDOT has adopted the R10 strategies into its DB manual for complex projects.

Two of the most successful innovative delivery projects that implement the R10 strategies:

- Northwest Corridor (NWC) I-75/I-575 Managed Lanes (November 2013)
- I-285/SR-400 Interchange Reconstruction and CD Lanes (January 2015)

Mr. Darryl VanMeter, State Innovative Delivery Engineer, summarized the benefits of implementing the R10 products in the following five areas:

- Facilitates an open dialogue among agency participants to map project complexity

- Defines effective project planning methods
- Identifys project execution tools to achieve what matters the most for the project
- Optimizes project expenditure plans at the program level
- Provides maturity self-assessments for implementing 5DPM (Five-Dimensional Project Management Process) project planning methods and execution tools in complex projects.

State of Idaho Port of Entry Study

<i>Project ID</i>	RP 248
<i>Cost</i>	\$100,000
<i>Duration</i>	11 months
<i>Submitter</i>	Idaho Transportation Department Ned Parrish 3311 West State Street Boise, Idaho 83707 208-334-8296
<i>Links</i>	http://www.highvalueresearch.org



Project Summary and Benefits

The Idaho Transportation Department’s Division of Motor Vehicles (DMV) requested a study to review best practices for State Ports of Entry (POE) Programs, examine new and emerging technologies for commercial vehicle enforcement, and develop recommendations for future operations of Idaho’s program. Researchers from Cambridge Systematics were selected for the study because of their experience evaluating POE programs in Arizona and Texas. The research team also included an expert in POE technologies, such as Weigh-in-Motion (WIM) and Automated Vehicle Identification (AVI).

This 12-month project included a review of Idaho’s POE Program, which has 17 fixed and approximately 200 rover sites, and compared our business processes to industry best practices. Researchers surveyed a sample of industry stakeholders to assess satisfaction with POE services and to better understand customer needs. The team also reviewed new and emerging technologies for use in POE operations. The research team developed concepts of operation (ConOps) for POE facilities around the state. They recommended ConOps for three types of fixed facilities and two types of rover sites. The Cop Ops identifies the infrastructure, technology, and staffing needs for each type of facility. At fixed facilities and higher volume rover sites, for instance, they recommended installation of WIM technology. They also recommended acquisition of AVI technology at fixed facilities.

The research team provided a variety of other recommendations for future operations of the program. These recommendations included acquiring an updated online permitting system to enhance customer service, developing integrated data warehouse, and relocating one fixed POE facility, which is poorly located to serve truck traffic on I-84/86 in southern Idaho. DMV has embraced the 5-tiered concepts of operation and other study recommendations.

They presented findings and recommendations from the study to ITD Executive Management and the Idaho Transportation Board in the fall of 2016. In addition, the following actions have been taken to implement report recommendations:

- State funding has been allocated in the ITD Statewide Transportation Improvement Program (STIP) to expand installation of WIM/AVI systems at fixed POE sites.
- They received funding to acquire an updated online permitting system and will be issuing an RFP in May 2017.
- A project was added to the STIP to relocate the Cotterel fixed facility serving the I-84/86 corridor in southern Idaho by 2020.
- A major software modernization project is currently underway, which will address the need for an integrated data warehouse for the POE Program.
- POE program needs were incorporated into ITD's new Statewide Freight Plan, which was finalized in January 2017.

The study has provided a roadmap for program operations going forward and has provided evidence to support efforts to make needed improvements. Implementation of study recommendations will enhance program efficiency and effectiveness. The changes underway will also strengthen customer service as well as minimizing delays and enhancing the mobility of commercial truck traffic in Idaho.

Growing a Constructive Culture at the Idaho Transportation Department

<i>Project ID</i>	RP 233
<i>Cost</i>	\$493,782
<i>Duration</i>	36 months
<i>Submitter</i>	Idaho Transportation Department Ned Parrish 3311 West State Street Boise, Idaho 83707 208-334-8296
<i>Links</i>	http://www.highvalueresearch.org

Project Summary and Benefits

The purpose of this project was to assist ITD Executive Management in establishing a more constructive work culture within the department and to strengthen leadership within the agency. The research team was led by staff from Montana State's Center for Health and Safety Culture, which has expertise in culture change. The team also included James Johnson, who is an expert in organizational and individual assessment and performance coaching, and Tom DeCoster, who has expertise in management development and communications.

The project was conducted over a 3-year period. During the course of the study, the research team provided guidance and recommendations to assist agency management in communications planning, development of leadership training, and strengthening employee evaluation and recognition with the goal of fostering a work environment that is results-driven, supports collaborative problem-solving, and actively engages employees to achieve excellence.

As part of this effort, the department held annual leadership development summits; developed and delivered a suite of leadership training courses and staff training courses focusing on agency mission, customer service, and communications; instituted a leadership assessment and coaching program for managers and supervisors throughout the organization; and revised the employee assessment tool to focus on desired cultural behaviors (e.g., takes initiative, solves problems, results-focused, accountable for decisions/actions, adapts to changing needs, strives for continuous improvement, innovative, collaborative, and communicates effectively).

The project also included an evaluation component. Periodic Organizational Culture Inventory (OCI) surveys were conducted with employees, and structured interviews were done with agency managers and supervisors. The research team also looked at changes in organizational outcomes during the study period, and reported that service efficiency improved in a number of key areas despite staffing reductions aimed at making ITD leaner.

They also reported that there was a significant increase in employee efforts to implement innovations to improve service delivery and efficiency during the study period.

Since completion of the project, ITD has taken a number of actions to implement study recommendations, including:

- Establishing a Constructive Culture Workgroup, led by our Chief Human Resources Officer, to oversee and facilitate sustained organizational culture improvement efforts.
- Launching a new program for identification and development of emerging leaders as well as a talent management program.
- Offering leadership training to new managers and supervisors and rolling out a new course for managers and supervisors focusing on setting expectations for employees, developing performance plans, and coaching.
- Utilizing individual development plans to grow the skills and capabilities of department managers and supervisors.
- Conducting a Leadership Summit focusing on employee innovation. As part of the summit, more than 150 employees tackled a variety of organizational problems in a Rapid Innovation Event.
- Finally, executive management has committed to conducting ongoing organization-wide culture assessments and individual leader assessments every two years.

The change in the department has been dramatic since the project began. In the fall of 2016, ITD was selected as one of three finalists for Innovative Company of the Year by the Idaho Technology Council, a first for a public-service agency in Idaho. Over this period, ITD has also made significant improvements in its winter maintenance operations. During the past winter, ITD roads were free of snow and ice 73 percent of the time, up from 28 percent in 2010 despite parts of Idaho enduring one of the worst winters in 35 years.

The department also has received a number of national awards during this period, and ITD enjoys strong support from the Governor and Legislature, due in part to the culture shift within the agency. A recent column about the department by Idaho Governor Butch Otter illustrates this:

http://apps.itd.idaho.gov/Apps/MediaManagerMVC/transporter/2017/031017_Trans/031017_GovsColumn.html

Effects of Intersection Right-Turn Lane Design and Skew on Safety and Operations

<i>Project ID</i>	ICT-R27-111
<i>Cost</i>	\$255,415
<i>Duration</i>	57 months
<i>Submitter</i>	Illinois Department of Transportation 1611 Titan Drive Rantoul, Illinois 61866 217-300-2373
<i>Links</i>	https://apps.ict.illinois.edu/projects/getfile.asp?id=4949

Project Summary and Benefits

From 2006 to 2014, IDOT implemented modifications to ten right-turn approaches in and around Peoria, Illinois. The modifications were intended to improve the line of sight of right-turning passenger vehicles by reducing the skew of the approach angle, while allowing semi-tractor trailer trucks to make right turns without encroachment.

Research was conducted to evaluate the modified sites using traffic crash-based safety analyses, and to identify geometric variables that influence right-turn crashes. The traffic crash-based evaluation of the test approached with three years of before- and after-modification data provided insight into the safety impact of the modified right-turn lane design. The “after” data was collected between May 2012 and July 2015. Additionally, eight hours of field data were collected at each site, resulting in 160 hours of observations (80 hours at the test sites plus 80 hours at the 10 control sites.) A total of nearly 19,000 vehicles were observed at the test and control sites combined.

The field data was collected for four main variables: driver head-turn behavior, lateral placement in the turn lane, stop type, and stop location. The test and control comparisons revealed that drivers traveling through the modified right-turn lane design (test sites) used safer driving behaviors compared with the control sites with the traditional design, such as fewer exaggerated head turns and fewer roll-and-go stops.

The results of this research provided recommendations on what types of sites would make good candidates for the installation of the modified right-turn lane design in Illinois. The modified design included sharpening the flat approach angle typical in the traditional designs, reducing the radius, adjusting the stop bar position, and modifying the corner island to improve safety by increasing the line of sight of approaching through traffic. At some locations, the corner island was removed or redesigned to achieve the geometric improvements. At other locations, additional pavement markings were placed around the radius to help delineate a better approach for passenger cars, while also allowing large trucks to complete the turn without striking the curb (See Figure 1).

The overall findings of the study show that the modified right-turn lane design has significant safety benefits. The results of the empirical Bayes (EB) method (See Table 1 Attached) indicated statistically significant reductions in subject approach crashes (59.0%), and right-turn crashes at the subject approaches (59.6%) at 95% level of confidence (LOC). More specifically, older-driver crash analysis showed a 70% significant reduction in right-turn crashes, and younger-driver crash analysis showed a 66% reduction for right-turn-related crashes as a result of the modified right-turn lane design.

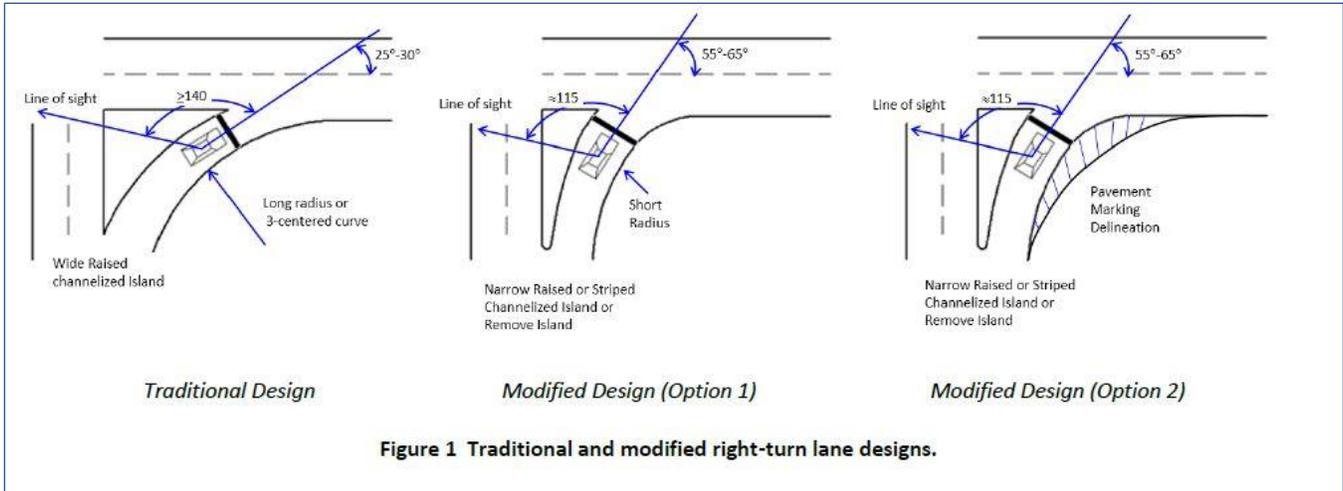
An analysis was also conducted to determine the economic effectiveness of the modified right-turn lane design at the test sites in the Peoria area. Economic costs and benefits of the modified design were calculated and annualized to determine the benefit to cost ratio of the modified right-turn lane design. The resulting benefit to cost ratio indicates that the accrued benefits exceed the annualized cost of the modified right-turn lane design over a period of 15 years by a factor of 13.8 or almost \$14 to \$1.

In many instances, modifications to the right turn approach can be as minimal as pavement markings to alter the radius and thus the skew angle. "IDOT is modifying its design policies regarding intersection design to incorporate results of the study and is encouraging its districts to utilize the intersection retrofit at high-crash intersections that meet the criteria for improvement," says Dan Mlacnik, IDOT Bureau of Design and Environment Engineering Policy Unit Chief. "The findings are also being shared with the design community to enhance future intersection designs in Illinois." To that end, IDOT held a webinar "Illinois DOT Safety Projects Series: Modified Right Turn Lane Design" on October 25, 2016. There were 139 participants in the webinar representing 58 cities throughout Illinois and 3 other states. The webinar is available for viewing on IDOT's [YouTube channel](#).

Table 1

Crash Type	Annual Average Crash Frequency				
	Observed/ After	Naive B&A		Empirical Bayes	
		Expected	Reduction	Expected	Reduction
Total Intersection Crashes	53.67	91.33	41.2%*	95.47	44.2%*
Intersection Injury (K,A,B,C) Crashes	13.00	21.33	39.1%*	22.93	43.6%*
Subject Approach Crashes	21.67	57.33	62.2%*	52.43	59.0%*
RT Related Crashes at Subject Approach	15.00	53.67	72.0%*	36.74	59.6%*

* denoted statistical significance





Evaluation of PCC Pavement and Structure Coring and In-situ Testing Alternatives

<i>Project ID</i>	ICT-R27-137
<i>Cost</i>	\$287,500
<i>Duration</i>	41 months
<i>Submitter</i>	Illinois Department of Transportation 1611 Titan Drive Rantoul, Illinois 61866 217-300-2373
<i>Links</i>	https://apps.ict.illinois.edu/projects/getfile.asp?id=5109

Project Summary and Benefits

The concrete paving industry has long asserted that field coring and curing practices damage the sample and thus produce lower strength test results than what is constructed in the field. IDOT/ICT established this research project and partnered with paving industry stakeholders serving on the technical review panel for the study.

The objective of this research was to (1) investigate practical curing practices for field coring samples to provide best estimates of in-place concrete strength, and (2) evaluate non-destructive test methods to reduce the need for coring. The researchers determined that the 5-day conditioning period for the core specimen can be replaced with a 1-day conditioning procedure (See Figure 1). The research also examined the effect of moisture conditioning of the core samples, and the effect of the presence and location of embedded rebar within the core sample.

The project results gave the Illinois Department of Transportation (IDOT) and industry another test method for acceptance of concrete when standard concrete cylinders are not readily available or if there are disputes in the tested strength of concrete. The results from this study are assisting IDOT in establishing procedures to estimate the in-place strength of concrete with greater accuracy. This information will be used by IDOT to improve implementation of pay-for-performance specifications for Portland cement concrete (PCC) construction. When a contractor does not have enough cylinders for testing or disputes arise, these procedures will allow the contractor to accelerate construction time by reducing the conditioning period from five days to one day. This will allow contractors to put traffic on the pavement faster, which will ultimately reduce construction costs.

As IDOT moves toward pay-for-performance PCC, IDOT has implemented a Modified AASHTO T-24 in the manual of test procedures (see attached test method) effective January 1, 2017, and has updated the Portland Cement Concrete Level 1 Technician Course for trainees to learn how to conduct the test properly. IDOT presented the research findings and proposed modified test procedure to the AASHTO Subcommittee on Materials at the

Annual Meeting in July 2016 in Greenville, SC. Also, IDOT will be submitting the modified coring procedure as a revision to AASHTO T-24 in the summer of 2017.

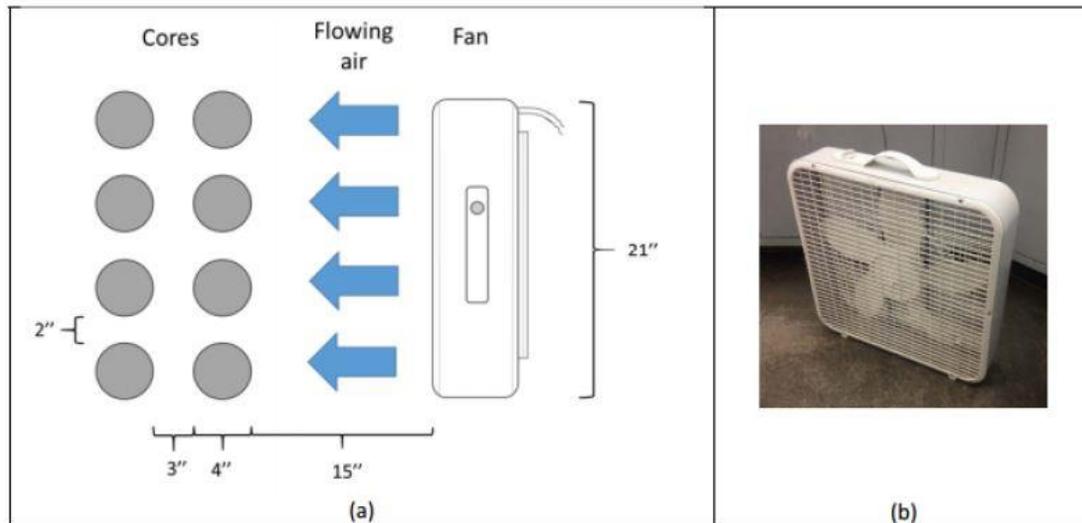


Figure 1 (a) geometric configuration of fan and cores for 1-day dry core conditioning, and (b) photograph of standard box fan

Evaluation of PG Graded Asphalts with Low Levels of ReOB, and Chemical and Compositional Characterization of Recycled Binders

<i>Project ID</i>	ICT-R27-162 & ICT-R27-SP28
<i>Cost</i>	\$174,345
<i>Duration</i>	28 months
<i>Submitter</i>	Illinois Department of Transportation 1611 Titan Drive Rantoul, Illinois 61866 217-300-2373
<i>Links</i>	https://apps.ict.illinois.edu/projects/getfile.asp?id=4772

Project Summary and Benefits

IDOT is continuously encouraged by industry groups to allow more recycled binders into their asphalt mixes. Not only is the use of reclaimed asphalt pavement (RAP) and reclaimed asphalt shingles (RAS) being strongly encouraged by the asphalt industry, but other binder modifiers such as bio-oil and recycled engine oil bottoms (ReOB) are sometimes used as well. It is widely known that using RAP, RAS, and ReOB in binder have some ancillary effects on hot-mix asphalt mixtures (HMA) such as increased brittleness, which often leads to premature cracking and decreased longevity.

The 2015 IDOT/ICT study, “Testing Protocols to Ensure Performance of High Asphalt Binder Replacement Mixes Using RAP and RAS” developed a mixture testing protocol, the Illinois Flexibility Index Test (I-FIT), to predict cracking susceptibility of HMA mixtures correlating to the longevity or service life of the pavement. Although the I-FIT test predicts cracking and fracture energy of a mix, IDOT needed additional information about the properties and chemical composition of the recycled binders.

Following the original I-FIT research project, IDOT/ICT produced two additional studies: *Evaluation of PG Graded Asphalts with Low Levels of ReOB*, and *Chemical and Compositional Characterization of Recycled Binders*. These studies concluded that asphalt cement with RAP and RAS levels above 20% could result in short- and long-term cracking potential. This high RAP and RAS content asphalt can also be in a highly oxidized state and therefore be in an already critically aged condition, which reduces the overall life of the HMA pavement. The research also showed HMA pavements with increasing ReOB percentages (3, 6 and 9%) in asphalt binder could be more susceptible to overall cracking-related damage. The most notable observation is that ReOB accelerates hardening, especially between short-term aging (STA) and long-term aging (LTA). Figure 1 demonstrates the impact of these different aging conditions on the flexibility index (FI).

The results of these studies have provided additional guidance to IDOT, and their asphalt suppliers, on how much RAP and RAS can be used without affecting long-term performance. Additionally, the study provides

recommendations and an implementation plan with critical thresholds that can be obtained from a series of chemical, compositional, and rheological tests (See Figure 2). This research was of particularly high value to IDOT. The relatively low cost of these research studies provided IDOT with valuable information to make informed policy decisions moving forward.

Based on the findings of the research, IDOT was able to reinforce its policy to industry of not allowing ReOB in asphalt binder because of its high acceleration of aging. In addition, IDOT was able to use data driven results to emphasize to industry that HMA mixtures with RAP and RAS levels above 20% could have decreased performance due to short-term and long-term cracking.

IDOT anticipates that the FHWA and other State DOT’s will use the results of these studies to make their own determinations and policy decisions regarding the use or amount of RAP, RAS, and ReOB. The results also demonstrated that additional research needs to be done to study the effects that aging has on all recycled asphalt binders (e.g., unknown modifiers, bio-oils).

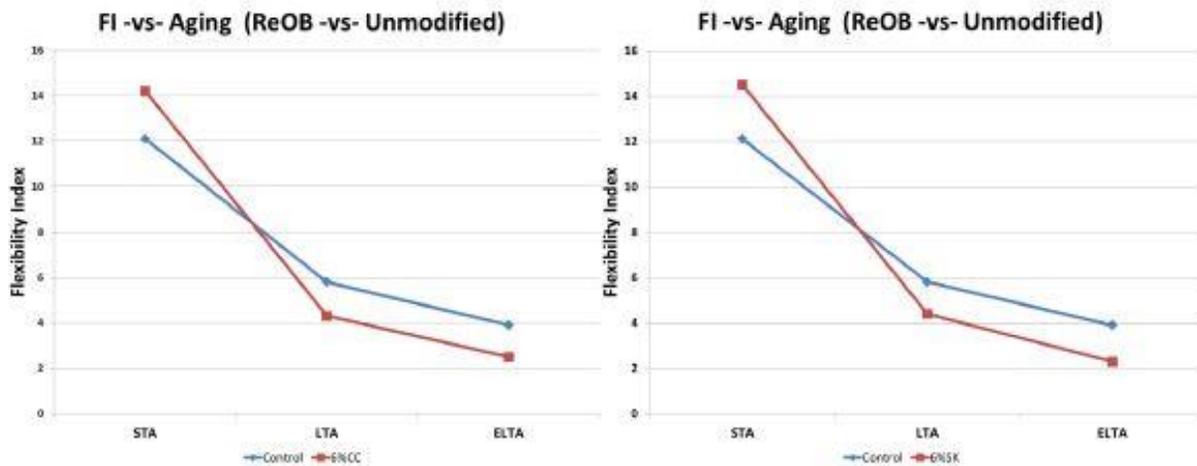
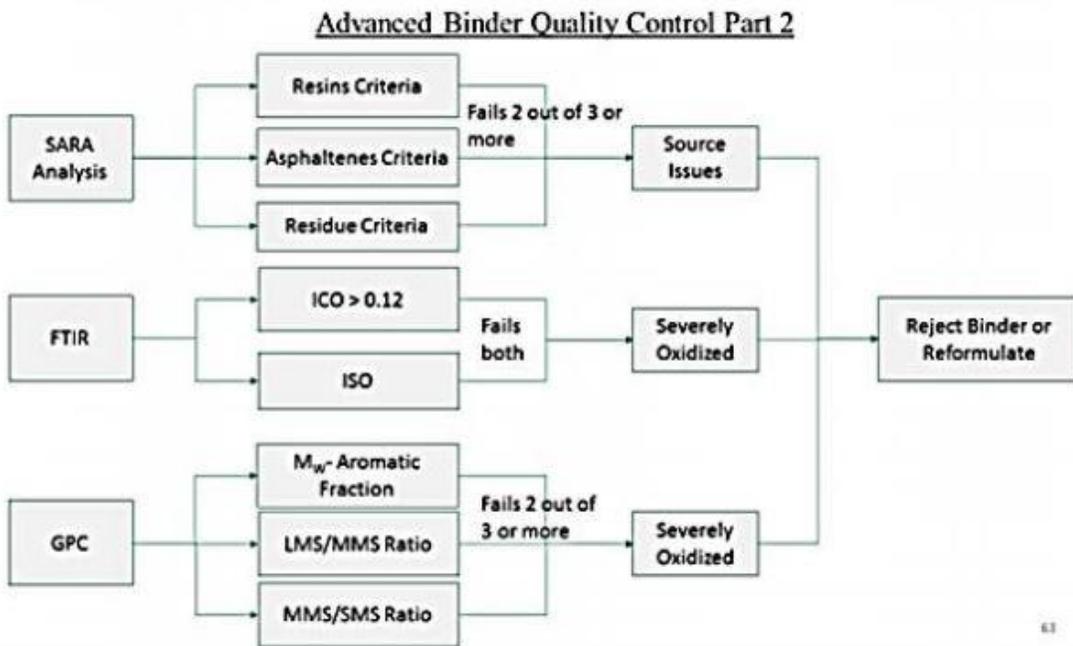


Figure 1 Impact on the FI of aging under different aging conditions for (a) mixes prepared with control and CC-type ReOB and (b) mixes prepared with control and SK-type ReOB

Figure 2 Proposed Rheological Testing Protocol



Strengthening of Bridge Wood Piling Retrofits for Moment Resistance, Phase II

<i>Project ID</i>	ICT-R27-134
<i>Cost</i>	\$350,000
<i>Duration</i>	41 months
<i>Submitter</i>	Illinois Department of Transportation 1611 Titan Drive Rantoul, Illinois 61866 217-300-2373
<i>Links</i>	https://apps.ict.illinois.edu/projects/getfile.asp?id=4931

Project Summary and Benefits

This project examined degraded timber piles that were stabilized using fiber reinforced polymers (FRP). Illinois' local system has over 1,000 bridges of this type that may benefit from this type of strengthening from FRP-retrofitted piles. FRP retrofitting involves the installation of either fiber sheets or strips (See Figure 1), which are then infused with an epoxy-like polymer substance. According to Jeff Burke, IDOT's Technical Review Panel Chair, the first spark triggering the interest in this project was the collapse of a bridge supported on timber piles back in 2008 in DeKalb County, Illinois. This project focused on load rating and FRP retrofitting abutment timber piles and the long-term performance of FRP-wrapped timber piles.

To carry out this research, the Principle Investigator used both timber piles taken from the field and newer piles that the research team could age in the lab. The newer piles were subjected to a large number of thermal/humidity cycles that mimic 20 years of summer and winter climate conditions. Researchers used these aged piles to

- (1) determine how much load a deteriorated pile could sustain,
- (2) see whether a process using FRP would be an effective way to reduce the rate of future deterioration, and
- (3) prolong the life of the structure by reinforcing deteriorated piles.

The results of this project demonstrated that the accelerated aging procedure caused substantial damage to unmodified timber piles, but did not visibly damage the FRP composite piles. In addition, using five and ten layers of FRP retrofit improved the peak strength of the piles by 70% and 82%, respectively, compared to the unretrofitted specimens. Compared with the unretrofitted specimens, FRP wrapping improved the ductility of the piles by more than 90%.

As a result of this research, IDOT has introduced repair and strengthening standard details for FRP pile repair (See Figure 2). This will aid bridge owners in local jurisdictions to prolong the life of timber-supported structures using FRP, rather than tearing down a structure because of the condition of the timber piles. IDOT has implemented an improved load rating analysis process for timber piles at both the piers and abutments based on the FRP repair method.

