RESEARCH IMPACTS
2018

Better

Faster

Cheaper
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INTRODUCTION

Research Impacts 2018: 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 2018.”

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

Connecticut DOT  Development of the Digital Design Environment at the CTDOT Phase 1
Maryland DOT  GIS-Based Subsurface Exploration System
New Hampshire DOT  Dirt Isn't Just Under Your Fingernails
Pennsylvania DOT  Storm Water Control Management & Monitoring

Region 2

Florida DOT  Application of Demographic Analysis to Pedestrian Safety
Kentucky Transportation Cabinet  Snow and Ice Route Optimization
South Carolina DOT  Ranking of Pavement Preservation Practices and Methods
Tennessee DOT  Innovative Strategies for Public Involvement for TDOT

Region 3

Indiana DOT  Friction Surface Treatment Selection: Aggregate Properties, Surface Characteristics, Alternative Treatments, and Safety Effects
Iowa DOT  Traumahawk
Michigan DOT  Wireless Data Collection Retrievals of Bridge Inspection / Management Information
Wisconsin DOT  Critical Factors Affecting Asphalt Concrete Durability

Research Impacts 2018: Better—Faster—Cheaper
Region 4
Montana DOT Rockfall Hazard Process Assessment
Nevada DOT Streamlining Hydrologic Prediction Processes Using New and More Accurate Techniques and Methods
Utah DOT Using a Safety Forecast Model to Calculate Future Safety Metrics
Wyoming DOT Mitigation Strategies to Reduce Truck Crash Rates on Wyoming Highways

High Value Research in Safety and Pavements

Additionally, AASHTO publishes two topic-specific brochures each year to highlight key research areas. The topics for 2018 are safety and pavements, and each of the RAC regions voted to select two additional projects for each brochure. The 2018 brochures highlight the projects below. These featured safety and pavement projects are also noted in the table of contents.

Safety

Region 1
Connecticut DOT Enhancing Connecticut’s Crash Data Collection for Serious Injury and Fatal Motor Vehicle Collisions
New Jersey DOT Evaluation of Raised Pavement Markers (RPMs)

Region 2
Louisiana DOTD LaSET: Louisiana Safety Evaluation Tool
South Carolina DOT Integration of the Incident Command System (ICS) Protocol for Effective Coordination of Multi-Agency Response to Traffic Incidents

Region 3
Iowa DOT Blue Lights on Iowa DOT Snow Plows
Michigan DOT Comparison of Alternative Pedestrian Crossing Treatments

Region 4
Caltrans Collecting Work Zone Accident Data
Oregon DOT GOAL ONE: A SAFE RETURN EACH AND EVERY DAY Safety Guidelines for Transportation Researchers
## Pavements

### Region 1
- **New Hampshire DOT**
  - Testing Asphalt in Lab and at Project
- **New Jersey DOT**
  - The Use of Porous Concrete for Sidewalk

### Region 2
- **Florida DOT**
  - Alternative Aggregates and Materials for High Friction Surface Treatments (HFST)
- **North Carolina DOT**
  - Alternate Methods for Evaluation of Moisture Sensitivity of Asphalt Mixtures

### Region 3
- **Kansas DOT**
  - Well Bonded Superpave Overlays on HMA (CISL Experiment No. 17)
- **Ohio DOT**
  - Development of an Overlay Design Procedure for Composite Pavements

### Region 4
- **Washington State DOT**
  - Improved Methodology for Benefit Estimation of Preservation Projects
- **Washington State DOT**
  - Rapid Road Rehab (R3): Web-based Road Rehabilitation Planning, Design and Construction Decision Support Tool

## Learn More

The electronic version of this document, as well as the brochures “Research Makes the Difference 2018,” “Safety Research 2018,” and “Pavement Research 2018,” may be found on AASHTO’s research website, [research.transportation.org](http://research.transportation.org).

## Acknowledgments

Cover image sources (top to bottom): Tennessee DOT, Iowa DOT, Indiana DOT.
Evaluation of High-Rate Settling Technology for Sediment Control in Roadway Construction Sites

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Project Summary and Benefits

This investigation provided important insights and demonstrated the relevance of large-scale, reproducible sediment basin testing techniques to improve current practices and to achieve greater in-field performance. It made use of a large-scale sediment basin at the Auburn University Erosion and Sediment Control Testing Facility (AU-ESCTF) intended to test several sediment basin design configurations. The investigation involved several types of performance measurements of the current standard design and evaluated alternatives aimed at the improvement of sediment basin performance.

One of the great aspects of the AU-ESCTF apparatus is the ability to control testing conditions, enabling measurements to be taken without unpredictable runoff and erosion contributions on active construction sites. This sediment basin testing apparatus enables a method to test systematically basin configurations and treatment technologies in controlled scenarios. These scenarios, while replicating field conditions, enable repetitions of tests, which in turn provides a higher degree of certainty that the measurements and results are consistent. Results of these tests will lead to improved design guidance that practitioners can refer to when incorporating sediment basins as an element of the stormwater pollution prevention plan for construction sites.

The constructed sediment basin has a total storage of 2,790 ft³ (79.0 m³). The metered water and sediment introduction apparatus were developed to allow researchers to control the inflow of material into the basin. Hydrological analyses were used to determine applicable flow and sediment rates for testing, which lends to a uniformed testing procedure that can be applied in various geographical areas based on local rainfall and soil.
hydrology characteristics. A phased testing regime allowed for evaluating sumps, modified baffles, and high-rate lamella settling technology.

The basin was subjected to a number of tests in eight series to evaluate treatments under replicated events and overtopping conditions. Data collection included: water quality parameters (TSS, turbidity, and temperature), inflow rates, basin stage levels, sediment deposition volumes, and sediment sampling for particle characterization. Such measurements were used to evaluate the performance of various tested practices in the basin. The developed methodology allowed AU-ESCTF researchers to provide testing guidance for the evaluation of sediment basin technology.

The following are the conclusions of this research project:

- Observed results showed that the use of an excavated sump in the forebay had no significant effect on water quality treatment in the basin in terms of turbidity. In terms of sediment weight, the alternative with an excavated sump increased in 1.6% the sediment capture in the forebay region. The sediment weight was also increased by 3.3% within Bays 1 through Bay 4. While these changes are too significant, the presence of an excavated sump increase the capture of larger sediment particles outside the sediment basin, resulting in easier maintenance for the basin.

- The use of a modified coir first baffle with 10.9% percent open area was shown to be less effective in treating turbidity than the standard ALDOT baffle configuration.

- The MFE-I was determined to be the ALDOT standard configuration with excavated sump in the forebay. The MFE-I was used for Phase II testing of the high-rate lamella settlers in the upward and parallel flow configurations.

- Both lamella settler configurations treated stormwater more effectively than the MFE-I system without the settlers, and the most effective was the alternative with parallel flows (S7 treatment). The drop in turbidity between Bay 1 and Bay 4 for S7 treatment was more significant than the corresponding one for S6 treatment (lamella settlers with upward flow) by 18.2%. When comparing this drop between S7 and S5 treatment (MFE-I), the difference is 29.0%.

- During all overflow tests performed, the sediment basin had a higher efficiency during the overtopping event than did during the empty fill condition. This indicates that having dead storage in the basin is important to provide dilution to highly turbid receiving flows, and to dissipate the energy, reducing resuspension of settled particles. Future studies should focus on other scenarios with the sediment basin partially filled, for instance 10% or 30% filled prior to the second inflow admission.

- Cold water temperatures have an effect in decreasing sediment basin effectiveness. With lower temperatures and higher water viscosity it has been noticed that the turbidity decay over time is less pronounced than conditions at higher temperature. However, further investigations on the effects of temperature are still necessary to assess the effects of temperature to settling in sediment basins in a more comprehensive way.
The TSS-Turbidity relationships derived in this study varied according to the location in the sediment basin and according to the turbulence in the basin. During inflow conditions, the levels of TSS were much larger in Bays 1 and 2 than the values measured in Bays 3 and 4. When inflows stopped, the TSS-Turbidity correlation improved significantly, which indicates that turbulence in the earlier stages of the filling can result in resuspension of larger sediment particles, which in turn impact TSS. Finally, the drop in TSS across the four bays was much more pronounced than the drop in turbidity, which points to the usefulness of dividing the sediment basin with porous baffles.

Measurements of turbidity at various depths and locations in the basin pointed to the loss of performance of the sediment basin over the three test repetitions, particularly in the case when the basin is initially empty. From all tested treatments, the lamella settler with parallel flows (S7 treatment) was the one with best performance in preventing large increase in turbidity levels in the basin over the three test repetitions.

Particle size distribution (PSD) results obtained with laser diffraction technology indicated that the fraction of larger suspended sediment present in the approach channel and Bay 1 inflow is much higher than in the rest of the sediment basin. Also, a comparison between the PSD results upstream and downstream from the lamella settler indicated a measurable drop in the number of particles in the size range of 12 µm to 100 µm, which indicates that this is the range of sediment sizes that these plate settlers are more effective in capturing.

The last experimental conditions tested, which were added to the initial scope of work to the project, evaluated the alternative use of a small lamella settler unit to decrease the turbidity of the sediment basin effluent, and discharged by the skimmer. The smaller storage provided by the small lamella settler did not impact the turbidity, but created a buffer than prevented any turbidity spike at Bay 4 to be discharged. However, when flocculant was mixed and added to the inflows in the small settler unit, there was a significant drop in turbidity from the skimmer discharge and the settler discharge. The levels of turbidity were consistently under 100 NTU, and the average settler discharge turbidity was four times smaller than the skimmer inflow.

Numerical modeling results obtained with CFD flow simulations of the basin filling process demonstrated that the porous baffles have a large impact in dropping the average velocity at the bottom of the basin during early stages of the filling process. Over time, the positive impacts of porous baffles decrease since the overall velocities in the basin decrease with the gradual volume accumulation.

Future research efforts should use results from this project, allowing for further improvements to enhance the performance of sediment basins used in the field while also lending to educational outreach that will continue to increase the general knowledge in the ESC industry. The recommended topics for the continuation of this research are the following:

1. Flow characterization in sediment basins undergoing filling and dewatering processes are still largely unknown and most design recommendations are based on empirical evaluations.
2. Continuation and expansion of research in temperature impacts of sediment basins. Enabling methods improve the performance of sediment basins operating with low temperature runoffs.
3. Extensively evaluate the use of lamella settler tanks to treat skimmer discharges using flocculant rather than applying these at the entrance of the sediment basins. The rationale is that a wide range of sediment particles entering sediment basins can be removed by a settling process. With more parsimonious use of flocculants to treat only the finest fractions discharged by skimmers, it is expected that the discharge of these chemicals in the environment can be reduced, along with the overall consumption of flocculants in construction sites.

4. More extensive application of flow simulation may provide further insights into the processes and geometry characteristics of basins, and result in some design recommendations. Such design recommendations will point to more effective basin geometries and construction details.
A Study of the Effects of Pavement Widening, Rumble Strips, and Rumble Stripes on Rural Highways in Alabama

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| Submitter  | Alabama Department of Transportation  
Ron Johnson  
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Project Summary and Benefits

Evolution of the Implementation of Paved Shoulders, Shoulder Rumble Strips, and Shoulder Rumble Stripes on Rural Highways

A survey was distributed to all state transportation agencies in the United States to verify the state of the practice of the implementation of paved shoulders, shoulder rumble strips, and shoulder rumble stripes as countermeasures to avoid run-off-the-road (ROR) crashes in two-lane rural roads. The survey was completed by 20 state transportation agencies in the country.

Results showed that 70% of the agencies implement paved shoulders when new pavement are constructed, while only 40% of the agencies have shoulder paving as stand-alone projects. While all agencies consider traffic volume as a factor in defining shoulder width, 85% also consider functional classification as a factor. Some geometric design elements such as horizontal and vertical alignment are not relevant factors when defining the shoulder width. Only 20% and 15% of the states consider horizontal and vertical alignment, respectively, as a factor that establishes the width of the shoulder.

Shoulder width was the main factor to determine whether shoulder rumble strips and stripes should be applied. The need for applying shoulder rumble strips and stripes was also highly influenced by speed limit (70% of the states) and area type (65% of the states.) Most states only have a policy for rural roads when speeds are higher than 50 miles per hour. Some agencies reported that noise would be a serious problem if rumble strips and stripes were applied in urban areas. Presence of bicyclists was a relevant factor (65% of the states) when
deciding which shoulder width should be the minimum for applying shoulder rumble strips and stripes; in most cases, this value is 4 feet.

All state transportation agencies apply paved shoulders and shoulder rumble strips as an effort to prevent crashes; 80% of the agencies also apply shoulder rumble stripes. The range of shoulder widths varies from 1.5 feet to 12 feet; the general practice for most agencies is that paved shoulders are at least 4 feet wide. The majority of the agencies reported that no study to evaluate the effectiveness of the treatments had been performed.

Crash frequencies and crash rates were the most reported methods of safety evaluation for most agencies that conducted related studies, which shows limitations as the results of these methods cannot lead to conclusions as relevant as the ones resulting from an Empirical Bayes analysis, for example.

**Effects of Pavement Widening, Rumble Strips, and Rumble Stripes on Rural Highways in Alabama**

This study evaluated data from 101 projects in Alabama representing 678 miles of segments on two and four-lane rural roads that had 2 to 4 ft of paved shoulders constructed, and in some cases, rumble strips or rumble stripes were scored into the pavement within the shoulder. The evaluation of the effectiveness of the implemented countermeasures after ALDOT’s policy was based on an EPDO analysis, an Empirical Bayes method, and a benefit-cost analysis. For two-lane roads, the EPDO analysis showed a reduction of EPDO scores of 3.78% for the combined effect of paved shoulders and shoulder rumble strips, 3.51% for the combined effect of paved shoulders and shoulder rumble stripes, and 10.67% for paved shoulder only. For four-lane roads, there was a reduction of EPDO scores of 11.10% for the combined effect of paved shoulders and shoulder rumble strips and a reduction of 4.01% for paved shoulder only. It can be inferred that all methods reduced ROR crashes; however, a comparison between treatments is not recommended, as the method can be sensitive to small sample sizes and different traffic volumes.

The EB method was performed applying the Highway Safety Manual SPF. For two-lane rural roads, the analysis resulted in CMFs of 0.79, 0.82, and 0.72 for the combined effect of paved shoulder and shoulder rumble strips, the combined effect of paved shoulder and shoulder rumble stripes, and paved shoulder only respectively. For four-lane roads, CMF for the combined effect of paved shoulder and shoulder rumble strips was 0.84 and for paved-shoulder only it was not significant or reliable. Similar conclusions to the EPDO analysis resulted from the EB analysis: all treatments reduce ROR crashes. Again, a comparison between treatments is not recommended, since it cannot be assumed that it is better to implement paved shoulders without scoring, as the 95% confidence intervals for the CMFs overlap.

Benefit-cost ratios also showed that all treatments improve safety, providing more benefits that the cost for their implementation. On two-lane roads, B/C ratios were 42:1, 33:1, and 53:1 for the combined effect of paved shoulder and shoulder rumble strips, the combined effect of paved shoulder and shoulder rumble stripes, and paved shoulder only respectively. On four-lane roads, B/C ratio was 42:1 for the combined effect of paved shoulder and shoulder rumble strips and 19:1 for the paved shoulder-only treatment.

**Recommendations**

This study recommends that state transportation agencies should perform statistical analyses, especially applying methods outlined in the HSM, when data is available to quantify the effectiveness of treatments examined in this study. It will be important to provide agencies enough information on the safety effectiveness of the countermeasures applied to avoid crashes. This safety effectiveness evaluation showed that ROR crashes
are reduced by all three implemented countermeasures in two and four-lane rural roads in Alabama. It is recommended that ALDOT continues implementing their policy. For conclusions regarding the comparison between treatments, a follow-up study with additional years of data and sites is recommended.
Catastrophic Icefall Hazard Assessment, Avoidance Procedures & Mitigations Strategies - Phase II Site-Specific Studies

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| Submitter  | Alaska Department of Transportation  
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Links
http://www.dot.state.ak.us/stwddes/research/assets/pdf/4000-168.pdf

Project Summary and Benefits

Icefall hazards are not routinely considered by the civil engineering and geologic/natural hazards community. Slabs of ice have the potential to cause significant damage to persons or structures beneath the fall path. Engineers lack the design criteria available for dealing with this “ghost-like” hazard. The April 6, 2012 icefall event near MP 113 along the Seward Highway resulted in serious injury to a motorist. As a result, Alaska DOT&PF has undertaken research aimed to better understand icefall hazards and quantify risk of impact along state highways. The icefall hazard research project was initiated in 2015 and was broken down into two distinct phases: Phase No. 1- Literature Review (completed February 28, 2016) and Phase No. 2- Site-Specific Icefall Hazard Studies.

This research report summarizes the results of Phase No. 2 and details the results of onsite studies and preliminary icefall hazard technical evaluations and risk assessments. It also provides key icefall predictive indicators and a range of recommended mitigation solutions worthy of further consideration. Site studies were completed in September of 2016 (Visit No. 1) and March of 2017 (Visit No. 2) in order to evaluate summer and winter conditions, respectively. We assessed a total of seven sites -- four along the Seward Highway south of Anchorage and three sites along the Richardson Highway north of Valdez. We documented sources of upslope water during site Visit No. 1 and, measured and observed ice slab dimensions for Site Visit No. 2. Six out of the seven sites contained well-developed ice slabs available for observation. Small-scale active ice sloughing was observed at MP 113.2 along the Seward Highway due to slope heating.
Ice will generally develop when air and rock slope surface temperatures are below 32 degrees Fahrenheit, and when there is an upslope source of water captured by the rock slope. Solar radiation intensity; air and bedrock surface temperatures; and a consistent supply of water all affect ice slab growth rate and thickness. Steady-state surface water overflow appears to be a primary causative factor in generation of large ice slab formations. Ice will develop an adhesion strength between the rock surface and the ice slab and this adhesive bonding is the primary source of stability during subfreezing temperatures.

When the temperature of the rock slope surface exceeds 32 degrees Fahrenheit, melting of the adhesive interface bond commences. During periods of prolonged slope heating which act as a “triggering mechanism” towards instability, the adhesive bond may be compromised and the ice slab may be subject to failure. For slopes with angles less than approx. 4V:1H, sliding is the primary instability mechanism. For slope angles approaching near-vertical or even overhung, falling or localized slab toppling are possible failure mechanisms. Once the ice slab has failed, icefall impacts are possible along the roadway section.

“Direct impact” are those events where the falling ice mass makes initial impact. Depending of available catchment ditch width, direct impacts could fall within the ditch or could impact the roadway. Secondary effects from impact include “shatter” (break-up) and “splatter”, with icefall shatter being responsible for casting ice fragments horizontally away from the impact location. Direct impact events could impart a significant force to those surfaces being impacted, on par with that imparted from rockfall events. Potential icefall predictive indicators include air and bedrock surface heating. In general, south facing, dark-colored high density bedrock will heat up faster than the local ambient air temperature.

A study by Graveline and Germain found that an increase in cumulative melting degree days is empirically correlated with icefall occurrence, meaning that icefall is possible during prolonged periods where average daily temperatures exceed 32 degrees Fahrenheit. The ice mass itself is also subject to strength reductions as a function of temperature increase. Ice with coarse-grained granular structure and entrained air can indicate weakening. Preliminary icefall impact risk assessment was completed at the seven sites, based on icefall history, traffic volume, sight distance, and slope height, and available catchment width. The MP 113 site along the Seward Highway was classified as having a “High” risk of icefall impact; MP 14 along the Richardson Highway was ranked as having “Moderate to High” impact risk; and, the MP 52 site along the Seward Highway was found to have a “Low to Moderate” level of icefall impact risk. The other four sites were ranked as “Low” icefall impact risk.

There are a range of potential solutions that could be considered for sites with elevated icefall impact risk. These include monitoring with instrumentation, upslope drainage path modification, traffic pattern modifications, slope re-grading (i.e. blasting), or adaptation of rockfall structures like barriers and netting. Ice removal is also an option, however, ice scaling is considered to be relatively risky and would likely be a “last resort”.