IDOT, Christian County, and the FHWA Illinois Division Office produced a training video, available on [YouTube](#), that demonstrates an actual FRP construction project. The strengthening and repair methods were also presented to the Illinois Association of County Engineers at their annual meeting. The strengthening and repair methods developed as a part of this research will allow local jurisdictions to maximize their funds, keep structures open without restrictions, and ensure safety of their bridges for the traveling public. Principal Investigator Bassem Andrawes, professor in the Department of Civil and Environmental Engineering at the University of Illinois at Urbana-Champaign, believes this study is of prime importance. He states: “This project addresses one of our nation’s most pressing issues, namely, the deterioration and crumbling of our transportation infrastructure.”



Figure 1 Fiber Reinforced Polymer (FRP) lab specimens

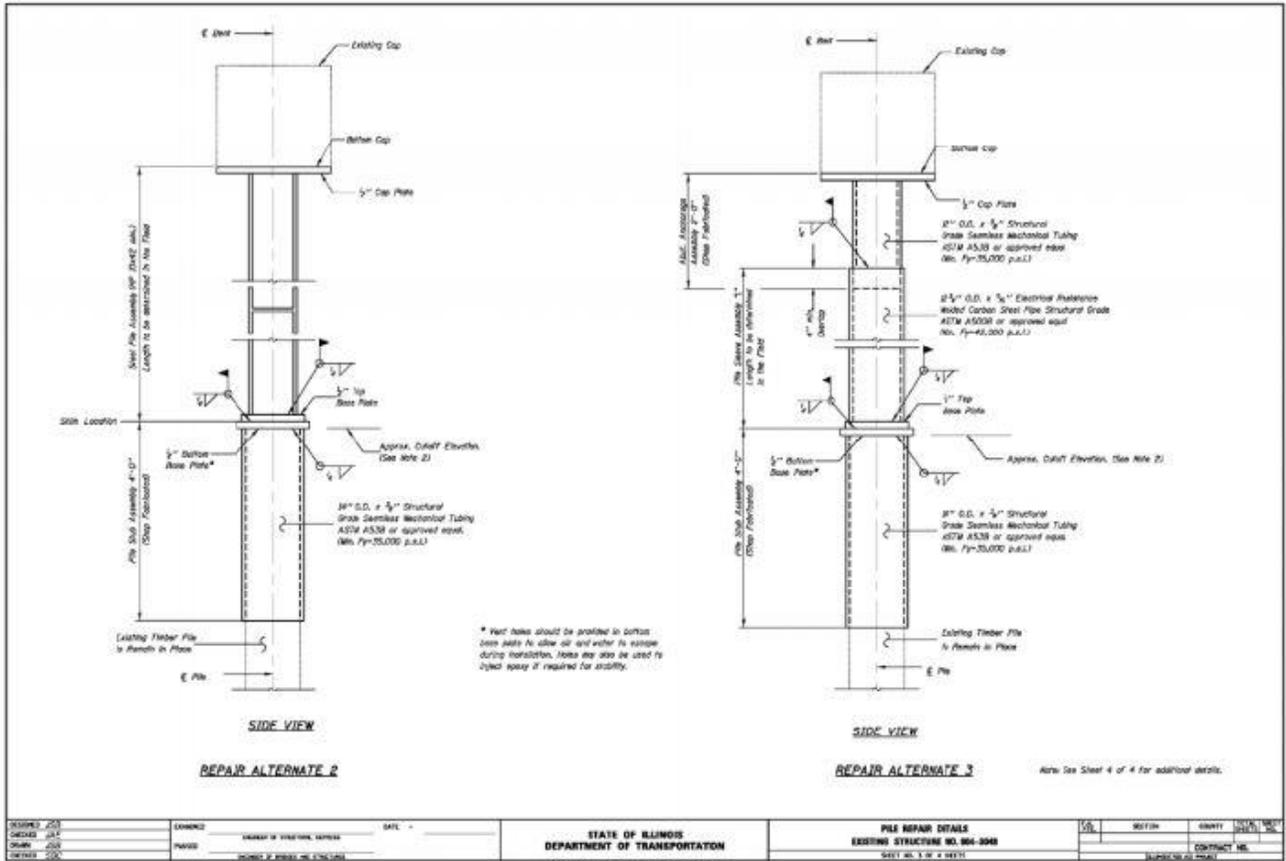


Figure 2 Sample FRP repair standard details

Development of a Cost-Effective Concrete Bridge Deck Preservation Program

<i>Project ID</i>	SPR-3320
<i>Cost</i>	\$340,871
<i>Duration</i>	84 months
<i>Submitter</i>	Indiana Department of Transportation Tommy Nantung 1205 Montgomery Street West Lafayette, Indiana 47906 765-463-1521
<i>Links</i>	

Project Summary and Benefits

Concrete bridge decks across the State of Indiana have experienced ongoing degradation caused by applications of deicing salts during the winter. Salt water collects on the deck and permeates the concrete through the cracks and the deck surface, allowing chlorides to initiate corrosion of the reinforcing steel. Over time, corrosion of the reinforcement leads to the need for costly deck repairs or deck replacement prior to the expected service life of the bridge. The use of localized crack sealers and deck surface sealers has the potential of providing a cost-effective method of deck preservation that could be implemented across the State to prolong the life of bridge decks.

The objective of this study was to investigate potentially effective and economic bridge deck preservation methods to significantly extend the service life of bridge decks, and as a result, extend the life of bridge structures. A literature review and survey of State Departments of Transportation were completed to guide the development of the experimental program and construction of test specimens. The experimental program included continual monitoring of macrocell specimens exposed to a salt-water ponding regimen for a period of 1600 days, autopsy of the specimens to correlate observed interior corrosion with measured corrosion activity, and application of a deck sealer to specimens with preexisting corrosion to evaluate the sealer's effectiveness in slowing the rate of corrosion. Deck sealer performance was investigated further by correlating the occurrence of corrosion with sealer penetration depth and chloride penetration profiles. Preliminary field tests of sealer applications were also completed to inform the development of field application methods.

The results of this research program clearly indicate that crack and deck sealing can be highly effective in preventing corrosion of reinforcement resulting in a significant extension of bridge life along with a reduction in lifecycle costs. Recommendations are provided regarding product selection and application to enable cost effective implementation of a bridge deck sealing program across Indiana and other parts of the country with

exposure to deicing salts. The results of this research are already being implemented across Indiana where five districts have sealed over 400,000 square feet of bridge deck. Statewide sealing will commence Spring 2017.

Guardrails for Use on Historical Bridges

<i>Project ID</i>	SPR-3714
<i>Cost</i>	\$300,000
<i>Duration</i>	47 months
<i>Submitter</i>	Indiana Department of Transportation Tommy Nantung 1205 Montgomery St. West Lafayette, Indiana 47906 765-463-1521
<i>Links</i>	

Project Summary and Benefits

Federal and state laws protect historically significant bridges, and railings on these bridges can be subject to protection because of the role they play in aesthetics. Unfortunately, original railings on historic bridges do not typically meet current crash-test requirements and typically do not meet current standards for railing height and size of permitted openings.

The primary objective of this study was to develop strategies that can be used to address existing railings on historic bridges and to develop solutions that meet current design requirements. Based on this research, three retrofit strategies were developed which include an inboard railing, curb railing, and simulated historic railings. Simulated railings were developed to cover a variety of historic concrete and steel railings. These railings meet current crash requirements while integrating geometric features of the historic railing.

Through the use of the strategies developed in this research program, it is possible to retain the historic railing appearance of the majority of historic bridges in Indiana. In many cases, it is also possible to improve aesthetics. Most importantly, however, these strategies allow for improvement in the safety of the traveling public. In addition to the modification, selection, and design of the bridge railing, the bridge deck is also impacted by changes made to the railing.

Due to increased force levels recently required by AASHTO, deck overhangs require significantly more reinforcement than past practice. These increases are being realized on all bridge decks and can pose particular challenges for the attachment of railing to historic bridges. Therefore, a secondary objective of this project was to investigate the design of the deck overhang and determine whether reduced amounts of reinforcement are possible.

Experimental testing of half-scale and full-scale overhang specimens was conducted, and the results were analyzed. Failures of in-service bridge railings were also evaluated. It was found that the failure mode assumed

by current design specifications is inconsistent with behavior and a significant reduction in transverse reinforcement relative to that currently required by the AASHTO design specification can be achieved.

Based on this research, recommendations are provided for the more efficient and economic design of bridge deck overhangs which are applicable not only for historic bridges, but for all concrete bridge decks. There are significant benefits to safety and economy in implementing these recommendations. INDOT has shared the research results with the chair and vice-chair of the AASHTO Subcommittee on Bridges and Structures T-7 - Guardrail and Bridge Rail. In addition, INDOT is developing modifications to the Bridge Design Manual to incorporate the deck overhang reinforcing recommendations. The proposed modifications will then be sent to the INDOT-ASCE Structural Committee and FHWA for approval.

Analysis of the Multiple Stress Creep and Recovery Asphalt Binder Test and Specifications for Use in Indiana

<i>Project ID</i>	SPR-3810
<i>Cost</i>	\$210,000
<i>Duration</i>	30 months
<i>Submitter</i>	Indiana Department of Transportation Tommy Nantung 1205 Montgomery Street West Lafayette, Indiana 47906 765-463-1521
<i>Links</i>	

Project Summary and Benefits

The Superpave high-temperature binder test protocol has been shown to be inadequate for characterizing the high-temperature behavior of asphalt binders, especially those with polymer modifiers. Recently, an alternate specification based on the Multiple Stress Creep Recovery (MSCR) test has been proposed to address the shortcomings of the Superpave high-temperature binder specifications. This study investigated the merits of implementing the MSCR test protocol as a replacement for the conventional Performance Graded (PG) high temperature test.

A statistical analysis was conducted on a dataset containing six-years of companion test results from the Indiana Department of Transportation (INDOT) to compare how the MSCR and PG procedures differ in grading various binders. In addition, an experimental study was conducted using sixteen different modified and unmodified binders. The results indicate that the MSCR test is a suitable replacement for the PG test since it provides a better tool to rank modified asphalt binders as well as unmodified ones. That is, creep compliance from the MSCR test more fundamentally represents binder behavior at high temperatures compared to the PG rutting parameter.

The MSCR results clearly showed differences in how various modifiers affect binder behavior, which may prove useful in future forensic evaluations. In addition, the very simplified approach, known as grade-bumping, used in the current Superpave mix design system to account for high traffic levels and low speed limits can be eliminated when using the MSCR test, which provides a more robust and meaningful way to account for the effects of traffic. A statistical comparison of the conventional PG and MSCR binder test results with mixture flow number testing showed that the MSCR test better predicted mix behavior and therefore would better predict pavement performance than the conventional PG rutting parameter.

Performance of Warranted Asphalt Pavements: Smoothness and Performance of Indiana Warranted Asphalt Pavements

<i>Project ID</i>	SPR-3813
<i>Cost</i>	\$120,000
<i>Duration</i>	29 months
<i>Submitter</i>	Indiana Department of Transportation Tommy Nantung 1205 Montgomery Street West Lafayette, Indiana 47906 765-463-1521
<i>Links</i>	

Project Summary and Benefits

Warranted asphalt pavements have been placed in Indiana, on a trial basis, since 1996 in an attempt to improve pavement performance, increase quality, and prevent premature failures. However, in terms of initial capital costs, these are more expensive when compared to similar non-warranted asphalt pavements. As a result, to assess the benefits of warranted asphalt pavements, their performance life and the initial and maintenance costs were simultaneously evaluated.

The study reviewed different warranty types, the benefits and concerns related to warranted projects, and experience with warranties in various states and in Indiana. Data from the warranted asphalt pavements constructed in Indiana were analyzed and compared to data from non-warranted pavements in a variety of ways.

Overall, warranted asphalt pavements perform more efficiently than similar non-warranted asphalt pavements. Warranted asphalt pavements deteriorate more slowly and their service lives can be 10 to 14 years longer than traditional non-warranted asphalt pavements. When initial capital costs are considered, warranted asphalt pavements are 15 to 40% and 47 to 61% more cost-effective over short- and long-term comparisons with non-warranted asphalt pavements. Results of five sets of pairwise comparisons indicate that in terms of service life, warranted pavements actually outlasted the comparable non-warranted pavements by one to seven years and performed more efficiently during their service lives.

Results of this study revealed that warranted asphalt pavements perform superior to and more cost effectively than the similar non-warranted pavements. Both projected and actual service lives were found to be greater for warranted pavements. Based upon the findings of the study, reinstating an asphalt pavement warranty program could not only save money, but provide better pavement life and thereby improved service to the

Indiana traveling public. INDOT is in the process of reinstating the asphalt warranty program for high volume roads with high truck traffic beginning the next construction season.

Bridge Deterioration Models to Support Indiana’s Bridge Management System

<i>Project ID</i>	SPR-3828
<i>Cost</i>	\$150,000
<i>Duration</i>	23 months
<i>Submitter</i>	Indiana Department of Transportation Tommy Nantung 1205 Montgomery Street West Lafayette, Indiana 47906 765-463-1521
<i>Links</i>	

Project Summary and Benefits

The Indiana Department of Transportation commissioned this project to update the bridge deterioration models that are used in the Indiana Bridge Management System. The need for such update was motivated not only by changes, over the decades, in bridge construction technology and inspection quality but also by the current availability of more reliable traffic and climate data.

In addressing this research need, this study developed families of curves representing deterioration models for each bridge component (deck, superstructure, and substructure). The study categorized the model families by their administrative region, functional class, and superstructure material and design type. The study used data from the National Bridge Inventory database to develop both deterministic and probabilistic models, and used the NBI condition ratings as the response variable. The explanatory variables include the bridge component age, truck traffic volume, climate severity, past repair history, and the superstructure material and design types.

The developed models are helping INDOT’s bridge engineers in both project-level and network-level management of this infrastructure. At the project level, INDOT is using the models to enhance the tracking of the physical condition of bridge components and to specify when maintenance, rehabilitation and replacement of each individual bridge component can be expected. Thus, INDOT is placed in a better position to customize bridge repair or replacement schedules that incorporate the physical condition, functional obsolescence, and pre-specified performance thresholds. Ultimately, the models help in the long-term scheduling, programming and budgeting of bridge repair actions for individual bridges.

At the network level, component-specific deterioration models are useful for system-wide needs assessment over a specified future time horizon, valuing the state’s bridge assets, and as a key input in quantifying the system-wide consequences of funding shortfalls or funding increases. INDOT is currently incorporating these deterioration curves into dTIM asset management system used for programming bridge projects.

Estimation and Prediction of Statewide Vehicle Miles Traveled (VMT) by Highway Category and Vehicle Classification

<i>Project ID</i>	SPR-3829
<i>Cost</i>	\$150,000
<i>Duration</i>	20 months
<i>Submitter</i>	Indiana Department of Transportation Tommy Nantung 1205 Montgomery Street West Lafayette, Indiana 47906 765-463-1521
<i>Links</i>	

Project Summary and Benefits

Vehicle Miles Traveled (VMT) is a critical measure of highway system performance that is used extensively in highway management not only for reporting to oversight agencies such as the FHWA but also for financial analysis, resource allocation, and impact assessments. In the current era as highway revenue from fuel taxes continues to fall and direct user charging such as VMT fees become increasingly attractive, consistent and reliable VMT estimates have become critical for evaluating highway funding options. In the current practice at most highway agencies including INDOT, there exists several alternative methods for VMT estimation that typically yield a spectrum of estimates that are inconsistent and in certain cases inaccurate. Therefore, this study was commissioned by INDOT to develop a benchmark method for VMT estimation and to provide calibration factors for adjusting the VMT estimates derived from the other VMT estimation methods.

The benchmark method developed in this study was a segment-level framework that decomposes the entire road inventory into links and for each link, determining the product of the traffic volume and the inventory length. With regard to the local road system, this process was more complicated: a sample of counties of different spatial locations and degrees of urbanization were used, and cluster analysis, geographic information systems (GIS), and spatial interpolation techniques were used to expand the VMT estimates from the local road samples to the population of all counties in the state.

The results of this study indicate that there is significant variation of VMT estimates from the various estimation methods. Calibration factors were developed for reconciling the estimates from the other methods with the benchmark estimates, and these factors were duly validated. For the benefit of intended end users and stakeholders, an electronic platform was developed to facilitate implementation of the framework. It was determined that the current statewide VMT (2013) is 78 billion vehicle-miles, and this is expected to grow to 95 billion vehicle miles in 2035. INDOT incorporated the research results into the alternative funding mechanism

decision support tool and the Transportation Funding Outlook Tool (INDOT Financial Educational Tool used in discussions with Indiana Legislators).

T-Scan: Stationary LiDAR for Traffic and Safety Studies - Object Detection and Tracking

<i>Project ID</i>	SPR-3831
<i>Cost</i>	\$400,000
<i>Duration</i>	37 months
<i>Submitter</i>	Indiana Department of Transportation Tommy Nantung 1205 Montgomery Street West Lafayette, Indiana 47906 765-463-1521
<i>Links</i>	

Project Summary and Benefits

This study investigates the feasibility of using laser ranging technology (LiDAR) to collect traffic data at intersections for traffic and safety studies. A novel LiDAR-based method was proposed as a portable traffic scanner (TScan) capable of detecting and tracking trucks, cars, pedestrians, and bicycles.

The scope of the research study included the development of a signal processing algorithm and a user interface, their implementation in a Purdue mobile research laboratory, and evaluation of the unit performance to confirm its practicality for safety and traffic engineering applications. The developed TScan experimental unit includes the Velodyne HDL-64E laser sensor integrated with the Purdue instrumented van equipped with a telescoping mast, video cameras, a computer, and an internal communications network. The developed TScan method detect, classified and tracks vehicles, pedestrians, and bicycles within an intersection area. The resulting trajectories are stored for future processing with engineering applications to count vehicles and vulnerable road users, to collect data for signal warrants, and to proactively evaluate safety with the traffic conflicts technique. The FHWA-sponsored Surrogate Safety Analysis Model (SSAM) was interfaced with the TScan method for extracting traffic conflicts and collisions.

The results allow building trailer-based prototype units for evaluation by end users. This novel and truly interdisciplinary research demonstrates the usefulness of LiDAR sensors in developing breakthrough systems for collecting microscopic good quality intersection data from roadside locations for a wide range of traffic and safety studies routinely conducted by the consulting industry and in-house by transportation agencies. Furthermore, the experience gained during the project and the obtained solutions are important steps towards a new generation of roadside infrastructure expected to support the dual function of future transportation engineering systems: (1) supporting the navigation task of autonomous vehicles, and (2) efficiently monitoring traffic and safety on future roads used jointly by human-operated and autonomous vehicles and preserving the collected data for analysis and improvements.

The project has provided results that allow the current pre-implementation phase of the project, in which the research team is developing two prototype TScan units to be evaluated by the INDOT users before actual implementation in the INDOT districts. The units will be used for major data collection efforts at intersections. This will reduce the human effort on data collection and processing and will increase not only the quality of data but also the availability of certain type of data such as traffic conflicts.



Site Selection for New Lighting Technologies	
<i>Project ID</i>	SPR-3833
<i>Cost</i>	\$135,800
<i>Duration</i>	30 months
<i>Submitter</i>	Indiana Department of Transportation Tommy Nantung 1205 Montgomery Street West Lafayette, Indiana 47906 765-463-1521
<i>Links</i>	



Project Summary and Benefits

It has been reported that nationwide, about one quarter of the roadway travel commonly occurs after dark and half of the roadway traffic fatalities occurred at night. The nighttime traffic crash fatality rate is about three times the daytime traffic crash fatality rate. This study was conducted to investigate the lighting effects on traffic safety at Indiana intersections. The following tasks were completed during the course of this study:

- Illuminance values at the selected intersection sites were measured. The performance of the new and existing luminaires was evaluated based on the measured luminance distributions.
- Crash modification factors (CMF) for various types of intersections were developed. The crash modification factors for intersection lighting were developed with the Indiana crash data. The resulted CMF values for Indiana intersection lighting include, 0.88 for overall intersection lighting, 0.90 for four-leg intersection lighting, and 0.84 for three-leg intersection lighting. That is, when lighting is provided at intersections, the crashes are expected to reduce by 12%, 10%, and 16% at the above mentioned three intersection groups, respectively. A much greater reduction was found for roundabouts.
- This study evaluated new lighting projects with life cycle benefit and cost analysis and lighting solid state luminaire retrofit projects with life cycle cost analysis.

Many of the solid state options showed significant reduction in life cycle costs when compared to the older high pressure sodium technology and a short return period on the initial investment to retrofit. The benefits estimated in new lighting project applied the CMF developed in this study and the project was well justified from economic perspective. To facilitate the life cycle analysis on new lighting projects and lighting retrofit projects, an MS excel based worksheet has been developed in this study, so it is recommended this worksheet be used as a standard procedure when life cycle cost analysis and life cycle benefit and cost analysis need to be performed by the agency. The illuminance based evaluations and the developed CMFs provide INDOT useful tools for intersection lighting design and safety assessments. The life cycle cost methods with the application

software will enable INDOT to conduct project evaluations effectively. The research results also provide a rational basis for INDOT to develop or modify the standard related to intersection and lighting.

Performance of Deicing Salts and Deicing Salt Cocktails

<i>Project ID</i>	SPR-3864
<i>Cost</i>	\$85,000
<i>Duration</i>	21 months
<i>Submitter</i>	Indiana Department of Transportation Tommy Nantung 1205 Montgomery Street West Lafayette, Indiana 47906 765-463-1521
<i>Links</i>	

Project Summary and Benefits

While the use of deicing and anti-icing is valuable for the safety of the travelling public, some concrete pavements have shown premature deterioration at the joints. This damage occurs long before the service life of the concrete pavement has been reached (e.g., damage typically occurs between 6 and 12 years while concrete pavements last in excess of 30 years) requiring costly repairs (estimated at over a million dollars a mile) that impact the travelling public.

While the problem began to receive national attention in 2008, many proposed solutions continued to use the same specifications and construction procedures that had been historically used while emphasizing attention to quality control. INDOT led the nation in developing a new way of thinking about the problem by pointing to the fact that two primary factors appear necessary for damage to occur: increased fluid saturation and a chemical reaction that occurs between deicing salts and the cement matrix. It was demonstrated that a little known reaction can occur between the concrete and the deicing salt, especially when calcium chloride deicing salt is used.

This research project focused on examining this chemical reaction specifically when salt blends (combinations of sodium and calcium chloride) were used with a wide range of Indiana materials. This work resulted in the development of:

- A test method that was approved by AASHTO in 2016 to quantify the potential reaction between materials used in making concrete and deicing salts using low temperature differential calorimetry,
- Recommendations on the benefits and volume of supplementary materials that can be used to reduce the potential for calcium oxychloride formation. This work was adopted by AASHTO PP-84, performance engineered measures, to improve concrete durability.

- A simple model to calculate the potential impacts of deicing salt blends that are commonly used to contribute to the potential damage to concrete.

The findings of this work have significant impact on concrete pavements in Indiana and the nation. The use of the new AASHTO test methods and specifications is already resulting in use of mixtures that are substantially less susceptible to joint damage resulting in reduced maintenance costs to the travelling public at little to no increase in the initial cost of the pavement. The impacts of this research results are (1) changes in INDOT Section 501 Standard Specification for new concrete pavement construction, and (2) a decision to stay with the purity of sodium chloride for materials specification. The benefit of this research result is based on calculation from a few concrete joint patching projects in 2016. The future cost savings are in a form of pavement rehabilitation cost avoidance \$1 million/lane mile.

Identifying Effects and Applications of Fixed and Variable Speed Limits

<i>Project ID</i>	SPR-3900
<i>Cost</i>	\$90,000
<i>Duration</i>	23 months
<i>Submitter</i>	Indiana Department of Transportation Tommy Nantung 1205 Montgomery Street West Lafayette, Indiana 47906 765-463-1521
<i>Links</i>	

Project Summary and Benefits

The purpose of this research project was to implement and evaluate a variable speed limit system in Indiana. The project was comprised of three research studies. The first investigated a need for variable speed limit signage, the second developed a methodology to evaluate the effectiveness of static speed limit signage, and the third assessed variable speed limit signage adjacent to an active workzone in Indiana.

The research developed analysis techniques to quantify increases in crash rates during congested conditions that can be used to estimate back of queue crash rate increases on approaches to work zones. Figure 1. Single Variable Speed Sign Figure 2. Paired Variable Speed Signs Variable speed limits can potentially reduce speeds approaching queues, thus reducing the severity of crashes. A methodology was created to evaluate speed limit signage using probe vehicle data, which will be useful to operations engineers nationwide. In addition, a vehicle matching methodology was developed using laser speed devices which provide individual vehicle speed reductions as a result of speed limit signage.

Using these approaches the following conclusions were made:

- Paired variable speed limit signs (Figure 2) outperform single signs (Figure 1) when attempting to slow vehicles.
- Operators and managers should use at least three pairs of variable speed limit signs to obtain any tangible reduction in driver speeds.
- Variable speed limit signage should be placed upstream of the expected back of queue location.
- Placement of speed limit signage can be actively monitored using crowd sourced probe vehicle data.

Although INDOT is still deliberating if they will use variable speed limit signs, this research provides design guidelines (both sides, 3 sequential pairs) for deploying variable speed limit signs. The study also provides quantitative data that can be used to estimate the expected reduction on speed when they are deployed.



Figure 1



Figure 2

Chemical Modification of Uniform Soils and Soils with High/Low Plasticity Index

<i>Project ID</i>	SPR-3940
<i>Cost</i>	\$125,000
<i>Duration</i>	23 months
<i>Submitter</i>	Indiana Department of Transportation Tommy Nantung 1205 Montgomery Street West Lafayette, Indiana 47906 765-463-1521
<i>Links</i>	

Project Summary and Benefits

The addition of chemicals, often Lime Kiln Dust (LKD) and Portland cement, into the subgrade during construction to improve soil workability, compactability, and engineering properties is a common practice. Many DOTs have been using chemical modification for more than 20 years and, in fact, 90% of current subgrade is treated. Nevertheless, problems persist. The Indiana Department of Transportation (INDOT) Design Manual states that subgrade clays with low plasticity ($PI < 10$) must be treated with cement. When these soils are encountered in the field, small variations of the soil's PI around the threshold require changes in treatment. Also, when high plasticity clays (density < 95 pcf, or $PI \geq 25$) are found in the subgrade, they must be replaced with suitable soils. In addition, uniform granular soils (dune sands) do not stabilize with lime products or with a low dosage of cement, and current knowledge does not provide information about their stabilization. These problem soils, widely available in Indiana and in other States in the Midwest, have resulted in significant construction delays and cost increase due to change orders.

An extensive laboratory research performed on a variety of clayey soils with low and high plasticity and on uniform (dune) sands showed that by providing flexibility to the types of chemical treatments allowed, all these soils could be improved without the need of replacement or change orders. The research showed that by increasing the percentage of LKD, from a typical 4-5% to 6-7% for low plasticity soils or to 7-8% for high plasticity soils, the desired results in terms of overall stabilization of the subgrade and Unconfined Compression Strength (UCS) were met. Combinations of LKD and Portland cement also accomplished the desired objectives, with a reduction of the amount of the chemicals needed by about 2%. Uniform sands were successfully stabilized with the addition of Portland cement, about 5%, and with water to cement ratios of 2, to allow workability of the treated soil.

The research found that by providing flexibility to the Design Manual in terms of percentage of chemical to be used and by allowing combinations of chemicals, e.g., LKD and Portland cement, problem soils can be stabilized.

This additional flexibility will result in significant savings by avoiding change orders and associated construction delays due to the encountering of soils in the subgrade different than those expected.

A Decision Support System for Optimized Equipment Turnover

<i>Project ID</i>	RB14-014
<i>Cost</i>	0
<i>Duration</i>	43 months
<i>Submitter</i>	Iowa Department of Transportation 800 Lincoln Way Ames, Iowa 50010
<i>Links</i>	

Project Summary and Benefits

The Iowa Department of Transportation (DOT) primarily uses two classes of snowplow trucks: single-axle (A07) and double-axle (A12). These two classes of vehicles made up about 77% (\$7.88 million) of the heavy equipment budget for fiscal year (FY) 2015. This research project investigates the predominant factors and analyzes equipment data to determine an optimal normal replacement model for the Iowa DOT's single-axle A07 and double-axle A12 vehicles considering maintenance cost, equipment replacement cost, and residual resale values.

Two methods were considered: age of vehicle and cumulative maintenance costs. In FY 2014, the fleet inventory for single-axle A07 and double-axle A12 vehicles was 364 and 456, respectively, with estimated purchase costs of approximately \$134,500 and \$150,000 per vehicle, respectively. Currently the Iowa DOT uses a 15-year depreciation for these vehicles. Thus, for FY 2015, the Iowa DOT planned on purchasing 24 single-axle A07s and 31 double-axle A12s.

The Iowa DOT provided the researchers with nine years of historical data for these vehicles, including purchase cost, maintenance cost, purchase date, and actual and estimated resale values. The estimated resale values were derived from actual data and through internal expert opinion. The resale value curve assumes 100% purchase price value at year 0 and approximately 12% of purchase price for single-axle A07s and 11% for double-axle A12s at year 17. It's an exponential curve with the greatest decrease in value in the initial years. Additionally, the Iowa DOT provided an estimated inflation adjustment of 4.23% based on historical data, which was used to adjust maintenance event costs for comparative analysis. Using these data, the researchers were asked to evaluate and recommend a normal replacement model that would minimize total cost.

Accordingly, we developed a series of simulations evaluating total cost of ownership for vehicles. We modified the simulations by replacing vehicles every 1, 2, 3, ..., 15 years as well as replacing the top 20, 30, 40, ..., 160 most expensive vehicles in terms of cumulative maintenance costs. We ran each scenario 30 times for 500 years each to allow for the full effect of modified variables. The total cost of ownership (TCO) equation was the cost of

purchasing each truck plus the estimated maintenance cost per truck minus the value of the truck when sold. The total purchase price of both classes of vehicles included a base cost and modification costs for extra equipment. It was necessary to estimate the total purchase price due to total data not provided by the Iowa DOT. Furthermore, maintenance costs were calculated only for work performed on the vehicle and not for work performed on modification equipment and those data were not provided by the Iowa DOT. For the analysis performed, the additional costs were 38% above the vehicle purchase price for single-axle A07 vehicles and 41% above the purchase price for double-axle A12s. Furthermore, it was assumed that the resale value of each vehicle included the modification equipment.

Based on the data provided by the Iowa DOT and the estimated resale value curve of the vehicles, our research indicated that the optimal replacement model is eight years for single-axle A07 vehicles and six years for double-axle A12 vehicles. Assuming the resale value curve is accurate, we estimate that the Iowa DOT would save approximately \$1.8 million for single-axle A07s and \$6.47 million for double-axle A12s per year by moving from a 15-year normal replacement model to eight years for single-axle A07s and six years for double-axle A12s.



Low-Cost Rural Surface Alternatives: Demonstration Project

<i>Project ID</i>	TR-664
<i>Cost</i>	0
<i>Duration</i>	23 months
<i>Submitter</i>	Iowa Department of Transportation 800 Lincoln Way Ames, Iowa 50010
<i>Links</i>	

Project Summary and Benefits

The goal of this project was to implement several stabilization methods for preventing or mitigating freeze-thaw damage to granular surfaced roads, and identify the most effective and economical methods for the soil and climate conditions of Iowa. Several methods and technologies identified as potentially suitable for Iowa were selected from an extensive analysis of existing literature provided in Iowa Highway Research Board (IHRB) Project TR-632.

Using the selected methods, demonstration sections were constructed in Hamilton County on a heavily traveled two-mile section of granular surfaced road that required frequent maintenance during previous thawing periods. Construction procedures and costs of the demonstration sections were documented and subsequent maintenance requirements were tabulated through two seasonal freeze-thaw periods. Extensive laboratory and field tests were performed prior to construction, as well as before and after the two seasonal freeze-thaw periods, to monitor the performance of the demonstration sections. A weather station was installed at the project site and temperature sensors were embedded in the subgrade to monitor ground temperatures up to a depth of 5 ft and determine the duration and depths of ground freezing and thawing.

An economic analysis was performed using the documented construction and maintenance costs, and the estimated cumulative costs per square yard were projected over a 20-year timeframe to determine break-even periods relative to the cost of continuing current maintenance practices. The post-thawing field tests showed that the composite moduli of the macadam sections were about five times higher than the control sections. However, the macadam sections with non-woven- (NW-) geotextile had lower moduli than the corresponding sections without the NW-geotextile. The chemically and geosynthetically stabilized sections also had significantly increased moduli. The moduli of the aggregate column and geocomposite sections were similar to the control sections. However, these two methods are aimed at improving freeze-thaw resilience by improving drainage, not by increasing stiffness.

Based on survey photos taken on 11 different dates during the two freeze-thaw periods, most of the stabilization methods examined can minimize frost boils and potholes and improve the surface conditions of granular surfaced roads to varying degrees. Even the roadway surface treated with bentonite was much drier and tighter than the other sections during the thawing period. However, the sections with chloride surface treatments showed more ice lenses during freezing, and were more prone to potholes and washboarding during the thawing period. Additionally, the geocomposite drain section suffered significant rutting during the 2015 thawing period, which may require further study. The subgrade under the macadam sections also exhibited improved strength, stiffness, and frost-susceptibility ratings compared to the control and other demonstration sections.



Improving the Accuracy of Camber Predictions for Precast Pretensioned Concrete Beams

<i>Project ID</i>	TR-625
<i>Cost</i>	0
<i>Duration</i>	54 months
<i>Submitter</i>	Iowa Department of Transportation 800 Lincoln Way Ames, Iowa 50010
<i>Links</i>	

Project Summary and Benefits

The camber of a precast pretensioned concrete beam (PPCB) is relatively complex because it is sensitive to variations in several parameters, including the mix design; tolerances on prestressing forces and moisture control; bed configuration; curing process and handling; storage environment; and support location during storage. In addition, the aggregate types, cement, and admixtures used in the concrete mix play a significant role in the mix's creep and shrinkage behavior, which in turn significantly affect the long-term camber.

The method that the Iowa Department of Transportation (DOT) used to formulate the camber for PPCBs frequently overpredicted the long-term camber of some of the most often used long PPCBs in Iowa bridges, while it underestimated the long-term camber of shorter PPCBs. Therefore, a systematic study was undertaken to identify the key parameters affecting camber, needed improvements to construction practices, and potential refinements to the predictive analytical models. The discrepancy between the predicted and actual camber is reduced by addressing the concerns associated with each of these areas.

Implementing the study recommendations is expected to significantly improve the accuracy of the camber measurements and predictions. As a result, the difficulties during bridge construction by the inaccurate camber values when the PPCBs are erected on-site will be alleviated, thereby reducing construction schedule delays, improving bridge serviceability, and decreasing costs.



RWIS Network Planning: Optimal Density and Location

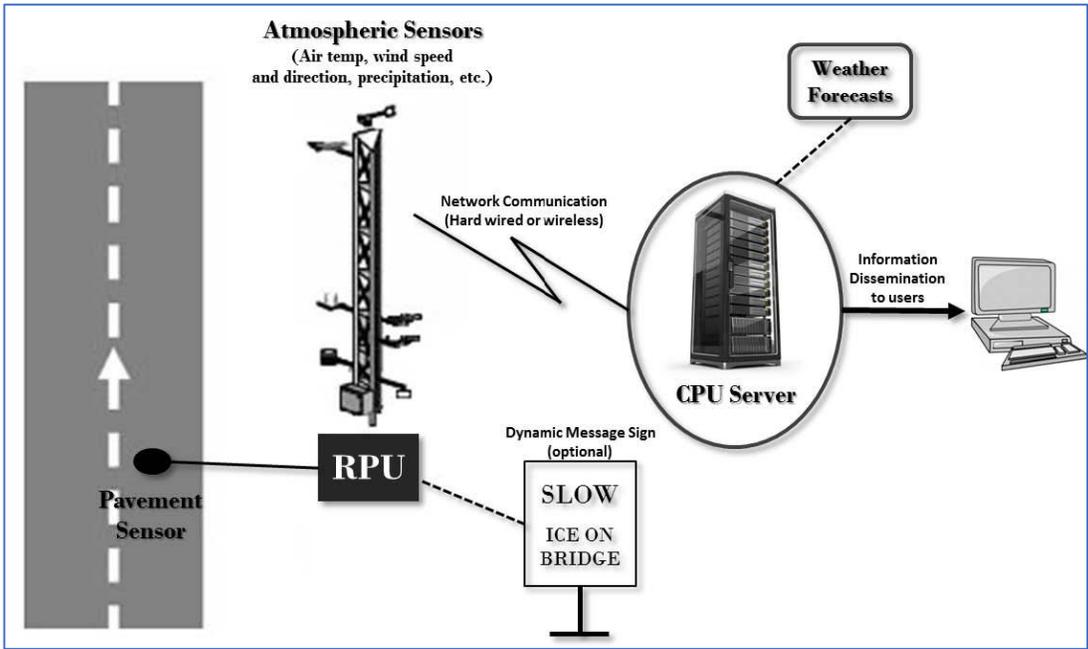
<i>Project ID</i>	TPF-5(290), Aurora Project 2010-04
<i>Cost</i>	0
<i>Duration</i>	40 months
<i>Submitter</i>	Iowa Department of Transportation 800 Lincoln Way Ames, Iowa 50010
<i>Links</i>	http://weatherview.iowadot.gov/

Project Summary and Benefits

Accurate and timely information on road weather and surface conditions in winter seasons is a necessity for road authorities to optimize their winter maintenance operations and improve the safety and mobility of the traveling public. One of the primary tools for acquiring this information is road weather information systems (RWIS) that include various environmental and pavement sensors for collecting real-time data on precipitation, pavement temperature, snow coverage, etc.

Many transportation agencies have invested millions of dollars in establishing their current RWIS network and continue expanding their network for better winter maintenance decision support and traveler information provision. While effective in providing real-time information on road weather and surface conditions, RWIS stations are costly to install and operate, and therefore can only be deployed at a limited number of locations. Considering the vast road network that often needs to be monitored and the kind of varied road conditions that could occur during winter events, a sufficient number of RWIS stations must be installed over a given region and they must be placed strategically so that they are collectively most informative in providing the inputs required for accurate estimation of the road weather and surface conditions of the entire highway network. Despite this significance, there are few guidelines and tools available for transportation agencies to optimize their RWIS network and thus maximize the return of their investment.

This project has attempted to address this gap by investigating various important factors that need to be considered in RWIS network planning process, and developing alternative approaches for determining the optimal location and density over a regional highway network. Three methods were utilized in order to optimize various important factors. Surrogate measure based method gives priority to those locations that have the highest exposure to severe weather and traffic. Cost-benefit based method assumes that the benefits of an RWIS station at any location can be defined and estimated. Spatial inference based method maximizes the ability to forecast and estimate conditions over an entire region based on data from individual RWIS stations. All three methods have benefits and potential impacts to the agencies utilizing the data provided.



Repair of Distortion-Induced Fatigue Damage in Bridge No. 135-87 (043SB and 044NB) Using Newly-Developed Strengthening Schemes

<i>Project ID</i>	KS-16-06
<i>Cost</i>	0
<i>Duration</i>	45 months
<i>Submitter</i>	Kansas Department of Transportation Richard Kreider 2300 SW Van Buren Topeka, Kansas 66611 785-296-1195
<i>Links</i>	http://dmsweb.ksdot.org/AppNetProd/docpop/docpop.aspx?clienttype=html&docid=9654903

Project Summary and Benefits

To investigate the performance of the angles-with-plate retrofit, two field tests were performed that monitored behavior of the bridge both before and after the retrofit was installed. Results from these field tests were compared with results from complementary finite element analyses to determine the overall effectiveness of the retrofit.

In the bottom web-gap region, where cracking is most prevalent in the bridge, the angles-with-plate retrofit was successful at lowering stress demands that would lead to crack propagation. The same conclusion could not clearly be made for all cases in the bridge's less problematic top web-gap region, so a secondary set of finite element analyses was performed to gain a better understanding of what was happening in that region. Further analyses of the two common types of distortion-induced fatigue cracking determined that, while not always large, the angles-with-plate retrofit was successful in reducing stress demands in the top web-gap region. It was concluded that the angles-with-plate retrofit was an effective repair for the problematic bottom web-gap regions of the bridge, and if needed, can be used effectively in the less demanding top web-gap region.



Stabilization of Unpaved Shoulders Over Moderate and Weak Subgrade Using Geosynthetics

<i>Project ID</i>	K-TRAN: KU-13-2
<i>Cost</i>	0
<i>Duration</i>	33 months
<i>Submitter</i>	Kansas Department of Transportation Richard Kreider 2300 SW Van Buren Topeka, Kansas 66611 785-296-1195
<i>Links</i>	

Project Summary and Benefits

The cyclic plate loading tests showed that the geocell and geogrid effectively reduced the accumulated permanent deformations as compared with the unreinforced sections. The geocell-reinforced soil-aggregate mixture slightly outperformed the unreinforced aggregate of the same thickness over a 5% CBR subgrade. The geogrid-reinforced soil-aggregate mixture performed significantly better than the unreinforced aggregate of the same thickness over 3% and 5% CBR subgrades. The plate loading tests also suggested that the topsoil cover resulted in large permanent deformations and rapid failure. Aggregate bases are recommended for unpaved roads. A 50% soil and 50% aggregate mixture is recommended for vegetated unpaved shoulders. Topsoil should not be used as a cover if unpaved shoulders are subjected to traffic. Geogrid is recommended to improve aggregate bases if needed. Geocell is recommended to improve soil-aggregate mixture if needed.



Soil Saver Wall Performance and Potential Modifications for Aquatic Organism Passage

<i>Project ID</i>	K-TRAN: KU-14-2
<i>Cost</i>	0
<i>Duration</i>	29 months
<i>Submitter</i>	Kansas Department of Transportation Richard Kreider 2300 SW Van Buren Topeka, Kansas 66611 785-296-1195
<i>Links</i>	http://dmsweb.ksdot.org/AppNetProd/docpop/docpop.aspx?clienttype=html&docid=9525112

Project Summary and Benefits

It was observed in the flume testing that excellent performance for the control of grade was provided by the soil saver wall for both the standard and notched walls. The V-notch wall appeared to have the potential to provide for better AOP for low flows, therefore this configuration is preferred. Additional flume study to quantitatively evaluate the hydraulic efficiency of the V-notch soil saver wall is recommended.



Developing a Bridge Scour Warning System	
<i>Project ID</i>	K-TRAN: KU-14-1
<i>Cost</i>	0
<i>Duration</i>	35 months
<i>Submitter</i>	Kansas Department of Transportation Richard Kreider 2300 SW Van Buren Topeka, Kansas 66611 785-296-1195
<i>Links</i>	

Project Summary and Benefits

A systematic statewide system would be preferable for monitoring scour-capable events at bridges across the state. Kansas Department of Transportation (KDOT) could leverage existing United States Geological Survey (USGS) and National Weather Service (NWS) tools to monitor scour-critical bridges or pursue a vendor to offer a turn-key solution. For critical locations, additional measures could be implemented at specific sites to offer more information or a higher level of monitoring.

Development of an Optimal Ramp Metering Control Strategy for I-12	
<i>Project ID</i>	LTRC 14-1SS
<i>Cost</i>	\$178,003
<i>Duration</i>	29 months
<i>Submitter</i>	Louisiana Department of Transportation and Development Tyson Rupnow 4101 Gourrier Avenue Baton Rouge, Louisiana 70808 225-767-9124
<i>Links</i>	http://www.ltrc.lsu.edu/pdf/2017/FR_570.pdf

Project Summary and Benefits

The objective of the research was to identify the optimal ramp metering control strategy and the anticipated operational benefits over LADOTD's existing fixed-time strategy along a 15-mile stretch of I-12 in Baton Rouge, LA. Traffic simulation tools were used to model the existing traffic conditions on the I-12 corridor using collected and calibrated traffic data. The algorithms that were the most suitable to the conditions on I-12 were determined and tested to find the one that is capable of optimizing traffic throughput and travel time reliability, along with minimizing delays on the mainline. The evaluated ramp metering strategies included the ALINEA local ramp metering control and mixed strategies case, which included Heuristic Ramp Metering Coordination (HERO) and the local ALINEA control. The different strategies and combinations of strategies were compared to LADOTD's current fixed-time ramp metering strategy. The three performance measures considered were travel time, speed, and vehicle hours travelled (VHT).

A corridor and section-by-section analysis showed that none of the eastbound sections experienced any significant improvements. However, in the westbound direction, three sections experienced significant improvements in the different performance measures: Range-O'Neal, O'Neal-Millerville, and Millerville-Sherwood. The travel time reductions on these sections were as high as 45 seconds and 30 seconds for ALINEA and the mixed strategies, respectively. The increase in speed was 9 mph and 13 mph for ALINEA and the mixed strategies, respectively. For the VHT, both strategies achieved reductions that reached 100 veh-rs for each of the three sections. When the ALINEA and mixed strategies were compared to one another, the mixed strategy showed more significant improvements. An implementation plan was identified in the study and LADOTD is in the process of procuring and installing the necessary hardware and infrastructure to facilitate that implementation.

Roller Compacted Concrete over Soil Cement under Accelerated Loading

<i>Project ID</i>	LTRC 12-7P
<i>Cost</i>	\$479,154
<i>Duration</i>	55 months
<i>Submitter</i>	Louisiana Department of Transportation and Development Tyson Rupnow 4101 Gourrier Avenue Baton Rouge, Louisiana 70808 225-767-9124
<i>Links</i>	



Project Summary and Benefits

With the increasing use of shale gas exploration, agricultural and logging activities on the low volume roadways, the Louisiana Department of Transportation and Development (LADOTD) are interested in thin applications of Roller Compacted Concrete (RCC) on the order of 4-8 inches thick. The objective of the study was to determine the constructability and load carrying capacity of thin RCC pavements over stabilized soil base as a design option for low volume roadways having frequently heavy and overloaded truck trafficking.

For this purpose, six full-scale accelerated pavement testing (APT) sections were designed and constructed at the Louisiana Pavement Research Facility (PRF) in Port Allen, Louisiana. Each section was about 72 feet long and 13 feet wide. A heavy vehicle load simulation device - ATLaS30 was used for the APT loading. The test sections included three RCC thicknesses (4 in., 6 in., and 8 in.) and two base designs: a 150 psi unconfined compressive strength (UCS) cement treated soil base with a thickness of 12 inches and a 300 psi UCS soil cement base with a thickness of 8.5 inches over a 10 inch cement treated subgrade. The RCC mix consisted of a well-graded aggregate blend using #67 limestone and manufactured sand with a Type I Portland cement of 11.4% and optimum moisture content of 6.5%.

Test results indicated that a thin RCC over stabilized soil base generally has a superior structural performance and load carrying capability. Load-induced fatigue cracking that may be initiated at or near saw-cutting joints was a primary pavement failure mode for a thin RCC pavement. It was found that the 6 inch RCC sections carried an estimated 87.4 million and 19.4 million ESALs to failure for the strong and weak base, respectively, and the 4 inch RCC section over the strong base also performed well with an estimated 19.2 million ESALs to failure. The APT results further led to a development of a thin RCC fatigue model and a thickness design procedure specifically for the design of thin RCC-surfaced pavement structure.

Finally, the potential economic benefits of using thin RCC pavement structure for Louisiana low volume pavement design were demonstrated by a direct comparison of two design alternatives with a similar pavement

design life. Overall, the initial construction cost savings for a 5-in. RCC slab over a 7-in. HMA surfacing would be approximately \$113,087 per lane mile and \$2,261,740 for a typical 2-lane, 10-mile long roadway project.

Implementation of Asphalt Mixture Performance Testing into 2016 Louisiana Standard Specifications for Roads and Bridges

<i>Project ID</i>	FHWA/LA/536 and FHWA/LA/558
<i>Cost</i>	\$563,408
<i>Duration</i>	40 months
<i>Submitter</i>	Louisiana Department of Transportation and Development Tyson Rupnow 4101 Gourrier Avenue Baton Rouge, Louisiana 70808 225-767-9124
<i>Links</i>	

Project Summary and Benefits

This submittal is a combination of two research projects that resulted in the successful implementation of asphalt mixture performance testing into the LADOTD's standard specification of roads and bridges. Historically, Louisiana's Quality Control and Quality Assurance (QC/QA) practice for asphalt mixtures in pavement construction was based on controlling properties of plant produced mixtures, (i.e., gradation and asphalt content, voids filled with asphalt, air voids, moisture susceptibility tests), and roadway parameters (i.e. pavement density and smoothness). These controlling properties have served Louisiana well, yet with growing interest in considering alternative and sustainable paving materials such as rubber modified asphalts (CR), reclaimed asphalt pavement (RAP), recycled shingles (RAS), and warm-mix asphalt (WMA) technologies, there is a pressing need to implement laboratory mechanical testing capable of ascertaining an asphalt mixture's long-term performance capability.

The first study was focused on identifying candidate performance tests, which could be used to screen potential problem mixtures prior to construction. This research presented an evaluation of Hamburg Loaded Wheel Tracking (LWT, AASHTO T 324) and Intermediate Temperature Semi-Circular Bending (SCB, ASTM D8044 – 16) tests for rutting and cracking evaluation, respectively, of commonly produced mixtures from around the state. This research also presented a framework for the development of a balanced asphalt mixture design (BMD) methodology adopted by LADOTD. Fifty-one mixtures were evaluated with both the SCB and LWT tests. The results of the research determined that the LWT and SCB tests were both practical, inexpensive, and effective in identifying mixtures that would be resistant to rutting and fatigue cracking respectively. In order to have meaningful research implementation of performance testing, the agency needed to develop a performance-based specification (PBS), which measures the mechanical and/or engineering properties of asphalt mixture as performance predictors of finished pavements. Such a PBS must be verified by actual field performance data.

The second concurrent study developed specification guidelines as well as a framework for the implementation of PBS for Louisiana. To achieve this objective, nine asphalt paving projects were selected across the state. Fourteen pavement sections that includes twenty-one asphalt mixtures were selected. A suite of laboratory evaluations using LWT and SCB tests were performed to evaluate the rutting (in terms of rut depth, RD) and cracking resistance (in terms of critical strain energy release rate, Jc), respectively. From the comparison analyses, it was observed that the LWT measured rut depths of six mm or less and ten mm or less can be the tentative quality limits for the high and low traffic Louisiana asphalt pavements, respectively. Similarly, the minimum SCB Jc values of 0.6 and 0.5 kJ/m² for high and low traffic asphalt pavements, respectively, seemed to serve well as the tentative criteria to avoid crack related problems. With these criteria, asphalt mixture producers are not as restricted as in the past. Thus, allowing greater innovation in asphalt mixture design for performance.

By implementing performance testing, the contractors in Louisiana are freer to innovate with higher recycled content (RAP, RAS) and sustainable mixture technologies (WMA, CR, green binders). This freedom to innovate can result in more sustainable asphalt mixtures for the taxpayer of Louisiana. It has also, resulted in more constructible HMA mixtures. A large Louisiana HMA producer has mentioned to LADOTD that, “I am using innovations in materials selections and proportioning to design a better asphalt mixture with the Louisiana BMD specifications”. With these innovations in available technologies and improved compaction, LADOTD is confident that the HMA materials being specified and produced (as a result of these research projects) will be more durable and allow for more environmentally friendly production practices.

Advanced Composite Materials in New England's Transportation Infrastructure: Design, Fabrication, and Installation of ACM Bridge Drain System

<i>Project ID</i>	NETC 09-03
<i>Cost</i>	\$165,000
<i>Duration</i>	36 months
<i>Submitter</i>	Maine Department of Transportation Dale Peabody 16 State House Station Augusta, Maine 04333 207-624-3305
<i>Links</i>	http://netc.w3.uvm.edu/research/reports/

Project Summary and Benefits

Advanced composite materials (ACM), also known as fiber-reinforced polymer (FRP) composites, have increasingly been used in bridge applications. FRP composites have been used in the rehabilitation and retrofit of beams, columns and decks. FRP composites are corrosion resistant and lightweight materials, which can be manufactured using different processes. The properties of FRP composites can be optimized for particular structural applications by selecting the type and orientation of fiber reinforcement and the polymer matrix. For these reasons FRP composites have the potential to be a cost-effective and durable solution for specific applications in the transportation infrastructure.

The New England Transportation Consortium (NETC) has conducted two research projects to date to identify those applications within the transportation infrastructure in New England where FRP composites could replace traditional materials used in civil engineering. The primary objective of NETC 01-1 was to identify obstacles for the widespread adoption of FRP composites in New England's transportation infrastructure with the goal of promoting its implementation (Breña et al. 2006). The second project, NETC 01-1-T2: Phase I, was conducted to identify and select an application for which FRP composites offered a cost-effective alternative to conventional construction materials. The goal was to select a prototype application that could be competitively fabricated and installed in the transportation infrastructure throughout New England. A standard drain system that could be used throughout bridges in New England to eliminate the problems with corrosion and leakage that occurs when using traditional materials, and to extend the service life of bridge drains was selected (Breña and Civjan 2009).

The main objectives of the project are to:

- 1) Design and fabricate a standard FRP drain that can be produced economically for use throughout New England bridges; and

2) Install the fabricated drain system in two representative bridge applications in New England to provide information on its performance, and ease of construction.

The major obstacles or gaps for the implementation of FRP drains in highway bridges include the lack of material, fabrication and installation specifications, the unavailability of standard designs, and the unknown performance during service. The value of the project is to address these gaps. FRP drain systems can be used both for new construction and rehabilitation projects.

The project deliverables include standard details and material and construction specifications that can be adopted immediately by DOT's. Also material coupon testing was completed and two manufacturer's have been found to meet the materials criteria. MaineDOT has adopted the specifications on numerous bridge projects to date. Up front material costs on these drains are greater than conventional steel drains. However costly bridge deck repair and bridge drain replacements are avoided in the long term. It is anticipated that as the product usage grows, manufacturer's will be able to reduce costs.