Based on the results of the Preliminary Icefall Impact Risk Matrix, we recommend that DOT&PF consider installation of remote monitoring instrumentation at MP 113 and MP 52 along the Seward Highway, and MP 14 along the Richardson Highway. This set-up should include a camera and weather station (like RWIS) and should also include installation of a pyranometer and slope surface (bedrock) temperature gauge. All of these would allow for observation of ice behavior with respect to changing weather conditions. Additionally, slope excavation and/or upslope drainage diversion should be considered for MP 113. Excavation of the slope would provide for greater catchment and push the slope away from the traveled roadway. The drainage diversion would reduce the volume of water being captured by the slope crest.
A traffic pattern modification consisting of a proposed two lane diversion will help to provide additional horizontal offset between the slope and the traveled lanes during periods of slope warming. The MP 14 site along the Richardson needs a temporary (i.e. short-term) one lane traffic diversion during expected periods of slope warming, when bedrock surface temperatures are expected exceed 32 degrees Fahrenheit for when active ice melting is observed. Given the site’s highway width constraints, a barrier is considered to be one of the only effective long-term (low maintenance) solutions available for icefall hazard mitigation.
## Seismic Performance of Reinforced Concrete Filled Steel Tubes in Soil

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| **Submitter**  | Alaska Department of Transportation  
Carolyn Morehouse  
3132 Channel Drive  
Juneau, Alaska 99811  
907-465-8140 |

### Project Summary and Benefits

Reinforced concrete filled steel tube (RCFST) pile-columns, also known as RCFST drilled shafts, are structural elements used in bridge support systems in regions of high seismic activity. This system consists of a steel tube that is filled with concrete and internal longitudinal and transverse reinforcement. This system has several advantages over traditional systems. Beyond increased strength and deformation capacities, this type of elements serve as a foundation element (pile) inground and as a column aboveground. Moreover, the steel tube serves as permanent formwork, which in turn contributes toward accelerated and cleaner construction processes. The main goal of the research described in this document aimed to study the effects of soil stiffness on the performance of RCFST pile-column specimens.
From AWOS/RWIS to Caltrans Aviation Weather Information (AWI)

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| Submitter  | California Department of Transportation  
Melissa Clark  
1727 30th Street 3rd Floor, MS-83  
Sacramento, California 95816  
916-227-4172 |

Project Summary and Benefits

Aviation Weather Information Web Portal. The objective was to capitalize on new technology that enables the importing of data from public weather providers to be viewed from one website. This approach offers multiple weather reporting types from existing, credible, weather agencies on a single website giving a broader picture of weather that could affect aviation in areas that otherwise would not have this capability. Before the development of the prototype system, users needed to access disparate, independently operated systems to obtain wind and temperature conditions, forecasts, warnings, and advisories, which was time consuming and demanded different means of access. Centralizing the information enables users to obtain multiple data feeds in one place, providing a comprehensive picture of the conditions affecting air travel to make a more informed and efficient assessment. The transfer is expected to be completed in the Spring of 2018. The system will improve safety and increase efficiency in Caltrans as well as other aviation agencies. The system will help aviators to make more informed decisions; enable more system/airport managers to access meteorological conditions data in order to enhance operational safety, reliability and efficiency; and it will enable residents and travelers to access weather information in larger areas. The unified data source will provide for better aviation related trip planning.
California Department of Transportation

Collecting Work Zone Accident Data

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| Submitter  | California Department of Transportation  
             Juan Araya  
             1120 O Street  
             Sacramento, California 95814  
             916-653-2575 |

Project Summary and Benefits

Work zone related injuries and fatalities are a major safety concern in California and nationwide. According to the Federal Highway Administration, one work zone related injury occurs every 14 minutes, and one fatality occurs every 15 hours, resulting in an average of 96 injuries and 1.6 fatalities per day. Work zone accidents and injuries have a high cost, including medical fees, loss of life, property damage, lost earnings, travel delay, vocational rehabilitation, administrative costs, legal fees, pain, and diminished quality of life. Based on five years of data for California, the average yearly cost of all work zone incidents is approximately $382 million.

Various ideas to prevent work zone incidents have been considered, such as keeping workers in vehicles, changing driver behavior with publicity campaigns, using full road closures, or working at night when traffic is reduced. But data to justify a particular mitigation measure was unavailable. Although databases and data sources exist, such as the Statewide Integrated Traffic Records Systems (SWITRS) based on California Highway Patrol crash reports and the Caltrans Traffic Accident Surveillance and Analysis System (TASAS), they report only locations and outcomes, not causes. To address the causes, more information is needed about the incidents, the severity of the injuries, contributing factors, and resulting property damage. In addition, methods to estimate the associated costs and remedies can be useful.

Caltrans, in partnership with the University of California, Davis Advanced Highway Maintenance and Construction Technology (AHMCT) Research Center, extracted and classified traffic collision report data on incidents occurring near work zones across California between 2006 and 2010. This information was codified in terms of contributing factors and outcomes, designed to allow analysis of the data for planning and managing work zone operations to improve worker and motorist safety. The comprehensive database based on five years
of data includes the information needed to develop mitigation measures. It provides answers on what kind of incidents occur in work zones and the cause. This data-driven, decision-support tool facilitates safer work zone planning and management. Caltrans can also evaluate the cost-benefit of different work zone protection systems.
Connecticut Department of Transportation

Low Cost Wireless Fatigue Crack Monitoring System Using RFID Arrays

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| Submitter  | Connecticut Department of Transportation  
            Bradley Overturf  
            2800 Berlin Turnpike  
            Newington, Connecticut 06111  
            860-594-2089 |

Project Summary and Benefits

The ability to rapidly assess the structural integrity of transportation systems is of critical importance to bridge owners and the public, at large, for elongated service life, reduced maintenance cost, and safety. Our transportation systems typically have everyday cyclic loads, which could induce fatigue crack on the metal structures, which could develop to unexpected sudden failure below the design load. The traditional crack monitoring systems, e.g., nondestructive evaluation or continuous monitoring with fiber optic sensors are typically expensive and require a high level of experience, which hindered widespread use of these monitoring systems for bridge inventory.

In recent years, wireless smart sensors have been state-of-the-art in civil structural health monitoring due to its versatility and low cost. Among them, radio frequency identification (RFID) has drawn attention by researchers to monitor strain and cracks leading their research in this area with in-house developed RFID tags. RFID is the wireless use of electromagnetic fields to transfer data, and is typically used in transportation such as freight tracking, railroads, E-ZPass, and many other industries. Currently, RFID tags are mass produced at a very low cost, the communication protocols are standardized and efficient, making RFID an ideal wireless communication infrastructure for dense arrays of sensors, i.e., pervasive sensing.

An RFID crack system consists of a passive tag, or tags, attached on a metal surface, and a data acquisition unit. The data acquisition unit typically consists of a PC with software, data logger, and antenna, but it could be replaced by a handheld wireless unit. Once electromagnetic waves are transmitted from the antenna to the tag wirelessly, a portion of the waves are reflected to the antenna back. If there is any damage or cracks, the
percentage of the reflected waves changes; i.e., the cracks can be detected. This works for an ideal laboratory environment without any interference; however, there are many interferences from the environment and metal surfaces. Damage sensitivity was not studied for commercial RFID tags at all, and if multiple tags are to be used for pervasive sensing, the configuration of tags and possible coupling effects have not been studied.

This project aimed to develop a very low-cost passive wireless crack sensor using commercial RFID tags for crack detection of field metal structures. We developed two configuration of wireless crack sensor using a single RFID tag and multiple RFID tag arrays. To enable communication between the tags and the reader antenna, we found a reasonable substrate material between the tag and the metal surface. Without the substrate material (i.e., if the tag is attached directly on the metal surface), there is no reflected power.

A preliminary study to determine a good read distance between the sensor and the antenna was conducted. We found a good read distance is 3 feet or less; however, the sensors were responsive with up to 15 feet read distance. Since the read distance is constant before and after damage, the crack damage was able to be identified by comparing the changes of the received power.

The first major experimental study was on the crack detection capability and sensitivity to damage of both sensor configurations: single-tag and multiple-tag. For a single-tag configuration, the received power decreased in terms of increased damage on the tag sensor showing a good damage sensitivity. For a multiple-tag configuration, we compared the received power of many different arrangements to find the highest received power. For each case, we confirmed the damage sensitivity of multiple sensors. Therefore, the RFID tags sensors were experimentally validated for crack detection.

The next important experimental study was on the dynamic crack detection capability of the sensor when a crack is propagating. To do that, we created a standard metal specimen for crack propagation tests, and measured the change of the received power to validate the capability of this crack sensor for dynamic crack. Both single-tag configuration and multiple-tag configuration were employed for crack detection tests under crack propagation until failure. The received power of the RFID tag sensors changes to the crack progression. To give more objective reference, the received power from the RFID tags are matched with digital image correlation.

The final results showed that the developed sensors have great potential to effectively detect the existence, location, and the degree of cracks. Therefore, the complete damage sensitivity of the RFID-based crack sensors were successfully validated. The developed sensors are ready to be installed on any metal structures in the field and tested for its performance. The cost of a single tag is less than 10 cents if mass purchased, the substrate material is cheap EVA foam, rugged exterior adhesive can be used to elongate the life of sensors, and one data acquisition system can be used to scan many tags on multiple bridge sites. Through this project, a handheld reader has been purchased to show the potential to monitor bridges on-site using this equipment easily. Further research on field implementation, crack monitoring with handheld equipment, and autonomous crack detection system as well as manuals, photos, and test parameters are detailed in the report.
Connecticut Department of Transportation

Development of the Digital Design Environment at the CTDOT -- Phase 1

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| Submitter  | Connecticut Department of Transportation  
Bradley Overturf  
2800 Berlin Turnpike  
Newington, Connecticut 06111  
860-594-2089 |

Links  
http://www.ct.gov/dot

Project Summary and Benefits

The overall objective of this project was to improve CTDOT project delivery by streamlining and improving the quality of the designs; to reduce the time needed to access plan archives; and to submit and review engineering documents and drawings electronically. Installation of a digital design environment encompassing electronic document generation, management, signatures, project advertisement, and support services was planned. The result would be a secure, efficient, standardized project design platform to help reduce project costs, decrease project development times, and provide both accountability and storage for project documents.

Ideally, the system would keep all project related data together for all disciplines throughout the entire project lifecycle using ProjectWise (PW) Online by Bentley Systems which is an integrated engineering content management system. Bentley Systems enables project teams to work cohesively and share their project information and tools. The system is hosted by Bentley Systems Incorporated. This led to creating a production environment of PW Online and using the system on pilot transportation infrastructure projects to facilitate digital submissions and the transfer of active and legacy projects on CTDOT’s server infrastructure to the ProjectWise production environment. ProjectWise Online now serves as CTDOT’s primary Engineering Content Management System (ECMS).
Connecticut Department of Transportation

Advancing the State of Bridge Weigh-In-Motion for the Connecticut Transportation Network -- Final Report

**Project ID**  SPR 2290

**Cost**  

**Duration**  35 months

**Submitter**  
Connecticut Department of Transportation  
Andrew J. Mroczkowski  
2800 Berlin Turnpike  
Newington, Connecticut 06111  
860-594-3296

**Links**  
http://www.ct.gov/dotsi/site/default.asp

**Project Summary and Benefits**

Bridge Weigh-In-Motion (BWIM) uses the dynamic response of a bridge to determine gross vehicle weight, speed, and axle spacing of truck traffic to quantify the loads in a transportation network. The advantage of BWIM is that it does not require installation of sensors in the pavement, nor use any axle locators in the roadway.

Research in BWIM methods has been conducted in Connecticut since 2004, with the goal of moving this technology closer to deployment in Connecticut. Benefits of BWIM can be realized for the design and management of pavements, and results in less risk and increased cost savings. Improved oversize/overweight truck permitting, bridge load rating and truck re-routing all enable informed decisions and improved expectations of performance that translate into sound investment decisions for the Connecticut Department of Transportation (CTDOT). With this goal, this project has continued BWIM data collection at the Meriden (I-91) Bridge, making data collected since 2013 available to CTDOT in a queryable format, and providing a testbed for further improvement and understanding of BWIM data processing and bridge monitoring techniques in general.

Furthermore, the project has developed a portable monitoring system in two configurations that can be deployed for BWIM purposes in Connecticut, for single day or multiple months duration. As part of the project, these BWIM systems were deployed on various bridge types in Connecticut to identify best practices, and to evaluate performance and potential for application by CTDOT. The project has moved the state of knowledge and practice of BWIM in Connecticut to enable deployment of this technology by CTDOT.
Enhancing Connecticut’s Crash Data Collection for Serious Injury and Fatal Motor Vehicle Collisions

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| Submitter  | Connecticut Department of Transportation  
             Flavia Pereira  
             2800 Berlin Turnpike  
             Newington, Connecticut 06111  
             860-594-2882 |

Project Summary and Benefits

The Connecticut Crash Data Repository hosted by the Connecticut Transportation Safety Research Center (CTSRC) houses extensive data on all traffic crashes in Connecticut. However, pre-crash data and certain driver behaviors are unavailable as they cannot be gathered through traditional crash investigatory approach that does not involve use of an event data recorder. An Event Data Recorder (EDR), sometimes referred to as an automotive black box, is a valuable tool that can provide comprehensive snapshot of the entire crash event –- pre-crash, crash and post-crash -- including driver behavior on seatbelt use, gas, and brake pattern. This study focused on enhancing Connecticut’s crash data collection for serious injury and fatal motor vehicle collisions using the EDR data.

CTSRC facilitated two separate week-long (40 hour) EDR technician courses for certified law enforcement officers. This course trained officers to become certified EDR Technicians. A total of 60 local law enforcement officers throughout the state of Connecticut were trained and certified to provide regional support for future crash investigations. To evaluate the accuracy and completeness of the data obtained from the EDRs, CTSRC worked with the trained technicians and local law enforcement to identify five serious or fatal motor vehicle crashes to perform a detailed analysis of the original crash report and the resulting report revised using data downloaded from the EDR. Local law enforcement that participated in this project notified CTSRC of a serious or fatal crash as soon as it occurred. CTSRC then worked with the police department to obtain the rights to download the EDR data via a search warrant. The police department completed a draft version of the report without using the EDR data and then updated their report after using the downloaded EDR data.
The five case studies varied in type of collision, vehicles involved, cause of crash, injury severity, and driver behavior. Two of the collisions involved a vehicle striking a pedestrian, whereas the other three involved head-on collisions between two vehicles. The EDR downloads conducted in this study produced valuable data that was unavailable from traditional reconstruction techniques. This enhanced data allowed for the precise analysis of each collision. In all circumstances, the download of data produced complimentary evidence in the crash and did not contradict the officer’s original report, when compared to the analysis of the physical evidence located at the scene of a crash. However, the EDR downloads were contradictory to the statements of one driver, who fatally injured a pedestrian, when there were no other witnesses. Without the EDR data, to show the vehicle did not turn and that the vehicle was traveling at a high rate of speed, this crash may not have resulted in as severe charges against the driver. The use of an EDR download enables the investigators to develop more accurate and reliable supplemental data to support collision reconstruction.

Findings from this study showed that EDR data can help evaluate the true cause of a collision as well as identify reckless driver behavior. In addition, the continued documentation of the enhanced information gathered through the utilization of an EDR will produce a comprehensive database, allowing for in-depth analysis and improved overall highway safety. Furthermore, the ready availability of EDR data, in a crash database, will enable highway safety researchers to address numerous elusive research questions.

While the use of an EDR is not recommended to replace a traditional collision reconstruction, it should be used as a tool to enhance the accuracy of the investigation, allowing for a more inclusive and complete report. The EDR data allows for the collection of unbiased factors, leading to a comprehensive and undisputable evaluation of many facts, including driver behavior and vehicle dynamics. This allows all stakeholders to precisely evaluate the true cause of a collision and ensure that a complete examination of an event is conducted. Through an increased utilization and study of EDR data, all stakeholders can ultimately use this data to improve road safety within Connecticut.
Development of Prototype On Board Unit for Connected Vehicle Initiatives

**Project ID** 2017-01

**Cost** $154,000

**Duration** 14 months

**Submitter** District of Columbia Department of Transportation
Stefanie Brodie
55 M Street SE, Suite 500
Washington, D.C. 20003
202-524-8534

**Links**

**Project Summary and Benefits**

This project focused on creating a platform for the development and evaluation of connected vehicle applications that can enhance safety and mobility, reduce environmental impacts, and improve operations within DDOT’s operational region. First, the current status of DDOT’s intelligent transportation system (ITS) infrastructure was evaluated and suggestions for improvements to support CV initiatives were made. VTTI developed an onboard unit (OBU) package for installation in five DDOT work trucks to support V2I communications.

VTTI developed and integrated a number of software packages with the goal of improving DDOT’s operating efficiency. Two software applications previously created by VTTI and based on the existing Virginia Connected Corridors (VCC) infrastructure, VCC Monitor and VCC Mobile, were adapted by integrating the data collected by the OBE installed in DDOT’s trucks (i.e., temperature and pothole data). Furthermore, an Android smartphone application was developed from the ground up to collect road surface data, detect potholes, and send that information to VCC Monitor for easy identification and tracking. To support DDOT’s data analytics goals using the real-time data transmitted by the equipped DDOT vehicles, VTTI provided DDOT with the necessary information to access and interact with the data in the VCC Cloud. This platform will position DDOT on the cutting-edge of Intelligent Transportation Systems (ITS) research in a short period of time, with efforts targeted specifically at local transportation challenges.
FDOT TPAS Commercial Truck Parking Detection Technology Evaluation

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| Submitter    | Florida Department of Transportation  
               David Sherman  
               605 Suwannee Street  
               Tallahassee, Florida 32399  
               850-414-4613 |
| Links        | http://www.fdot.gov/research/ |

Project Summary and Benefits

Rest areas along Florida’s interstate highways are heavily used by commercial trucks for overnight parking. Many rest areas regularly experience 100% utilization of the commercial truck parking spaces during the evening and early morning hours. Drivers may spend significant amounts of time searching for a place to stop for the night -- often when they are already tired.

University of Florida researchers tested several in-pavement systems which automatically detect the presence of vehicles in commercial truck parking areas, with the goal of creating a system that would remotely inform truck drivers of vacancies. The researchers evaluated whether commercially available products were able to reliably detect vehicles in commercial truck parking spaces at interstate rest stops. They focused on accurate detection of vehicles in parking spaces, cost, and installation, setup, and maintenance requirements. Evaluation of sensor durability was also evaluated, but on a limited basis, due to the relatively short term of the project.

Three different products were tested which use two detection methods: SensIT uses magnetic and infrared detection while both the Sensys and CivicSmart use microwave radar. Both methods involve sensors which are placed in the pavement in an array at each of the monitored parking spaces. These sensors communicate wirelessly with an electronic device that aggregates the information and relays it to a central location. The information would be sent to SunGuide for processing.

The Florida Department of Transportation (FDOT) will make the truck parking availability information accessible to users of the FL-511 app or third party applications that are based on FDOT-supplied data feeds. A rest area along I-75 in Columbia County (FDOT District 2) was selected as the test site. Specific test areas of the commercial parking facility were chosen for installation of the detection technologies. Video cameras were also set up in the test areas as a quality control mechanism to confirm the results. At least one month of data was collected for each type of in-pavement sensor technology provided by the vendors. Generally, all three vendor-provided technologies were able to detect the presence of vehicles accurately, at 95% accuracy or greater.
Pricing or maintenance issues may guide the choice of technology. Trucking is crucial to the economic life of Florida. [The technology] allows drivers to easily locate a place to stop, thereby reducing the time needed to check rest areas for available spaces. It also helps them plan a safer, more efficient trip and avoid driving while fatigued at the end of a long shift.
Application of Demographic Analysis to Pedestrian Safety

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| Submitter  | Florida Department of Transportation  
David Sherman  
605 Suwannee Street  
Tallahassee, Florida 32399  
850-414-4613 |
| Links      | http://www.fdot.gov/research/ |

Project Summary and Benefits

This research developed a demographics-based methodology that identified the qualitative and quantitative relationships between dependent variables, such as pedestrian crashes and severe injury crashes, and independent variables, including demographic and social factors, road environmental factors, neighborhood land use attributes, and individual characteristics in low-income areas. The research identified important factors that affect pedestrian crash frequency and injury severity and quantified their relationship and degree of impact.

Based on the results and findings, the research made specific recommendations for both engineering countermeasures and pedestrian safety education/outreach plans that resonate with a given area’s demographics to effectively improve pedestrian safety in low-income areas. It also provided guidelines on how a Florida Department of Transportation (FDOT) District or a transportation agency can identify low-income areas with higher pedestrian hazards and how they can implement recommended engineering countermeasures and education/outreach plans. This research project was completed in April 2017.

The project principal and research team members presented the project results, findings, and recommendations via (1) University Transportation Center (UTC) Spotlight Conference (December 2016), (2) Transportation Research Board (TRB) Annual Meeting (January 2017), (3) Florida Pedestrian and Bicycle Safety Coalition meeting (April 2017), (4) Florida Section Institute of Transportation Engineers (ITE) Summer Meeting (June 2017), and (5) Center for Urban Transportation Research (CUTR) webcast (October 2017), to actively disseminate the information and conduct technology transfer so agencies and transportation professionals can use and benefit from this important research. All presentations were well-received. The research team also published several research papers based on this project via transportation journals and national conferences.

In 2017, the FDOT Central Office, FDOT Districts, local transportation agencies, and the Florida Pedestrian and Bicycle Safety Coalition focused more on implementation of the recommended countermeasures provided in the project final report. These countermeasures include roadway lighting and lighting levels, midblock crossings,
bus stop improvements, Road Safety Audits, grassroots WalkWise pedestrian and bicycle safety education, education via business sweeps on high-crash corridors, social media outreach, and High-Visibility Enforcement (HVE).

Based on the latest crash data available from the Florida Integrated Report Exchange System (FIRES) as of February 26, 2018, the number of pedestrian fatalities in Florida was reduced from 665 in 2016 to 612 in 2017, a significant 8% reduction. An even more significant reduction (nearly 21%) in bicyclist fatalities was observed, from 140 in 2016 to 111 in 2017. Many lives have been saved and injuries avoided. The research findings and the recommended engineering and education countermeasures from this project, along with the joint efforts from FDOT and local transportation agencies, contributed significantly to this reduction, and demonstrated success in improving pedestrian safety. Clearly, implementation of the research results will lead to defined benefits for the sponsor agencies that outweigh the cost of the research and implementation.
Impact of Transit Stop Location on Pedestrian Safety

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| Submitter   | Florida Department of Transportation  
               David Sherman  
               605 Suwannee Street  
               Tallahassee, Florida 32399  
               850-414-4613 |
| Links       | [http://www.fdot.gov/research/](http://www.fdot.gov/research/) |

Project Summary and Benefits

This research project developed viable improvement and implementation strategies for designing, locating, and relocating stops to include enhancement to local traffic and engineering controls that will reduce potential for problematic crossing. A systematic process for reviewing bus stops in regards to pedestrian safety was developed as part of this research project.
Project Summary and Benefits

High Friction Surface Treatment (HFST) is a thin overlay placed on top of an existing roadway to enhance pavement friction. HFST is typically installed by applying a layer of epoxy and spreading a layer of high-quality polish-resistant bauxite aggregate bonded to the pavement surface as specified in the Florida Department of Transportation (FDOT) Specification 333. Although HFST is comparatively more expensive with shorter service, the research findings indicated the use of HFST has a direct impact of crash rate reductions for tight curves, wide curves/tangents, and intersection approaches. Tight curves were shown as the best improvements with 84% reduction in wet weather crashes and 44% overall in total crashes. In addition, the average benefit to cost (B/C) ratio was between 18 and 26 (depending on calculation method).

The project developed a user HFST guideline booklet which provides guidance on the project selection, materials, and construction best practices. This information will directly help district-wide safety initiatives.

Based on the research findings, both the State Safety Office and State Materials Office teamed together to streamline HFST project application procedures, and developed a revised HFST specification for immediate field use. The research findings resulted in the development and statewide implementation of usage guidelines and revised specification (section 333). These have also been adopted by some local counties as well.

Other states like Nevada, Georgia and California have requested our FDOT Guidelines and Specifications to support their HFST projects. This information has also been used by AASHTO’s Transportation Curriculum Coordination Council (T3) towards building an online training course called, “Best Practices for High Friction Surfaces”. The project addressed a series of materials, construction, and performance related issues associated with HFST such as surface delamination and durability, and provided solutions/recommendations to those issues. Those solutions/recommendations have been implemented in the new specification. In addition, a user-
ready booklet, titled “High Friction Surface Treatment Guidelines: Project Selection, Materials, and Construction” was developed to provide additional insight and guidance.

The project has assisted in promoting the technology to improve safety, education, durability, and construction practices. Advancements include:

1) Documented safety benefits with crash data and friction performance (10 year history).

2) Developed training materials for department use.

3) Improved HFST specification and construction practices to decrease product failures, better inspection practices, and appropriate use of products on existing pavement systems.

4) Better materials characterization and their interaction at the laboratory level.

5) Project explored potential new mix designs for asphalt based friction products utilizing high friction aggregates.
**Flash Tracking for Accelerated Project Delivery (APD)**

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| **Submitter**     | Georgia Department of Transportation  
                   | Darryl VanMeter       |
|                   | 600 W. Peachtree Street  
                   | Atlanta, Georgia 30308 |
|                   | 404-631-1703           |

**Links**

**Project Summary and Benefits**

Many transportation agencies are striving to deliver technically complex projects with efficiency and speed while capital resources are decreasing and transportation needs are growing. GDOT has pursued many innovative approaches to achieve timely project delivery with quality. One such innovative approach is Flash Tracking (faster Fast Tracking), which has been studied, implemented, and validated in the four projects in Georgia:

1. SR_299 bridge replacement over I-24
2. Jimmy Deloach Connector,
3. SR 47 bridge replacement over Little River
4. Riverside Drive Roundabouts at I-285

(see Link for document that includes description of time/cost savings)

Flash Track projects can be difficult to manage given the heightened degree of concurrency between scope definition, engineering, procurement, and construction.

The objective of this research project was to examine existing Flash Track practices identified by the Construction Industry Institute (CII), Virginia Department of Transportation (VDOT), and literature for those most suitable for GDOT. GDOT subject matter experts and stakeholders validated these practices per experience working on the four GDOT Flash Track projects mentioned above. These projects were evaluated for applicability of the existing flash tracking practices as well as identifying new GDOT-specific flash tracking practices.

Although Flash Tracking is a relatively new concept, GDOT continues to explore and implement it through research by identifying, assessing, validating, and ranking suitable Flash Track practices. GDOT is also working with VDOT on the national level to engage other states in expanding the set of Flash Track practices to develop a comprehensive Flash Track Framework that can be implemented by any state DOT pursuing accelerated project delivery.
Field Test Based Guidelines Development for the Integration of Unmanned Aerial Systems (UASs) in GDOT Operations

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<td>Duration</td>
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</tbody>
</table>
| Submitter  | Georgia Department of Transportation  
Carol Comer  
600 W. Peachtree Street  
Atlanta, Georgia 30308  
404-631-1703 |

**Project Summary and Benefits**

Unmanned Aerial Systems (UAS) are increasingly being considered for government and civilian applications in the United States. “The FAA’s vision for fully integrating UAS into the National Airspace System (NAS) entails UAS operating harmoniously, side-by-side with manned aircraft; occupying the same airspace; and using many of the same air traffic management systems and procedures.” However, there are numerous issues, e.g., policies and certification requirements, with integrating unmanned aircraft into manned airspace that require collaboration across industry, government, and academia.

Several state DOTs have begun using UAS technology for different purposes, including construction project tracking, structural inventory, road maintenance, environmental monitoring, and traffic/safety-related applications. GDOT previously completed a feasibility study aimed at (1) identifying user requirements for each GDOT division or office that could potentially benefit from UAS; and (2) matching these user requirements with corresponding UAS design characteristics and costs. The current phase of GDOT UAS research is to determine the technological feasibility, benefits, and limitations of UAS deployment in a field-testing environment, as well as legal and social implications thereof.

This research has enabled GDOT to implement an intermodal UAS program that is governed by GDOT Policy 3545-1, Policy and Operational Guidelines for Small Unmanned Aircraft Systems (Drones), in addition to federal and state laws, and that is administered by a UAS Program Manager at GDOT. See link above for further details on the program. Currently, a handful of state DOTs -- including GDOT -- are working to institutionalize UAS into their operations to not only ensure safety but also to leverage cost- and time-saving innovations offered by UAS.
Guide to Assist Idaho Local Highway Jurisdictions in Evaluating Route Requests for Trucks Up to 129,000-Pounds

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| Submitter  | Idaho Department of Transportation  
Ned Parrish  
P.O. Box 7129  
Boise, Idaho 83707  
208-334-8296 |

Project Summary and Benefits

A significant number of local highway jurisdictions in Idaho lack the engineering expertise and financial resources to conduct detailed assessments when requests are received to increase weight allowances for local roadways beyond the current legal limit for gross load weight of 80,000 pounds. Idaho Code 49-1004A (1) states "the authority having jurisdiction may designate routes ... for vehicles not exceeding ... 129,000 pounds, utilizing criteria established by the board based upon road and bridge structural integrity and engineering standards". These higher load limits can enable private freight organizations to better compete in domestic and global markets by allowing them to distribute freight more efficiently.

The Idaho Transportation Department contracted with researchers at the University of Idaho to develop an easy to use guide to assist local agency staff in evaluating these requests. The guidebook has been distributed to local agencies and researchers presented information on the use of the guide to local officials. This guidance has been well received and is a tool that local officials can use when conducting roadway assessments ranging from review of available data and current conditions to full engineering studies where appropriate.
Development of a Proposed Overweight Vehicle Permit Fee Structure in Illinois

**Project ID**  ICT PROJECT R27-152  
**Cost**  $300,000  
**Submitter**  Illinois Department of Transportation  
Megan Swanson  
126 East Ash Street  
Springfield, Illinois 62704  
217-782-3547

**Project Summary and Benefits**

Permits are one of the most effective and common tools for state agencies to regulate the operation of oversize and overweight (OSOW) vehicles by ensuring the safety of passenger and freight traffic and minimizing damage to pavements and bridges while promoting commerce and the safe movement of goods and services. Although the State of Illinois uses a relatively comprehensive permit system, many of its parts have not been revised for more than 30 years. Therefore, the objective of this study was to revise the current permit system by evaluating up-to-date impacts of overweight vehicles.

In this study, impacts of overweight vehicles were evaluated according to three aspects (bridge damage, pavement damage, and traffic safety) and individual fees were developed for each. The most recent databases on infrastructure condition and state-of-the-art prediction/classification algorithms were employed to produce the realistic and up-to-date assessment of OW vehicles' impact. Before this project, Principal Investigator Imad Al-Qadi says, “there were no proper models that could relate the pavement and bridge service lives to overweight trucks quantitatively.” In addition to suggesting a quantitative and scientific-based fee formula for the use of roads and bridges in the state of Illinois, this is the first time that a fee related to safety has been incorporated.

To do this, the research team had to quantify the safety impacts of a variety of situations involving OSOW vehicles and use models to develop an estimation of the impact of an individual OSOW vehicle on traffic safety. This includes the monetary impact of accidents on both the infrastructure and the people involved according to Professor Yanfeng Ouyang, who led this part of the project. Finally, a combined permit fee was recommended as
a function of miles to be traveled, as well as axle configuration and weight information, by aggregating the calculated individual fees.
Cost Benefit Analysis and Implementation of NDT Testing of INDOT Bridge Decks

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| Submitter  | Indiana Department of Transportation  
Tommy Nantung  
1205 Montgomery Street  
West Lafayette, Indiana 47906  
765-463-1521 |
| Links      | [https://doi.org/10.5703/1288284316343](https://doi.org/10.5703/1288284316343) |

Project Summary and Benefits

Bridge decks often require frequent maintenance and rehabilitation due to reinforcement corrosion and concrete delamination. Through effective and proactive monitoring, highway agencies can acquire the information needed to make optimal timing decisions for deck repair or replacement. Nondestructive testing (NDT) has been shown to reliably locate corrosion and delamination. Therefore, the Indiana Department of Transportation sought additional knowledge on the alternative NDT methods and their reliability, limitations, and costs, and possibility of statewide deployment. However, system-wide NDT monitoring of any infrastructure entails a large expenditure outlay; such monitoring therefore needs to be justified by comparing its costs to the potential savings that would accrue if such monitoring were to lead to timely actions.

This study developed a framework that addresses this challenge. The framework considers two strategies for managing a network of bridge decks: a condition-based strategy that involves monitoring and repair, and a time-based strategy that involves repairing over specific time intervals without condition monitoring. The study calculated the life-cycle cost of each management strategy as the sum of the two key cost categories: monitoring costs and repair costs over life cycle. The study estimated that if NDT is used as the monitoring platform system-wide, the unit monitoring cost will be $0.04 to $0.35 per square foot of deck, depending on the technology used. The average is $0.22 per square foot of deck.
The study found that the benefits of NDT monitoring program far outweigh its costs, with a rate of return of $3.68 to $10.42 in repair savings for every $1.00 investment in that program. The study also analyzed the sensitivity of the results to the key evaluation factors.
**Project Summary and Benefits**

The ultimate objective of the current study was to provide accurate, reliable, and first-hand data and information to determine the site-specific, cost-effective pavement surface friction treatment for reducing friction related vehicle crashes. To support this ultimate objective, there were three secondary objectives:

(i) To correlate the friction performance of high friction surface treatment (HFST) with laboratory test results;

(ii) To evaluate the long-term friction performance of various pavement preservation treatments, including chip seal, microsurfacing, ultrathin bonded wearing course (UBWC), and diamond grinding; and

(iii) To develop models that can be utilized to determine the dynamic crash modification factors (CMFs) for estimating the cost-effectiveness throughout the service life of a specific friction surface treatment.

Intensive laboratory testing was performed to examine the frictional properties of imported calcined bauxite for HFST at locations with extreme friction demands and local steel slag for friction treatments at locations with less extreme friction demands or minimal pavement life. Laboratory accelerated polishing was conducted to investigate the factors that may affect the durability and friction performance of HFST (Fig. 1).

Field evaluation was conducted through test strips under actual traffic polishing to further evaluate the durability and friction performance with respect to surface friction and macro-texture, single-layer and double-
layer applications, aggregate loss, interface bonding, and effect of snow plow. Field testing had been conducted to evaluate the durability and friction performance of actual pavement preservation treatment sections, including chip seal, microsurfacing, UBWC, and diamond grinding, specially selected for the current study.

The friction variations were identified over a period of up to eight years for regular chip seal and fog-sealed chip seal. Microsurfacing demonstrated a friction performance better than chip seals. The trend of friction variation associated with UBWC depended to a large extent on traffic volume. The trend of friction variation over time for diamond grinding on HMA pavement was different from that on concrete pavement. Evidently, these preservation treatments can be used to restore pavement friction and reduce friction related vehicle crashes.

The regression models have been developed from the field friction measurements (Fig. 2) and can be utilized to predict the long-term friction performance of pavement preservation treatments, including chip seal, microsurfacing, UBWC, and diamond grinding. The analysis of crash data revealed that in Indiana, 13% of all crashes occurred on curves, resulting in 22% of total fatalities, and for crashes on curves, 32% occurred when pavements were wet. To quantify the probabilistic association between vehicle crash and friction performance, a total of 60,000 vehicle crashes between 2010 and 2014 were matched to 65,000 friction measurements made by INDOT. Data-matching was conducted with respect to GPS coordinates through data sorting and data reduction using commercial statistical analysis software. GIS software was utilized to visualize the combined dataset and remove the abnormal data manually.

Three prediction models were developed to estimate the crash rates in terms of pavement friction level for interstate, state, and US highways, respectively. Diagnostics was performed to validate the proposed models. Comparison of these models was performed with the models published in other studies (Fig. 3). Although mixed results were obtained, the models developed in this study rely on well documented historic friction and crash data and can produce more convincing prediction results for Indiana. In addition, the proposed models can be universal models that can be employed to determine the CMFs not only for HFST, but also for other friction surface treatments. It is estimated that a newly installed HFST can provide a CMF of up to 0.727, 0.567, and 0.348 for State road, U.S. highway, and interstate, respectively, when surface friction is restored from 0.20 to 0.55.
Figure 1 Photos of samples for laboratory and field tests

(a) Coupons for polished stone value test  (b) Slabs for laboratory polishing  (c) Test strips for traffic polishing

Figure 2 Friction variations over time for pavement preservation treatments

(a) Chip seal  (b) Microsurfacing  (c) UBWC  (d) Diamond grinding

Figure 3 Crash rate reductions predicted using different models
Indiana Department of Transportation

Evaluating the Impacts of Time-of-day Tolling on Indiana Roadways

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<td>Submitter</td>
<td>Indiana Department of Transportation&lt;br&gt;Tommy Nantung&lt;br&gt;1205 Montgomery Street&lt;br&gt;West Lafayette, Indiana 47906&lt;br&gt;765-463-1521</td>
</tr>
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</table>

**Project Summary and Benefits**

As public private partnerships continue to pick up pace in infrastructure delivery and operations, it has become increasingly important to evaluate the feasibility of various road tolling approaches to quantify the risks associated with such investments. Recognizing that a blanket toll does not help mitigate congestion, agencies are turning to time-of-day (TOD) tolling. The Indiana Department of Transportation commissioned this research project to evaluate TOD tolling feasibility in Indiana.

This report describes the development and implementation of a simulation framework and accompanying software tool to estimate various TOD tolling scenarios, the expected impacts in terms of traffic flow patterns, traveler route choices, amount of travel, travel time, revenue, and social welfare, compared to a base case scenario (no toll). The framework reduces drastically, the time and effort in TOD tolling evaluation and is applicable to other prospective tolling locations. In addition, the visualization feature can illustrate traffic diversions from the toll road to neighboring routes due to the tolling and display the ranking of the most impacted road segments in the study area.

Using Interstate 465 in Indianapolis as the case study corridor, the analysis supports the notion that TOD tolling can effectively mitigate congestion and generate revenue. For instance, the average speed increases about 8% to 10%; vehicle miles traveled decrease by 25%; vehicle hours traveled reduces by 27%; and revenue goes up to $146 million for I-465 corridor (2015-2025). The simulation also confirms marginal welfare improves 3-4 times during peak hours on I-465. The research advocates for holistic approaches in road toll evaluation because tolling impacts are found to be spread across the adjacent network. And to consider a broader spatial scope that includes neighboring roads instead of the toll road only. The developed software tool can be integrated
seamlessly with standard software packages for demand analysis and geospatial visualization for analyzing any TOD initiative.
Indiana Department of Transportation

Evaluation of Alternative LiDAR Platforms and Sensors for Asset Management

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| Submitter  | Indiana Department of Transportation  
                       Tommy Nantung  
                       1205 Montgomery Street  
                       West Lafayette, Indiana 47906  
                       765-463-1521 |

Project Summary and Benefits

Mechanically stabilized earth (MSE) walls are extensively used for many civil infrastructure projects. Traditional geotechnical analysis of retaining walls focus on settlement, lateral displacement at the top of the wall, and a variety of stability measurements. It is not uncommon for an MSE wall installation to be composed of several hundred panels. The long term performance of the entire MSE wall system is dependent upon each panel being placed according to the systems design.

The objective of this project was to perform a field study at a mutually agreeable site to evaluate the feasibility of using a Static Terrestrial Laser Scanner (STLS) and a mobile Light Detection and Ranging (LiDAR) system to measure the vertical deflection of Mechanically Stabilized Earth (MSE) wall panels. The study has shown that 3D point clouds collected by STLS can be used to measure relative differential panel displacement changes. Figure 1 shows an example deformation map where three different locations on the point cloud (i, ii, iii) were independently measured and found to have sub-centimeter accuracy. Mobile mapping systems were found to be able to provide differential panel displacement at the 2cm level depending on the visibility of different panels and quality of the used ranging and navigation units.