Rivet Testing of Rivets Taken from Maine Truss Bridge	
<i>Project ID</i>	ME 16-14
<i>Cost</i>	\$12,000
<i>Duration</i>	12 months
<i>Submitter</i>	Maine Department of Transportation Dale Peabody 16 State House Station Augusta, Maine 04333 207-624-3305
<i>Links</i>	http://maine.gov/mdot/tr/docs/report1614t.pdf



Project Summary and Benefits

The Maine Department of Transportation (MaineDOT) has removed 25 rivets from an existing, older truss bridge. Many such truss bridges have low rating factors as determined using Federal Highway Administration (FHWA) and the American Association of State Highway and Transportation Officials (AASHTO) guidelines due to the assumption of conservatively low rivet strength properties in the absence of known properties. Often times the low rating factors require that the bridge be posted to limit heavy truck loads. This creates problems for the trucking industry and businesses that rely on our bridges to move commodities, especially in rural areas where alternative routes can be extremely long.

To provide the MaineDOT with better information regarding rivet properties, The University of Maine (UMaine) has tested the rivets in tension to determine their strength properties. Work conducted under this task included assessing the best test method based on existing literature, fabricating test fixtures, machining test specimens from each rivet, conducting the strength tests, determining rivet strength properties from the test data, and reporting the test results to the MaineDOT in this report. Rivet testing was conducted according to ASTM F606 Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets and ASTM E8 Standard Test Methods for Tension Testing of Metallic Materials with variations as noted in the report. Rivets were machined to produce tension specimen with threaded grips at each end and a turned-down shank with dimensions adjusted from the standards to match provided rivet specimen. Rivets were tested in tension and mean yield strength (0.2% offset) was found to be 43.7 ksi and mean ultimate strength was found to be 69.6 ksi. For comparison, the Manual for Bridge Evaluation 2011 Second Edition AASHTO gives for ultimate strength values “unknown rivet type and origin” as 50 ksi, Carbon Steel ASTM A141 or ASTM A502 Grade 1 as 60 ksi and ASTM A502 Grade II as 80 ksi.

Since the completion of this rivet testing, MaineDOT has used the results on numerous bridges for load rating analysis and benefited by not having to post the bridge for truck loads and not having to conduct further, more expensive testing and analysis. As a case study the Aroostook River Bridge in Caribou was re-analyzed using the

new allowable rivet strength values. The analysis improved the load ratings such that heavy trucks can still use the bridge safely. If the bridge was posted for heavy trucks it would have meant a 31 mile detour. Additionally, the new load rating eliminated the need for a \$130,000 repair to upgrade the rivet connections.

Use of the SHRP2 Eco-Logical framework to Develop a Programmatic approach to Endangered Atlantic Salmon

<i>Project ID</i>	N/A
<i>Cost</i>	\$250,000
<i>Duration</i>	42 months
<i>Submitter</i>	Maine Department of Transportation Dale Peabody 16 State House Station Augusta, Maine 04333 207-624-3305
<i>Links</i>	http://maine.gov/mdot/maspc/

Project Summary and Benefits

Back in 2010, MaineDOT had an annual backlog of about 40 informal and formal Biological Assessments for salmon-related projects requiring USFWS review and fewer than seven were being processed due to extremely heavy workloads and highly detailed information requests. Less than 20% of annual consultations for the Atlantic salmon were reaching completion in time to deliver projects during a very constrained construction window. With the assistance of a \$250,000 grant from the SHRP2 Implementation Assistance Program, MaineDOT worked with its partners following the Eco-Logical framework to develop and adopt a programmatic consultation for the Atlantic Salmon species. With help from the grant, the department moved forward in several key areas.

First, even before the funds arrived, MaineDOT completed a gap analysis comparing Eco-Logical's Integrated Ecological Framework with its own environmental screening process. Through this examination of internal processes, it became clear that most of the ESA consultation sequence was out of MaineDOT's purview, limiting its ability to affect change. A partnership was formed between FHWA, USACE, USFWS and NMFS. Through this partnership, each agency informally analyzed its internal ESA Section 7 processes, tracked its ongoing ESA Section 7 consultations, and committed to eliminating duplicative steps.

The grant award coincided with MaineDOT's adoption of several department-wide performance measures under its 2012 strategic plan. A primary measure was delivery of at least 80% of projects within 30 days of the scheduled advertise date. The programmatic approach (Maine Atlantic Salmon Programmatic Consultation) to ensure vital protections for the endangered Atlantic salmon is cutting project-approval times for 60% of projects that are likely to affect the species. This is a combined effort of MaineDOT, the Federal Highway Administration, the U.S. Fish and Wildlife Service, the U.S. Army Corps of Engineers, and the Maine Turnpike Authority to expedite the Endangered Species Act Section 7 consultation process for projects that impact the Atlantic

salmon. Finalized in early 2017, the approach includes a programmatic biological assessment (PBA) prepared by MaineDOT, a programmatic biological opinion (PBO), and a related in-lieu fee mitigation program.

Once a project qualifies for programmatic coverage, informal consultations are completed within 14 days and formal consultations are completed within 30 days. Specific benefits of the programmatic approach include the following:

1. approximately 60% of MaineDOT projects requiring Section 7 consultation for Atlantic salmon will qualify for expedited processing under the PBO;
2. individual BAs (typically 50 to 100 pages) can be replaced by a standard two-page checklist form that reflects the protocols and performance standards of the PBO;
3. the timeframe for informal USFWS consultation and concurrence is reduced from about 8 months to 1 month;
4. parties can focus on projects outside the PBO that may have greater impacts on the species.

A MaineDOT biologist typically spent between 80 and 100 hours developing a 50- to 100-page BA. Simply not having to draft a BA for 45 projects each year results in a cost savings of over \$150,000. More significantly, this frees technical staff to spend those hours in the field gathering data needed to improve habitat connectivity.

NOTE: In FFY13 and 14, state DOT's contributed 4% of their SP&R funds towards the SHRP2 Implementation Assistance Program. This project was completed using a \$250,000 Eco-Logical IAP grant.

The Clear Roads Transportation Pooled Fund project: Reaping Benefits at MaineDOT

<i>Project ID</i>	TPF-5(353)
<i>Cost</i>	\$25,000
<i>Duration</i>	48 months
<i>Submitter</i>	Maine Department of Transportation Dale Peabody 16 State House Station Augusta, Maine 04333 207-624-3305
<i>Links</i>	http://clearroads.org/

Project Summary and Benefits

The Maine Department of Transportation Strategic Plan outlines several objectives and strategies for optimizing operational performance of the system and maintaining acceptable levels of regional mobility. On critical component of the Plan states that MaineDOT will “deliver a snow and ice control program that provides balance between available funding, highway safety, environmental, and/or infrastructure impacts as well as establish measurement of impacts to customers due to weather events.” Some of the performance metrics include average salt usage per storm per season and average time to bare and wet pavement on the higher traffic volume corridors. With a \$36 million per year budget for statewide snow and ice control and lofty expectations for mobility, safety, environment and infrastructure, following best practices and adopting new technologies is a must.

Enter the Clear Roads Transportation Pooled Fund program, <http://clearroads.org/>. Clear Roads is an ongoing Transportation Pooled Fund (TPF 5-353) program led by the Minnesota Department of Transportation, focused on rigorous testing of winter maintenance materials, equipment, and methods for use by highway maintenance crews. Started in 2004, Clear Roads has grown to include 34 member agencies, each contributing \$25,000 annually to fund research and technology transfer efforts. Representatives from the participating departments of transportation meet twice a year to discuss and prioritize projects, share effective practices, and review research results.

Primary activities of the program are:

1. Evaluating winter maintenance materials, equipment, and methods under real-world conditions;
2. Developing specifications and recommendations;

3. Studying and promoting innovative techniques and technologies that will save agencies money, improve safety, and increase efficiency;
4. Supporting technology transfer by developing practical field guides and training curriculum to promote the results of research projects.

Benefits to MaineDOT:

1. Developing and Evaluating Safe Winter Driving Messages: Maine DOT's "Ice and Snow, Take it Slow" program.
2. Mapping Weather Severity Zones: These results have been used to compare Maine's costs and material usages to other states and it has served as a springboard for other winter severity efforts.
3. Snow and Ice Control Environmental Best Management Practices Manual (July 2015): This report has been used to respond to entities regarding numerous environmental issues and concerns.
4. Snowplow Operator and Supervisor Training (August 2014-April 2017): Numerous slides have been integrated into the WISE College snow and ice training.
5. Monitoring Stockpiles of Solid Winter Maintenance Materials (February 2017): MaineDOT is in the process of evaluating how to improve current stockpile measurement practices.
6. Roadway Salt Best Management Practices (November 2015): Best practices to help update aspects of salt specifications.
7. Annual Survey of State Winter Maintenance Data (ongoing): This snow and ice comparison tool is an ongoing resource for all member states.
8. Product Experience Surveys (ongoing): These product surveys yielded the implementation of numerous high-performance plow blades as well as the Tow Plow.
9. Computer-Based Training: These videos are used as reference materials on various snow and ice topics and are provided at MaineDOT's intranet web page.
10. Pacific Northwest Snowfighters: The PNS establishes standards for liquid chlorides and corrosion protection.

In addition, Clear Roads membership has provided a first-name relationship with counterparts in 34 states and has proven invaluable not just for snow and ice, but for nearly any topic. MaineDOT is also working on a snow and ice automated performance measurement system using RWIS that was originally developed in Idaho. Although it is not a research product, the system was developed as a result of one of the meetings.

Intelligent Dilemma Zone Protection System at High-Speed Intersections

<i>Project ID</i>	SP409B4K
<i>Cost</i>	\$138,940
<i>Duration</i>	34 months
<i>Submitter</i>	Maryland Department of Transportation Hua Xiang 707 N. Calvert Street Baltimore, Maryland 21202 410-545-2953
<i>Links</i>	

Project Summary and Benefits

The objective of this project is to design, deploy, and evaluate an Intelligent Dilemma Zone Protection System (I-DZPS) that is capable of improving intersection safety by reducing side-angle crashes and rear-end collisions. These two types of crashes, plaguing many high-speed intersections, are likely due to drivers' decisions when they are trapped in their respective "dilemma zone," defined by the Institute of Transportation Engineers (ITE) as the space between two points on an approach to a signalized intersection, beginning at a point where approaching drivers—when shown a yellow display—will stop at the stop line of the intersection and ending where drivers—again, when shown a yellow display—will proceed through the intersection before the light turns red. Between these two points, drivers are faced with the dilemma of deciding whether to stop or proceed through the intersection. This is a dilemma because they may not be able to stop comfortably at the stop line, nor pass the intersection before the light turns red. Dilemma zones for drivers vary in location and length with vehicle approaching speeds, reaction times, and vehicle deceleration or acceleration constraints.

The I-DPZS was developed by the University of Maryland and its early version was deployed by the Maryland Department of Transportation State Highway Administration (SHA) at the intersection of US 40 and Red Toad Road in Cecil County, Maryland in 2012. The system can dynamically extend the all-red phase (every signal in all directions of the intersection is red, to provide additional clearance time, ranging from 0.5 to 3.0 seconds) when it detects a potential red-light running vehicle. It can also proactively alert approaching drivers to reduce speeds with roadside sensors or variable message signs if available. In this project, the improved version of I-DPZS was deployed at two high-speed rural intersections (US 40@Western Maryland Parkway and MD 213@Williams/Locust Point Road), and it consists of the following principal components:

- (1) two wide-range sensors to track the speeds and locations of all vehicles within the identified dilemma zones;

(2) software to predict the response of drivers during the yellow phase and to activate the all-red extension function if needed; and

(3) a web-based module for responsible engineers/technicians to monitor the system's performance from a control center or a designated remote location.

The intersection of US 40 and Western Maryland Parkway in Washington County, Maryland, is highlighted in this summary. The three-leg intersection is located where Western Maryland Parkway (three approaching lanes, two for left-turn and one for right-turn vehicles) ends at US 40, a four-lane divided highway with a posted speed limit of 55 mph. The neighboring intersections are about 1,400 feet and 4,500 feet away on either side along US 40 and the target approach has an on-ramp to I-81 700 feet upstream. There were 15 crashes recorded at this intersection between 2010 and 2012, and 12 of them were potentially related to the responses of drivers in the dilemma zone. This intersection's I-DZPS, activated in October 2016, includes one web-based monitoring module, two sensors on the eastbound US 40 for vehicle detection and all-red activation, and one sensor on westbound US 40 for green extension under actuated control.

Mitigation Techniques to Modify Driver Performance to Improve Fuel Economy, Reduce Emissions, and Improve Safety

<i>Project ID</i>	76389
<i>Cost</i>	\$264,260
<i>Duration</i>	43 months
<i>Submitter</i>	Massachusetts Department of Transportation Curtis Bradley 10 Park Plaza, Suite 4150 Boston, Massachusetts 02160 857-368-8851
<i>Links</i>	http://www.massdot.state.ma.us/

Project Summary and Benefits

The purpose of this research project was to evaluate training and operation techniques that would promote MassDOT employee driver safety, improve fleet fuel efficiency, and reduce GHG emissions. Based on the research and analysis it was determined that real time feed back assisted in reducing speeding and aggressive driving. It should also be noted that training had an impact on reducing idling rates, specifically in the first month of training.

Tow Plows Save Time and Money on Winter Maintenance

<i>Project ID</i>	2013-0065 Z1
<i>Cost</i>	\$181,476
<i>Duration</i>	42 months
<i>Submitter</i>	Michigan Department of Transportation Michael Townley 8885 Ricks Road Lansing, Michigan 48909 517-636-0144
<i>Links</i>	http://www.michigan.gov/mdot/0,4616,7-151-9623_26663_59797---,00.html

Project Summary and Benefits

As winter maintenance costs rise, Michigan Department of Transportation (MDOT) set out to estimate the costs and benefits of incorporating tow plows into its winter maintenance equipment fleet, and to determine the most effective way of using these plows in terms of overall cost, mobility challenges and the safety of the traveling public. The field evaluation showed no differences in pavement friction behind tow plows as compared to regular plows, suggesting they both have the same snow removal effectiveness. Tow plows clear a 25-foot-wide path instead the 12-foot-wide path of a front plow.

The approach has the potential to save 27 to 65 percent in the total costs for plowing, including both direct costs and travel delay savings. With the right equipment configuration in a fleet, they lead to significant savings in direct costs while providing the same level of service with less staff and lower snow removal times. Both regular plows and tow plows operated in the same speed range. Although traffic behind the tow plows was generally congested during plowing, the overall vehicle delay along these routes during winter events was significantly less than when only regular plows were used.

The cost-benefit analysis showed that assuming the use of 17 tow plows on MDOT-maintained four- and six-lane expressways, MDOT could save \$1.9 million annually in direct costs, such as salt, equipment, and labor. Savings are significantly higher when accounting for reductions in travel delays. Tow plows can also increase public safety and reduce plow driver fatigue by lowering the amount of time plows spend on the road.

MDOT is piloting the use of tow plows and collecting data on their effectiveness as the agency determines whether to expand tow plow use within Michigan and identifies which interstates would benefit most from tow plow use. This project also involved the development of a training video, which helps MDOT more effectively instruct operators on the use of this promising technology.

Finding a Lower-Cost Ultra-High Performance Concrete for Highway Bridges

<i>Project ID</i>	2013-0068 Z1
<i>Cost</i>	\$354,794
<i>Duration</i>	35 months
<i>Submitter</i>	Michigan Department of Transportation Michael Townley 8885 Ricks Road Lansing, Michigan 48909 517-636-0144
<i>Links</i>	http://www.michigan.gov/mdot/0,4616,7-151-9623_26663_59797---,00.html

Project Summary and Benefits

Ultra-high performance concrete (UHPC) surpasses traditional concrete mixes by offering exceptional freeze-thaw resistance, reduced susceptibility to cracking, and far less reinforcement corrosion from deicing salts. Existing UHPC products are proprietary and protected by patents. They require specialized mixing equipment and steam curing, making them up to 10 times more expensive than traditional concrete products. However, this project successfully developed a UHPC laboratory mix at half the cost of a proprietary mix. Silica fume, silica powder, and steel fibers are the most expensive components of UHPC. Researchers conducted several laboratory tests to evaluate how changing the relative amounts of these materials affects the concrete's performance.

Researchers also tested three different cements:

- 1) Portland Type I white cement,
- 2) Portland Type V, and
- 3) a mix of Portland Type I and ground granulated blast furnace slag (GGBS).

Traditionally white cement is used in UHPC, but the other types are less expensive options. In all, 28 UHPC mixes were created with various combinations of components. The quantity of silica powder had very little impact on the concrete performance parameters tested. This suggests that silica powder can be omitted from a UHPC mix to reduce its cost significantly. Reducing fiber content did have a sizable impact on both compressive and tensile strength.

Researchers recommended a mix that used the blend of Portland Type I and GGBS as cement, 25 percent silica fume and no silica powder. In the lab, this mix achieved the standards to be considered UHPC at less than half

the cost of a proprietary mix. While this mix performed well in laboratory tests, it was not successfully produced at a commercial scale during a demonstration project. Initial investigation suggests that a densified silica fume used in the demonstration project performed differently than the lower carbon content silica fume in the laboratory mix. The development of a relatively inexpensive UHPC mix in the laboratory has led MDOT to take the next implementation steps. MDOT has conducted a pilot construction project, but not successfully mixed large scale batches. As part of an implementation project, MDOT is purchasing a mixer to successfully scale up field production.



Soil Stabilization with Recycled Materials Improves Subgrade Performance

<i>Project ID</i>	2013-0065 Z3
<i>Cost</i>	\$214,819
<i>Duration</i>	27 months
<i>Submitter</i>	Michigan Department of Transportation Michael Townley 8885 Ricks Road Lansing, Michigan 48909 517-636-0144
<i>Links</i>	http://www.michigan.gov/mdot/0,4616,7-151-9623_26663_59797---,00.html

Project Summary and Benefits

As much as 40% of the land area in Michigan contains weak subgrade soils that need modification to provide sufficient support for construction vehicles regular traffic on completed roadways. Poor soils encountered on a project site must be stabilized prior to construction. One technique used is called undercutting, where the old soil is removed and replaced with a new material. The other option is mixing a new material with strengthening properties in with the current soil, which is called subgrade stabilization.

Research was needed to evaluate the long-term performance of soils that have been stabilized with recycled byproducts from manufacturing processes. Researchers examined three samples of weak soils that were classified and subjected to a number of laboratory tests. The recycled materials used were selected based on their availability in large quantities and included cement kiln dust, lime kiln dust, fly ash and concrete fines. A series of mix designs were used to determine the minimum percentage of recycled material required for stabilization. Then pavement design inputs for the mixes were generated. Finally, laboratory freeze-thaw tests and a limited number of field tests were conducted to determine the long-term durability of the stabilized subgrade mixes.

For all soil types, a combination of cement kiln dust, lime kiln dust, and fly ash mixed into the subgrade at rates of between 4% and 12% was identified as a feasible long-term stabilizer. Fly ash at 15% and high-calcium lime kiln dust at 6% were effective for some soil types as short-term modifiers to create a working platform for construction. Concrete fines and a second type of lime kiln dust, dolomite lime kiln dust, were both ineffective as either long-term stabilizers or short-term modifiers. Field studies were conducted on several projects constructed within the last 10 years where the subgrades were stabilized, some locations with recycled materials. These studies revealed that the stabilized layers successfully retained their strength after hundreds of freeze-thaw and moisture cycles.



Hydraulics Inspection Vehicle Explorer (HIVE) Enhances Culvert Inspections

<i>Project ID</i>	N/A
<i>Cost</i>	\$1,500
<i>Duration</i>	2 months
<i>Submitter</i>	Minnesota Department of Transportation Shannon Fiecke 395 John Ireland Boulevard, MS 330 St. Paul, Minnesota 55155 651-366-3738
<i>Links</i>	



Project Summary and Benefits

For culverts that do not allow physical entry by a human, the answer has been upwards of \$100,000 for a fiber-optic remote control video crawler along with a van to haul all the equipment and cables. But, the cost for this better information may be more attainable for departments tasked with managing hydraulic infrastructure. The total cost is a little under \$2,000, can be operated by one person, and the entire unit fits in a standard 11x17 office paper box. It is called the Hydraulic Inspection Vehicle Explorer or HIVE.

The HIVE is an enhanced radio-operated car, which a MnDOT district maintenance office invented to inspect culverts and pipes to determine if any repairs or replacement is needed. Often culverts and pipes are too small or difficult for a person to enter to visually inspect it, so the vehicle is operated via radio control with a camera and lights to record and view conditions with just one specialist at the site. It has discovered damage in culverts underneath roads long before the problem becomes an emergency. The waterproof remote control unit was modified by Rochester MnDOT workers in the inventory department with the help of radio-operated car hobbyists. Due to the success of this unit, they have built similar devices for other MnDOT districts and are creating an online guide for parts, repairs and operation. By using the HIVE unit, eight culverts changed from no work needed to repair needed in initial operations, because large joint separations or broken flanges with exposed soil visible were detected by video far into the pipe.

In one case study, an end-of-pipe inspection showed significant pipe damage that would typically result in a full replacement costing about \$45,000. However, HIVE video footage showed that the damage was limited to just 12 feet of the pipe near the end. Instead of replacing the entire pipe, a \$1,000 repair was implemented resulting in \$44,000 savings. A Best Practices Manual for Enhanced Culvert Inspections, funded through the MnDOT research program and due out in Summer 2017, will feature the Hydraulic Inspection Vehicle Explorer. This project was the 2016 winner of the Minnesota Governor's Better Government Award.

Sinusoidal Rumble Strip Design Identified With Less Nuisance Noise, But Similar Safety Benefit

<i>Project ID</i>	MPR-4(037)
<i>Cost</i>	0
<i>Duration</i>	23 months
<i>Submitter</i>	Minnesota Department of Transportation Shannon Fiecke 395 John Ireland Boulevard, MS 330 St. Paul, Minnesota 55155 651-366-3738
<i>Links</i>	http://www.mndot.gov/research

Project Summary and Benefits

Due to noise complaints from the public, MnDOT and the Minnesota Local Road Research Board have both been investigating a rumble design that utilizes a sinusoidal wave-like pattern, which has been found to reduce external nuisance noise. This study investigated several variations of sinusoidal centerline rumble to find the design that has the highest level of interior vehicle noise with the lowest level of exterior vehicle noise. Researches also evaluated the navigability of sinusoidal rumbles by other vehicle types, such as motorcycles and bicycles. Finding a less obtrusive design that still protects drivers was essential due the increased likelihood of legislation to limit the usage of rumble strips because of the push-back counties were facing from property owners across who live near rumble strips.

The study recommends the sinusoidal design with a 14" long wavelength that oscillates between 1/16" below the pavement surface to 1/2" below the pavement surface. This recommended design generates an internal noise above the minimum recommended levels from NCHRP Report 641 – significantly higher for passenger cars. The internal noise generated by the rectangular corrugated design is more noticeable for pickup trucks. Another advantage of the recommended sinusoidal rumble design is that it allows for a fully recessed pavement marking, which is anticipated to increase the life of the pavement marking.

This study also found that motorcyclists are often uncomfortable with crossing split design rumble strips. The split design rumble requires the motorcycle to traverse a rumble, a centerline joint, and another rumble. Motorcyclists had much greater comfort traversing the single centerline rumble. The study recommended that centerline rumbles consist of a single longitudinal rumble. MnDOT material engineers, however, raised valid concerns with constructing rumbles across a longitudinal concrete joint, so a draft MnDOT technical memo requires a single centerline rumble be installed on bituminous pavements and the split rumble be installed on concrete pavements. MnDOT recently released a draft revision to its technical memo on rumble strips that incorporates findings from the study. Due to the success of this study and past related research, MnDOT districts

have already begun installing sinusoidal rumble strips. Adoption of sinusoidal rumble strips will only increase once the state publishes the revised technical memo later this year.

Implementation of Floating Weir System for Surface Skimming of Temporary Stormwater Ponds

<i>Project ID</i>	MPR-4(020)
<i>Cost</i>	0
<i>Duration</i>	4 months
<i>Submitter</i>	Minnesota Department of Transportation Shannon Fiecke 395 John Ireland Boulevard, MS 330 St. Paul, Minnesota 55155 651-366-3738
<i>Links</i>	http://www.mndot.gov/research

Project Summary and Benefits

This study provides design information for temporary stormwater ponds with floating head skimmers to remove suspended sediment and nutrient loads from stormwater runoff on active construction sites. Researchers created designs for temporary stormwater ponds on construction sites that computer models say should remove approximately 80% of total suspended solids from stormwater runoff. These designs will help contractors meet EPA requirements for stormwater pond dewatering. This study created a design table that helps designers pick the right size weir. This and the accompanying skimmer detail are being used on projects already. This directly satisfies a requirement of the Construction Stormwater Permit. Although the design table needs to be converted into a standard drawing, it is already being used as a non-standard detail.

Investigation of MDOT's Full-Depth Reclamation and Cold In-Place Recycling Projects--State Study 250

<i>Project ID</i>	250-MS
<i>Cost</i>	0
<i>Duration</i>	0 months
<i>Submitter</i>	Mississippi Department of Transportation Cynthia Smith PO Box 1850 Jackson, Mississippi 39215 601-359-7650
<i>Links</i>	

Project Summary and Benefits

Dr. Isaac Howard of Mississippi State University recently completed work for the Mississippi DOT under the title of State Study 250. Due to the study's broad scope, the final report was submitted in three volumes:

- (1) Laboratory and Laboratory and Field Investigation of US Highway 49 Portland Cement Stabilized Full Depth Reclamation (FDR),
- (2) Cold In-Place Recycling (CIR) Characterization Framework and Design Guidance for Single or Multiple Component Binder Systems, and
- (3) Evaluation of Approaches to Improve Longitudinal Joints in Mississippi overlay projects.

Each of these reports demonstrated exemplary research that the Mississippi DOT can and will continue to implement into both their design and construction operations. The first report consisted of both a field and laboratory investigation into a high traffic application of FDR (US Highway 49 in Madison County) within the State of Mississippi. This volume of the study used distress data collected in-house by MDOT as well as field sampling and coring to make a determination of current performance of the FDR layers. In addition, the laboratory testing determined the structural characteristics of the FDR materials such as compressive strength, elastic modulus, and layer coefficient based on the AASHTO 1993 Pavement Design Guide. As indicated in the report, the primary intention of this study was an exploration into issues related to high traffic FDR while at the same time leveraging actual field data from the US Highway 49 Project.

The second volume, characterizing CIR system frameworks, outlined specific design parameters for both single and multiple component binder systems. The single binder systems consisted of either cement or emulsified asphalt while the multiple binder system consisted of some combination of the two. The laboratory investigation developed a test matrix which gives MDOT the ability to balance both economical and

performance factors into its design practices. This will have direct benefit to MDOT as it outlined a new laboratory design procedure for these specific systems. The MDOT Materials Division plans to adopt this mix design procedure upon the next application of CIR within the state.