Based upon this preliminary investigation, we believe the mobile LiDAR system can provide a very efficient mechanism for performing a first order (coarse) inspection of MSE walls to identify locations with abnormal deflection that warrant further inspection. The ability of this technology for the performance evaluation of MSE wall functionality would be enhanced by recent technical advances in mobile mapping technologies (e.g., improved position and orientation using modern Global Navigation Satellite Systems coupled with Inertial...
Navigation Systems as well precise laser ranging and scanning units). These LiDAR techniques are more scalable than traditional surveying.

This study can be used as a starting point for defining acceptance criteria for new projects, as well as performance measures to monitor long-term performance of MSE walls, or changes in performance associated with natural disasters.

Figure 1
Blue Lights on Iowa DOT Snow Plows

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| Submitter    | Iowa Department of Transportation  
Brian Worrel  
800 Lincoln Way  
Ames, Iowa 50010  
515-239-1471 |

Links

Project Summary and Benefits

This was an internal study executed through Iowa DOT maintenance staff. Since 2009, Iowa Department of Transportation’s winter operations vehicles have been hit 233 times, 141 of those crashes resulted in nearly $1.8 million in combined motorist and state property damage and 47 injuries. During the winter of 2013/2014 alone there were 39 crashes resulting in approximately $770,000 in damages and seven injuries.

The project sought to increase safety by allowing the Iowa DOT to add rear-facing white and blue lights in addition to the amber warning lights on vehicles as part of a pilot project. The lights were only used during winter operations, a time in which snowplows are often moving much slower than the flow of traffic due to plowing and spreading material on the roadway. This slower speed is often one of the causes of crashes with snowplows.

Iowa DOT equipped all the trucks in the central part of the state with the blue and white lights. Blue and white lights were also installed on at least two trucks in each of the other five Iowa DOT districts. For many of the trucks that were not upgraded with blue and white lights, additional amber lights were added to determine if that impacted the visibility of the vehicles. By making the vehicles more visible to motorists, the Iowa DOT hoped to:

- Improve motorist, emergency responder, and Iowa DOT worker safety.
- Reduce potential for secondary crashes.
- Reduce motorist and state of Iowa property damage.
- Improve motorist mobility.
- Improve emergency responder and Iowa DOT efficiency.
- Improve Iowa DOT equipment uptime.
DOT snowplow trucks were involved in 10 crashes over two winters during the study in which motorists struck the rear-end of the snowplow trucks or sideswiped them. That is a dramatic reduction compared with 29 crashes over two previous winter seasons in which the snowplow trucks operated with only flashing amber lights. The use of these particular blue and white lights was to solve a rear-end collision problem. The focus was on the safety of the public drivers, the snowplow truck drivers, and the officers who investigate the crashes. The initial cost of $110,000 was for purchase and installation of the lights on the snowplow trucks utilized for this study. A bill signed by the Iowa Governor on March 7, 2018 authorized the continued installation and use of blue and white lights on Iowa DOT snow plows. Mounting the lights on the remaining plows would cost an additional $335,000 for implementation.
Study of the Impacts of Implements of Husbandry on Bridges

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| Submitter  | Iowa Department of Transportation  
Brian Worrel  
800 Lincoln Way  
Ames, Iowa 50010  
515-239-1471 |

Project Summary and Benefits

Little is known about how agricultural vehicles, which come in a variety of configurations and are known as implements of husbandry, affect bridges on our secondary roadways. The behavior of bridges with these vehicles, particularly in regard to live load distribution and impact, is not explicitly encompassed within the design, rating, and posting vehicles presented in current American Association of State Highway and Transportation Officials (AASHTO) specifications. Due to the large axle loads and varying axle spacings associated with implements of husbandry, the current AASHTO vehicles used for bridge testing, such as the HL-93 design truck and the HS20 rating truck, may not accurately represent husbandry vehicles.

The objectives of this study were to develop guidance for engineers on how implements of husbandry loads are resisted by traditional bridges, with a specific focus on bridges commonly found on the secondary road system; provide recommendations for accurately analyzing bridges for these loading effects; and make suggestions for the rating and posting of these bridges. This research provides much-needed information about the effects of husbandry vehicles on bridges and the applicability of current AASHTO specifications for these vehicles.

The empirical equations developed from the field testing and finite element modeling provide a good estimation of the LLDFs and are recommended for consideration in designing and rating slab-over-girder bridges for husbandry vehicles. However, the equations have limitations in that small numbers of some bridge types were included in the analysis. More steel-concrete, steeltimber, and timber-timber bridges should be added to the study to increase the confidence in the empirical equations. Suggested bridge restriction signs, including speed limit and load posting signs, were developed based on the AASHTO Manual for Bridge Evaluation and the Federal Highway Administration (FHWA) Manual on Uniform Traffic Control Devices for Streets and Highways.
I-74 Mississippi River Bridge Virtual Reality Simulation

**Project ID**  
17-SPR2-001

**Cost**  
$49,303

**Duration**  
5 months

**Submitter**  
Iowa Department of Transportation  
Brian Worrel  
800 Lincoln Way  
Ames, Iowa 50010  
515-239-1471

**Links**

**Project Summary and Benefits**

A virtual reality display was developed for the I-74 Mississippi River crossing for use in educating the public about the new structure and particular emphasis on the Threatened and Endangered Species mitigation work associated with the mussel ecosystem in the river. The immersive virtual environment makes it possible for the Iowa DOT and other agencies to give a more complete understanding of how infrastructure projects will look and interact with the surrounding environment. Environmental aspects focus on the large-scale mussel relocation as part of the project, in which a total of 140,600 mussels were relocated from the river bed in the project area. Users can “interact” with these mussel species and learn about their importance to the ecosystem. The virtual reality display takes the viewer into the river environment to “pick up”each mussel as a U.S. Fish & Wildlife Service biologist provides information about the species. This piece of our public involvement activities for the project provide an opportunity to communicate the DOT’s environmental commitments to the public.

Interactions with the new structure include driving across the new four-lane I-74 River Bridge, walking along the multi-use path and getting a gorgeous view of the Quad Cities from the scenic overlook, and standing on top of the arch to get a bird’s-eye-view of the reconstructed interstate. Travelling installations of the experience has been featured at the TRB annual meeting as well as several locations near the project site. Based on the positive feedback and success of this pilot, the Iowa DOT is currently developing two user experiences for public outreach and education.
Iowa Department of Transportation

Traumahawk

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| Submitter  | Iowa Department of Transportation  
Brian Worrel  
800 Lincoln Way  
Ames, Iowa 50010  
515-239-1471 |

Links

Project Summary and Benefits

A smartphone app sponsored by the Iowa DOT and developed by the University of Iowa is being used to enhance communication between first responders and emergency room staff at hospitals and clinics. Use of the app by eastern Iowa law enforcement and first responders is part of a research study of emergency response times.

The app, known as TraumaHawk, was first released in 2013 for use by Iowa State Patrol troopers and advanced life support paramedics in the area around Iowa City. The app provides a way for law enforcement and first responders to collect a half-dozen very specific photos of a crashed vehicle that are automatically sent to emergency room personnel. Researchers say having advance notice of crash severity and location can help save lives. With that advance notice, emergency rooms can more thoroughly prepare for incoming victims. In the past, ER staff were notified of the condition of a patient only minutes prior to arrival. With TraumaHawk, an alarm sounds when images are being relayed. Staff can then view the images directly from the crash scene.

The project also develops on-the-scene training of law enforcement and first responders for recording photographic evidence and training of emergency room personnel in how to interpret the information collected. A key part of the project is that it doesn’t merely send photos, it allows trained professionals to assess patterns of injury based upon crush and intrusion patterns of the damaged vehicle. As part of the research, the traditional process for trauma alerts was examined for estimated time of arrival data for a one-month period. Timing for the TraumaHawk alerts during the same time period relative to actual ETA was also examined. During the study period, 32 cases were studied. Of these 32, the time between the trauma team receiving initial information and patient arrival was 12 minutes; for TraumaHawk, the advanced notice was received at the trauma center 26 minutes before patient arrival, more than doubling notification time. Phase 1: Development of the App. Phase 2: Evaluation of Time Savings. Phase 3: Scale to Implementation. Phase 4 (Currently underway): Regional Expansions.
### Project Summary and Benefits

ER surveys were conducted at 15 bridge sites. Five soil samples were also collected at each site with a drill rig from the surface to 10 feet (3 meters) using thin-walled Shelby tubes. The samples were tested in the EFA and classified according to the Unified Soil Classification System. Analysis showed that the rapid in situ data obtained from an ER field survey can be used to categorize the level of soil erodibility. As such, ER surveys may be used to characterize the soils at future bridge sites or prioritize existing bridges for additional testing to measure the scour potential. Moreover, ER surveys may be used to determine which existing bridges should be closed or closely monitored for scour potential during a flood event. Preliminary analytical models to predict soil critical shear stress using ER and other soil parameters were constructed. The selected preliminary model and ER prediction of soil erodibility were validated using one site. Implemented test method with $125,000 benefit over a 3-year period.
Improving the Traffic Safety Culture in Kansas

**Project ID**  K-TRAN: KU-15-2

**Cost**  $59,980

**Duration**  16 months

**Submitter**  Kansas Department of Transportation  
Richard E. Kreider, Jr.  
2300 SW Van Buren  
Topeka, Kansas 66611  
785-296-1195


**Project Summary and Benefits**

The main objective of this research was to provide guidance to the Kansas Department of Transportation (KDOT) in establishing strategies to improve the traffic safety culture in Kansas. This was done by analyzing crash data with respect to the seven coalition districts in Kansas. A detailed literature review along with a survey of existing conditions in 27 states was carried out. Web research was carried out to determine existing safety culture programs both in the United States and internationally. The applicability of the documented safety culture programs is determined based on the crash analysis of the coalition districts. The summary of the crash statistics and traffic safety culture programs, shown in Appendix C of the final report, was presented at the coalition meetings in order to positively impact the state’s traffic safety culture.
Guidelines for Replacement of Deficient Bridges with Low-Water Stream Crossings in the Rural Midwest

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| Submitter    | Kansas Department of Transportation  
               Richard E. Kreider, Jr.  
               2300 SW Van Buren  
               Topeka, Kansas 66611  
               785-296-1195 |

Project Summary and Benefits

Nine recent LWSC projects in Kansas are examined in detail. The structures include an unvented ford, a hybridtype ford, three vented fords, a low-water box culvert, a low-water bottomless culvert, and two low-water bridges. Eight of the projects are completed and one has been delayed by regulatory issues. Each case study includes a description of the structure and relevant information on the crossing history; road and traffic characteristics; stream characteristics and hydrology; governmental permits and regulatory issues; project costs; and maintenance requirements and performance to date.
Well Bonded Superpave Overlays on HMA (CISL Experiment No. 17)

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| Submitter    | Kansas Department of Transportation  
                   Richard E. Kreider, Jr.  
                   2300 SW Van Buren  
                   Topeka, Kansas 66611  
                   785-296-1195         |

**Project Summary and Benefits**

This study compares the bond strength of these materials by compacting a fresh HMA layer in the laboratory on top of cores taken from milled and non-milled highway sections. These cores were treated with different tack materials and application rates in order to find the optimal bond strength. The samples were tested in direct tension at two days, similar to KDOT’s construction quality assurance tests for the in-situ interface bond strength. Preliminary results indicate that SS-1HP does not improve bond strength at rates below 0.05 gal/yd2 (0.23 liter/m2) while EBL performs well at a rate that is 50% of the manufacturer’s recommendation. Trackless tack achieved acceptable bond strength as well. Surface texture was significant in achieving acceptable bond strength in some cases.

A full-scale accelerated pavement testing (APT) was also performed, and the results showed that EBL had better bond strength and slightly less permanent deformation, but showed no difference in cracking. Further APT testing with variable application rates of SS-1HP indicated that the KDOT-recommended rate of 0.05 gal/yd2 (0.23 liter/m2) showed good performance as a tack coat material based on the in-situ strain, in-situ bond strength, laboratory bond strength, and bond energy. Strain at the overlay interface and the existing HMA pavement was lowest for this rate. Although very heavy application of SS-1HP showed somewhat good performance, such high rate tends to decrease the interface bond strength as when evaluated in-situ as well as in the laboratory. Comparison of the SS-1HP test sections in the two APT experiments of this study indicates that the cleanliness of the milled surface is a big contributor to interface bonding.
Kentucky Transportation Cabinet

Kentucky Snow and Ice Removal Route Optimization

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<td>Jason Siwula</td>
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<td>200 Mero Street</td>
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<tr>
<td></td>
<td>Frankfort, Kentucky 40622</td>
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Links: [https://uknowledge.uky.edu/ktc_researchreports/1577/](https://uknowledge.uky.edu/ktc_researchreports/1577/)

Project Summary and Benefits

The Kentucky Transportation Cabinet (KYTC) typically spends $40-80 million per year on the facilities, trucks, labor, and materials needed for snow and ice removal and road treatments (e.g., application of salt). Trucks used for snow and ice removal operations follow a designated network of snow and ice removal routes. These routes are evolved as new roadways and lanes were added in each county. Routes are prioritized into categories based upon traffic volumes, with interstates and parkways receiving the highest priority.

Each county has an appointed number of trucks and facilities available to address its needs and frequently each truck will have multiple routes with no clear pattern geographically. Where counties lack sufficient staff to treat all routes in a manner consistent with policy, KYTC contracts with private firms to provide additional trucks and drivers. This snow and ice removal system, which was created manually, has been in place for some time and functioned effectively. However, KYTC recognized that there was the potential to improve the system using GIS-based analytical tools. While high-traffic routes always receive the highest priority, optimizing the routing system can bolster efficiency, increase safety, and reduce the amount of time and funding needed to treat roadways during winter storms, in the process saving KYTC considerable time and money.

At the request of KYTC, Kentucky Transportation Center (KTC) researchers developed a route optimization model to improve the efficiency the Cabinet’s snow and ice program. KTC researchers used GIS-based analytical tools to identify optimal truck routings and indicate where more or fewer trucks were needed based on objective data as well as input from local drivers. Researchers used ArcMap’s Network Analyst, specifically its Vehicle Routing Problem analysis, to delineate improved truck routings. The model included factors such as county level salt.
capacity, salt facility location, truck types, and roadway attributes. The analysis was based on a typical winter storm of one inch of snowfall. Modeled routes were designed around a route tree concept that structures each truck assignment on a central high priority road before branching off to adjoining lower priority roads. This design allows truck drivers to become more familiar with the roads on their route. As a result, drivers will react better to a non-typical winter storm and understand the safest and most effective way to treat the routes on schedule and still minimize the time needed to do so.

Model results for select counties have identified the potential for KYTC to treat all routes in each of those counties on schedule using fewer trucks, which is projected to translate into significant cost savings for KYTC. Two counties in District 6 (Grant and Pendleton) can eliminate six trucks with more efficient routings, resulting in savings of at least $150,000 per year. Similar results emerged for two counties in District 7 (Clark and Montgomery), where route optimization demonstrated the opportunity to eliminate three contract trucks, yielding a minimum of $75,000 in savings per year. Accounting for just these four counties, KYTC is projected to save nearly a quarter million dollars per year. Implementation in the four initial counties was tested during the 2017-18 winter season. KYTC requested that KTC apply the model to additional counties to yield further cost savings across the state. Continued implementation of the model in more counties will lead to further route optimization and savings for KYTC.
Kentucky Transportation Cabinet

Development and Delivery of the Project Manager's Boot Camp

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| Submitter   | Kentucky Transportation Cabinet  
Jason Siwula  
200 Mero Street  
Frankfort, Kentucky 40622  
502-564-3730 |

Project Summary and Benefits

The Kentucky Transportation Cabinet’s (KYTC) Department of Highways strives to develop and deliver the projects scheduled in the Six-Year Highway Plan, a document approved by the General Assembly that outlines major highway capital improvement projects. A project is considered successful when it is delivered to its projected construction letting on time, within the construction budget estimate, and provides a quality solution that fits the project purpose and need. A possible reason is that employees now attain project management roles earlier in their careers due in part to staff turnover. Turnover prevents employees from gradually acquiring and progressively applying new project management skills. Currently, new project managers may be charged with managing high levels of responsibility before they have accumulated sufficient experience dealing with project challenges.

After identifying inexperienced project managers as a contributing factor to challenges in the project development process, Kentucky Transportation Center (KTC) researchers sought to determine an appropriate corrective action. They began with capturing knowledge from KYTC’s remaining project management subject-matter experts (SMEs). KTC researchers conducted in-depth interviews with each SME and documented their responses. The responses were then synthesized and reviewed to determine which project management path within the KYTC system is the most consistently successful.

After identifying inexperienced project managers as a contributing factor to challenges in the project development process, Kentucky Transportation Center (KTC) researchers sought to determine an appropriate corrective action. They began with capturing knowledge from KYTC’s remaining project management subject-matter experts (SMEs). KTC researchers conducted in-depth interviews with each SME and documented their responses. The responses were then synthesized and reviewed to determine which project management path within the KYTC system is the most consistently successful.

The Project Management Body of Knowledge, which contains best practices for project management, served as a barometer to measure these aspects of project management. KTC interviewed stakeholders from each division that plays a role in the project development process to understand their interactions with project management and how those can be improved to ensure success. KTC researchers used this knowledge to develop a KYTC
project management outline with members of the KYTC Office of Project Development and Highway Districts. The outline was expanded into modules that could be translated into training components for new project managers.

The result was the Project Manager’s Boot Camp (PMBC). PMBC is an 8-day course delivered over two months that offers comprehensive project management training. The training furnishes practical guidance on building project teams; overseeing project work; accelerating project delivery; and adaptive management procedures that can be used to keep design, planning, and construction on schedule. Individual course modules cover a wide range of subjects, including project cost management, professional ethics, managing consultants, and how to orchestrate the work performed by various divisions within KYTC. PMBC underscores the importance of project managers adopting a holistic approach to project implementation and oversight, emphasizing that project managers are ultimately responsible for project delivery.

To ensure the course met the needs of the attendees, a self-assessment was administered multiple times during PMBC to measure participants’ level of knowledge about the requirements of project management and their confidence in being able to fulfill those requirements. The data collected from these self-assessments revealed a noticeable improvement in all areas of project management knowledge among all participants.

The original project funded two offerings of PMBC. Both written student surveys and verbal feedback showed each iteration was enthusiastically received by KYTC staff. Along with developing course material, KTC researchers compiled material that catalogues and describes the content of each course module. The resulting document will serve as a living resource that project managers can reference for reminders on project management.

As KYTC updates its procedures, policies, and strategies for project delivery, this document will be revised as well. Having an accessible, updatable source of project management knowledge in a compact, easy-to-use format will alleviate problems that arise due to staff turnover and knowledge management challenges. PMBC has reenergized KYTC’s project management efforts and helped to establish a standard that other state transportation agencies can look to for guidance and technical assistance.

Witnessing the success of PMBC for internal staff, KYTC requested development of an abbreviated PMBC training for consultant project managers. This effort was termed Project Manager’s Boot Camp Xpress. Consultants wishing to serve as project managers for KYTC are now required to complete this course before they manage projects for KYTC. Consultant project managers are trained not only on consultant project management expectations but also on the expectations that their KYTC project manager faces.