The third and final volume of the study evaluated methods to improve longitudinal construction joints on Mississippi overlay projects. With MDOT moving more into pavement preservation practices, the amount of thin lift overlays has increased considerably throughout the state. This volume of the study addressed ways to minimize both moisture and air intrusion into the longitudinal construction joint primarily by measuring field permeability with equipment developed in-house at Mississippi State University. The field investigation also evaluated RePLAY, an agricultural-based joint sealer product, and determined it to be of valid application on future MDOT projects. After evaluating final reports as well as the recommendations and procedures found therein, the Research Division at MDOT feels that the comprehensive research performed by Dr. Howard and his team at Mississippi State University warranted a nomination for the High Value Research Award for the State of Mississippi.

Using Online Surveys and Facebook Ads to Solicit Customer Feedback

<i>Project ID</i>	TR201706
<i>Cost</i>	\$1,108
<i>Duration</i>	5 months
<i>Submitter</i>	Missouri Department of Transportation Bill Stone 1617 Missouri Boulevard Jefferson City, Missouri 65109 573-526-4328
<i>Links</i>	https://library.modot.mo.gov/RDT/reports/TR201706/MoDOTResearchSummary_Facebook.pdf



Project Summary and Benefits

MoDOT explored an alternative public survey mechanism as a way to gauge the percent of customers who think that completed projects were the "Right Transportation Solution." Instead of having a consultant conduct a mailed survey, the department created an online survey in-house using SurveyMonkey and used social media (namely a Facebook targeted ad) to promote it. The pilot included an urban and a rural project (the recently completed I-64 Daniel Boone Missouri River Bridge project in the St. Louis District and an ADA project in Buffalo, MO from the Southwest District). The District created a communications and marketing plan to complement the Facebook ad, which targeted people within a certain radius of the project. For the Daniel Boone project, 612 responses were obtained, 314 coming from the Facebook ad (the rest resulting from the Division's marketing efforts).

The survey results were overwhelmingly positive with 95% of respondents indicating that the project was the Right Transportation Solution. The benefits of this new survey mechanism included reduced cost, improved response rate, real-time feedback, real-time results, survey customization, demographic information and repeatability. The pilot survey demonstrated an innovative method of gauging public feedback which satisfied the concerns of the Executive Team and continues to validate MoDOT's planning process. This new survey methodology is being deployed statewide with each District able to select relevant projects. MoDOT's Executive Team is excited by the real-time results and real-time dialogue of this innovative approach and wants to explore the use of this mechanism for future outreach efforts.

Instrumentation and Monitoring of Rustic Road Geosynthetic Reinforced Soil (GRS) Integrated Bridge System (IBS)

<i>Project ID</i>	TR201417
<i>Cost</i>	\$84,999
<i>Duration</i>	33 months
<i>Submitter</i>	Missouri Department of Transportation Jennifer Harper 1617 Missouri Boulevard Jefferson City, Missouri 65109 573-526-3636
<i>Links</i>	https://library.modot.mo.gov/RDT/reports/TR201417/cmr16-019_reduced.pdf

Project Summary and Benefits

An instrumentation and monitoring system was implemented for a geosynthetic reinforced soil (GRS) integrated bridge system (IBS) constructed in Boone County, Missouri in 2014. The project location is subjected to relatively frequent flash flooding, which was a significant consideration in the design of the bridge and the design of the monitoring system. The monitoring system includes 26 surveying points on the bridge exterior to monitor external movement; settlement plates and inclinometers to monitor vertical and horizontal exterior movement, respectively; earth pressure cells to monitor total stresses within the abutment backfill; and vibrating wire piezometers to monitor pore pressures and drainage within the abutment backfill. The GRS-IBS was monitored for a period of 19 months after construction. The monitoring period included several high-water events, but none overtopped the bridge. The results indicate satisfactory performance, including negligible external and internal movements and rapid backfill drainage in response to groundwater level increases.

View [PDF document](#) for more detailed project research summary.



Evaluation of Erosion Control Blanket Properties and Test Criteria for Specification and Design

<i>Project ID</i>	TR201509
<i>Cost</i>	\$104,863
<i>Duration</i>	17 months
<i>Submitter</i>	Missouri Department of Transportation Bill Stone 1617 Missouri Boulevard Jefferson City, Missouri 65109 573-526-4328
<i>Links</i>	https://library.modot.mo.gov/RDT/reports/TR201509/cmr16-016.pdf

Project Summary and Benefits

A research project to investigate the product approval, design process, and ongoing product evaluation of erosion control blankets (ECBs) for the Missouri Department of Transportation (MoDOT) was conducted. An overview of federal and state environmental construction laws was performed noting the significance of ECBs on construction sites. Standardized erosion control testing, product approval, and design processes utilized by other state departments of transportation and those recommended by the National Transportation Product Evaluation Program (NTPEP) were researched for further insight to typical ECB applications.

A field investigation was established to study the effectiveness of two ECBs on a MoDOT construction site. MoDOT completed construction sites, which utilized ECBs, were also included in the investigation to evaluate how well vegetation was sustained and ongoing blanket degradation following site acceptance in accordance with the MoDOT Storm Water Pollution Prevention Plan (SWPPP). In addition to field site evaluations, surveys were developed and administered to record contractor and MoDOT employee ECB experiences and identify common problems and successful practices using ECBs.

Recommendations for ECB approval procedures and a design process for conditions representative of Missouri were developed using insight gained through the study of common ECB product acceptance and design, the field site investigation, evaluation of completed construction sites, and the surveys of ECB experiences. The NTPEP ASTM standardized testing was recommended as the basis for product approval. For ECB design, the Revised Universal Soil Loss Equation (RUSLE) was recommended and used to establish minimum performance requirements for both product acceptance and design. Digital maps were developed using ArcGIS for Missouri's representative hydrologic and geologic conditions for use in the RUSLE. The ECB approval procedures and design process, which were developed specifically for the state of Missouri, are recommended for implementation into the MoDOT Engineering Policy Guide (EPG). An ongoing product evaluation system was also developed for ECBs to document field performance and assist in identifying ECBs that should be removed from the approved

products list. A "train the trainer" session was conducted in Jefferson City, MO for MoDOT District staff on March 22nd by Saint Louis University (SLU) civil engineering faculty on how to execute the ECB research deliverables.

View [PDF report](#) for more detailed project research summary.



¾-inch Minus Base Course Type A Specification for Montana	
<i>Project ID</i>	8228-001
<i>Cost</i>	\$95,200
<i>Duration</i>	24 months
<i>Submitter</i>	Montana Department of Transportation Kris Christensen 2701 Prospect Avenue Helena, Montana 59620 406-444-6125
<i>Links</i>	http://www.mdt.mt.gov/research/projects/mat/crushed_base_course.shtml

Project Summary and Benefits

For some construction projects in Montana, obtaining materials that meet the current specifications for crushed base course aggregates having a maximum nominal size of 2 in. (CBC-5A) and 1½ in. (CBC-6A) is becoming more difficult due to declining natural resources. There are also issues with the clean, larger size materials raveling once they have been placed and then exposed to traffic.

This research project was initiated to examine multiple sources of crushed base course aggregates from around Montana to determine whether gradations having a smaller maximum particle size would perform at least as well as Montana CBC-6A and CBC-5A materials. Information from this research allowed a new standard specification to be suggested for ¾-inch minus crushed base course aggregates (CBC-7A) for the Montana Department of Transportation. One of the primary products of this research was a suggested gradation specification for ¾-in. minus crushed base courses for the state of Montana. Implementation of this specification will allow crushed aggregate mixes to be produced using smaller particle sizes, thereby expanding the availability of resources in many of the privately-operated gravel pits located throughout the state of Montana. Although this change in the specifications is expected to primarily benefit the producers by allowing them to more effectively utilize limited natural resources, it is unknown what impact that will have on the price of these commodities, making it difficult to conduct a meaningful cost-benefit analysis to quantitatively determine the monetary impact of this research. Nevertheless, by expanding the potential for greater use of available natural resources for road construction, improved environmental stewardship and resource conservation remains a qualitative benefit.

The introduction of a ¾-inch minus gradation specification may also allow the simultaneous use of materials for crushed base course aggregates and as shoulder gravel since the requirements are similar for the two materials. Furthermore, cement treated base course mixes may also be able to utilize the ¾-in. minus base course specification. The simultaneous use of ¾-in. minus gradation will allow contractors to specify a single material for multiple uses thereby simplifying their material acquisition and construction processes.

Assessment of Montana Road Weather Information System

<i>Project ID</i>	8229-001
<i>Cost</i>	\$152,000
<i>Duration</i>	25 months
<i>Submitter</i>	Montana Department of Transportation Kris Christensen 2701 Prospect Avenue Helena, Montana 59620 406-444-6125
<i>Links</i>	http://www.mdt.mt.gov/research/projects/rwis.shtml

Project Summary and Benefits

Weather presents considerable challenges to highway agencies both in terms of safety and operations. From a safety standpoint, snow, ice and other forms of precipitation may reduce pavement friction, increasing the potential for crashes. From an operations standpoint, heavy snow storms may affect the connectivity of the highway network due to closures that need to be cleared in an efficient and timely fashion. Further, travelers should be informed about unusual pavement conditions and road closures on time to minimize the effect of adverse weather on the safety and mobility of the traveling public. For these reasons, road weather information has become increasingly important for highway agencies particularly in regions that experience harsh winter weather conditions.

Road weather information has been used by highway agencies in many applications such as winter maintenance, traveler information, and other weather-related intelligent transportation system (ITS) applications. MDT currently has 73 RWIS stations throughout the state that have been used as a major source of weather data for transportation applications. This project was undertaken to perform a comprehensive review and assessment of the state road weather data collection program to ensure: the efficient use of weather data in various transportation applications and the optimum use of MDT resources.

MDT implementation considerations include:

- 1) requiring new RWIS sensor, hardware, and software options be as flexible as possible through the use of non-proprietary communications and compatibilities, allowing for easy integration of different equipment that may be superior or more economical regardless of the provider;
- 2) reducing RWIS data and camera image updates to 15 minutes or less for as some RWIS data users and literature suggest that 15 minutes can make a considerable difference in terms of winter maintenance treatments, especially at the start of a storm;

- 3) including a horizon view for aviation users at all ESS with PTZ cameras, especially where it will not detract from primary road monitoring images;
- 4) in areas with little or no RWIS coverage, making maintenance personnel aware of resources that provide additional weather observations from non-RWIS sites around the state; and
- 5) using the proposed data-driven site prioritization model with agency selected weights; to reflect knowledge and preferences; to plan future RWIS installations; and making site selection more objective.

Also, a number of future directions show promise and will be considered to reduce agency costs, and increase safety and mobility for travelers. Substantial benefits may be realized through modest investment in alerting capable software. Other directions requiring more substantial investment include obtaining a software service with advanced forecasting and treatment recommendations, or automated performance metrics. These two more costly directions may be the most beneficial overall, but would require changes to winter maintenance practices.

Overall the MDT RWIS program provides many benefits to MDT users and ultimately the traveling public. An extensive benefit-cost analysis was conducted to investigate outcomes related to using different software functionalities and geographic expansion alternatives. Agency specific benefits exceed costs for all three alternative software systems (i.e., alerting, forecasting and automated performance metrics) when considering the current ESS sites. The highest agency specific benefit-cost ratios were found to be possible with forecasting and automated performance metric functionalities. Total benefits, including societal benefits, exceed costs for all ESS expansion options (i.e., base, simple, non-invasive, and mobile) and all alternative software systems (i.e., alerting, forecasting and automated performance metrics). The highest total benefit-cost ratios were found to be possible with forecasting and automated performance metric functionalities. All cost benefit scenarios are calculated and presented in Chapter 6 of the final report. Benefits resulting from the implementation of this research include increased safety, including aviation safety; decreased crashes, improved operational effectiveness and efficiency; decreased operational costs; improved traveler information; and increased mobility.

Speed Limits Set Lower Than Engineering Recommendation

<i>Project ID</i>	8225-001
<i>Cost</i>	\$143,330
<i>Duration</i>	23 months
<i>Submitter</i>	Montana Department of Transportation Kris Christensen 2701 Prospect Avenue Helena, Montana 59620 406-444-6125
<i>Links</i>	http://www.mdt.mt.gov/research/projects/traffic/speed_limits_lower.shtml

Project Summary and Benefits

The purpose of this project was to provide MDT with objective information concerning the operational and safety impacts of setting posted speed limits lower than engineering recommended values. This practice has been used on Montana roadways for a variety of reasons, but the safety and operational impacts are largely unknown. This project involved four unique components: a comprehensive literature review, a survey of other state transportation agencies, collection of speed and safety data from a variety of Montana roadways, and an analysis of these data. The literature review revealed that little published information exists on the practice of setting posted speed limits lower than engineering recommended values. The survey was sent to all state transportation agencies with representation on the AASHTO Subcommittee on Traffic Engineering, which included a total of 71 representatives from 51 states or territories. A total 22 of the 28 responding agencies indicated that they engaged in the practice of setting speed limits lower than engineering recommendations.

About half of these agencies had a policy or guidance document describing the practice. Overall, few agencies reported evaluating the changes to operating speed or safety resulting from setting speed limits lower than engineering recommendations. About half of the 28 responding agencies evaluated driver compliance with the lower posted speed limit and found that the compliance was generally poor. Operating speed data were collected at three sites with posted speed limits set 5 mph, two sites with posted speed limits set 10 mph, two sites with posted speed limits set 15 mph, and one site with a posted speed limit set 25 mph lower than engineering recommendations. There were four comparison sites with posted speed limits set equal to the engineering recommended values.

Data were collected from each site on three unique days: one with no speed enforcement, one with light speed enforcement, and, one with heavy speed enforcement present. Statistical models were developed to describe mean operating speeds, 85th percentile operating speeds, and driver compliance with posted speed limits. The operating speed evaluation produced results that were consistent with other state transportation agency experiences when setting posted speed limits lower than engineering recommendations. When the posted

speed limit was set only 5 mph lower than the engineering posted speed limit, drivers tended to comply more closely with the posted speed limit. When the posted speed limit was set 15 to 25 mph lower than the engineering recommended speed limit, there appeared to be a low level of compliance with the posted speed limit.

The practice of light enforcement, which was defined as highway patrol vehicles making frequent passes through locations with posted speed limits set lower than engineering recommendations, appeared to have only a nominal effect on vehicle operating speeds. Known heavy enforcement, defined as a stationary highway patrol vehicle present within the speed zone, reduced mean and 85th-percentile vehicle operating speeds by approximately 4 mph. Additionally, known heavy enforcement increased the odds that drivers would comply with the posted speed limit.

The safety evaluation included reported crash frequency data from six sites with posted speed limits set 5 mph, five sites with posted speed limits set 10 mph, two sites with posted speed limits set 15 mph, and one site with a posted speed limit set 25 mph lower than engineering recommendations. The research team used the empirical Bayes (EB) before-after approach to develop Crash Modification Factors (CMFs) to describe the expected change in crash frequency when setting posted speed limits lower than engineering recommendations. The proposed EB analysis properly accounts for statistical factors such as: regression-to-the-mean, differences in traffic volume, and crash trends (time series effects) between the periods before and after posted speed limits were set lower than engineering recommendations. While data were only available for a handful of sites that implemented this practice, the before-after analysis found that there is a statistically significant reduction in total and fatal + injury crashes at locations with posted speed limits set 5 mph lower than engineering recommendations. Locations with posted speed limits set 10 mph lower than engineering recommendations experienced a decrease in total crash frequency but an increase in fatal + injury crash frequency. The safety effects of setting speed limits 15 to 25 mph lower than engineering recommendations is less clear as the results were not statistically significant, likely due to the small sample of sites included in the evaluation. MDT will use this information when making recommended speed zone limits to the Montana Transportation Commission.

Detectable Warning Devices (DWD) Evaluation

<i>Project ID</i>	N/A
<i>Cost</i>	0
<i>Duration</i>	169 months
<i>Submitter</i>	Montana Department of Transportation Craig Abernathy 2701 Prospect Avenue Helena, Montana 59620 406-444-6269
<i>Links</i>	http://www.mdt.mt.gov/research/projects/dwd.shtml

Project Summary and Benefits

Detectable warning devices (DWD) are a distinctive surface pattern of domes detectable by cane or underfoot that alert people with vision impairments of their approach to street crossings and hazardous drop-offs. They are used to indicate the boundary between pedestrian and vehicular routes where there is a flush instead of a curbed connection. Detectable warnings also indicate unprotected drop-offs along the edges of boarding platforms at transit stations and stops. In 2002 the Americans with Disabilities Act (ADA) in conjunction with their accessible guideline directions mandated that DWD's, also known as truncated domes, be incorporated by State Departments of Transportation at areas where pedestrians with visual impairment may come into conflict with vehicle traffic. Manufacturers took this opportunity to offer a variety of DWD designs involving materials that ranged from rubber mats, plastic panels, on-site dome molds, pre-cast blocks, and individual glue-on domes. All had a variety of attachment methods from the simplistic adhesive application to elaborate installations.

In 2003 the Montana Department of Transportation began the installation and testing of DWD's in Great Falls which is now being called the first phase of DWD in-service evaluations. Within several seasons, all DWD's had failed either due to snow removal or extreme environmental factors including numerous freeze/thaw cycles and chemical abrasives. Then, in and around 2007, the next generation of DWD's came in materials made of polycarbonates and composites such as vitrified polymers and glass/carbon. By then, due to input from DOT's reports on efficacy and contractor issues, the installation format now followed either a cast-in-place (into fresh concrete or asphalt cement) or surface applied units, which required heavy-duty adhesives and mechanical attachments. These new products were much more durable than their predecessors and easier to install with a minimum learning curve on the part of the contractor. These products are working well in warm, mild weather states where little or no maintenance is required during winter months. However, where used in northern tier states, DOT's were seeing damage (mainly in the loss of domes) when DWD's, where snow or ice removal using fixed blade or rotary blades, resulted in sheared or damaged domes and the loss of tactile function. The current

generation of DWD's is reflected in the use of metals such as stamped stainless steel and cast iron plate. These have proved exceptionally durable and easy to install.

Current research conducted by MDT has shown benefits from both types but have experienced failure with stainless steel when a fixed blade was used to remove snow and ice. MDT's goal was to identify DWD application(s) that are not intimidating for contractors to install and durable, with material(s) that stand up to harsh winter environments, chemical deicers, and indiscriminate maintenance. The only product to date which has proven to meet the above criteria is the cast iron units. These products are made in America, they can be reused, and they can be recycled. A win-win scenario. Although prices vary in different areas of the country, the reported average square foot price of plastic composite DWD's is at \$15-\$17 where cast iron units runs at \$17-\$20. Through research conducted to date by the Departments' Research Programs; MDT has elected to change their specifications to use only cast iron DWD's on applicable Federal-aid funded projects. In addition, local municipalities are now requiring that cast iron DWD's be the material of choice on their installations. In conclusion, life-cycle costs are substantially reduced and, since the adopted materials can be recycled and reused, environmental impacts are decreased.

Investigating Decision-Making Processes that Contribute to Impaired Driving

<i>Project ID</i>	P514-13-803
<i>Cost</i>	\$57,053
<i>Duration</i>	32 months
<i>Submitter</i>	Nevada Department of Transportation Manjunathan Kumar 1263 S. Steward Street Carson City, Nevada 89712 775-888-7803
<i>Links</i>	http://www.nevadadot.com/doing-business/about-ndot/ndot-divisions/planning/research

Project Summary and Benefits

The current study findings provide support for the efficacy of both theoretically- and empirically-based Alcohol-Impaired (AI) driving advertisements at reducing general willingness to drive after drinking among college students who are at particularly high risk for AI driving. The current study also identified several key factors contributing to general willingness to drive after drinking, AI driving willingness in AI driving vignettes, and AI driving behavior within a large sample of college students, one of the first steps necessary in developing an integrative AI driving model. The procedures utilized to develop the advertisements tested in the current study could serve as a template for scientific advertisement development and preliminary efficacy testing for future AI driving advertisements. Specifically, the rational and emotional AI driving advertisements utilized in the current study were the result of a thorough review of the theoretical and empirical literature. Theoretically-based advertisement scripts were subjected to rigorous focus group testing with members of the target population (college students; see full final report document for details). These preliminary steps ensured the development of theoretically-consistent and empirically-sound advertisements, increasing the validity and generalizability of study results.

Findings from the current study suggest that this intensive process of advertisement development was effective in producing advertisements that had the desired effect on general willingness to drive after drinking. Focusing on building AI driving prevention and intervention programs that are empirically-supported before large-scale dissemination is paramount to the responsible use of consumer resources and making the maximal positive impact on AI driving morbidity and mortality rates. The current study also provides critical information on the efficacy of the created theoretically- and empirically-based online video advertisements at reducing general willingness to drive after drinking. The tightly controlled nature of the study design and the use of a high-risk subgroup of the college population (students endorsing recent driving after drinking) allow for both more confident and more generalizable conclusions about the effectiveness of the current AI driving advertisements

to be drawn. These findings suggest a broader implementation of these advertisements may reduce AI driving rates and further exemplify the value of employing intensive focus group testing and preliminary efficacy testing prior to deployment of community-level AI driving prevention or intervention programs. Widespread internet accessibility and usage in college and young adult populations increases the potential reach of online AI driving prevention and intervention programs and decreases the cost and burden of program dissemination, making the type of AI driving advertisement used in the current study ideal for larger-scale dissemination.

The methodology and materials utilized in the current study (i.e., intensive focus group testing with members of the target population, preliminary advertisement testing) could also be applied with other at-risk populations to produce advertisements that have the maximum likelihood of impacting the target population. Advertisements similar to those used in the current study could be easily converted and communicated through various media (e.g., billboards, radio advertisements, television advertisements) for more comprehensive dissemination. If applied on a larger scale, the impact of rational and emotional decision-making advertisements on objective measures of AI driving, such as alcohol-related MVCs and DUI offenses could be evaluated to determine the impact of the advertisements on the most burdensome consequences of AI driving: serious injuries and fatalities.

Safety and Design Guidelines for Marked and Unmarked Pedestrian Crosswalks at Unsignalized Midblock Crossing Locations

<i>Project ID</i>	P284-10-803
<i>Cost</i>	\$160,000
<i>Duration</i>	59 months
<i>Submitter</i>	Nevada Department of Transportation Manjunathan Kumar 1263 S. Steward Street Carson City, Nevada 89712 775-888-7803
<i>Links</i>	http://www.nevadadot.com/doing-business/about-ndot/ndot-divisions/planning/research

Project Summary and Benefits

The Nevada Strategic Highway Safety Plan (SHSP) has identified pedestrian issue as one of the five Critical Emphasis Areas (CEAs). Although the number of fatalities and injuries are improving both nationally and statewide, the vulnerability of this population continues to be a top priority. A large percent of pedestrian fatalities occurred in marked crosswalks, and the greatest proportion of pedestrian serious injuries and fatalities occurred at intersections. This study developed a statewide guideline for marked and unmarked crosswalks. Generally, marked crosswalks should be installed at locations where there is substantial conflict between vehicular and pedestrian movements, or there is a need to provide a path to direct pedestrians. Given specific sites, the developed Mark/Unmark Choice Tool shall be applied for final decision.

A specific set of guidelines helps engineers make sound decisions for the placement of marked crosswalks. Several layouts of guidelines have been accepted by the majority of practicing traffic engineers. In general, the layouts incorporate key elements such as pedestrian and traffic volumes, pedestrian demographics, location and availability of other treatment types and vehicle speed. Since most states and cities tend to make their own guidelines, there is no uniformity among them. Hence, new guidelines can be established, based on the general guideline layout documented in the literature, for conditions in Nevada.

Assessment of Asphalt Concrete Reinforcement Grid in Flexible Pavements

<i>Project ID</i>	26962A
<i>Cost</i>	\$68,500
<i>Duration</i>	35 months
<i>Submitter</i>	New Hampshire Department of Transportation Elizabeth Klemann 5 Hazen Drive Concord, New Hampshire 03302 603-271-8995
<i>Links</i>	https://www.nh.gov/dot/org/projectdevelopment/materials/research/projects/26962a.htm

Project Summary and Benefits

The reinforcing grid has been in place for several years and the roadway sections continue to perform well. This study gathered data at multiple impulse loads, but only evaluated the data from the highest loading. The deflection measurements at the highest loading between the grid and non-grid test sections did not show conclusively that the grid reinforcement provided structural benefit. The effect of the grid reinforcement on the overall stiffness of the pavement structure was not apparent based on the highest impulse loading. Evaluation of the data from the lower loads is being conducted in a new study to see if there is a benefit to the pavement at lower loads.

Does injecting polyurethane foam into roadway subgrades avoid frost heaving?

<i>Project ID</i>	15680H
<i>Cost</i>	\$38,000
<i>Duration</i>	70 months
<i>Submitter</i>	New Hampshire Department of Transportation Elizabeth Klemann 5 Hazen Drive Concord, New Hampshire 03302 603-271-8995
<i>Links</i>	https://www.nh.gov/dot/org/projectdevelopment/materials/research/projects/15680h.htm

Project Summary and Benefits

The goal of the project was to determine if treating the roadway subbase materials with expanding polymer foam would improve frost heaving, rut formation, and ride quality conditions sufficiently to make the roadway a candidate for the pavement preservation program. Some improvement was seen, but not enough for the roadway to be a candidate for pavement preservation treatments. Major pavement work is still needed but on a slightly longer interval. The costs of improvements did not justify the minimal benefits observed.

The Future of Rapid Bridge Deck Replacement

<i>Project ID</i>	15680X
<i>Cost</i>	\$79,794
<i>Duration</i>	34 months
<i>Submitter</i>	New Hampshire Department of Transportation Elizabeth Klemann 5 Hazen Drive Concord, New Hampshire 03302 603-271-8995
<i>Links</i>	https://www.nh.gov/dot/org/projectdevelopment/materials/research/projects/15680x.htm

Project Summary and Benefits

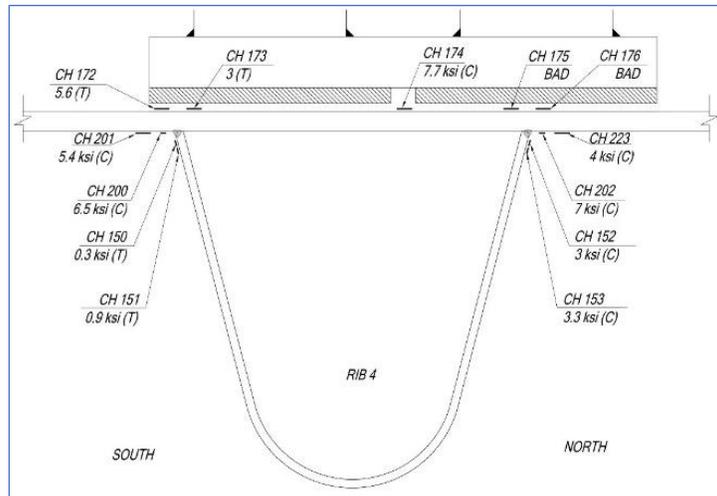
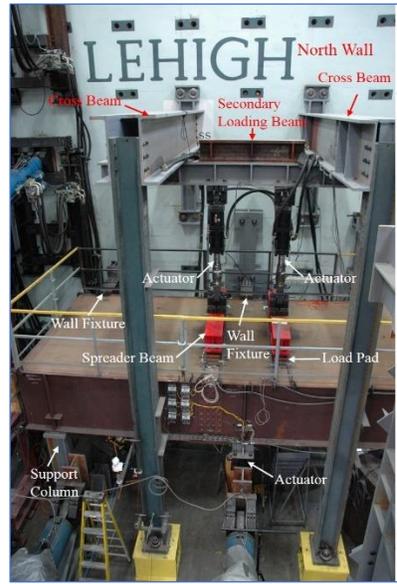
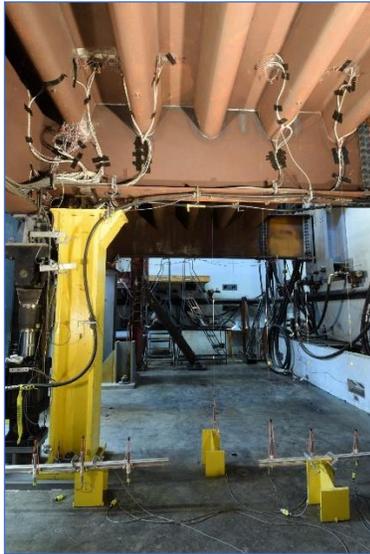
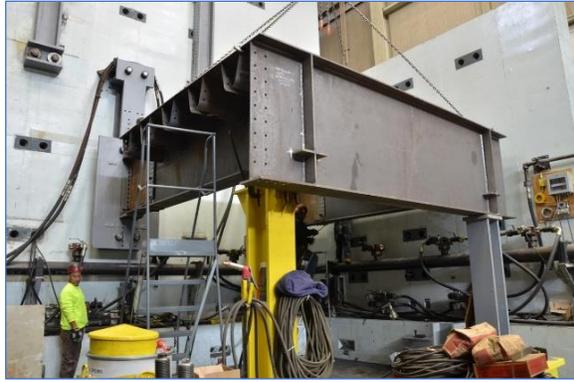
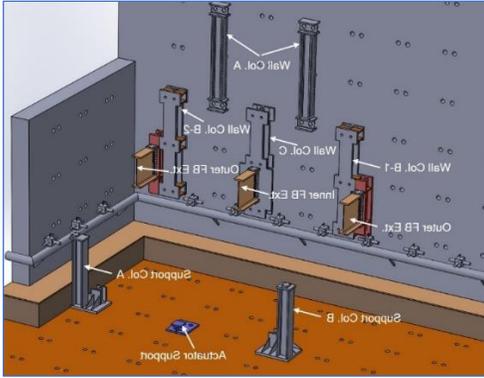
This demonstration project attempted to use pre-fabricated bridge slabs on a crowned bridge with a 23-degree skew. Techniques developed to lift and move the deck panels were successful. The adhesive between the panels did not perform in the field as it had in the lab. Minor slippage occurred in two or three of the nine panel joints. This project showed crowned and skewed panels can be successfully transported and lifted. However, the skew generates large lateral forces during tensioning that tend to slide the panels and this was not sufficiently resisted by the applied adhesive.

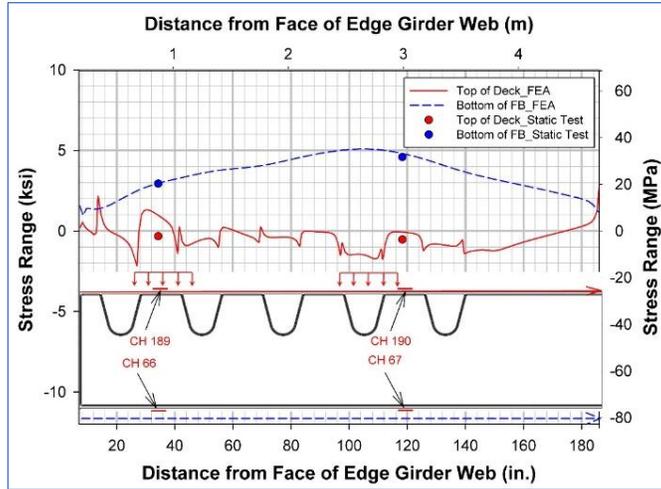
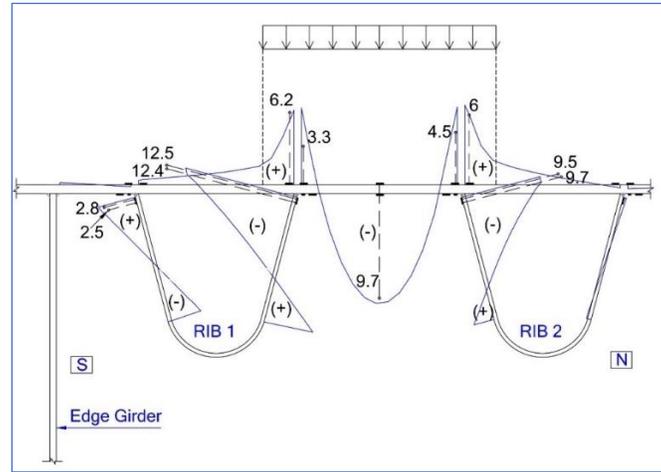
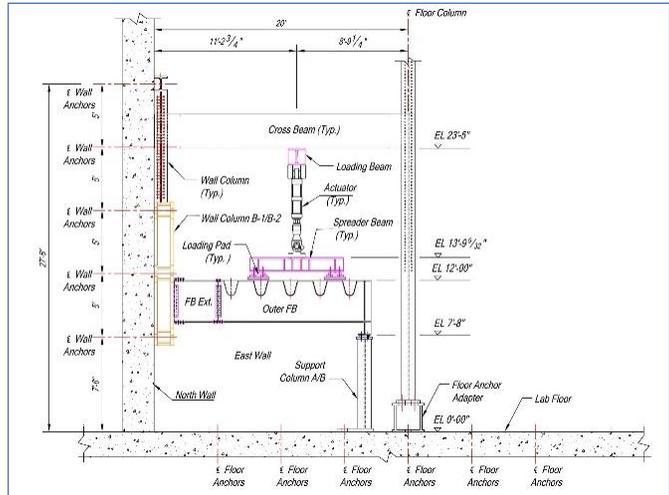
Design and Fabrication of Orthotropic Deck Details, Volumes 1 through 7

<i>Project ID</i>	NJ-2016-002
<i>Cost</i>	\$914,398
<i>Duration</i>	72 months
<i>Submitter</i>	New Jersey Department of Transportation Priscilla Ukpah 1035 Parkway Avenue Trenton, New Jersey 08625 609-530-5157
<i>Links</i>	http://www.state.nj.us/transportation/refdata/research/ReportsDB.shtm

Project Summary and Benefits

The research developed cost-effective details for fitted rib-to-floor beam connections, and rib-to-deck plate connections for orthotropic bridge decks. In addition, the study provided critical information on issues related to fabrication and installation of the orthotropic deck design for the proposed Wittpenn Bridge, and the expected performance of the orthotropic deck in service under fatigue limit state loading, ensuring effective life cycle cost. The research also highlighted the need for developing rational tolerances for economic domestic fabrication of orthotropic decks. The preliminary studies of the mockup specimens showed that a rib-to-deck plate connection employing a 70% PJP weld with a 5/32 in. (4 mm) root face on the rib wall 440 and maximum 0.020 in. (0.5 mm) fit-up gap, and a rib-to-floor beam connection employing a PJP weld with 1/8 in. (3 mm) double bevel on the floor beam web and a maximum fit-up gap of 1/8 in. (3 mm), were most cost-effective for the proposed orthotropic deck design. These details should be implemented for the proposed orthotropic deck design to achieve economic fabrication. The laboratory studies of the full scale prototype demonstrated that deviation from the specified fabrication tolerances, which were observed during the specimen installation, did not affect the performance of the deck. A rational assessment of fabrication and installation tolerances is necessary and is highly recommended for cost-effective domestic fabrication of the orthotropic deck.





Optimizing Work Zone Lighting

<i>Project ID</i>	NJ-2016-004
<i>Cost</i>	0
<i>Duration</i>	11 months
<i>Submitter</i>	New Jersey Department of Transportation SM Mamun-ar Mac Rashid 1035 Parkway Avenue Trenton, New Jersey 08625 609-530-2897
<i>Links</i>	http://www.state.nj.us/transportation/

Project Summary and Benefits

This project investigated the visual needs of workers and drivers in work zones, and the technical performance of new technologies and approaches for improving visual effectiveness while reducing glare and visual chaos. The work zone lighting and traffic control guidelines for several different scenarios, based on the findings from this study are summarized below:

LONG-TERM, STATIONARY PROJECTS: ILLUMINATION SYSTEMS

- Portable Trailer-Mounted Light Tower: 110 foot spacing provides 5 footcandles of illumination within two traffic lanes.
- Balloon Lights: Distance (D, feet) at which illuminance (E, footcandles) is produced by a balloon light with a light output (L, lumens) and a mounting height (H, feet) can be estimated by the formula provided in the study.
- Semi-Permanent High Mast Lighting: Used for projects of several months duration and staggered arrangement spaced 320 feet apart per side provides 10 footcandles along six traffic lanes.

Signage and Delineation

- Sign Sheeting Materials: ASTM Type III sufficient in most conditions; Type IV or XI for very bright, complex visual environments and Increased font size (>8 inches) for legibility at longer distances.
- Barricades and Barrels: ASTM Type I sufficient in most conditions; Type IV or XI for very bright, complex urban environments.

Warning Lights

- All Flashing Lights: "High-low" flashing rather than "on-off" should be used.

- Vehicle-Mounted Beacons and Lights: Peak intensity at least 600 candelas (effective intensity 430 candelas) for daytime visibility; Peak intensity of 200 candelas (effective intensity of 140 candelas) for nighttime visibility; and green lights equipped with dimming for glare control.
- Barricade Lights: Type A for rural environments; Type B for urban locations, and sequential flashing for lane closure tapers.

SLOW-MOVING OPERATIONS: ILLUMINATION SYSTEMS

- Vehicle-Mounted Light Towers: Not recommended; glare can be problematic and light levels excessive.
- Vehicle-Mounted Balloon Lights: For movement, provide 1 footcandle 15 feet ahead of slow moving equipment and 50 feet ahead of fast-moving equipment; visual tasks such as inspection of pavement for defects may require higher illuminances of at least 5 footcandles; and use equation on reverse to estimate illuminance.

Signage and Delineation

- Barrel Wrap (if used): ASTM Type I sufficient except in most brightly illuminated, complex urban environments.

Warning Lights

- Vehicle-Mounted Beacons and Lights: Peak intensity at least 600 candelas (effective intensity 430 candelas) for daytime visibility; peak intensity of 200 candelas (effective intensity of 140 candelas) for nighttime visibility; “high-low” rather than “on-off” flashing should be used; and green lights equipped with dimming for glare control.

EMERGENCY INCIDENTS: ILLUMINATION SYSTEMS

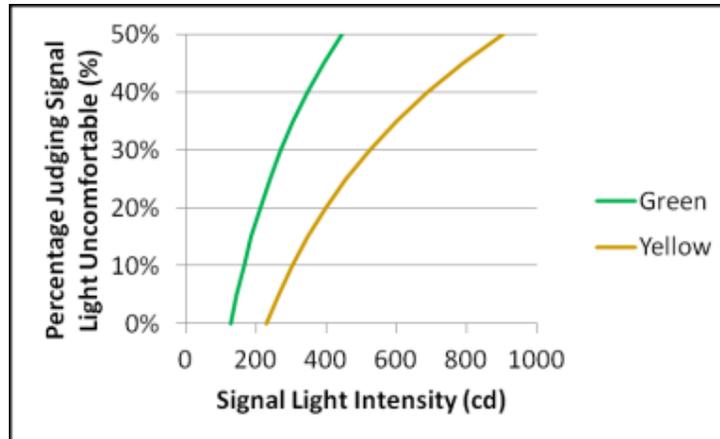
- Vehicle Headlights: Direct away from oncoming traffic.

Signage and Delineation

- Traffic Cones: Use devices with ASTM Type IV or XI sheeting.

Warning Lights

- Vehicle-Mounted Beacon: Consider dimming and switching off flashing lights if multiple vehicles are present, and use “high-low” rather than “on-off” flashing.
- Barricade Lights (if available): Use Type B barricade lights, and use sequential flashing to indicate lane closure .
- Flares: Use flares or other warning devices initially.



Impact of Freight on Highway Infrastructure in New Jersey	
<i>Project ID</i>	FHWA-NJ-2016-004
<i>Cost</i>	\$475,760
<i>Duration</i>	36 months
<i>Submitter</i>	New Jersey Department of Transportation Kimbrali Davis 1035 Parkway Avenue Trenton, New Jersey 08625 609-530-2735
<i>Links</i>	http://www.state.nj.us/transportation/refdata/research/

Project Summary and Benefits

This study addressed the impact of overweight trucks on the infrastructure systems in New Jersey. A unified database with all available data regarding pavement, bridge, and weigh-in-motion (WIM) was developed. The team proposed and the pavement and bridge deterioration models to evaluate the effect of overweight trucks on the service life of pavement and bridge structures. Furthermore, the research team conducted a life-cycle cost analysis (LCCA) to analyze the associated cost due to the movement of freight on the highway network.

Based on the results obtained from the developed models and various data, the team established a decision-making tool incorporating future traffic growth, service life prediction models, and impact of changes in truck regulations and policy. For bridges, most of the damage cost incurred by overweight trucks is attributed to the bridge decks due to the presence of a larger proportion of overweight trucks, larger wheel loads from overweight trucks, and fewer axles per truck. Deck damage costs are about 6-7 times of the girder damage costs. For pavements, a linear relationship is found between the overweight percentage and the reduction ratio of pavement life regardless of the variation in traffic loading and pavement structure. In general, one% increase in percentage of overweight truck may cause 1.8 % reduction of pavement life. The estimated state-wide average cost of moving one ton of overweight load per one mile is about \$0.33, in which about 60% of the damage cost is attributed to pavement and 40% to bridges. Based on the current permit fee structure from NJDOT, the damage cost for loads exceeding legal limit is not covered by the weight-based fee.

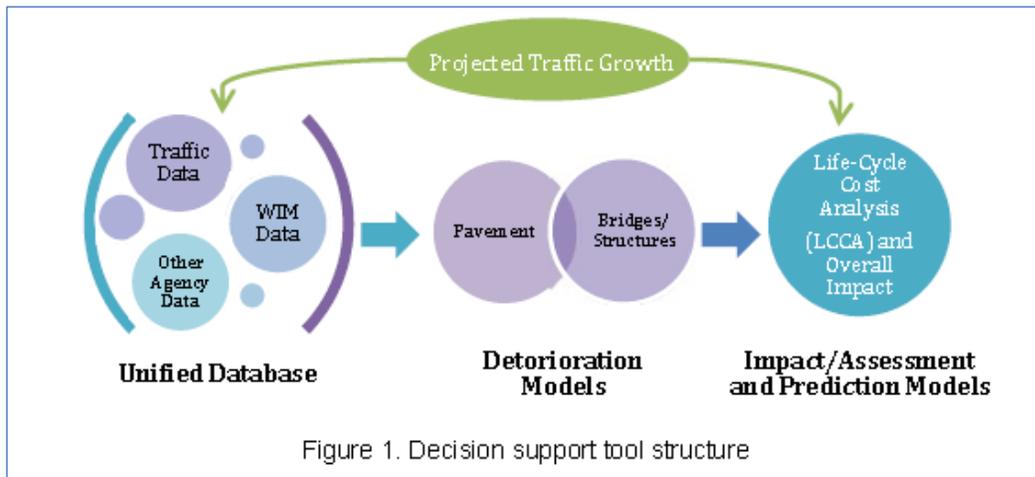


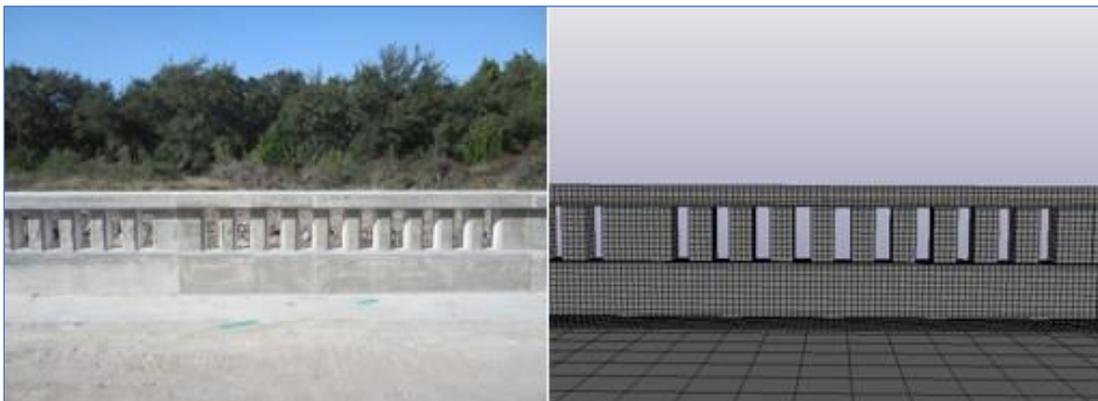
Figure 1. Decision support tool structure

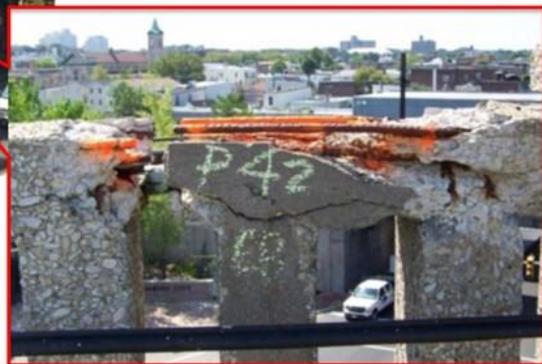
Mash Testing of Historical Concrete Balustrade (Route 139 Rehabilitation: Pulaski Skyway Contract 2)

<i>Project ID</i>	NJ-2017-XXX
<i>Cost</i>	0
<i>Duration</i>	38 months
<i>Submitter</i>	New Jersey Department of Transportation Giri Venkateela 1035 Parkway Avenue Trenton, New Jersey 08625 609-530-8038
<i>Links</i>	http://www.state.nj.us/transportation/refdata/research/

Project Summary and Benefits

In this project, a historic aesthetic balustrade on the Pulaski Skyway has been re-designed to meet the safety requirements in accordance with the AASHTO MASH. The new barrier design, as well as three vehicles (single unit truck, pickup truck and small car) have been developed using LS-DYNA to simulate crash testing. A parametric study with regard to different barrier height, post width and spacing, was performed to optimize the design. The best design was chosen for actual crash testing, and three vehicles were crashed into the new barrier. After three successful crash tests at TL-4, the simulations were calibrated and validated. At the conclusion of this project, the state of New Jersey will have a safe, crashworthy, and aesthetically pleasing historic-looking barrier that can be used anywhere in the country. This barrier will improve the look of any bridge it is placed on, and will save lives as well. No longer will the aesthetics of a bridge be compromised for safety.





Time	0.000s	0.002s	0.004s
TL-4 Test			
FEA			

Time	0.000s	0.002s	0.004s
TL-4 Test			
FEA			

Time	0.000s	0.002s	0.004s
TL-4 Test			
FEA			

Worker Safety Issues of Wi-Fi Devices

<i>Project ID</i>	FHWA-NJ-2017-XXX
<i>Cost</i>	\$117,448
<i>Duration</i>	20 months
<i>Submitter</i>	New Jersey Department of Transportation Giri Venkiteela 1035 Parkway Avenue Trenton, New Jersey 08625 609-530-8038
<i>Links</i>	http://www.state.nj.us/transportation/refdata/research/

Project Summary and Benefits

Wireless-based devices, each of which is transmitting and receiving electromagnetic (E&M) energy at a measurable Power Density, and new protocols such as Bluetooth, Bluetooth Low Energy (BLE), and cellular Long-Term Evolution (LTE), and new Wi-Fi standards (i.e., 802.11n, 802.11a) continue to be added to the radiated Radio Frequency (RF) Spectrum. Radio Frequency Electromagnetic (RF-E&M) Field exposure occurs from the use of various RF-enabled devices, e.g., the New Jersey Department of Transportation has Bluetooth sensors used to collect data for travel times on State roadway systems and these data are used to transmit accurate real-time information to the motoring public.

The new research documented in this report answers the questions related to the repair of these Bluetooth transmitters:

- (1) What are the RF-exposure health risks to the employee?
- (2) What steps can be taken to mitigate any risks from RF transmitted sources?

This research also goes beyond Bluetooth and Bluetooth LE, and considers the risk from second generation (2G) and 3G cellular radiators and other 801.11 standards equipment now in production. In all cases the levels measured were well below the safe exposure levels established in the United States of America. Nevertheless, the effects of this exposure on worker health and safety are considered and how to mitigate any possible negative effects discussed.



Analysis of Energy Efficient Highway Lighting Retrofits

<i>Project ID</i>	C-14-12
<i>Cost</i>	\$204,370
<i>Duration</i>	5 months
<i>Submitter</i>	New York State Department of Transportation Robert Sack 50 Wolf Road, POD51 Albany, New York 12203 518-457-4445
<i>Links</i>	https://www.dot.ny.gov/divisions/engineering/technical-services/trans-r-and-d-repository/C-14-12-Final%20Report_June%202015.pdf



Project Summary and Benefits

Light Emitting Diode (LED) solid state lighting was evaluated to see if it is economically beneficial as well as to see if it improves lighting characteristics on the roadway. The study found that estimated 7% - 48% energy cost savings can be achieved with conversion to LED lighting with the payback period in terms of savings is around 4-41 years. More savings can be achieved once maintenance savings are recognized because maintenance will be required less. Safety can be improved as increasing light levels is shown to reduce vehicular and pedestrian accidents. Quality of life is generally also improved due to the perceived increase in security as well as the aesthetically appealing cool color of LED's. To implement the findings, a joint Program Opportunity Notice (PON) 3090 was released by New York State Energy Research and Development Authority (NYSERDA) and New York State Department of Transportation (NYSDOT). Research project *C-15-08: LED Roadway Lighting Benefits and Costs Collaboration* has been initiated to demonstrate results of this research project. This implementation project is scheduled for completion in March 2018.

Public Opinions of Roadway Assets using Roadway Reviews and Focus Groups

<i>Project ID</i>	FHWA/NC/2016-04 NCDOT-RP-2016-04
<i>Cost</i>	0
<i>Duration</i>	11 months
<i>Submitter</i>	North Carolina Department of Transportation Mustan Kadibhai 1549 Mail Service Center Raleigh, North Carolina 27699 919-508-1819
<i>Links</i>	https://connect.ncdot.gov/projects/planning/Pages/ProjDetails.aspx?ProjectID=2016-04

Project Summary and Benefits

Background

Currently, the NCDOT has a robust system for measuring the conditions of roadway assets and maintaining them accordingly. However, to most effectively allocate resources, it is vital that transportation agencies like the NCDOT incorporate stakeholder feedback into their asset management decisions. For this reason, the NCDOT recently began integrating resident feedback from an annual statewide transportation customer service survey administered online, via mail, and over the phone into their asset management practices. While these surveys continue to offer valuable insight into customer opinions about an array of NCDOT services, they provide minimal information about which assets roadway users prioritize and the “why” behind their opinions. Knowing these details are important because, while quantitative information like that gleaned through the NCDOT’s asset management measurement systems is valuable for determining when assets may need improvements, in-depth qualitative feedback from customers can better help the agency identify which assets should be improved first given limited funds and human resources. Through this study, the NCDOT sought to gain more comprehensive opinions from North Carolina residents about roadway assets.

Specific Research Objective

As North Carolina’s population continues to grow, the usage of roadways is increasing and the needs of roadway users are increasing. In spite of this growth, however, the human and financial resources available to manage roadway assets continues to be limited. As such, the Roadway Reviews project was initiated to enhance the asset management decisions by NCDOT, with the purpose of:

- 1) Objectively determine expectations that North Carolina residents have for North Carolina’s roadways
- 2) Identify roadway features that residents believe are most important on different types of roadways

What research work was done?

This study was designed to capture the wide range of North Carolina's roadway features, geography, and residents. Research was purposefully conducted in each of North Carolina's three geographic regions:

- 1) Mountain,
- 2) Piedmont, and
- 3) Coastal.

Study sites included six locations selected to reflect the state's diverse economic conditions and geographic areas such as Asheville, Charlotte, Rocky Mount, Jonesville, Burlington, and Wilmington. These are the same locations that were chosen for the 2011 study. Similarly, this project focused on examining opinions about varied roadway features and roadway types. Survey and focus group questions revolved around eleven roadway features commonly maintained by the NCDOT. The routes surveyed by participants included a mixture of primary roadways, secondary roadways, and interstates. Routes were selected to ensure that each route incorporated an array of different types of facilities in various conditions.

Impact, or Potential Impact, of Implementing Research Results

This project provides a report and summary PowerPoint file for use by NCDOT staff. Products can and will be used in any number of meetings, both internal and external to DOT, marketing/promotional materials, and even for reporting at the national level. The data gained from this study will be used to adjust departmental targets to address areas of deficiency and to reduce spending on areas of over-performance.

Benefits of Research Results

The product of this research greatly benefits the department by advising policy makers on where taxpayers would like to see their money spent regarding roadway maintenance and comparing that to where and how we are currently allocating funds. It also helps provide a forum for public input and give the NCDOT an opportunity to engage with the public. The value of the this public engagement cannot be overstated.

Preventive Maintenance Criteria for Motor Fleet Vehicles

<i>Project ID</i>	FHWA/NC/2015-11 NCDOT-RP-2015-11
<i>Cost</i>	0
<i>Duration</i>	23 months
<i>Submitter</i>	North Carolina Department of Transportation Neil Mastin 104 Fayetteville Street Raleigh, North Carolina 27601 919-508-1865
<i>Links</i>	

Project Summary and Benefits

Background

Preventive maintenance (PM) is a key component of effectively managing an equipment fleet in a fully functional and safe working order. Periodic servicing is important to maintaining a reliable high quality fleet and minimizing equipment downtime (Milwaukee 2008). Regularly draining and replacing engine oil is a common PM action performed to maintain engine health and prolong engine life. The North Carolina Department of Transportation (NCDOT) operates and maintains a fleet of on-road and off-road equipment that includes approximately 7,900 engine driven machines. Regular oil changes for these machines result in significant costs due to the required labor, replacement oil and filters, and disposal of used oil, as well as downtime for the machine. Provided that oil of sufficient quality can be maintained, PM costs can be reduced by extending oil drain intervals. Oil drain intervals are typically scheduled based on machine use and/or calendar days. Oil changes are scheduled for 5,000 miles or 200 hours intervals or annually, whichever comes first, in the current NCDOT PM program. This schedule is generally applied to all classes of equipment in the fleet without regard to type, use, OEM recommendation, or past experience.