To date, 244 consultant project managers have attended Boot Camp Xpress. Both the full version of PMBC and Boot Camp Xpress have proven to be effective and efficient methods of knowledge delivery. Continuing to deliver and refine these courses will be critical for helping Cabinet staff and consultants build their project management skills, enabling them to successfully undertake and deliver vital capital infrastructure projects that are critical for the state’s future.
Live Load Rating of Cast-in-Place Box Culverts in Louisiana

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| Submitter         | Louisiana Department of Transportation and Development  
                       Tyson Rupnow  
                        4101 Gourrier Avenue  
                        Baton Rouge, Louisiana 70808  
                       225-767-9124 |

**Project Summary and Benefits**

This study is focused on live load rating of eight cast-in-place (CIP) reinforced concrete box culverts from LA-DOTD’s inventory. The fill heights over the selected culverts varied but were chosen to be mostly with low soil fill since this condition is known to pose rating challenges. Refined live load rating factors considering HL-93 design truck and 10 different legal trucks were determined for each of the eight culverts. Live Load test results showed that the culverts are performing well and load posting was not required though the computed LRFR rating factors were less than one. These results are expected to save the Department a considerable amount of money.
Hamburg Wheel-Track Test Equipment Requirements and Improvements to AASHTO T 324

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| Submitter        | Louisiana Department of Transportation and Development  
Tyson Rupnow  
4101 Gourrier Avenue  
Baton Rouge, Louisiana 70808  
225-767-9124 |

**Project Summary and Benefits**

The Loaded Wheel Test (LWT) is a laboratory-controlled rut depth test that uses loaded wheel(s) to apply a moving load on hot-mix and warm-mix asphalt (HMA, WMA) specimens to simulate traffic load applied on asphalt pavements. In the 1970s, Helmut-Wind Incorporated of Hamburg proposed a test method and developed specification requirements to measure the combined effects of rutting and stripping susceptibility. The equipment developed was named the Hamburg Wheel Tracking Device (HWTD) and has been used for over four decades worldwide. The HWTD measures the combined effects of rutting and moisture damage (stripping) by rolling a steel wheel across the surface of an asphalt concrete slab that is immersed in a temperature-controlled water bath. The interest and use of LWT in performance specifications, alternatively referred to as rut testers or torture testers, has seen an increase in recent years. This interest can be attributed to several factors, including the use of such devices by FHWA and many state Departments of Transportation (DOTs). Other important factors in this increased popularity are the ease of use and good correlation to field performance, which led many DOTs to incorporate LWT tests in their specifications as a pass or fail acceptance criteria.

As the popularity of this test equipment increased, several manufacturers started producing their own variation of the LWT. Those machines were built using various solutions and technologies for controlling the wheel speed, measuring the rut depth, water bath temperature control, and reciprocating mechanisms, to name a few.

AASHTO T 324 Standard test Method Standard Method of Test for Hamburg Wheel-Track Testing of Compacted Hot Mix Asphalt (HMA) was published to standardize these solutions among different manufacturers. However, several research studies showed significant variations amongst different manufacturers of LWTs in meeting AASHTO T 324 test specifications.

The objectives of this research were to:
1) Document the capabilities of available commercial Hamburg test equipment,

2) Determine Hamburg test equipment capabilities, components, or design features that ensure proper testing and accurate, reproducible results, and

3) Provide proposed revisions with commentary to AASHTO T 324 to enable the use of a performance type specification for Hamburg test equipment.

A comprehensive experimental program was conducted to evaluate the capability of commercially available HWT equipment as well as their ability to accurately measure, control, and maintain the desired test conditions as specified in AASHTO T 324. A novel approach to calibrate LWTs as per AASHTO T 324 specifications using GoPro video camera and images processing algorithms was developed. After performing a comprehensive evaluation of the machines conforming to AASHTO T 324, it was concluded that available HWT machines did not meet all the requirements set forth in AASHTO T 324. This included requirements for the waveform, the temperature range, and the reporting parameters.

One reason for some of the observed differences was attributed to the ambiguity of the specification and the lack of detailed requirements for the different aspects of the test method. Based on the results of the experimental program, major revisions to AASHTO T 324 and to the configurations of the available HWT machines were recommended. Modifications were proposed to address equipment capabilities, components, or design features in order to ensure proper testing and accurate, reproducible results. Proposed modifications were discussed to ensure repeatable measurements and that the results from different manufacturers are comparable. These modifications included change to temperature measurement and range, impression measurement system, data collection, and data analysis and reporting.

AASHTO Committee on Materials and Pavement implemented the proposed revisions of AASTO T 324. With these modifications, state agencies can reliably use LWT results in their new generation of engineered asphalt mixture design for greater innovation in pavement performance. By implementing the proposed changes to AASHTO T 324, state agencies and contractors are assured of reliable LWT results as a part of their Balanced Asphalt Mixture Design process. This allows for innovations in materials selection such higher recycled content (RAP, RAS, CRM) and sustainable mixture technologies (WMA, CR, green binders). This freedom to innovate can result in more sustainable asphalt mixtures for the taxpayer across the county. Additional reliability will increase the lifespan of our roadways and allow for innovative mixture designs that can save construction costs.
LaSET: Louisiana Safety Evaluation Tool

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| Submitter  | Louisiana Department of Transportation and Development  
Tyson Rupnow  
4101 Gourrier Avenue  
Baton Rouge, Louisiana 70808  
225-767-9124 |
| Links      |             |

**Project Summary and Benefits**

This project developed a single web-based data management application that provides both detailed tracking of low-cost road safety improvement projects over years and the ability to analyze their effectiveness (in regard to crash reductions). The web-based feature makes it accessible on standard computer web browsers, tablets and portable computer devices. The application’s ability to both collect project data and perform analysis means that user access is not limited by location or function. Another benefit of being web-based, means that software will not have to be installed on each computer that will access the data.

Data quality and reliability is aided by the standardization of how project data is entered into the application and by the validation rules that prohibit invalid entries. Project data will grow over time as new low cost safety improvements are implemented. This will allow, as crash reduction effectiveness is evaluated, for more accurate and cost effective decisions over time. The tool was piloted by the Louisiana DOTD in three Districts in 2015. The pilot proved successful and has been implemented statewide for use in all nine Districts.
**Incorporating the Increase in Pile Resistance (Setup) into Design Saves Costs**

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| **Submitter**    | Louisiana Department of Transportation and Development  
|                  | Tyson Rupnow  
|                  | 4101 Gourrier Avenue  
|                  | Baton Rouge, Louisiana 70808  
|                  | 225-767-9124         |

**Project Summary and Benefits**

Incorporating even a small percentage of pile setup into a rational pile foundation design can result in significant cost and time savings, including allowing:

(a) shorter pile lengths,  
(b) smaller pile sizes,  
(c) fewer pile quantities and hence fewer piles to drive (time wise), and  
(d) reduction of the size of driving equipment (using smaller hammers and/or cranes).

Following the findings of this research study, the DOTD started to incorporate setup into the design of pile foundations for the various infrastructures using the calibrated setup resistance factor, setup = 0.35. The benefits of incorporating pile setup in terms of cost and time savings have been realized.
Development and Evaluation of Pile “High Strain Dynamic Test Database” to Improve Driven Capacity Estimates

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| Submitter  | Maine Department of Transportation  
Dale Peabody  
16 State House Station  
Augusta, Maine 04333  
207-624-3305 |
| Links      | [http://maine.gov/mdot/research/docs/reports/BrdgRsch_14-01p2.pdf](http://maine.gov/mdot/research/docs/reports/BrdgRsch_14-01p2.pdf) |

### Project Summary and Benefits

The Maine Department of Transportation (MaineDOT) has noted poor correlation between predicted pile resistances calculated using commonly accepted design methods and measured pile resistance from dynamic pile load tests (also referred to as high strain dynamic tests) conducted in accordance with ASTM D-4945. The MaineDOT requested that the University of Maine examine and evaluate their current static pile capacity design methodologies using the results from dynamic load tests on piles as a standard. Capacity can be used interchangeably with the term “resistance” used by AASHTO in LRFD applications. The intent of the final product is to provide MaineDOT with calculation methods that provided the most reliable capacity estimates. More reliable calculation methods will result in more cost efficient designs.

The work was essentially divided into two phases: the creation of a database which encompassed selected, available project data and comparison of static capacity analysis methods to investigate which combination is most reliable. A new rock bearing method, the Intact Rock method (IRM), is proposed that relates capacity to rock type in Maine. The proposed IRM and Canadian Geotechnical Society (CGS)methods were compared to dynamic test results, and the results indicated that the proposed IRM had significantly better predictions. The Intact Rock Method (IRM) had been adopted by MaineDOT for estimating the static geotechnical resistance of pile end bearing on rock. The IRM eliminates some of the conservatism related to bedrock jointing. MaineDOT also has been following the study recommendation to perform more direct shear tests to optimize the estimation of side friction resistance of piles in till.
GIS-Based Subsurface Exploration System

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| Submitter    | Maryland Department of Transportation  
              Hua Xiang  
              707 N. Calvert Street, MS C-412  
              Baltimore, Maryland 21202  
              410-545-2953      |

Project Summary and Benefits

In 2012, MDOT SHA set a goal to develop a Geographic Information System (GIS) based subsurface exploration database. This database allowed engineers to better track, record, evaluate, analyze, share, and visualize the geotechnical subsurface data. Prior to this project MDOT SHA’s geotechnical data was managed by Field Exploration Division (FED) via a paper process which resulted in significant efficiency loss due to transcription errors, data accessibility, data transport, and other issues. Further enhancements have been added to the developed application since the project ended in 2014. The program has achieved major cost savings to the administration as outlined below.

Electronic Data Requests

When an electronic boring request is received through the GIS-based interface, it is first validated by the Boring Request tool to identify if the boring locations are on a private property or wetlands. The tool also identifies all previous borings near the requested locations to avoid redundant drilling. After the automated review, the request is reviewed and validated by an engineer and a work order is added to the drilling queue. The system component saves substantial costs by reducing time spent preparing hand written forms, catching errors early on (out-of-state coordinates, private property, missing data, etc.), consolidating and tracking review correspondence, and spatially presenting the boring locations with reference to utilities, right-of-way, and other roadway asset locations.

Remote Field Data Capture

All data is now electronically collected in the field on a mobile device. Data is captured and provided real-time to project engineers. This component eliminates the time preparing hand written forms and converting to electronic data, and provides immediate quality control.

Automated Project Tracking
Throughout the requesting, drilling, and data delivery, the flow of data is automatically tracked, allowing the program to provide all users a real-time look at the project queue. This includes the status of every project and the program as a whole. Automated project tracking eliminates the need to prepare weekly progress reports and project engineers no longer need to contact FED for status updates.

**Historic Boring Data**

All Boring data is now saved and provided spatially in this program. Users can generate gINT files for any set of historic borings. Additionally, when a boring is requested near a location that was drilled in the past, this historic data is automatically provided to avoid duplication.

**Quantified Cost Savings**

This project has resulted in an estimated MDOT SHA cost savings of almost $1M per year. The estimated savings for each component is listed below. The cost savings from catching errors (utilities, private property etc.) are not included in these conservative estimates. Such cost savings will increase as the quantity of archived data increases.

- System Component Electronic Data Requests : $168,000 saved per year
- Remote field data capture: $224,000 saved per year
- Automated Project Tracking: $87,360 saved per year
- Historic Boring Data: $480,000 saved per year

**TOTAL COST SAVINGS: $959,360 per years**
**Project Summary and Benefits**

MDOT has identified the need to increase the efficiency of collecting bridge condition data by taking advantage of tablet technology capabilities and the technology to display and record information in 3D. MDOT can take advantage of advancing technologies to help its bridge inspectors and managers meet new national requirements for inspection data and increase the usefulness of collected data.

MDOT worked closely with a development team from Michigan Technological University to develop the “3D BRIDGE app.” The 3D BRIDGE app is a mobile software tool designed to facilitate bridge inspection processes by enabling inspectors to collect and record element level bridge inspection data using 3G/4G network-enabled tablet devices. The application automatically renders a 3D model of the desired bridge using data from MDOT’s bridge management databases. The 3D model enables inspectors to more easily record and visualize the defects and element level data associated with the bridge at specific locations along the infrastructure elements. To develop the application, the team examined the state of the practice across the country to understand available options and interviewed bridge inspectors to better understand their needs for a flexible, user-friendly, field-usable bridge inspection software tool.

Because 3D models of all bridges are not yet available, the team developed a server application to query MDOT’s Bridge Management System database for element-level bridge components to create a sufficiently representative bridge model appropriate for bridge inspections. 3D models can be fine-tuned where additional information is needed. Using a set of intuitive navigational views, the user can traverse the bridge and mark the surface with location-specific Element Level defect information, photos, and comments. Defect markers are proportionally sized based on the defect quantity and color coded to match condition states.

The application also has a summary view for reviewing the aggregate defect information in element level and National Bridge Inventory level formats. An application user manual is available to help MDOT staff apply the tool. MDOT plans to use the project’s resulting app to fulfill its vision of utilizing advancing technologies to
increase the efficiency of its bridge management process. By advancing the state of practice for bridge applications, MDOT will be a leader in using 3D models to help record location-specific defect information that can also inform bridge deterioration modeling. A final implementation phase would make the tool available throughout MDOT’s bridge management and maintenance programs.
Comparison of Alternative Pedestrian Crossing Treatments

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| Submitter    | Michigan Department of Transportation
              Michael Townley
              8885 Ricks Road
              Lansing, Michigan 48909
              517-636-0144 |

Links

Project Summary and Benefits

Pedestrian safety is an important issue for MDOT, but getting drivers to consistently yield to pedestrians at crosswalks is a significant challenge. The gateway treatment, which consists of yield for pedestrian signs installed at each lane line, is an inexpensive strategy to increase driver yielding rates. The established strategies for increasing driver yielding rates include the rectangular rapid flash beacon and pedestrian hybrid beacon. With installation costs of $20,000 and $100,000, respectively, they are too expensive for widespread implementation. The gateway treatment developed in this research is a promising and less-expensive option, costing only $1,200.

The project evaluated the effectiveness of the gateway treatment. The research team installed the signs in several configurations at various sites, including non-signalized intersections, traffic circles, trail crossings, midblock crosswalks and interstate highway ramp entrances. To evaluate the influence of the message imprinted on the signs, researchers also tested a gateway configuration using all blank signs. Researchers evaluated whether the impact of the gateway treatment on driver behavior would persist over time. They collected speed information to assess if gateway installations affected speed reductions. The gateway configuration significantly improved driver yielding rates at several sites. Under baseline conditions (that is, without the gateway treatment), many locations had yield rates of less than 10 percent. After installation of the signs, yield rates increased to more than 90 percent in some circumstances. The gateway treatment also had a traffic-calming effect, leading to speed reductions of between 4 and 10 miles per hour (mph), even when pedestrians were not present.

MDOT published a user guide to aid implementation of the gateway treatment. This guide describes the signs needed, installation time and costs, and anticipated driver-yielding compliance for eight types of sites based on the number of lanes and the presence of a refuge island. The guide also includes recommendations such as the use of curb extensions at certain locations and the use of flexible delineators where signs are particularly vulnerable to being struck by cars.
**Association of Michigan’s Older Adult Crashes with Roadway Features**

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| **Submitter** | Michigan Department of Transportation  
Michael Townley  
8885 Ricks Road  
Lansing, Michigan 48909  
517-636-0144 |

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**Project Summary and Benefits**

Aging can produce declines in the physical and psychological skills needed for driving. To help older adults maintain their independence and continue driving, MDOT in recent years has focused research on implementing engineering measures that can make driving safer and less stressful for them.

As part of that effort, this project identified additional ways that MDOT can use roadway features to improve driving safety for older adults. The researchers first conducted a comprehensive literature review to identify similar studies of crash-related roadway features and engineering improvements that benefit older drivers. They then reviewed Michigan crash data from 2010 to 2014 to identify locations, time of day and weather conditions for crashes in which older drivers were disproportionately involved. The third step was to survey Michigan roads and compare MDOT’s current engineering standards with those in the “FHWA 2014 Handbook for Designing Roadways for the Aging Population” which revealed opportunities for MDOT to enhance highway safety for older drivers. Researchers recommend implementing a variety of design features, including intersections skewed at no less than 75 degrees and using offset left-turn lanes, raised channelization medians, and overhead street name signs. The study results also may help MDOT make more informed decisions about where to invest resources to improve driving safety for older adults.
Drivers who committed hazardous actions by crash type

- Angle
- Head On
- Head On-Left Turn
- Other/Unknown
- Rear End
- Rear End-Left Turn
- Sideswipe-Opposite
- Sideswipe-Same

65yrs-and-older drivers vs 64yrs-and-younger drivers
3-D Mapping of Bridges and Riverbeds with Underwater Sonar

**Project ID** 2017-40, 1027133

**Cost** $29,993

**Duration** 7 months

**Submitter** Minnesota Department of Transportation
Shannon Fiecke
395 John Ireland Boulevard., MS 330
St. Paul, Minnesota 55155
651-366-3738

**Links** [http://dotapp7.dot.state.mn.us/projectPages/pages/projectDetails.jsf?id=17869&type=CONTRACT](http://dotapp7.dot.state.mn.us/projectPages/pages/projectDetails.jsf?id=17869&type=CONTRACT)

**Project Summary and Benefits**

MnDOT’s hydraulics unit tested 3D mechanical scanning sonar equipment (Teledyne Blueview BV5000) to collect inspection data on four Minnesota bridges. Bridge inspectors found 3D acoustic imaging extremely useful for identifying underwater site conditions and defects, riverbed terrain, debris location, and scour characteristics. Underwater acoustic 3D imaging enhances substructure assessments and diver safety for routine inspections, pre- and post-construction scans, emergency examinations and riverbed mapping. It was particularly useful in assessing damage after a flood.

The next step is to develop an underwater imaging policy and reach out to MnDOT districts, counties, cities, and bridge owners to promote the imaging capability of 3D sonar. The hydraulics unit also plans to develop a list of bridges suitable for underwater imaging and train field personnel on the use of imaging techniques and inspection.
Institutionalizing Bicycle and Pedestrian Counting

**Project ID** 2017-02, 99008, 177

**Cost** $120,000

**Duration** 25 months

**Submitter** Minnesota Department of Transportation
Shannon Fiecke
395 John Ireland Boulevard, MS 330
St. Paul, Minnesota 55155
651-366-3738

**Links** [http://dotapp7.dot.state.mn.us/projectPages/pages/projectDetails.jsf?id=38256&type=DOCUMENT](http://dotapp7.dot.state.mn.us/projectPages/pages/projectDetails.jsf?id=38256&type=DOCUMENT)

**Project Summary and Benefits**

This project was the third and final phase of a MnDOT initiative to develop a bicycle and pedestrian monitoring program in Minnesota. The implementation team developed 22 permanent count locations across the state, a program for lending equipment to local agencies, and a bicycle and pedestrian data collection manual. The team also created the following: procedures to lend equipment for short-term counts; various templates for organizing and reporting traffic counts; a template for an annual report on bicycle and pedestrian counts; statewide bicycle and pedestrian traffic monitoring plans; and a bicycle and pedestrian monitoring task force.

MnDOT has invested more than $250,000 in counting technology due to the success of this implementation project. This project also helped Hennepin County evaluate counting technologies and monitor sites of their own. As a result, Hennepin County invested in their own equipment and created a bicycle monitoring program consisting of more than 60 sites. There are only a handful of states with an automated counting program; Minnesota is now among the national leaders, thanks to this project.
MnDOT District Training Promotes Benefits of Snow Fence Program

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| Submitter  | Minnesota Department of Transportation  
Shannon Fiecke  
395 John Ireland Boulevard, MS 330  
St. Paul, Minnesota 55155  
651-366-3738 |
| Links      | [http://dotapp7.dot.state.mn.us/projectPages/pages/projectDetails.jsf?id=14659&type=CONTRACT](http://dotapp7.dot.state.mn.us/projectPages/pages/projectDetails.jsf?id=14659&type=CONTRACT) |

Project Summary and Benefits

Researchers developed a training program for MnDOT district staff to learn about MnDOT’s snow fence program and methods to promote snow fence use among private landowners. They worked with maintenance staff and program delivery staff in District 8 to develop and test the snow fence outreach program.

A survey showed market improvements in staff knowledge of the program and willingness to promote it. Landowner participation grew from four sites to 15, mostly due to maintenance staff participation, and the number of standing corn rows grew 30 percent. Surveys before and after the program suggested potential program improvements, including more program champions; outreach in spring and summer at community and farmer gatherings, as well as local and state fairs; and a clearer understanding of how program promotion fits within job responsibilities.

A market study was also completed, which demonstrated that nonliving snow fences, though the most expensive option for MnDOT, offer the largest benefit per acre. Landowners seem to prefer living snow fences and standing corn rows. MnDOT may wish to raise the annual payment for all living snow fences.
Field Guide Helps Local Engineers Stabilize Damaged Slopes

**Project ID**  
2017-17 & 2017-17G, 99008, 190

**Cost**  
$78,124

**Duration**  
27 months

**Submitter**  
Minnesota Department of Transportation  
Shannon Fiecke  
395 John Ireland Boulevard, MS 330  
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651-366-3738

**Links**  
http://dotapp7.dot.state.mn.us/projectPages/pages/projectDetails.jsf?id=14071&type=CONTRACT

Project Summary and Benefits

Following the investigation of 14 destabilized roadway slopes, researchers recommended eight techniques that local engineers can use to repair slopes without having to hire outside geotechnical engineers. These techniques were then developed into a simple, accessible field guide for county engineers. This field guide describes common slope failures and conditions that may contribute to each. It includes a simple, three-step flowchart that guides engineers to possible repair techniques by determining whether the damage is a creep or rotational failure, whether the soil is cohesive or granular, and if there are groundwater concerns. Based on engineers’ answers, the flowchart directs them to one or more of the eight possible slope stabilization techniques, providing photographs and repair methods that have been successful in addressing slope problems along Minnesota roadways.

This project was innovative in creating a targeted slope stabilization guide for local government engineers. Such a guide did not exist prior to this project. It is not intended to solve all slope problems, but should be a good starting point for many basic problems. Usage of this field guide is expected to reduce maintenance costs, by giving local engineers instruction on how to repair slopes that repeatedly fail, without requiring them to hire outside assistance. This project dovetails with ongoing MnDOT research efforts to develop software models for identifying slopes that are susceptible to flood damage.
Mississippi Department of Transportation

Development of a Data Quality Management Plan for Pavement Management System (PMS) Data

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| Submitter        | Mississippi Department of Transportation  
|                  | Cynthia Smith       |
|                  | P.O. Box 1850        |
|                  | Jackson, Mississippi 39215-1850 |
|                  | 601-359-7647         |

Project Summary and Benefits

This project was initiated to update MDOT’s existing pavement management process documentation, to develop a QMP for pavement management data collection activities, and to identify recommendations for improving the quality checks on pavement condition data collected by vendors. The Pavement Management Manual and the Network-Level Pavement Condition Data Collection Quality Management Plan are products developed under this research effort and are included as appendix attachments to the final report. The Pavement Management Manual contains relevant pavement management guidance and supplemental materials compiled into single document that describes current pavement management business practices. The Quality Management Plan follows the structure provided in the Practical Guide for Quality Management of Pavement Condition Data Collection (FHWA 2013) but is customized to MDOT’s business practices. The plan identifies data collection contractor quality control requirements and describes the actions needed to resolve any data inconsistencies that are discovered. The quality assurance process used by the agency is outlined and space is provided to record the quality checks that are conducted each time data is submitted by the contractor.
Intelligent Compaction-Infrared (IC-IR) Implementation in Missouri

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| Submitter        | Missouri Department of Transportation  
                  | Bill Stone  
                  | 1617 Missouri Boulevard, P.O. Box 270  
                  | Jefferson City, Missouri 65109  
                  | 573-526-4328 |
| Links            | https://library.modot.mo.gov/RDT/reports/TR201716/cmr18-003.pdf |

**Project Summary and Benefits**

The main goal of this project was to demonstrate the usage of IC, IR, and the Veta software to improve construction quality control and efficiency to make pavements last longer and to reduce maintenance cost. Through this project, MoDOT gained valuable insights with regard to the utilization of IC-IR. The thirteen MoDOT IC-IR asphalt projects in 2017 helped build up experience for both department personnel and contractors. The IC-IR project protocol was effective for planning and conducting field projects. The IC-IR data management is a key component of the protocol, ensuring a consistent data naming convention and submission. Project documents and files (some very large) were stored on MoDOT’s SharePoint site which was also accessible to contractors.

The IR implementation proved successful as a real-time indicator of any temperature segregation. In turn, the IR data and analysis reports can be used to fine tune the paving process accordingly, such as making use of a material transfer device and adjusting truck fleet and paving speeds. Improved calibration and enhanced training will help address any issues related to IR DMI and data sampling of a vendor’s systems and analysis performed with vendor software. The IC implementation has been utilized to maximize roller coverage with some exceptions. Any coverage issues can be resolved by planning the construction operations based on project location and alignment, lift thickness to be constructed, type of materials, and availability of equipment and resources, along with proper training. Issues with IC roller calibration can be overcome with additional vendor training. The GPS boundary measurements were successful with occasional issues that required sorting, inspection, and correction. Although IC-IR data management is still tedious, especially when IC or IR data needs to be exported or transferred manually, ongoing training with the protocol and additional experience will resolve these issues.
# Flood Inundation Mapping for the Lower Meramec River

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| **Submitter** | Missouri Department of Transportation  
Bill Stone  
1617 Missouri Boulevard, P.O. Box 270  
Jefferson City, Missouri 65109  
573-526-4328 |
| **Links**     | [https://pubs.er.usgs.gov/publication/sir20175116](https://pubs.er.usgs.gov/publication/sir20175116) |

## Project Summary and Benefits

After the lower Meramec River flooded and caused substantial impacts to transportation and area communities in St. Louis County, Missouri in the winter of 2016, a group of public and private entities banded together to develop and fund a project proposed by the U.S. Geological Survey (USGS) Missouri Water Science Center.

As a result, the Center developed online flood inundation mapping (FIM) tools targeted at a particularly hard hit reach of the river from Valley Park, Missouri to Fenton, Missouri. Flood profiles were computed for the stream reaches by means of a calibrated one-dimensional step-backwater hydraulic model which had already been developed by the U.S. Army Corps of Engineers (USACE). Two sets of digital flood inundation map libraries that spanned this combined 16.7-mile reach of the river were created by USGS in cooperation with the USACE, St. Louis Metropolitan Sewer District, Missouri Department of Transportation, Missouri American Water and FEMA Region 7.

The maps can be accessed through the USGS Flood Inundation Mapping Program website. They depict estimates of the area extent and depth of flooding corresponding to selected water levels (or stages) between streamgages at the respective upstream and downstream locations. The availability of timely flood inundation maps, along with internet information regarding current stage from the USGS streamgages and forecasted high-flow stages from the NWS, will provide emergency management personnel and residents with information that is critical for flood response activities such as evacuations, road closures, and post flood recovery efforts.
Project Summary and Benefits

Improving work zone road safety is an issue of great interest due to the high number of crashes observed in work zones. One method that DOTs use to inform drivers of upcoming work zones is work zone signage configuration. Any signage designs and configuration that deviate from national standards must be evaluated before their implementation.

Phase I of the research investigated the effect of an alternative merge sign configuration within a freeway work zone. In this alternative configuration, the graphical lane closed sign from the MUTCD was compared with a MERGE/arrow sign on one side and a RIGHT LANE CLOSED sign on the other side. The test sign proved to be a good alternative to the MUTCD sign.

Phase II of the research consisted of a driving simulator based study that evaluated a driver's response to work zone sign configurations. This study compared the Conventional Lane Merge (CLM) configurations against MoDOT’s alternate configurations in order to quantify better the differences between the two sign configurations. This research evaluated the effectiveness of the alternate merge sign configuration with respect to age and merge direction. The type of the sign did not have an effect on driving behavior.
Advanced Methodology to Determine Highway Construction Cost Index (HCCI)

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| Submitter  | Montana Department of Transportation  
Sue Sillick  
2701 Prospect Avenue, P.O. Box 201001  
Helena, Montana 59620  
406-444-7693 |

Project Summary and Benefits

A highway construction cost index (HCCI) is an indicator of the purchasing power of a highway agency. Thus, it must reflect the actual construction market conditions. However, the method previously used by MDT was not robust enough to meet this primary goal due to (1) a significantly insufficient sample size of bid items used in HCCI calculation and (2) inability to address the need to track cost trend of construction submarket segments such as, but not limited to, various project types, sizes, and locations.

This study resulted in the development of an advanced methodology to overcome these limitations using two new concepts: (1) dynamic item basket and (2) multidimensional HCCIs. The dynamic item basket process identifies and utilizes an optimum amount of bid-item data to calculate HCCIs in order to minimize the potential error due to a small sample size, which leads to a better reflection of the current market conditions.

Multidimensional HCCIs dissect the state highway construction market into distinctively smaller sectors of interest and thus allow MDT to understand the market conditions with much higher granularity. A methodology was developed to integrate these two concepts and a standalone MDT GIS visualization HCCI Calculation and Bid Analysis System was developed to automate the HCCI calculation process. The results show an eightfold increase in terms of the number of bid items used in calculating HCCIs and at least a 20% increase in terms of the total cost of bid items used. In addition, the multidimensional HCCIs reveal different cost-change patterns across different highway sectors. For example, the bridge construction market historically shows a very different trend compared with the overall highway construction market.

The new methodology is aiding MDT in making more-reliable decisions in preparing business plans and budgets with more accurate and detailed information about the construction market conditions. Further, the system is providing insights on the cost trends of a specific item; aiding in identifying project types, locations, and sizes with higher construction cost growth; and aiding in identifying hidden relationships such as cost-quality relationship.

Additional benefits include the following:
• Research team evaluated current practice and determined best statistical method to use.
• Research team brought in new practice procedures that may have been missed by MDT staff.
• Documented process.
• Help guidance available inside the tool.
• Tool can be used by anyone within MDT to produce customized results specific to the need versus one person posting the information to a shared site for all to use.
• Cost estimators are able to observe cost trends in real time.
• Potential to improve Engineer’s Estimate,
• Can be used as additional data for developing inflation rates.
• Results are comparable to national index and other states’ data.
• New GIS visualization tool to automatically mine construction cost data versus MDT staff spending over 40 hours each year.
• New tool allows dynamic statistical analysis versus static, one value result.

Also, the old method provided a statewide index that was based on all project types and most common materials used. The new tool provides options to:

• Select data from projects statewide or by district.
• Select data from specific project types.
• Select categories of materials or specific materials.
• Limit the range of data to a specific time period.
• View contract and project statics in addition to construction cost index.
• View results on a colored heat map with interactive features to see the specific information behind a data point.
• Export results to a spreadsheet for further analysis.
Montana Department of Transportation

Rockfall Hazard Process Assessment

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| Submitter  | Montana Department of Transportation  
            Sue Sillick  
            2701 Prospect Avenue, P.O. Box 201001  
            Helena, Montana 59620  
            406-444-7693 |

Project Summary and Benefits

The Montana Department of Transportation (MDT) implemented its first Rockfall Hazard Rating System (RHRS) between 2003 and 2005, obtaining information on the state’s rock slopes and their associated hazards. The RHRS data facilitated decision-making in an informal process over the next several years. MDT applied the RHRS ratings in an informal process, reviewing ratings and comparing them to event occurrences, maintenance needs, and rockfall mitigation project selection in the decade since completion. MDT found the RHRS to be a valuable tool providing relative rankings between sites. After nearly a decade of using RHRS, in 2015 MDT decided to develop a more comprehensive and updated Rock Slope Asset Management Program (RAMP) due to a combination of changed sites, a need for additional tools to aid in project selection, and a desire to incorporate principles of Transportation Asset Management (TAM) in managing rock slopes.

This research project resulted in an assessment of changes in MDT’s rock slope assets since 2003 and the gathering of data that allowed the development of an updated rock slope hazard assessment program with TAM-compatibility as an added benefit. The research project scope included identifying rock slope condition and risk factors, determining critical sites, incorporating benefit/cost analysis, and forecasting future asset condition based on various budget scenarios.

The objectives were to:

1) update rock slope rating criteria;
2) determine critical sites based on condition, risk, and cost/benefits using new decision support tools;
3) develop/cost benefit scenarios; and
4) evaluate compatibility of the RAMP process with MDT’s Transportation Asset Management program.

Online mapping platforms using MDT’s existing GIS platform, ArcGIS Online were developed. This platform significantly improves interacting with the RAMP data by moving from the previous Oracle platform into a
modern, user-friendly mapping platform. The entire RAMP database resides on the online platform, with photos of each site available through both read-only public and writable internal links. Tracking and recording rockfall events and their impacts to the Department and the public is facilitated using map-based forms that are instantly available online. MDT Geotechnical personnel and select individuals can enter event and maintenance information, improving long-term risk and costs analyses. Online map series of various decision support tools, minimal acceptable conditions, and rock slope failures are available to MDT personnel via the web.

The new MDT Rock Slope Asset Management Program (RAMP) includes a number of new enhancements. RHRS score components have been recombined to create sub-scores to isolate specific evaluation attributes. The slope’s Condition is calculated as a function of rockfall history and ditch effectiveness and scored using a 100 (good, like new condition) to 0 (poor or failed condition) linear score. Five new Condition State categories facilitate deterioration modeling and risk analysis. Evaluation of rockfall event records allow estimation of rockfall event likelihoods based on slope dimensions and condition for use in risk calculations. Programmatic cost estimates to improve the slope, also based on slope dimension and condition, allow rapid network-wide estimation of improvement costs. Performance Measures and Decision Support Tools help guide the planning process. Tools that leverage MDT’s cloud-based GIS services permit collection of rockfall events and maintenance activities across multiple computing platforms.

Fiscal analyses indicate that the 997 inventoried (on interstate or rated high hazard) and assessed rock slope assets have an average condition of 63/100 and represent a value of approximately $4 billion dollars to build again today. It is estimated, on average, there will be 27 significant rockfalls annually with an estimated annual risk cost of $3.5 million. Unchecked slope deterioration limits an average slope’s life span to approximately 104 years. A ‘Good’ condition slope has a 50% likelihood of deteriorating to ‘Fair’ in 36 years, with another 41 years to deteriorate further to a ‘Poor’ condition slope. Getting slopes that have deteriorated back to a modern, state-of-the-practice, ‘Good’ condition would require approximately 700 million dollars. The annual cost to maintain current conditions using a worst-first basis (current approach) is about $35 million per year. However, by including slope preservation efforts into a funding plan that maintains network conditions rather than relying solely on comprehensive reconstruction efforts, the annual cost is estimated to be $28 million per year. This results in a 19% or $7 million annual savings for the same outcome, and a 114% return on preservation investment.
Investigation of Prefabricated Steel Truss/Bridge Deck Systems

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| Submitter  | Montana Department of Transportation  
Sue Sillick  
2701 Prospect Avenue, P.O. Box 201001  
Helena, Montana 59620  
406-444-7693 |

Project Summary and Benefits

Steel truss bridges are an efficient and aesthetic option for highway crossings. They are relatively light weight compared to plate girder systems which makes them a desirable alternative for both material savings and constructability. A prototype of a welded steel truss constructed with an integral concrete deck has been proposed by a steel fabricator as a potential alternative for accelerated bridge construction (ABC) projects in Montana. This system consists of a prefabricated welded steel truss topped with a concrete deck that can be cast at the fabrication facility (for ABC projects) or in the field after erection (for conventional projects). This specific bridge and prefabricated construction technique are not well represented in the literature, and thus there was a need to identify potential bridge spans and traffic volumes where the proposed system is viable and economical.

A truss configuration was designed with economical wide flange vertical members and bolted diagonal member connections. The steel truss used a welded connection between the vertical compression members and top and bottom chords. The truss members and bolted connection configuration produced a system that satisfied the strength and fatigue requirements for an infinite-life design. A 205 feet span was used in this re-design since MDT had a plate girder design available also with the same span length from a recent project (the Swan River project.) This also allowed for cost comparisons to be readily prepared between the two systems. To further investigate the potential material and fabrication cost savings for the truss system, a three-dimensional finite element model was created to more accurately estimate the distribution of multiple lane and axle loads to the trusses in the system and attendant individual truss members. Results of this analysis indicated that a distribution factor for use with a 2D model could be lower than previously calculated using the relatively simple and typically conservative lever rule (by approximately 25 percent). In further analyses, this new distribution factor was used.

The 205 feet steel truss bridge was re-analyzed and designed using a two-dimensional finite element model with the refined distribution factors. Conventional and accelerated construction scenarios were considered in the
design of the truss members, connections, and splices. The conventional construction scenario assumed a single splice at midspan with a concrete deck cast after the truss was erected. For the accelerated construction scenario, the assumption was made that the truss elements with integral concrete deck would bridge the span in three segments (resulting in two splices). The steel weight of the bolted and welded steel trusses (assuming the use of conventional and accelerated construction) were 15% and 28% less than the steel weight of the Swan River plate girders. Using an average of the materials and fabrication estimates from various fabricators suggests a reduction in cost of 10% and 26% for the two construction alternatives, respectively.

Based on this investigation, a steel truss with integral concrete deck using either precast on the truss for accelerated bridge construction or cast-in-place for conventional construction, are attractive alternatives for bridge projects in Montana. For the case considered in this study, using a combination of bolted and welded connections in the trusses was found to offer good performance at a potentially lower cost than comparable plate girder construction. An implementation meeting was held with MDT staff, design consultants, construction contractors, and steel fabricators. The next step in implementation will be a field deployment of such a structure.
Streamlining Hydrologic Prediction Processes Using New and More Accurate Techniques and Methods

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| Submitter  | Nevada Department of Transportation  
Matt DeMattei  
1263 South Stewart Street  
Carson City, Nevada 89712  
775-888-7223 |
| Links      | https://www.nevadadot.com/ |

Project Summary and Benefits

The purpose of this research was to conduct a detailed analysis of storm events in the State of Nevada. The intended goal was to develop more realistic design storms for use by NDOT throughout the state. Each hydrometeorological homogeneous area (HHA) in Nevada was studied, except for Clark County, and the temporal and spatial distribution specific to storms in Nevada affecting NDOT drainage structures was analyzed.

The design storm approach presented in this research was divided into two main parts. The first is the temporal distribution defined by the hyetograph shape, also referred to as storm event analysis. The second is the spatial distribution defined by representative Depth Area Reduction Factors (DARFs). Within the HHA groupings, rain gauges exhibit similar statistical characteristics; the storm events were determined from the gauges in each of these HHAs. A storm event is defined as having an accumulation of at least 0.01 inches and no rainfall for a period greater than six hours between events. Incremental rainfall data for each gauge were segmented into discrete storm periods with a minimum inter-event time of six hours. The given rainfall event over a specific HHA can be widespread or isolated, and affecting multiple gauges or only a single gauge. The number of events for any specific gauge is likely to be much less than the overall total since a single gauge will not be affected by every rainfall that impacts a given HHA.

A cumulative hyetograph was developed for each storm event consisting of accumulated rainfall depth versus time for the event duration. These hyetographs were then made dimensionless by dividing each depth by the total depth, and each time step by the total duration. The resulting dimensionless hyetograph represented the percentage depth versus the percentage duration. Each hyetograph was then classified according to quartile, or a quarter of the event duration, during which the maximum accumulation of rainfall occurred.
To compare hyetograph shapes between HHAs, the 50th (median) and 90th percentile hyetographs were selected from the multitude of storm event hyetograph shapes for every gauge in each HHA. A key characteristic of the dimensionless hyetograph is the maximum slope (maximum increase in percentage depth versus percentage duration), which indicates when the maximum intensity occurred during a particular event. Each storm event was then characterized by quartile, duration, depth, average intensity, and maximum hourly accumulation. For a dimensionless median hyetograph, the maximum intensity is referred to as the median maximum intensity (MMI); the MMI typically varies by month.

The results of the research are currently being implemented. Reductions in peak flows and volumes will provide NDOT with opportunities to save money on stormwater infrastructure costs. The drainage work on current NDOT projects consumes approximately 10% of each project’s budget. Since the approach focused on HHAs, the potential benefits for NDOT include improved sizing of culverts and bridges based on design storms representative of the local hydrometeorological conditions.