Regular sampling and analysis of oil is not included in the program and oil quality is not explicitly considered when scheduling oil changes. This is largely due to the approximate two week time lag between oil sampling and receipt of the analysis results when analysis is performed by an independent laboratory. Engine oil, regardless of the type, decreases in quality throughout its useful life. Degradation may result from physical or chemical changes to the oil or from contamination by impurities. Degradation inhibits the ability of the oil to perform the critical functions of wear protection, thermal management, and corrosion inhibition necessary to maintain performance and maximize useful service life. Because oil provides vital protection to an engine, it is regularly drained and replaced to counter the effects of degradation and contamination.

Specific Research Objective

The purpose of this research was to monitor oil quality throughout extended drain intervals to determine the type, rate, and magnitude of resulting degradation, and to investigate the potential for extending oil drain intervals. This was achieved through the completion of the following tasks:

- 1) Establish an experimental PM program consisting of:
 - a. On-site oil analysis equipment necessary to measure oil quality parameters within a short period of time;
 - b. Threshold values for oil quality parameters;
 - c. Sampling and analysis procedures necessary to accurately collect and manage the analysis results; and
 - d. Individual machines selected from four equipment classes to be maintained on drain intervals determined by comparing the results with the parameter threshold values.
- 2) Investigate existing data from oil previously analyzed for the NCDOT to determine whether the data can be used to augment that from the experimental PM program and to aid in understanding how fuel use relates to oil performance.
- 3) Assess the impact of extended oil drain intervals in terms of oil quality, as well as economic and environmental benefits.

What research work was done?

A total of 952 samples of used oil were collected and analyzed from 47 machines that consisted of trucks in classes 0209 and 0210 and tractors in classes 0303 and 0311. Trucks in classes 0209 and 0210 were sampled at approximately 1500, 2500, and 5000 miles after the oil drain, while tractors in classes 0303 and 0311 were sampled at approximately 50 hour intervals. Machines on the extended program were sampled approximately every 1,500 miles or 50 hours beyond the normally scheduled oil drain. Analyses of fresh oil samples showed that both the conventional HD Fleet Supreme 15W-40 and synthetic Rotella T6 5W-40 are good quality oils with average TBN values of approximately 9.5 mg KOH/g and viscosity within the SAE standard limits for 40 weight oil. The measured TBN and viscosity of the fresh conventional oil was very similar to the typical values published by the manufacturer, while the measured TBN and viscosity of the synthetic oil was lower than the typical values published by the manufacturer. Analyses of the used oil sampled from the NCDOT equipment showed that the oils degraded chemically as the oil aged, but the observed viscosity degradation was not related to oil age. Contamination of the oil by water, coolant, dirt, or wear metals was not generally present.

FREEVAL-WZ: Planning-Level Extensions to NCDOT Freeway Analysis Tool

<i>Project ID</i>	FHWA/NC/2015-09
<i>Cost</i>	\$94,555
<i>Duration</i>	16 months
<i>Submitter</i>	North Carolina Department of Transportation John Kirby 104 Fayetteville Street Raleigh, North Carolina 27601 919-508-1816
<i>Links</i>	https://connect.ncdot.gov/projects/planning/Pages/ProjDetails.aspx?ProjectID=2015-09

Project Summary and Benefits

A major contribution was to develop default traffic volume distributions for different locations in North Carolina. As a result, the analyst can manipulate analysis inputs simply by specifying the geometry and AADT on freeway mainline and ramps. This greatly enhances the user-friendliness of the tool and reduces the analysis burden. Through the use of default values and streamlined data entry, the tool allows for the planning-level evaluation of a freeway work zone within a few minutes, as opposed to taking several hours in a traditional HCM analysis or multiple days or weeks, as is the case for a simulation-based analysis of work zone impacts.

Another major improvement to the analysis is the integration of recently developed freeway work zone capacity, free-flow speed, and speed flow models for the recently released Highway Capacity Manual Six Edition under NCHRP project 03-107. All procedures from that research, including adjustments for work zone shoulder work, lane closures, and directional crossovers are directly integrated into the FREEVAL-WZ software. Finally, the research team has created a customizable PDF report to provide a summary of the analysis that was performed in FREEVAL-WZ. In addition, a comprehensive user's guide for FREEVAL-WZ was developed and delivered to NCDOT as a project deliverable.

Performance Evaluation of Strong Post Double-faced W-beam Guardrail and Strong Post Double-faced Thrie-Beam Guardrail at MASH Test Level 4 (TL-4) and Test Level 5 (TL-5) Conditions

<i>Project ID</i>	FHWA/NC/2015-10
<i>Cost</i>	\$298,474
<i>Duration</i>	32 months
<i>Submitter</i>	North Carolina Department of Transportation John Kirby 104 Fayetteville Street Raleigh, North Carolina 27601 919-508-1816
<i>Links</i>	https://connect.ncdot.gov/projects/planning/Pages/ProjDetails.aspx?ProjectID=2012-11

Project Summary and Benefits

NCDOT engineers and officials will gain insights on guardrails' performance (including any redirection characteristics and system deflections) when impacted by a single-unit truck and tractor-trailer combination. They are using the research results to make informed design and installation decisions for the placement and use of double-faced W-beam and Thrie-beam guardrails. NCDOT officials have used the research to enhance safety and communicate their efforts on the prevention of cross-median crashes. The results can also be used to evaluate the effectiveness of providing safety hardware at higher standards than those currently recommended by the FHWA Office of Safety. The research results are used by NCDOT engineers as guidance to update the Roadway Standard Drawing for guardrail installation and to assist decision making in roadway improvement and/or resurfacing projects.

Alternative Stream Channel Maintenance at Bridge Crossings

<i>Project ID</i>	134821
<i>Cost</i>	\$729,467
<i>Duration</i>	40 months
<i>Submitter</i>	Ohio Department of Transportation Zona Kahkonen Keppler 1980 West Broad Street Columbus, Ohio 43223 614-466-2882
<i>Links</i>	http://cdm16007.contentdm.oclc.org/cdm/ref/collection/p267401ccp2/id/14624

Project Summary and Benefits

Background

Streams are dynamic systems. Flowing water erodes channel banks and beds and sediments are deposited within the channel and on floodplains to constantly shape and reshape the stream channel. Unfortunately, the natural movements and adjustments of stream systems are problematic for designers that must engineer bridge structures that remain in a fixed location. Historically, bridge design procedures have not given adequate consideration to sediment transport and the natural processes of channel aggradation (i.e., sedimentation), degradation (i.e., channel incision), and lateral migration of the channel. These natural processes often cause problems at the bridge opening that require maintenance to protect the structure. Throughout the state, the Ohio Department of Transportation (ODOT) county forces undertake routine maintenance of stream channels. Unfortunately, they have limited options available to solve maintenance problems and current approaches, primarily dredging and armoring, are not typically self-sustaining. Sites with recurring maintenance issues are a burden to county forces and leads to allowable, but repetitive and unnecessary impacts to the environment. This research project evaluated numerous alternative stream channel maintenance techniques and construction materials in an effort to improve stream channel maintenance outcomes.

Research Context

The goals of the research were to:

- 1) identify natural stream channel techniques and construction materials that are feasible alternatives to channel dredging and riprap bank armoring,
- 2) develop tools (e.g., decision matrix) and guidance to aid in the selection of techniques to solve maintenance issues,
- 3) assess the capabilities of county forces to implement pilot projects,

- 4) develop and test a rapid monitoring protocol to assess project outcomes post construction, and
- 5) evaluate pilot project performance and conduct an analysis of economic costs and savings.

Research Approach

The project team worked collaboratively with ODOT scientists, engineers, and county forces to:

- Identify bridges with recurring maintenance problems.
- Select natural channel design practices and construction materials to solve maintenance issues .
- Implement, assess, and monitor pilot projects (e.g., vanes, cross vanes, w-weirs, two-stage channels).
- Install and evaluate a flexible concrete cloth material for bank stabilization and culvert lining projects.
- Develop standard drawings and technical specifications to facilitate future design work.
- Create a decision matrix to guide practice selection and a monitoring protocol to assess performance.
- Document project outcomes, costs, and lessons learned to inform for future projects.

Research Findings and Recommendations

The findings of the research project suggest that:

- Natural channel design practices and novel construction materials can be successfully utilized by ODOT county forces and district staff to address channel maintenance problems at bridge crossings, sometimes resulting in considerable savings (~75% savings on two typical projects that were evaluated).
- County forces may not utilize natural channel design practices, which require more extensive permitting, when traditional maintenance (i.e., dredging, riprap) are already covered in Regional General Permit Section B.

As a result of these findings we recommend the following:

- ODOT should engage in discussions with the US Army Corps of Engineers to determine if natural channel design practices meet existing conditions of the Regional General Permit Section B.
- Provide additional opportunities for education and training on natural channel design practice selection, engineering design, and proper construction techniques in an effort to progressively build institutional capacity to implement these practices.
- Consider incorporating natural channel design principles and practices into new bridge or bridge replacement projects to address potential problems at sites that have extensive and challenging maintenance histories.

Route Optimization-Tech Transfer	
<i>Project ID</i>	135157
<i>Cost</i>	\$550,063
<i>Duration</i>	20 months
<i>Submitter</i>	Ohio Department of Transportation Zona Kahkonen Keppler 1980 West Broad Street Columbus, Ohio 43223 614-466-2882
<i>Links</i>	http://cdm16007.contentdm.oclc.org/cdm/compoundobject/collection/p267401ccp2/id/14438/rec/2

Project Summary and Benefits

Background

For winter maintenance purposes, the Ohio Department of Transportation (ODOT) deploys a fleet of approximately 1,600 snow plow trucks that maintain 43,000 lane miles of roadway. The deployment of such a large number of trucks over a vast maintenance area creates an operational problem in determining the optimal maintenance routes and fleet size. Route optimization may aid in determining the required number of trucks and the area that these trucks should maintain throughout the state of Ohio.

Research Context

The objectives of this project are to:

- Digitize base routes and input ODOT facilities and plowing locations.
- Remove county border restrictions and optimize routes for each truck in Districts 1, 2, and 10.
- Place GPS recorders in trucks and compare actual cycle times to the calculated cycle times.
- Set maximum cycle times and determine which garages may remove trucks and which need additional trucks.

Research Approach

The utilization of the Vehicle Routing Problem (VRP) in ArcGIS may provide ODOT with a tool to effectively optimize district fleets, thus determining the optimal fleet sizes. Operational parameters may be implemented into the VRP to include typical speeds traveled during snow events, level of service (LOS) requirements, truck descriptions, and safe turnaround areas for operators.

Research Findings and Recommendations

The results of this project will provide ODOT a tool to determine the minimum number of trucks needed to maintain the necessary roadways. In addition, the project provides ODOT a tool to assign assets to specific facilities and the most optimal routes for each truck in the district. This research may result in a reduction of fleet sizes and a significant cost savings while maintaining an equal or better LOS.

Improving Specifications to Resist Frost Damage in Modern Concrete Mixtures

<i>Project ID</i>	TPF 5-(297)
<i>Cost</i>	0
<i>Duration</i>	36 months
<i>Submitter</i>	Oklahoma Department of Transportation Ron Curb 200 NE 21st Street Oklahoma City, Oklahoma 73105 405-522-3795
<i>Links</i>	http://www.pooledfund.org/Details/Study/541

Project Summary and Benefits

The goal of the research is to produce improved specifications and test methods while improving the understanding of the underlying mechanisms of frost damage. Specifically, this work will seek to develop new test procedures that may be faster and/or more reliable than the existing methods. The objectives of this project are to:

- (1) determine the necessary properties of the air-void system to provide satisfactory frost durability in laboratory testing of laboratory and field concretes with different combinations of admixtures, cements, and mixing temperatures in salt environments;
- (2) determine the accuracy of a simple field test method that measures air void system quality with field and laboratory concrete;
- (3) determine the critical combinations of absorption and the critical degree of saturation on the frost durability in accelerated laboratory testing in the presence of deicer salts; and
- (4) establish new test methods and specifications for fresh and hardened concrete to determine frost durability and field performance.

Understanding the research on freeze-thaw mechanisms is important for two main groups:

- (1) practicing professionals; and
- (2) graduating undergraduate and graduate students.

A portion of this project will be dedicated to the development of a strong educational technology transfer program. It includes developing a short course that utilizes streaming video that can also be copied onto a DVD

for widespread dissemination. Practicing professionals frequently require information in a short time frame to respond to practice-based problems. The DVD and streaming video is a perfect approach to provide the needed information.



Bridge Deck Cracking: Effects on In-Service Performance, Prevention, and Remediation

<i>Project ID</i>	120103
<i>Cost</i>	\$317,073
<i>Duration</i>	23 months
<i>Submitter</i>	Pennsylvania Department of Transportation Lisa Tarson 400 North Street Harrisburg, Pennsylvania 17120 717-783-2444
<i>Links</i>	



Project Summary and Benefits

The main objectives of this project were:

- (a) to identify the causes of early-age cracking in concrete bridge decks,
- (b) to provide recommendations for effective mitigation of early-age cracking,
- (c) to assess the effect of cracks on the long-term durability and performance of concrete bridge decks, and
- (d) to identify the best and most cost-effective (on a life-cycle cost basis) remediation practices and optimum time to remediate to extend the life of bridge decks.

The project was completed in six tasks and a final report contains the details of the methods of data collection, analysis, and conclusions for each task.

Development of a Guidance Manual for Assessing Scour using the South Carolina Regional Bridge-Scour Envelopes

<i>Project ID</i>	2016-5121
<i>Cost</i>	0
<i>Duration</i>	45 months
<i>Submitter</i>	South Carolina Department of Transportation Terry Swygert 1406 Shop Road Columbia, South Carolina 29201 803-737-6691
<i>Links</i>	https://pubs.usgs.gov/sir/2016/5121/sir20165121.pdf

Project Summary and Benefits

The U.S. Geological Survey (USGS), in cooperation with the South Carolina Department of Transportation (SCDOT), conducted a series of three field investigations to evaluate historical, riverine bridge scour in the Piedmont and Coastal Plan regions of South Carolina. These investigations collected nearly 850 measurements of scour at 231 bridges. This large database provided valuable insights into scour trends and yielded the South Carolina bridge-scour envelope curves that can be used to evaluate all components of scour at riverine bridges in South Carolina. The findings of these previous scour investigations were recently (2016) synthesized into a single guidance manual detailing an integrated procedure for applying the South Carolina bridge-scour envelope curves. Additionally, a companion spreadsheet was developed to facilitate the application of the integrated procedure. The bridge-scour guidance manual represents the culmination of nearly 25 years of successful collaboration between SCDOT and the USGS.

The original work began in the early 1990s with Level 1 and Level 2 bridge-scour assessment programs. Findings from these early programs led to the previously noted field investigations, which were initiated in 1995. The work culminated with the recent publication (2016) of the bridge-scour guidance manual. The benefits of this study to SCDOT include a consolidated and concise guidance manual, a tool for applying scour calculations, and cost and time savings for SCDOT. The guidance manual gives designers a single, well-organized reference for scour computations with guidelines and examples for applying the South Carolina bridge-scour envelope curves. The spreadsheet provides SCDOT automated computational components of the integrated procedure used to evaluate scour potential at a selected bridge in a consistent and timely manner. The improved scour analysis process saves costs by reducing the amount of time needed to perform scour computations by approximately two person days per bridge at \$659.00, with an estimated savings of \$59,310.00 for every 90 bridges.

Construction cost savings are anticipated by minimizing the over-design of foundations for new bridge pile and drilled shaft designs at \$7,797.00 and \$71,573.00 per bent, respectively. A total cost savings of \$7.1 million is

estimated in construction savings for every 90 bridges, with the assumptions that there are an equal number of bridges having pile and drill shaft foundations and that each bridge has two interior bents. Increased cost savings are anticipated for bridges with more complex designs (i.e., more spans and higher costs for designing and constructing the foundations). Savings will be derived from having a better understanding of scour trends in South Carolina from use of the guidance manual and spreadsheet. Additional benefits of this study to the USGS and science include general guidance and insight into scour trends, as well as an enhanced understanding of general and regional trends in scour for states with similar regional characteristics to South Carolina. The Hydraulic Design Support Office of the SCDOT will implement this research through the release of a Memorandum and the incorporation of the Manual and Spreadsheet as part of the design process and procedures for scour in the Requirements for Hydraulic Design Studies. Further, SCDOT and USGS will provide hands-on training to use the Manual and Spreadsheet for SCDOT's Hydraulic Design personnel.



Reducing Wildlife-Vehicle Collisions in South Dakota	
<i>Project ID</i>	SD2014-03
<i>Cost</i>	\$80,000
<i>Duration</i>	17 months
<i>Submitter</i>	South Dakota Department of Transportation David Huft 700 East Broadway Avenue Pierre, South Dakota 57501 605-773-3358
<i>Links</i>	

Project Summary and Benefits

This research examined the impact of wildlife-vehicle collisions in South Dakota. The work identified incomplete reporting of crashes and carcass pickup as a fundamental problem limiting analysis and effective planning of mitigation actions. Implementation actions included adding animal species to standard crash reports and development of an inexpensive mobile app to report carcass species, sex, location, and date/time of pickup. Implementation recommendations also include stronger coordination between the SD DOT and the SD Department of Game, Fish and Parks to improve effective project development and programming decisions related to wildlife-vehicle collisions and mitigation. Implementation, which is underway, will significantly improve the quality and completeness of wildlife-vehicle collisions and enable more effective mitigation actions.



Transportation Systems Management and Operations Program Plan for South Dakota

<i>Project ID</i>	SD2014-06
<i>Cost</i>	\$125,000
<i>Duration</i>	11 months
<i>Submitter</i>	South Dakota Department of Transportation David Huft 700 East Broadway Avenue Pierre, South Dakota 57501 605-773-3358
<i>Links</i>	

Project Summary and Benefits

The objective of this project was the development of a comprehensive Transportation Systems Management and Operations (TSM&O) Program Plan for the South Dakota Department of Transportation. This plan guides business planning and strategic decision-making to advance SDDOT’s currently informal TSM&O program to one with a more effective and formalized approach to incorporating TSM&O into the department’s mission, goals and objectives, future planning initiatives at all timescales, and day-to-day activities. It presents a series of recommendations in the form of actions, tasks, and implementation steps. It also provides the rationale or “Business Case” for committing to its recommended actions, additional background on SDDOT’s current TSM&O capabilities, and an implementation strategy for executing the plan’s recommendations that summarizes each action’s feasibility, priority and schedule, and roles for identified SDDOT and partner agency staff.

Implementation, which is underway, will profoundly improve SDDOT's capabilities in the dimensions of Business Processes, Systems and Technology, Collaboration, Organization and Workforce, Performance Measurement, and Culture needed to establish and sustain effective TSMO program and activities.

Reuse of Aqueous Waste Streams in Transportation Applications

<i>Project ID</i>	SD2014-19
<i>Cost</i>	\$35,000
<i>Duration</i>	19 months
<i>Submitter</i>	South Dakota Department of Transportation David Huft 700 East Broadway Avenue Pierre, South Dakota 57501 605-773-3358
<i>Links</i>	

Project Summary and Benefits

Aqueous waste streams produced from commercial, industrial, and municipal processes may be potentially reused for transportation applications. The objectives of this project were to identify potential transportation-related applications for aqueous waste streams available in South Dakota, develop guidance for the beneficial reuse of aqueous waste streams, and evaluate the reuse of MIEX[®] brine generated by the Watertown Municipal Water Treatment Plant. This study identified many aqueous wastes from municipal water and wastewater treatment facilities, industrial and agricultural processes in South Dakota that can be potentially used for ice and dust control. Beneficial reuse of these waste streams requires a comprehensive evaluation of the effectiveness, safety, economics, environmental benefits and risks, and adherence to local, state, and federal regulations. The evaluation of MIEX[®] brine suggests that this brine can be used as a feed solution to produce final brine products at SDDOT facilities for winter road maintenance. Reusing the MIEX[®] brine in the Aberdeen region may reduce the cost of brine disposal for the City of Watertown and reduce the cost of winter road maintenance for SDDOT. Most significantly, the research developed comprehensive guidelines for evaluating and approving reuse of aqueous waste streams that have been adopted by the SD Department of Environment and Natural Resources.

Weather-Responsive Traveler Information

<i>Project ID</i>	SD2013-12
<i>Cost</i>	\$170,000
<i>Duration</i>	20 months
<i>Submitter</i>	South Dakota Department of Transportation David Huft 700 East Broadway Avenue Pierre, South Dakota 57501 605-773-3358
<i>Links</i>	

Project Summary and Benefits

This project developed technology and processes for improving the quality and completeness of traveler information related to weather-induced road conditions. One method was the use of snowplow-mounted data collection equipment to enable more frequent and timely condition reporting. The most innovative and effective method was to use predictions of road condition, generated by the winter maintenance decision support system, to generate threat warnings for adverse or deteriorating road conditions. The predictions identify the nature, relative severity, and expected onset and duration of conditions such as frost, snow, slush and ice on the road surface, as well as wind and visibility problems. This is the first system in the United States that communicates predicted road conditions to travelers. Use of time- and location-specific predictions enables SDDOT to inform travelers of vital information during the next 24-hour period, even during hours not manned by SDDOT staff. User surveys indicate that travelers find the information useful and easy to use, and that travelers use the information to adjust travel routes and timing.

Proactive Traffic Signal Timing and Coordination for Congestion Mitigation on Arterial Roads

<i>Project ID</i>	0-6920
<i>Cost</i>	0
<i>Duration</i>	11 months
<i>Submitter</i>	Texas Department of Transportation Wade Odell 200 E. Riverside Drive Austin, Texas 78704 512-416-4737
<i>Links</i>	



Project Summary and Benefits

This project developed a proactive signal control system to optimize signal phasing and timing plans by integrating data from traffic signals, loop detectors, and connected vehicles to reduce congestion on arterial roads and maximize the performance of intersections. This project also developed a framework for evaluating the advances of communication technologies in signal design. This project has not only prepared TxDOT for the connected vehicle environment that is fast approaching, but proved significant reduction in queue length and wait times in the research testbed of Houston. With queue lengths reduced by 60% and wait times reduced by as much as 50%, TxDOT has decided to implement the proactive traffic signals at 30 intersections in the Houston District. An effort to implement statewide will occur upon completion of a separate implementation project in December 2017.

This project has developed a proactive signal control system to optimize signal phasing and timing plans by integrating data from traffic signals, loop detectors, and connected vehicles to reduce congestion on arterial roads and maximize the performance of intersections. This project also developed a framework for evaluating the advances of communication technologies in signal design. This project has not only prepared TxDOT for the connected vehicle environment, which is fast approaching, but has yielded significant reductions in queue lengths and wait times in the research testbed of Houston. Queue lengths have been reduced by 60% and wait times have been reduced by as much as 50%. TxDOT has decided to implement the proactive traffic signals at in a separate implementation project at 30 intersections in the Houston District. An effort to implement statewide will occur upon completion of the implementation project in March 2018.

Mitigation of High Sulfate Soils in Texas

<i>Project ID</i>	5-6618-01
<i>Cost</i>	0
<i>Duration</i>	23 months
<i>Submitter</i>	Texas Department of Transportation Wade Odell 200 E. Riverside Drive Austin, Texas 78704 512-416-4737
<i>Links</i>	

Project Summary and Benefits

Two new treatment methods to mitigate high sulfate-induced soil heave were tested on US 82 in the TxDOT Paris District. Three test sections consisting of one control and two test sections were constructed on US 82 near Bells in Grayson County. The control section (Test Section 3) consisted of lime treated soil in normal practice. The two treatment sections (Test Sections 1 and 2) were lime-fly ash treated and lime treated sections. Both sections were constructed with extended mellowing period of seven days. It was important to evaluate the effectiveness of different chemical treatments for providing better stabilization of high sulfate soils in actual field conditions as many pavement projects are built on high sulfate soils in various districts.

Initial findings indicate that the stabilization solutions can prolong the life of pavements by 30% to 40% built on high sulfate soils with minimal distress. This translates into significant maintenance dollars savings for each TxDOT district, in some cases up to 100% of original construction costs, as there will be no need for complete rehabilitation of the pavements. In any given year, TxDOT spends over \$100 million on construction projects built on high sulfate soils, including partial and full-depth repairs. These annual savings can amount to at least \$75 million, considering that many treated roadways do not need full reconstruction, but only in localized sections. Also, safety is enhanced, as roughness coming from heave bumps will be reduced. This provides smooth riding conditions with minimal pavement roller coaster type bumps and valleys, leading to significant improvements to pavement infrastructure assets currently serviced by TxDOT.

Bridge Strengthening Design and Load Testing for a Continuous Steel Girder Bridge with Post-Installed Shear Connectors

<i>Project ID</i>	5-6719-01
<i>Cost</i>	0
<i>Duration</i>	8 months
<i>Submitter</i>	Texas Department of Transportation Wade Odell 200 E. Riverside Drive Austin, Texas 78704 512-416-4737
<i>Links</i>	

Project Summary and Benefits

The work on this project consisted of Phase I, Bridge Strengthening Design and Load Testing. The research team selected a non-composite continuous girder bridge in Texas for strengthening; design of the strengthening system; finite element analysis of the unstrengthened and strengthened bridge designs; and field load testing of the unstrengthened bridge, in order to obtain baseline data on the behavior of the existing bridge for later comparison with field load testing data for the strengthened bridge. A three-span continuous steel unit of a four-lane bridge crossing the Sabine River in Lakeport was chosen for strengthening using post-installed shear connectors as part of this project. Analysis of the Lakeport Bridge showed that after planned sidewalk and railing modifications are completed, the inventory load rating of the bridge will be HS 11.5. As part of this project, a strengthening system was designed that includes installation of post-installed shear connectors and allowance for limited flexural yielding at interior supports.

In a future project, Phase II will include monitoring construction operations during the installation of post-installed shear connectors, collecting information on construction costs and difficulties, and field load testing of the bridge after strengthening is completed, to verify the effectiveness of the strengthening system. Based on the findings in Phase I, a total of 372 post-installed adhesive anchor shear connectors will be installed to strengthen the Lakeport Bridge and achieve an inventory load factor rating of HS 20. This will represent an increase of nearly 75 percent in the load rating from the existing non-composite bridge. Based on predicted future truck traffic, it is expected that these connectors will have a minimum fatigue life of 32 years, which exceeds the minimum desired service life extension of the bridge of 25 years.

Improving Cold In-Place Recycling of Asphalt Pavements Using Solventless Emulsion

<i>Project ID</i>	14-8960, UT13.111
<i>Cost</i>	\$200,000
<i>Duration</i>	59 months
<i>Submitter</i>	Utah Department of Transportation David Stevens P.O. Box 148410 Salt Lake City, Utah 84114 801-589-8340
<i>Links</i>	http://www.udot.utah.gov/go/research



Project Summary and Benefits

UDOT Central Materials initiated research for cold in-place recycling (CIR) with solventless emulsion of asphalt pavements to improve the construction process and specification. This has been ongoing for the last few years. The consulting firm that performed the research developed a new approach for the mix design and the parameters that result in good CIR pavement performance. The engineered emulsion CIR material was found to behave more like an unbound material during the construction phase. Understanding this helped UDOT develop a density target based on field 30-gyrations pucks. The owner-control approach allowed us to use rolling patterns to set up the best compaction effort for mat density and to solve problems that come up in the field. The specification was completely reworked and performance tests added from the CIR research to indicate if the mat is ready to open to traffic. Although UDOT had some poor-performing CIR projects prior to conducting the research, we constructed four projects successfully in 2016 with the new specification for a total of approximately 30 centerline miles.