It is anticipated that the improved sizing will translate into cost savings. For example, a 200-foot long triple 10’ x 5’ box culvert may have been designed using a previously estimated peak flow of 1,000 cubic feet per second (cfs), whereas a new peak estimate of 700 cfs would result in a double 10’ x 5’ box culvert under similar slope and headwater restrictions. In this example, NDOT would benefit from a 33% reduction in culvert material costs. Currently, annual drainage improvement costs for NDOT are approximately $14 million per year. If 75% of the annual drainage expenses are for construction costs, then NDOT could potentially realize a cost savings of over $3 million per year, which translates into an annual drainage budget reduction of $10,500.00 for each 1% reduction in estimated precipitation. Furthermore, any savings NDOT gains from this study may be applied to other projects, which can lead directly to the potential implementation of additional safety measures for the traveling public.
Descriptive Statistics

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Median Duration 9-12 hr statewide
Mechanistic-Based Pavement Damage and Associated Cost from Overweight Vehicles in Nevada

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| Submitter  | Nevada Department of Transportation  
Matt DeMattei  
1263 South Stewart Street  
Carson City, Nevada 89712  
775-888-7223 |

Links: [https://www.nevadadot.com/](https://www.nevadadot.com/)

Project Summary and Benefits

Due to the significant and continuous freight transportation operations throughout the State of Nevada, it has become a challenge for the Nevada Department of Transportation (NDOT) to maintain the highway infrastructure at an acceptable level of service. In some circumstances, trucking companies use oversize and overweight vehicles to transport larger and heavier than standard loads across the state. The objectives of this study were to assess pavement damage attributable to overweight vehicles moving throughout the State of Nevada, and to provide a framework for a permit fee structure regarding overweight vehicle trips in Nevada.

The methodology utilized was based on mechanistic-empirical analysis of flexible pavements under overweight vehicle loadings, utilizing pavement performance models that have been locally calibrated to reflect conditions in Nevada. A comprehensive pavement response database was populated by conducting more than 8,000 3D-Move pavement analyses. Representative pavement structures and other various factors presented in the experimental plan were also taken into consideration. The vertical compressive strain at mid-depth of the asphalt concrete layers were evaluated, as these layers are directly correlated to asphalt concrete permanent deformation and asphalt concrete fatigue cracking.

The pavement response database was used to develop a Microsoft Excel package, referred to as the Overweight Vehicle Analysis Package (OVAP). The intent of this package is to conduct pavement damage and associated cost analyses of single-trip and multi-trip overweight vehicles. Based on the overweight vehicle data received, users input specific values into three primary categories within the database: Climatic Information, General Analysis Information, and Overweight Vehicle Axle Configuration. The package has been designed to produce pavement damage associated cost results, as well as load equivalent factor results since they are related to permanent deformation and fatigue cracking; while also providing a comparison between an overweight analysis vehicle and a reference vehicle.
Dirt Isn't Just Under Your Fingernails

**Project ID** 26962K

**Cost** $75,000

**Duration** 19 months

**Submitter** New Hampshire Department of Transportation
Ann Scholz
P.O. BOX 483
5 Hazen Drive
Concord, New Hampshire 03302
603-271-1659

**Links** [https://www.nh.gov/dot/org/projectdevelopment/materials/research/projects/26962k.htm](https://www.nh.gov/dot/org/projectdevelopment/materials/research/projects/26962k.htm)

**Project Summary and Benefits**

Limited Reuse Soils (LRS) include roadside soils, as well as “street wastes” (defined as ditching materials, catch basin clean outs, and street sweepings). It’s not an issue to NHDOT unless it’s EXCAVATED during construction or collected during maintenance operations. There are different levels of contaminated or impacted soils -- LRS is on the lower most end of that range. Based on data identified from other state departments of transportation, roadside soils are known to typically contain concentrations of regulated compactions above naturally occurring background concentrations, and therefore, have limited reuse potential.

One such regulated compound is polycyclic aromatic hydrocarbons (PAHs), for which there is no allowable background concentrations in NH because they are manmade. They are also carcinogenic. We learned that LRS may be encountered in all topsoil adjacent to roadway surfaces. In instances where topsoil is not present, LRS can be expected to be encountered in soil from the top of ground to a depth of six inches (6”). Handling this material is expensive. Less material handled means less material being required to be disposed of, less of a financial impact, and is also better for the environment. We can attack this on all fronts within NHDOT; the design, construction, and operations/maintenance units can work as a unified team with a goal of reducing the department’s impact of LRS.
**Project Summary and Benefits**

New Hampshire DOT is responsible for providing a safe and efficient roadway system, so understanding asphalt structure is very important. In the past, asphalt was simply a combination of gravel and bitumen, a tar-like substance. Modern binders are a much more complex mix of bitumen and other chemical additives. In modern asphalt design, aggregates and binders are selected to improve the physical properties of the final mixtures, including stiffness, wear resistance, and cracking.

Repairing roadways often requires the removal of old pavement. Rather than just placing the old asphalt in a landfill, it is sometimes added to the new asphalt mix as a way of recycling the materials. When recycled asphalt pavement (RAP) is included in new asphalt, the residual binder can impact the properties of asphalt mix because two (or more) binders are now part of the mix. This study looked at whether the measured properties of the asphalt mixtures varied between the plant-produced construction mix or a lab-made mix of the same formula.

This project evaluated the physical properties of 14 mixtures that contained varying amounts of RAP and different grades of binders by measuring parameters associated with stiffness and cracking. Addressing cracking is important because the process can accelerate the aging of the roadway. Cracking occurs when water seeps through cracks in the pavement and in low temperature, can freeze and expand the cracks. Stiffness is a measure of strength and predicts how well a roadway pavement will support the traffic without rutting. The study shows that stiffness-based characteristics of the binders that include recycled pavement materials correlate well between the laboratory-made mixes and the material from the field production plant. However, when considering cracking parameters, test results on the pavements containing recycle pavement was not well correlated between the lab mixes and the plant mixes. This difference in cracking parameters suggests that there may be additional aging of the binder during the reheating process of the laboratory-made mix. We can
use the results knowing that the continued use of RAP is a wise way to recycle old pavement. However, additional work is needed to fully understand how the aging of the residual binder from the recycled pavement impacts the resistance to cracking of the new asphalts.
New Jersey Department of Transportation

Evaluation of Raised Pavement Markers (RPMs)

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| Submitter  | New Jersey Department of Transportation  
Pragna Shah  
1035 Parkway Avenue  
Trenton, New Jersey 08625  
609-530-8025 |
| Links      | [http://www.state.nj.us/transportation/refdata/research/](http://www.state.nj.us/transportation/refdata/research/) |

Project Summary and Benefits

Raised pavement markers (RPMs) have been used throughout the world since the 1930s. In the State of New Jersey, RPMs are used along all centerlines and skip lines, regardless of traffic volume, roadway geometry, or roadway classification. The extensive use of RPMs has increased interest in understanding the safety benefits of RPMs, promising cost-effective alternatives or modifications, as well as the best practices in maximizing their utility. Under the auspices of the New Jersey Department of Transportation (NJDOT), Rutgers University is conducting a study evaluating RPMs.

This chapter presents the results of a comprehensive literature review on this subject. The review of previous studies has led to the following observations:

- There is no consensus regarding whether and how RPMs affect crash rate. Depending on scope and data, different studies report different magnitudes of safety changes (positive or negative) after RPMs are implemented.
- There are various alternatives and modifications possible for RPMs, such as rumble strips and traffic tape. The use of these alternatives varies by state.

In the next step, this project will develop a methodological framework for quantifying the cost-effectiveness of RPMs and their alternatives according to specified road and traffic characteristics.
The Use of Porous Concrete for Sidewalk

**Project ID**  
FHWA-NJ-2018-001

**Cost**  
$162,662

**Duration**  
21 months

**Submitter**  
New Jersey Department of Transportation  
Priscilla Ukpah  
1035 Parkway Avenue  
Trenton, New Jersey 08625  
609-530-5157

**Links**  
[http://www.state.nj.us/transportation/refdata/research/](http://www.state.nj.us/transportation/refdata/research/)

**Project Summary and Benefits**

The primary objective of this study is to evaluate the various factors that influence the performance of porous concrete in sidewalks. These include hydraulic performance to meet Department of Environmental Protection (DEP) regulation and structural performance to meet typical sidewalk strength requirements as well as life cycle cost and maintenance requirements. Several mix designs were tested to evaluate structural and hydrological performance and energy budget. A cost-benefit analysis comparing porous pavements for sidewalks to conventional concrete and asphalt alternatives, including environmental permitting, initial construction, and maintenance costs was performed. A guide document on the use of porous concrete and porous asphalt for sidewalks was provided.

The use of porous concrete for sidewalks can be effective in mitigating stormwater runoff. For soils with low permeability, an auxiliary subsurface drainage system may be needed. A porous sidewalk needs to be periodically maintained to avoid clogging resulting from debris and sediments. Porous sidewalks should be free from water especially in the winter to avoid failure due to freeze and thaw. Resistance to raveling is very important for the long term performance of pervious concrete. There is a need for research to evaluate raveling resistance and factors that can influence this resistance such as aggregate type, addition of sand, cement content and chemical additives.

Other findings from this research include:

1. There is a need to establish vibration and compaction criteria for preparation of lab specimens for compression, flexure, tension and modulus testing. Construction of porous sidewalks requires skilled labor and is recommended to do test segments prior to construction of the actual sidewalks.
2. The addition of some sand to pervious concrete can improve its strength and may improve its resistance to raveling. There is a need to evaluate the effects of adding sand to mix and its effects on strength and porosity.

3. More data on field performance is needed. Tests of cores from field can provide information on the effect of periodic maintenance or lack there-of on void ratio, density, permeability and strength of in-situ sidewalks. It is recommended that a porous concrete and porous asphalt test sidewalks be constructed for short-term and long-term monitoring.

4. The initial construction cost of porous concrete is slightly greater than that of conventional concrete for sidewalks without subsurface drainage systems. The initial construction cost of porous asphalt sidewalks is much cheaper compared to conventional concrete. The literature review showed that the service life of porous concrete varies and it may be shorter than of conventional concrete. Although there are cost savings from storm water best management practices, the life cycle cost of porous concrete sidewalk may be still higher than that of conventional concrete sidewalk due to the shorter life.

5. Additional research should be considered for energy measurement additional pervious concrete mixes with different source aggregates of different color and size. Comparisons between conventional asphalt and concrete and pervious asphalt and pervious concrete should be conducted. Another approach to studying the energy budget of surface materials would be to experiment inside a controlled chamber to ensure the desired environmental conditions.
New Jersey Department of Transportation

Design and Evaluation of Bridges for Scour Using HEC 18

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**Project Summary and Benefits**

The overall objective of this study was to develop a rational and defensible process for estimating scour depths for New Jersey's bridges on non-tidal waterways. The study commenced with a comprehensive literature review of theory and predictive models for bridge scour. This included a web-based survey of scour practice for DOTs within the U.S. in order to assess the varied scour design and evaluation methods used by transportation agencies. HEC-18 methods and other available models and best practices were critically reviewed and compared to develop the most appropriate scour evaluation procedure for New Jersey.

The study also investigated the geotechnical, hydrologic, and hydraulic factors affecting scour behavior. In addition, a detailed review of the Stage II studies for the bridges on New Jersey’s Scour Critical List was undertaken to identify significant parameters and trends. The major project deliverable is a new Scour Evaluation Model (SEM) that reflects New Jersey’s unique geologic and hydrologic/hydraulic conditions. In general, the New Jersey SEM is a tiered, parametric, risk-based decision tool. In applying the model, a variety of geotechnical, hydrologic, and hydraulic data are inputted for a particular bridge. These data are analyzed to determine two risk ratings, one geotechnical and the other hydrologic/hydraulic. The user then enters the risk ratings into a two-dimensional Risk Decision Matrix to generate a priority rating that varies according to risk level. This, in turn, generates recommended actions, which may include priority installation of countermeasures, real time scour monitoring, or removal from the Scour Critical List. Bridge importance (ADT and detour length) is also evaluated and factored into the final priority rating. A complete set of flowcharts are provided for application of the SEM. Although the model is principally designed to evaluate the scour risk of existing bridges, some of the model components are useful for designing new bridges as well.
Laboratory Dynamic Modulus of Asphalt Mixes and Resilient Modulus of Soils

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| Submitter    | New Mexico Department of Transportation  
              Marguerite Johnson  
              7500B Pan American Freeway, NE  
              Albuquerque, New Mexico 87109  
              505-490-3502 |

Project Summary and Benefits

This research project developed a dynamic modulus test database for three plant produced and two laboratory prepared asphalt mixes in addition to mastercurves for all mixes. Inputs of viscosity and dynamic shear modulus based on Witczak models were provided for each mix; a newly modified viscosity based Witczak model was also developed as a part of this study and has proven to be superior to traditional models currently included in Mechanistic Empirical Pavement Design Guide (MEPDG).

Pavement design engineers are currently utilizing the results of this study in pavement ME designs. The results have provided pavement design engineers with the necessary tools to understand material response to different environmental and physical loading conditions as well as soil behavior. Furthermore, dynamic modulus and resilient modulus testing has provided a more accurate approach to mechanistic material characterization and pavement distress prediction, thus eliminating subjective empirical interpretations and an improvement in pavement design methodology.
New Mexico Department of Transportation

Optimal Use of Falling Weight Deflectometer And Ground Penetrating Radar

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| Submitter  | New Mexico Department of Transportation  
              Marguerite Johnson  
              7500B Pan American Freeway, NE  
              Albuquerque, New Mexico 87109  
              505-490-3502 |

Links

Project Summary and Benefits

This research project developed detailed guidelines for the combined application of Ground Penetrating Radar (GPR) and Falling Weight Deflectometer (FWD) for rapid and efficient subsurface pavement evaluation and performance prediction; inputs for pavement ME analysis were also developed as a part of the study. Pavement field exploration and pavement design engineers are currently utilizing research results for pavement investigation and forensics.

Implementation of research results have allowed cost, time, and labor savings due to a decrease in invasive coring in addition to an increase in safety. The incorporation of the range of dielectric constant of unbound layer thickness predictions has improved accuracy for thickness predictions and as a result information inputted into FWD backcalculations has reduced analysis time and increased accuracy for layer moduli. The combined implementation of GPR and FWD has resulted in increased pavement prediction performance, thus allowing for appropriate maintenance and rehabilitation scheduling.
Mechanical and Rheological RAP Characterization of NMDOT Mixes

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| Submitter    | New Mexico Department of Transportation  
               Marguerite Johnson  
               7500B Pan American Freeway, NE  
               Albuquerque, New Mexico 87109  
               505-490-3502 |

**Project Summary and Benefits**

This research project evaluated the mechanical and rheological RAP Characterization of NMDOT mixes and binders. Additionally, distress from field data and ME Design were evaluated to determine the effects of Recycled Asphalt Pavement (RAP) in HMA. Currently three of the districts are utilizing RAP to its fullest extent of 35% and two of the districts are utilizing RAP to the extent of 15% both for construction and maintenance projects. Laboratory and field evaluations of RAP in HMA mixes have helped predict pavement distresses more accurately as well as helped produce better laboratory RAP mix design estimation. Furthermore, an increase in RAP has increased rutting resistance.
Alternate Methods for Evaluation of Moisture Sensitivity of Asphalt Mixtures

Project ID | FHWA/NC/2014-04
---|---
Cost | $298,000
Duration | 34 months
Submitter | North Carolina Department of Transportation
| Mustan Kadibhai
| 1549 Mail Service Center
| Raleigh, North Carolina 27699
| 919 508 1819


Project Summary and Benefits

Background

The North Carolina Department of Transportation (NCDOT) requires that asphalt mixtures used in pavement construction meet the NCDOT moisture sensitivity specifications prior to approval of the job mix formula (JMF). Foaming-based warm mix asphalt (WMA) mixes that use water injection technologies such as Astec’s Double Barrel foamed technology, or use Zeolite additives such as Advera, tend to fail the current required tensile strength ratio (TSR) tests. However, pavements constructed with these same WMA mixes in the United States and in North Carolina have performed well to date. Either the current TSR test protocol needed to be modified or a new test(s) is needed for WMA mixes.

Specific Research Objective

The objectives of the proposed research were:

1. To evaluate whether the residual trapped moisture in WMA mixtures affects the TSR test results, and investigate if the curing of compacted specimens is required for WMA mixtures that is different from the hot mix asphalt (HMA) mixtures;
2. To evaluate the stiffness, fatigue performance, and rutting potential of the foaming-based WMA mixes in a moisture-conditioned state so that the actual degradation of these mixes can be compared directly to the results of TSR and indirect tensile (IDT) strength tests; and
3. To explore modifications to the current TSR test protocol or to develop alternative test methods such as impact resonance and colorimeter analysis that can be used in lieu of TSR tests for foaming-based mixes.
What research work was done?

These objectives were accomplished by performing IDT tests to obtain the TSR in the traditional manner, dynamic modulus (AASHTO TP79) and impact resonance (IR) tests for stiffness characterization. The feasibility of impact resonance technology to quantify the effect of moisture damage was explored. These tests were performed on a WMA and three hot mix asphalt (HMA) mixtures using the modified AASHTO T283 procedure that is currently used by NCDOT. The percentage of stripping determined from the colorimeter analysis of the fractured surfaces of the specimens was used as a reference test method to indicate the level of stripping in WMA and HMA mix.

At the advent of this research project, the title of the project was “Effectiveness of TSR Test for Evaluating Moisture Sensitivity of WMA Mixes.” However, it was quickly realized that just looking at the curing period for WMA versus HMA mixes was not a viable way to explore the moisture sensitivity of the mixtures. The fact that the current TSR test protocol needs to be different for different mixtures is a major weakness of the AASHTO T283 test method among others.

In the past, asphalt technologists initially tested the compatibility of asphalt and aggregate sources using tests such as Texas Boil Test and ASTM Test Method D3625. However, these tests became less preferable since they were subjective in nature. Although, not part of the initial research objectives, a methodology evolved using colorimeter (Chroma meter) that now allows the boil test results to be quantified. This is the single most important breakthrough in evaluating the adhesive compatibility of asphalt and aggregate for any mixture design process that has evolved in the past 70 plus years. Based on the research methodology and findings of this research, a device known as Asphalt Compatibility Tester “ACT” was developed by a local North Carolina company (InstroTek, Inc.) that is now commercially available and first introduced at the 2018 Transportation Research Board (TRB) Annual meeting in Washington D.C. Figure 1 shows the ACT device.

The outcome of this research presents a new approach to asphalt-aggregate mixture design process. Currently, the moisture sensitivity is evaluated as the final step in the mixture design process. This NCDOT research suggests a methodology that first evaluates the moisture sensitivity or the adhesive compatibility of asphalt-aggregate in the presence of moisture before a mixture design process is even considered. The advantages of the new mixture design method include:

1) Allowing for the evaluation of the most cost-effective and economical selection of anti-strip additive;

2) Allowing design engineers to quickly select appropriate and compatible materials as quickly as in half-a-day compared to a couple of weeks;

3) Providing a quick quantifiable and reliable method for quality control and quality assurance in a single day as opposed to a week or more.

The methodology developed in this NCDOT research has tremendous potential for savings in time, material resources, and manpower. The “New NCDOT Asphalt-Aggregate Mixture Design” process is shown in the flow chart (Figure 3.)
Benefits of Research Results

In this research, two new methodologies were used to evaluate moisture sensitivity of asphalt-aggregate mixtures. The first approach used a commercially available colorimeter to quantify adhesive failure in asphalt concrete using the boil test. The second approach involved using the impact resonance (AFV) test to measure the adhesive and cohesive structural integrity of the compacted mixtures through evaluation of the intrinsic and fundamental stiffness measurement. The colorimeter along with the boil test allows the control of adhesive failure between asphalt-aggregate due to moisture sensitivity of the mixtures even before a full-scale mixture design procedure is considered. The cohesive failure in a mixture that is predominantly based on the structural integrity of the compacted mixtures can be controlled by the AFV test. Separate or combined, these two tests are superior to the current TSR tests conducted using the AASHTO T283 test procedure currently followed in asphalt-aggregate mixture design.