Based on historical data, the resulting cost savings with the CIR process are up to 30%, or \$1,870,000, on these four projects when compared with typical reconstruction using hot-mix asphalt. One additional CIR project is currently planned for 2017 using the new specification, and the 2016 projects will continue to be watched for long-term performance. The following three research reports provide additional details: [CIP Recycling Using Solventless Emulsion Phase IV](#), [Cold In-Place Recycle Phase III Supplemental](#), and [UT-14.08 Cold In-Place Recycle Phase III](#). Found below are images that include photos of vane shear and Marshall hammer performance tests, and the four CIR projects in 2016. [Project files](#) that include three research reports, presentation slides on UDOT's CIR research and construction experience, UDOT's updated CIR specification (special provision), and a portion of UDOT's Materials Manual with updated guidelines for design and field acceptance of CIR projects, can be found online at the highvalueresearch.org site (log in required.)







Examining the Potential Impacts of Maintenance Investment and Capital Reinvestment in Vermont’s Roadway Infrastructure Network

<i>Project ID</i>	SPR-RSCH018 - 743
<i>Cost</i>	\$75,974
<i>Duration</i>	11 months
<i>Submitter</i>	Vermont Agency of Transportation Jonathan Razinger 1 National Drive Montpelier, Vermont 05633 802-498-7586
<i>Links</i>	http://vtrans.vermont.gov/sites/aot/files/highway/documents/materialsandresearch/completedprojects/Disinvestment%20Final%20Report%20%28VTrans%20Approved%29.pdf

Project Summary and Benefits

This project involves the innovative funding strategy of strategic reinvestment/disinvestment. It considers a suite of disinvestment alternatives including deferment of action, modification of standards, decommissioning assets, and a change of jurisdiction. Strategic reinvestment/disinvestment generally involves:

- 1) clearly prioritizing transportation goals and objectives,
- 2) identifying the projects and/or assets that are most important to obtaining various goals as well as projects and/or assets that are the least important or least critical in obtaining those goals, and
- 3) consciously defunding or reducing funding allocated to lower priority transportation assets and ideally reinvesting those savings into higher-priority assets.

This project summarizes the current state of practice related to the implementation of different reinvestment/disinvestment strategies at the state level and examines how some of these strategies may be employed in the state of Vermont. Candidate corridors are identified for disinvestment based on quantifiable measures of how critical or important the corridors are to traffic flow throughout the entire roadway network. The Network Robustness and Critical Closeness Accessibility indices developed in past projects are used to identify these corridors. Unique to this research, the project developed a Vulnerable Populations Index to consider how disinvestments might impact access to critical services (i.e., access to hospitals and police/fire services), and whether or not the disinvestment might have a disproportionate impact on vulnerable populations in the state. VTrans staff is very excited about how the VPI can be used in disinvestments, and to achieve one of Governor of Vermont's goals which is to identify how capital projects can benefit vulnerable populations.

Using Remote Data Collection to Identify Bridges and Culverts Susceptible to Blockage During Flooding Events

<i>Project ID</i>	SPR-RSCH017 - 740
<i>Cost</i>	\$145,338
<i>Duration</i>	23 months
<i>Submitter</i>	Vermont Agency of Transportation Jonathan Razinger 1 National Drive Montpelier, Vermont 05633 802-498-7586
<i>Links</i>	http://vtrans.vermont.gov/sites/aot/files/highway/documents/materialsandresearch/completedprojects/UAV%20Bridges%20Culverts%20Final%20Report%20%2812-15-2016%29.pdf .

Project Summary and Benefits

Debris blockages of transportation-related river and stream crossing structures such as bridges and culverts can cause flooding at lower flow volumes than predicted by floodplain delineations. These types of flooding events contribute to the damage that was observed during both Tropical Storm Irene and the heavy rainfall in the spring and summer of 2013. Flooding occurs (1) when rain falls over a prolonged period of time, (2) when intense rain falls over a short period of time, or (3) when an ice or debris jam reduces the capacity of a crossing structure and causes a river or stream to overflow onto the surrounding area.

The focus of this project is on the third type of flooding, specifically due to debris jams at crossing structures – culverts and bridges. Debris jams can also cause riverbank erosion, impede migration of aquatic creatures, and adversely impact wildlife habitats. A new approach to mapping potential debris blockages that can produce actionable information in a timely manner at a reasonable cost would be highly valuable to Vermont agencies at many levels of government.

The objectives of this project were to pilot test the use of an unmanned aerial vehicle (UAV) to gather stereo imagery of streambeds upstream of crossing structures, and develop a process of rapidly transmitting actionable information about potentially blocking material to stakeholders. A new system was developed in this project to identify potentially obstructing debris using a lightweight, easily-deployable UAV. The system was pilot-tested to provide safe, timely, and cost-effective information about potentially blocking material at vulnerable bridges and culverts. A process was also developed and tested for automating detection of these potential obstructions and outputting a data table containing an extracted thumbnail image of each identified obstruction.

Long-Term and Short-Term Measures of Roadway Snow and Ice Control Performance

<i>Project ID</i>	SPR-RSCH018 - 733
<i>Cost</i>	\$117,550
<i>Duration</i>	35 months
<i>Submitter</i>	Vermont Agency of Transportation Jonathan Razinger 1 National Drive Montpelier, Vermont 05633 802-498-7586
<i>Links</i>	http://vtrans.vermont.gov/sites/aot/files/highway/documents/materialsandresearch/completedprojects/20161025%20Final%20Report%2010-26-2016.pdf

Project Summary and Benefits

National roadway snow and ice control (RSIC) performance measures are not meaningful or accurate enough to capture roadway conditions throughout Vermont's network. This project develops a long-term performance measure, the Average Distribution Deviation, to measure the recovery time for the entire distribution of vehicle speeds rather than the recovery of a single measure like mean speed providing a more comprehensive assessment of RSIC performance that can be used for quality assurance of staff productivity, equipment allocation, and process evaluation. This project also develops a short-term measure using a thermal imaging video system that can provide near instantaneous feedback to inform the rate of application of chemicals by and routing of snow and ice control vehicles.



High Speed Ground Penetrating Radar for Road Pavement and Bridge Structural Inspection and Maintenance

<i>Project ID</i>	SPR-RSCH017 - 738
<i>Cost</i>	\$138,965
<i>Duration</i>	25 months
<i>Submitter</i>	Vermont Agency of Transportation Jonathan Razinger 1 National Drive Montpelier, Vermont 05633 802-498-7586
<i>Links</i>	http://vtrans.vermont.gov/sites/aot/files/highway/documents/materialsandresearch/completedprojects/Final%20Report%20-%20738%20-%20High%20Speed%20GPR%2010-17-2016.pdf

Project Summary and Benefits

This research developed a systematic methodology of employing ground penetrating radar (GPR) including instruments, subsequent data processing, and interpretation that can be used regularly as part of Vermont's roadway pavement and bridge evaluation program. GPR is a non-destructive evaluation technique that can be used without drilling destructive cores. It can also be used to identify better locations for cores. This project implemented and improved a high speed GPR system that allows driving speed roadway and bridge deck inspection. This facilitates inspections without road closures which are more efficient and safe. More inspections can be performed with the same resources.

Cost-Effective and Rapid Concrete Repair Techniques

<i>Project ID</i>	SPR-RSCH017 - 739
<i>Cost</i>	\$50,000
<i>Duration</i>	32 months
<i>Submitter</i>	Vermont Agency of Transportation Jonathan Razinger 1 National Drive Montpelier, Vermont 05633 802-498-7586
<i>Links</i>	http://vtrans.vermont.gov/sites/aot/files/highway/documents/materialsandresearch/completedprojects/UVM%20Project%20739%20Concrete%20Repair%20Final%20Report%203-13-2017.pdf?1

Project Summary and Benefits

The combination of age and severe environmental loading in Vermont has created the situation where the concrete in many transportation structures is in distress or well on its way to being distressed. The information collected during this project, along with the computer-based GUI have potential utility to Vermont Department of Transportation (VTrans) in concrete structure maintenance and repair. One overarching concept is that properly-timed applications of relatively low-cost maintenance actions can reduce the rate of degradation, and delay or prevent the need for costly repairs. These actions include the application of sealers to critical components, such as curbs, fascia and piers; the maintenance of proper drainage and gutters on expansion joints; and the maintenance of bearings to allow for proper movement of the bridge structure.

A second concept is that concrete repair and bridge maintenance decision-making is a complicated topic requiring consideration of bridge inspection history; structural characteristics peculiar to the particular type of design; available repair techniques; economic considerations; maintenance and inspection personnel; and above all, safety of the public. The computer-based GUI developed in this project collects and presents much of this information in a potentially useful manner. It may be possible to use this GUI and the associated information database as the basis of a tool that is directly useful to VTrans, or as a framework guiding the design and development of such a tool.

Structural Study of Cold Central Plant Recycling

<i>Project ID</i>	103659
<i>Cost</i>	\$3,315,753
<i>Duration</i>	51 months
<i>Submitter</i>	Virginia Department of Transportation Catherine McGhee 530 Edgemont Road Charlottesville, Virginia 22903 434-293-1973
<i>Links</i>	http://vtrc.virginiadot.org/



Project Summary and Benefits

The Virginia Transportation Research Council (VTRC) contracted with the National Center for Asphalt Technology (NCAT) to place three sections containing Cold Central Plant Recycling (CCPR) on the NCAT Test Track in 2012. As a result of the study, which showed excellent performance of a system including CCPR and full-depth reclamation (FDR), a Virginia Department of Transportation (VDOT) construction project consisting of reconstruction and lane widening was awarded in 2016 using these techniques. The construction project, located in Interstate 64 in eastern Virginia, is a seven-mile long project that will reconstruct the two existing lanes and add a third lane to the inside in both directions. The added lane will include CCPR while the reconstructed lane will include both CCPR and FDR. The design using recycling techniques was presented as an alternative to using traditional asphalt mixtures. VDOT estimated that the use of recycling techniques saved approximately \$10 million.

Investigating the Cost-Effectiveness of Nutrient Credit Use As an Option for the Virginia Department Of Transportation's Stormwater Permitting Requirements

<i>Project ID</i>	105218
<i>Cost</i>	\$116,800
<i>Duration</i>	11 months
<i>Submitter</i>	Virginia Department of Transportation Catherine McGhee 530 Edgemont Road Charlottesville, Virginia 22903 434-293-1973
<i>Links</i>	http://vtrc.virginia-dot.org

Project Summary and Benefits

The purpose of this study was to determine the feasibility of the Virginia Department of Transportation (VDOT) participating in water quality trading (WQT) in lieu of constructing onsite structural best management practices (BMPs) to achieve compliance with Virginia water quality standards for stormwater runoff for linear development projects. The objectives of the study were (1) to assess the potential credit demand for VDOT projects, focusing on the James River watershed as a case study, and (2) to compare the costs to VDOT of constructing BMPs and participating in WQT. Based on 19 years of historical data, VDOT could have used between 1 and 63 pounds of phosphorus credits per year and a median of 11 pounds of phosphorus credits per year for the James River watershed if current WQT guidelines had been in place over a period of time. In the hypothetical scenario where VDOT's participation in the WQT was allowed in lieu of VDOT's construction of nine BMPs, VDOT would have realized an average cost savings of 51%. These results suggest that participating in WQT at current market rates in lieu of constructing onsite structural BMPs is an economically feasible solution for VDOT to manage stormwater quality. The study recommended that VDOT's Location and Design Division continue purchasing stormwater credits for those projects that are eligible for WQT. To date, approximately 525 pounds of Nutrient Credits have been purchased by VDOT for various stormwater requirements. As a result, VDOT has saved an estimated \$16 million since it began purchasing credits in place of constructing stormwater BMPs (details below).

Scoping Study to Identify Potential Project Types and Situations that Will Not Create PM Hot Spots

<i>Project ID</i>	TPF-5(284)
<i>Cost</i>	\$1,600,000
<i>Duration</i>	63 months
<i>Submitter</i>	Washington State Department of Transportation Jon Peterson Research Office, PO Box 47372 Olympia, Washington 98504 360-705-7499
<i>Links</i>	http://www.nearroadaqpf.com/welcome

Project Summary and Benefits

Results from the “Scoping Study to Identify Potential Project Types and Situations that Will Not Create PM Hot Spots” shows that fine particulate matter emissions (PM_{2.5}) from on-road mobile sources are decreasing dramatically over the coming years and coarse particulate matter emissions (PM₁₀) have dropped, although not as sharply. In 2006, the EPA issued the PM Hot Spot Rule, along with qualitative guidance for assessing the near-road air quality impacts of “projects of air quality concern” (POAQC) in PM₁₀ and PM_{2.5} nonattainment and maintenance areas. This guidance provided several examples of what may be a POAQC, including a roadway with 125,000 annual average daily traffic (AADT) and 8% trucks. In 2010, EPA included these same examples in guidance for quantitative hot-spot assessments. Because the quantitative guidance requires extensive data collection and analysis, there is significant interest in understanding how air quality impacts of EPA’s example POAQC projects change over time with fleet turnover effects.

This research evaluated emissions from on-road mobile sources using EPA’s example case of 125,000 AADT and 8% trucks for 2006 and investigated how impacts of the project vary by analysis year (2010, 2015, 2020, 2025, 2030, and 2035), truck percentage, and traffic volumes using both EPA’s Mobile Vehicle Emissions Simulator (MOVES) model and the California Air Resources Boards’ EMFAC model. For PM_{2.5}, fleet turnover effects sharply reduce project-level emissions over time. For example, for an analysis year of 2015, impacts from a highway project with 125,000 AADT and 8% trucks are approximately 50% less than impacts from such a project in 2006. However, for PM₁₀, fleet turnover effects are not as large, as non-exhaust emissions processes (re-entrained road dust emissions, tire wear and brake wear) increasingly dominate project-level inventories over time, and these emissions vary little by analysis year. The study highlights the importance of project location and relevant National Ambient Air Quality Standard (NAAQS) to POAQC determinations, as exhaust emission reductions achieved through fleet turnover effects and congestion relief measures will provide much more benefit in PM_{2.5} nonattainment areas than in PM₁₀ nonattainment areas.

Earthquake Safety: Building a Flexible Bridge	
<i>Project ID</i>	GCB1341
<i>Cost</i>	\$400,000
<i>Duration</i>	48 months
<i>Submitter</i>	Washington State Department of Transportation Lu Saechao Research Office, PO Box 47372 Olympia, Washington 98504 360-705-7260
<i>Links</i>	https://www.youtube.com/watch?v=1klORMqXNLO



Project Summary and Benefits

The innovative materials Shape Memory Alloy (SMA) and Engineered Cementitious Composite (ECC) have been incorporated into a Washington State Department of Transportation bridge in Seattle, Washington, the first in the world of its kind. These materials have been integrated into the columns to create a more seismic resilient structure, replacing conventional steel reinforcement and concrete. The spring-like behavior of these materials is expected to provide a serviceable structure after a substantial earthquake. The current design philosophy for bridges experiencing strong seismic ground motions is to have a low probability of collapse. Such bridges may suffer significant damage, including concrete cracking and spalling, and steel reinforcement yielding. This damage may require closure for column repair or bridge replacement, leaving the structure unusable.

SMA is a superelastic nickle-titanium alloy that replaces the steel reinforcement in the plastic hinge region of each column. Like steel, SMA undergoes elastic and inelastic deformation when forces are applied to the material to dissipate energy. Unlike steel, SMA will return to its undeformed shape after the force has been removed. ECC replaces concrete in the plastic hinge region to eliminate the cracking and spalling that conventional concrete would incur. Shape Memory Alloy (SMA) is currently used in medical, industrial and military applications. The most familiar is in eyeglass frame design. The highway bridge in this project is adapting the superelastic behavior of SMA to resist earthquake motions. Current bridge design manuals specify design procedures for the conventional materials of steel reinforcement and concrete in bridge columns. Special consideration was required to incorporate these innovative materials into standard design applications and processes. Attention was also required to incorporate these materials into standard practices of the local construction industry.

The University of Nevada-Reno (UNR) previously tested these materials in their structural testing laboratory. First, small test were performed on each material individually, to understand their material properties. Larger static tests were performed when the materials combined, similar to a full scale application. Then, scale test of full bridges were done on shake-tables to determine the material performance under real-world earthquake

ground motions. Funds from the Federal Highway Administration's Innovative Bridge Research and Deployment (IBRD) Program funds were granted to fund scaled structural testing of the configuration of this bridge and to procure the innovative material for construction. UNR's test results verified the final configuration of the SMA and ECC. Fifteen years of these tests were performed to be certain that the materials will perform as expected, enough to give engineers confidence to incorporate them into a highway bridge, open to the public.

The current design philosophy of resisting strong earthquake motions is to provide a means of dissipating energy by permanently damaging steel reinforcement and concrete in specific location in bridge columns, without collapse. Replacing steel reinforcement and conventional concrete with SMA and ECC will eliminate the need for extensive repairs to fixed damaged bridge components or replace entire bridges. This eliminates the need for subsequent construction, reducing the need for additional materials and labor. The bridge can remain open to traffic without the need to create potential traffic delays and detours, eliminating environmental and economic impact. While a minor increase in initial project cost for the innovative materials is necessary, this increase is negligible when compared to repair/replacement costs and the impact a closed structure could have on the local economy. The incorporation of SMA and ECC are compatible with existing construction practices. This means that there are no negative impacts to current architectural methods of forming concrete. By splicing SMA onto steel reinforcement and confining ECC where SMA is used, the materials can be confined to specific regions of the structure as needed. This means they can be utilized where they are most effective.

Bridge Design: Accounting for Shear Strength in Concrete-Filled Steel Tubes and Reinforced Concrete-Filled Tube Components

<i>Project ID</i>	T1461-04
<i>Cost</i>	\$250,000
<i>Duration</i>	32 months
<i>Submitter</i>	Washington State Department of Transportation Lu Saechao Research Office, PO Box 47372 Olympia, Washington 98504 360-705-7260
<i>Links</i>	http://www.wsdot.wa.gov/research/reports/700/shear-design-expressions-concrete-filled-steel-tube-and-reinforced-concrete

Project Summary and Benefits

Deep pile and drilled shaft foundations, frequently utilized in bridge construction are increasingly important for seismic design in Washington state, because of increased seismic design load demands in bridge design specifications. A common caisson type is a concrete filled steel tube (CFST) or reinforced concrete filled steel tube (RCFST). However, due to a lack of design guidelines, current WSDOT design methods are conservative and neglect the many benefits provided by composite action of the concrete and the steel tube, which may result in increased cost and size of the foundation. This research project experimentally investigated the shear resistance and deformation of CFST and RCFST members and developed an improved and more accurate shear strength expression. The experimental study included 22 large-scale CFSTs subjected to four-point bending. The study results indicate that the shear strength of CFSTs and RCFSTs is on average 2 times the current WSDOT expression. This new design expression for shear resistance has been proposed for implementation in the WSDOT Bridge Design Manual (BDM).

Benefits of CFST/RCFST:

- Permits smaller diameter and shorter caisson foundations resulting in cost savings associated with smaller piles and drilled shafts, less material and reduced construction time and cost.
- The steel tube serves as formwork and reinforcement for the concrete fill. The concrete fill restrains buckling deformation of the steel tube, and significant resistance and inelastic deformation capacity are achieved with CFT. These are valuable qualities for bridges that are in seismically active regions and are on sites with soft liquefiable soils.

- Versatile. Can be installed below ground (driven, vibrated or oscillated into the ground) or above ground (lifted into place, braced as needed, and then similarly filled with concrete without the need for temporary formwork).



Preliminary Analysis of Use of Mass Concrete in West Virginia

<i>Project ID</i>	RP-257
<i>Cost</i>	\$297,702
<i>Duration</i>	66 months
<i>Submitter</i>	West Virginia Department of Transportation Donald Williams 2030 Canterbury Drive Morgantown, West Virginia 26505 304-677-4000
<i>Links</i>	

Project Summary and Benefits

The significance of this research will provide a much more durable concrete that will have a long-term benefit cost return by not having to repair key bridge elements in the future. The information collected clearly showed cracking of concrete members based on temperatures differentials producing strains exceeding certain strength limits. The results showed that if the tensile stress in the concrete while curing exceeded 80% (20% safety factor) of the estimated tensile strength, the member cracked, thus becoming a “mass concrete” member. These strains could be accurately predicted by the FEM. As a result, a composite statewide mix design was developed and then tested in the FEM. The results showed that circular columns became mass at four feet, square at three feet, and rectangular at two feet. These numbers are different than the old specification that indicated the member has to exceed 4 feet. These final results are implemented into a phase two that uses the same modeling but a new mix design that is much cooler. The goal is to ultimately eliminate most concrete bridge elements as deemed mass concrete by either understanding their size, shape, or mix type.

Evaluation of Thin Polymer Deck Overlays and Deck Sealers

<i>Project ID</i>	0092-12-06
<i>Cost</i>	\$199,696
<i>Duration</i>	59 months
<i>Submitter</i>	Wisconsin Department of Transportation Andrew Eiter 4802 Sheboygan Avenue Madison, Wisconsin 53707 608-261-8620
<i>Links</i>	http://wisconsindot.gov/documents2/research/12-06-2nd-final-report.pdf

Project Summary and Benefits

Deterioration of concrete bridge decks is a major maintenance concern in Wisconsin, particularly in the northern snow-belt regions where deicing salt is used to treat roads and bridges during winter months. The salt that is necessary to keep traffic moving safely in winter can accelerate deterioration of bridge decks and corrode embedded steel components. Sealers and overlays are used to prevent corrosive chlorides from penetrating the concrete and improve skid resistance by mitigating the damaging effects caused by vehicles, deicing salts, and freeze-thaw cycles. These practices have resulted in varying levels of success in preserving affected bridge decks in a cost-efficient manner. Application can be expensive, time consuming, and result in traffic disruptions. Additionally, corrosion activity may continue unabated even after application if chloride contamination already exists.

This research was performed to explore cost-efficient solutions to these prevailing problems. Laboratory tests were performed on nine sets of different treatment systems to compare the performance of the selected systems against each other and a control group of uncoated specimens. Reinforced 15 in. x 15 in. x 4 in. concrete slab specimens matching conventional WisDOT mix designs were subjected to accelerated corrosion, freeze-thaw cycling, heat/ultraviolet/rain cycles and tire wear tests, including “snow plow” application. The overlay system with an epoxy resin and flint rock aggregate provided the best overall performance. Benefits of thin polymer overlays include lower deadweight and lane closure times compared to concrete overlays, and increases in surface friction, skid resistance and life expectancy. Applying overlays requires only eight hours of lane closure and can extend bridge deck life to seven to 15 years.

Recycled Materials Resource Center – Third Generation

<i>Project ID</i>	TPF-5(270)
<i>Cost</i>	\$400,000
<i>Duration</i>	39 months
<i>Submitter</i>	Wisconsin Department of Transportation Andrew Eiter 4802 Sheboygan Avenue Madison, Wisconsin 53707 608-261-8620
<i>Links</i>	http://www.pooledfund.org/Details/Study/499



Project Summary and Benefits

Over the past 15 years, State DOTs have made significant progress incorporating recycled materials and industrial byproducts in transportation infrastructure. Recycled materials add economic value, enhance service life, and promote sustainability by reducing emission of greenhouse gases, consumption of energy, and consumption of natural resource during construction. Despite these benefits, many recycled materials remain under-utilized due to technical and institutional barriers. The Recycled Materials Resource Center (RMRC) was created to assist State DOTs and FHWA in breaking down these barriers through research and outreach activities focused on the wise and safe use of recycled materials. The goal of the third generation RMRC was to provide the resources for applied research and outreach to increase utilization of recycled materials and industrial byproducts in transportation applications.

This year's activities included two research efforts and the development of a web application. Research on the benefits of recycled materials in road construction gathered direct information on sustainability assessment characteristics. Greenhouse gas emissions, energy, water consumption, and waste generation were reduced by 70% to 99% when states used recycled industrial byproducts such as fly ash, recycled concrete aggregate (RCA), and recycled asphalt pavement (RAP). The cost analysis indicated potential savings of up to \$17 million. RCA and RAP were examined as more cost efficient and environmentally friendly alternatives to traditional backfill sources in mechanically stabilized earth (MSE) walls. Results showed RCA is an adequate alternative while RAP is not. The online Geographic Information System (GIS) web application that was developed connects producers and consumers of recyclable material to help engineers and contractors make the best use of recycled materials in transportation projects.

Historic Winter Weather Assessment for Snow Fence Design Using a Numerical Weather Model

<i>Project ID</i>	WY-17/03F
<i>Cost</i>	\$19,178
<i>Duration</i>	17 months
<i>Submitter</i>	Wyoming Department of Transportation Enid White 5300 Bishop Boulevard Cheyenne, Wyoming 82009 307-777-4182
<i>Links</i>	http://www.dot.state.wy.us/home/planning_projects/research-center/final-projects-fy2009-to-fy2013.html

Project Summary and Benefits

The Project Champion revised the wind and winter precipitation tables for snow fence designs using the WRF model; compared the existing wind and winter precipitation table created by Dr. Ronald D. Tabler in 1997, with new data gathered by WYDOT and the University of Wyoming to gauge any significant changes in the data currently used by WYDOT; and assisted WYDOT in setting up policies and practices that revolve around the new wind and precipitation data generated by the findings in this report.



Planning Support for Mitigation of Wildlife Vehicle Collisions and Highway Impacts on Migration Routes in Wyoming

<i>Project ID</i>	FHWA-WY-1610
<i>Cost</i>	\$29,201
<i>Duration</i>	25 months
<i>Submitter</i>	Wyoming Department of Transportation Enid White 5300 Bishop Boulevard Cheyenne, Wyoming 82009 307-777-4182
<i>Links</i>	

Project Summary and Benefits

Wyoming Department of Transportation (WYDOT) continues to work extensively to mitigate wildlife-vehicle collisions. Wyoming has 27 identified deer-vehicle collision hotspots. Deer collisions at these hotspots, and other areas in Wyoming, pose a safety hazard and are costly. They often result in significant damage to vehicles, injury to vehicle occupants, and usually result in the death of the animal. WYDOT's estimated cost per collision is approximately \$11,600 in injury and property damage, and \$4,000 in the unclaimed restitution value of each mule deer that is killed. Fewer than half of deer collisions are reported. Unreported deer collisions are likely due to lesser damage to vehicles but usually results in an animal fatality. Injury and damage costs from deer-vehicle collisions total approximately \$24-29 million per year in Wyoming, with an additional \$20-23 million per year in wildlife costs. The hotspots correlate with migration routes and winter-use areas. By identifying problem areas, WYDOT is better able to address the issue and implement cost-effective mitigation practices to lower incident costs to the public and to the wildlife. In fact, by using data gathered from this study and other similar studies, Wyoming was able to install crossing structures in a number of identified high deer traffic locations. The data from this study allowed WYDOT to improve its knowledge of where wildlife-vehicle collisions occur.