The conclusions based on the results of this study are as follows:

1) The Boil Test with the use of colorimeter can be used as a preliminary quantifiable test to evaluate the compatibility between asphalt and aggregate.
2) Boil Test can be used to determine the amount of antistrip additive required, and even evaluate the most cost-effective antistrip additive that should be used.
3) If the TSR test is used as an acceptance or rejection criterion, then the damage ratio in the boil test should not exceed values of L*RB ratio of 10% or a CD*RB ratio of 5%.
4) The TSR value of a mixture can be estimated by measuring the damage ratio (L*RT) using a colorimeter on the fractured surface of a sample and should be more than 3.0.
5) Impact Resonance (AFV) test can be used to evaluate moisture sensitivity of asphalt concrete. This test measures both the adhesive and cohesive damage in mixtures including the structural integrating of the aggregate design structure (gradation) and is superior to the TSR test.

Figure 1

Figure 2
New NCDOT Asphalt-Aggregate Mixture Design Procedure

1. Select Asphalt, Aggregate Source & Gradation – Superpave Method
2. Evaluate Adhesive Compatibility using Boil Test & Chroma Meter
3. Select the most efficient and cost-effective antistrip additive
4. Use 5% Asphalt Content initially or from prior experience
5. Select Design Asphalt content using Superpave Mix Design Procedure
6. Accept Mix Design
7. Conduct IR test and E* Ratio for Moisture Sensitivity
8. Conduct TSR Test if desired and TSR Ratio for Moisture Sensitivity

Figure 3
Project Summary and Benefits

The purpose of this project was to develop a holistic bottleneck analysis approach to assist NCDOT in identifying, examining, modeling, and mitigating freeway bottlenecks at a system level compared to focusing on local bottlenecks only. The report was presented in two parts. Part 1 presents the systematic bottleneck identification and ranking methods developed and Part 2 contains the approach developed and case study.

To achieve the project goal, the research team undertook a series of research tasks, which included:

- Reviewing and synthesizing past experiences in bottleneck identification methods, mitigation strategies, and evaluation tools (at the micro-, meso-, and macroscopic levels);
- Developing a systematic methodology to identify and prioritize bottlenecks on freeways;
- Examining contributing factors of freeway bottlenecks and propose effective and efficient countermeasures to mitigate bottlenecks;
- Evaluating system performances before and after the implementation of the bottleneck mitigation projects using dynamic traffic assignment (DTA) models; and
- Developing a framework for ranking bottleneck mitigation projects by comparing their impact on system-wide bottleneck mitigation and travel conditions.
A performance-based framework was developed to assist in assessing and prioritizing candidate bottleneck mitigation alternatives. The general project ranking framework includes five components: (1) developing candidate bottleneck mitigation projects, (2) evaluating each project, (3) screening of projects, (4) benefit-cost analysis (BCA), and (5) sensitivity analysis. In addition, the research presents another bottleneck identification method and a case study was conducted. The researchers developed a bottleneck identification algorithm which uses two thresholds to detect congestion and to filter recurring bottlenecks, where the thresholds are selected based on a robust sensitivity analysis. Three different performance measures are developed to rank and characterize recurring bottlenecks.
Re-appraisal of the Specification for Aggregate Base Course (ABC)

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| Submitter  | North Carolina Department of Transportation  
             Mustan Kadibhai  
             1549 Mail Service Center  
             Raleigh, North Carolina 27699  
             919-508-1819 |

Links  

Project Summary and Benefits

Background

The current specification for acceptance of Aggregate Base Course (ABC) materials consists of a band-type gradation specification, which is essentially a “recipe” that dictates the mass percentages of the individual particle sizes constituting the ABC. These specifications were developed about a half century ago with few adjustments since then, and are similar to the majority of the DOTs around the country. The “recipe” specification is based on the assumption that the product will achieve the desired engineering performance as long as it meets the required gradation and is placed and compacted properly in the field. However, the biggest disadvantage of the “recipe” specification is that it cannot quantify the mechanical behavior of the aggregates under different traffic and weather conditions, which will determine the stress and moisture state.

Recent developments in mechanistic-empirical (ME) pavement design (i.e., Pavement ME Design) incorporate the mechanical properties of pavement materials, which include the unbound aggregates. Therefore, understanding the mechanical properties of ABC is critical for the prediction of pavement performance, and consequently design. Unfortunately, the current ABC specification is disconnected with the design process and required parameters (e.g., resilient modulus).

Specific Research Objective

The primary goal of this research was to develop a new approach to evaluate aggregate base course material. To do this, the following research objectives were assessed:
1. Identify and evaluate the physical properties (e.g., morphology, material, fabric) that influence the ABC performance.

2. Characterize the mechanical behavior of the ABC.

3. Develop relationships between material properties and mechanical behavior.

The research results in a better understanding of the behavior of ABC in conjunction with pavement design parameters (e.g., resilient modulus.)

**What research work was done?**

The research consisted of a wide range of experimental work to assess the physical properties and mechanical behavior. Specifically, the physical properties were evaluated using common index tests the NCDOT already performed on the ABC material: Specific Gravity, LA Abrasion, Maximum Dry Density, and Optimum Water Content. The morphological properties of the ABC were also assessed using a new asset acquired during this project, the Aggregate Imaging System (AIMS), where the sphericity, surface texture, and angularity of the aggregate can be easily assessed. The mechanical behavior of the ABC was evaluated by measuring the resilient modulus, following the standardized method employed by the NCDOT. As the resilient modulus not only quantifies the mechanical behavior but is also a direct input into the mechanistic-empirical (ME) pavement design process. Developing a relationship between the material properties and resilient modulus can lead to direct connections between the material evaluation and design.

**Brief Summary of Findings**

A summary of the findings is listed below:

- ABC materials meeting the current NCDOT gradation specification exhibited consistent resilient behavior, even when the material is gap-graded within the specification band.
- Furthermore, analytical models confirmed that the current gradation band produces material with adequate performance.
- Morphological properties of ABC, such as the surface texture and sphericity, are statistically most significant in predicting the resilient modulus of ABC. Furthermore, assessing the material properties, including angularity, surface texture, and sphericity, allows for a prediction of resilient modulus of the ABC material, which can be used in the design process. If it is deemed important to the NCDOT’s objectives, the department can improve the predictive model by using their existing database of experimental data, including MR, and adding results from AIMS for all aggregate sources of interest.
- Compaction processes may degrade ABC materials that are susceptible to crushing. This in turn affects the resilient modulus of the ABC by changing the fabric of the material. The compaction method used in the laboratory should match the compaction processes in the field as best as possible for a more representative resilient modulus.
- Varying the degree of saturation results in negligible differences in the measured MR. The majority of the MR results for a wide range of degree of saturation are within a relatively narrow band, indicating the inherent variability of the material may have a higher effect on the MR results for the sources studied.
Example digital images of an aggregate specimen: (a) initial image (b) binary image, and (c) particle contacts image
Planning Level Evaluation of the Effects of Ramp Metering on North Carolina Freeways

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</table>
| Submitter  | North Carolina Department of Transportation  
John Kirby  
104 Fayetteville Street  
Raleigh, North Carolina 27705  
919-508-1816 |

**Links**  

**Project Summary and Benefits**

The study supported the currently planned ramp meters by developing a state-specific method that can be incorporated into the NCDOT planning processes to evaluate any potential ramp metering projects in the future. The related frameworks of analysis were applied to the four westbound I-540 ramp meters to estimate the expected outcomes of the project. The I-540 analysis and frameworks resulting from this study focus on four major steps in the ramp metering process: 1) planning-level data collection, 2) planning-level analysis, 3) life cycle cost analysis, and 4) before-and-after installation evaluation.

Ultimately, the research team found that westbound I-540 ramp meters will provide estimated benefits of between $28,234,500 and $73,410,500 over the next ten years. The project produced a sound foundation for evaluating ramp metering outcomes on which the state can build a ramp metering program that is both sustainable and efficient.
**Project Summary and Benefits**

The duration of this research project was two years. The approach for this research included mixed methods, including a quantitative cost analysis as well as qualitative interviews, gathering relevant background information, and peer state comparisons. The data was collected from NCDOT and from online searches. Interviews were conducted either over the telephone, email, or in person at various locations across North Carolina.

First, a literature review and a document review of pertinent states was completed (i.e. Alabama, Kentucky, North Carolina, Texas). Next, a cost analysis was completed using NCDOT data in order to identify areas for potential cost savings, specifically relating to the mowing and spraying data. Seventeen interviews were conducted with NCDOT Roadside Environmental staff. A benchmarking analysis was completed by comparing NCDOT vegetation management practices to those of three other states (Alabama, Kentucky and Texas.)

Findings included:

- Replacing one mowing cycle with an additional spraying cycle on all systems may result in cost savings of $2.5 million annually. The most significant savings are associated with the implementation of Plant Growth Regulators (PGR) spraying on secondary roads. That may result in a savings of $1.4 million per year primarily from reduce mowing costs.
- The coordination of spraying and mowing is critical for maximizing the benefits of PGRs. The passage of NC House Bill 97 consolidated responsibilities for vegetation management from Roadside Maintenance and Roadside Environmental Units into one, with responsibility for all vegetation management practices administered solely by the Roadside Environmental staff.
• While secondary roads are mowed more frequently, interstates and primary roads are more likely to be sprayed with PGR applications. In addition, March through July are the most common times that PGRs are sprayed. Most division staff reported that spraying PGRs is associated with one less mowing cycle, with some believing spraying PGRs can save two mowing cycles.
Using Environmental DNA (eDNA) to Determine Hellbender Distribution—Phase I

Project ID | 135321
---|---
Cost | 
Duration | 6 months
Submitter | Ohio Department of Transportation
| Zona Kahkonen Keppler
| 1980 West Broad Street, Mail Stop 3280
| Columbus, Ohio 43223
| 614-466-2882

Links | http://cdm16007.contentdm.oclc.org/cdm/ref/collection/p267401ccp2/id/15513

Project Summary and Benefits

Background

The Eastern Hellbender (Cryptobranchus alleganiensis) is the largest aquatic salamander native to the state of Ohio. The Hellbender’s population has declined more than 80%. This species is endangered in Ohio and a candidate for federal listing. The Ohio Department of Transportation (ODOT) performs presence/absence surveys during the NEPA process. The survey is time consuming, expensive, and hazardous to both humans and hellbenders. The flipping of large rocks disrupts nesting sites causing unnecessary harm and stress, and can even injure or kill the species. Recent studies have shown that environmental DNA (eDNA) can detect hellbenders in streams. eDNA sampling is economical, rapid, and has no impact to the target species.

Research Context

The specific objectives for this project were to achieve the following research tasks:

1) Develop a species-specific primer to be used in genetic sampling which is exclusive to Eastern Hellbender.
2) Collect water samples from Ohio streams to test for Hellbender DNA.
3) Develop a standardized field collection protocol to ensure consistency, efficiency and reduce contamination.

Research Approach

Water samples were collected from an aquaculture facility at the Columbus Zoo and 3 creeks: Salt Creek, Scioto Brush Creek, and Duck Creek. Initial analysis of positive and negative controls were established. Hellbender species-specific primers were then designed and tested that amplify a region of the mitochondrial genome. The species-specific primers were then coupled with nested primers to increase PCR specificity and avoid non-
specific product from the environmental samples. PCR on the eDNA samples were carried out to test for presence/absence of the eastern hellbender.

**Research Findings**

Zoo raised hellbenders were placed at locations known not to contain the species. At these locations, one-liter water samples were taken and additional samples taken at regular intervals downstream. The specific primer set to the left D-loop of the mitochondrial genome (mtDNA) was developed, and using digital droplet PCR (ddPCR), the research team determined presence of the Hellbender eDNA and how far from the known animal locations the eDNA could be detected. The results indicated a limit of detection that is approximately 1/3 of a mile downstream from a known Hellbender location. While this is lower than other published results, samples were taken in the early winter months, a more dormant time of year for the animal, which may have influenced the amount of eDNA available.

**Research Recommendations**

A primary recommendation resulting from these findings includes conducting rigorous investigation into published primer sets for Hellbender mtDNA before concluding eDNA results. While other CytB primer sets may be useful, a CytB primer set established by Santas et al, 2013 was also briefly investigated without dramatically better results (nonspecific amplification was observed). Since most published qPCR reactions for Hellbender rely on Taqman probes, nonspecific amplification is less of a problem. However, additional nonspecific amplification would decrease the efficiency of the whole qPCR reaction, and ultimately the radius of detection for the animal. The D-loop primer set provided a larger (qPCR targets are usually 100-150 bp) and a potentially valuable amplicon that may have the potential to be used during sequencing to determine the number of individuals in a particular habitat. To achieve this result, the d-loop variation within animals of the Ohio River valley would need to be determined.
Project Summary and Benefits

Background

ODOT currently employs an overlay design procedure that works well for both flexible and rigid pavements. But for composite pavements, it tends to produce very conservative designs that are often deemed structurally unnecessary, especially for composite pavements already with thick asphalt overlays. This research was initiated to develop an improved deflection-based overlay design procedure.

Research Context

ODOT’s current procedure is based on a structural deficiency approach recommended by 1993 AASHTO Design Guide which was originally tailored for rigid pavements. The remaining structural capacity of the existing pavement is estimated from the measured surface deflections which are used to back-calculate the layer moduli and thus obtain the equivalent thickness of the existing pavement. The back-calculation model employed in the current procedure likely significantly underestimates the structural capacity of the existing AC/PCC composite pavements.

Research Approach

The principal methodology focused on improving the back-calculation model to reliably evaluate the remaining structural capacity of the existing AC/PCC pavements by producing reasonable estimates of AC/PCC moduli and equivalent thickness from the measured surface deflections.

Research Findings and Recommendations

A revised design procedure was developed and subsequently implemented into a design software program. It adopts an improved back-calculation model. The revised design procedure produces much more efficient overlay design thickness; many pavement sections examined now require several inches thinner than demanded by the current procedure. The potential cost savings can be substantial.
Project Components

*Evaluation:* Identify the deficiencies of current design software.

*Design:* Develop a new design procedure, aiming for improved layer moduli, capability to mitigate the effect of questionable deflection data, consideration of temperature effects.

*Validation:* Verify the consistency of revised design procedure Implementation: implement the procedure into a software program.
GOAL ONE: A SAFE RETURN EACH AND EVERY DAY -- Safety Guidelines for Transportation Researchers

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| Submitter   | Oregon Department of Transportation
             | Michael Bufalino
             | 555 13th Street
             | Salem, Oregon 97301
             | 503-986-2845 |

**Project Summary and Benefits**

In 2015, there were 642 fatalities from crashes in work zones. This equates to approximately 2% of all roadway fatalities nationally (FHWA 2017), and 1.76 work zone fatalities per day. The annual number of work zone fatalities varies. Fatality Analysis Reporting System (FARS) data indicate that 590 work zone fatalities occurred in 2011, 617 in 2012, 579 in 2013, 669 in 2014, and 642 in 2015. Work zone crashes occur at a higher rate than non-work zone crashes. FHWA reports that if fatalities occurred in work zone crashes at the same rate as non-work zone crashes, that would mean a total of 164 lives saved in 2015 (FHWA 2017).

Safety precautions are needed to protect the students from the associated increased risk of injury. In many cases, the students performing the work have little prior experience working on active roadways, and often minimal if any safety training. This project produced a student-focused manual video. After reviewing the manual student researchers will be expected to:

- Understand the likely hazards present in roadway work areas;
- Know how to prepare for working on roadway work sites; and
- Know how to conduct their work on roadways safely.

It is assumed that through the adoption of safe working practices, these students can reduce the risk of injuries or fatalities in highway and roadside work zones during research tasks, and with continued reinforcement, continue safe practices throughout their careers.
50 KSI Steel H-Pile Capacity

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| **Submitter**  | Pennsylvania Department of Transportation  
                 Lisa Tarson  
                 400 North Street  
                 Harrisburg, Pennsylvania 17120 |

**Project Summary and Benefits**

The objective of this study is to re-evaluate the adoption, with the objective of potentially extending the utilization of $F_y = 50$ ksi for the structural capacity of steel H-piles (AISC HP sections) for bridge foundations. Specific consideration is given to the current capacity equations, $P_n = 0.66A_sF_y$ and $P_r = 0.33A_sF_y$, with the objective of their confirmation or revision; potentially permitting fewer piles for a foundation and an associated cost savings. The impacts of any revisions, particularly upon foundation settlement, are evaluated and recommendations for the revision of DM-4 (as amended by SOL 483-14-04) are provided. Cost Savings: $7 to $10 million savings over the Decade of Investment period through statewide implementation of using 50 ksi steel for H-Pile design Capacity. This is a Construction and Materials savings.
# Storm Water Control Management & Monitoring

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| **Submitter**   | Pennsylvania Department of Transportation  
Lisa Tarson  
400 North Street  
Harrisburg, Pennsylvania 17120 |

## Links

## Project Summary and Benefits

Temple and Villanova universities collected monitoring and assessment data along the I-95 corridor to evaluate the performance of current stormwater control design and maintenance practices. An extensive inventory was developed that ranks plants in the basins according to their health and location. Three plant species performed poorly in bioretention design and alternatives are proposed. Grab samples were collected for storms approximately monthly and analyzed for a variety of road runoff constituents. Although a full year of data was not yet available, annual loading for total suspended solids (TSS) and nutrients were estimated. LiDAR data helped show that variations in basin performance occurred due to changes in stormwater capture during construction. Simulated runoff tests (SRTs) were conducted to study response during a large volume event. These SRTs were valuable in quantifying drainage areas and improving monitoring strategies. Recommendations are provided on hydrologic design, potential contaminant mobility, planting, and maintenance.
Ranking of Pavement Preservation Practices and Methods

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<td>South Carolina Department of Transportation Terry Swygert 1406 Shop Road Columbia, South Carolina 29201 803-737-6691</td>
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Project Summary and Benefits

South Carolina undertook research to identify methods to improve the implementation of pavement preservation strategies on asphalt concrete roadways with specific attention to pavements in the Non-Federal Aid Secondary system. The research identified five areas to help SCDOT increase the effectiveness of its pavement preservation program by:

1) Including more educational opportunities for decision makers related to pavement preservation to focus on long-term network preservation and planning;

2) Implementing the decision support concept based on Remaining Service Life to continuously increase the number of lane-mile-years included in the pavement preservation candidate pool (i.e., PQI ≥ 3.0);

3) Documenting additional information on preservation treatments to adequately track pavement preservation treatments;

4) Implementing a more detailed pavement condition evaluation protocol to monitor the actual life extension of pavement preservation treatments to include pre- and post-treatment condition assessment followed by routine evaluations on an annual basis; and

5) Implementing a system to quantify the benefit-cost ratio of pavement preservation treatments to better understand the effectiveness of different treatments in particular situations.

SCDOT has taken great strides to implement these findings. Evaluation protocols and cost-benefits of preservation treatments will be offered in Pavement Preservation Level II training conducted at Tri County Technical College by utilizing newly developed tools from this research project (i.e., the Pavement Preservation Treatment Selection worksheet and Pavement Preservation Treatment Benefit-Cost analysis tool). The training
will be offered in the fall of 2018 and targets district contract managers, RME, and ARME’s responsible for selecting the “Right Treatment on the Right Road at the Right Time” by determining the proper treatment selection in conjunction with maximizing Lane Miles of Surface Life added and staying within budgetary constraints. Additionally, the Director of Maintenance Office and Pavement Management established a Preservation Pool of Candidates report through the Department’s Intelligent Transportation Management application identifying segments with PQI’s >= 3.2 & <=4.0. The reporting feature should aid field personnel with project selection by using a targeted approach to determine routes eligible for various pavement preservation treatments.

Based on the findings of this research project, the Director of Maintenance Office issued Maintenance Directive #5 on January 13, 2017, detailing a methodology that will be used to determine the benefit cost and life extension of the various maintenance treatments used by SCDOT. This process will begin with the 2019 pavement preservation program and will be used to obtain a representative sample of the various treatments used so that the effectiveness of those treatments can be determined for the different geographical areas of the state. Targeted route segments for three sections each of chip seal, micro surfacing, and ultra-thin lift overlays (for a total of nine segments from the upper state and nine segments from the lower state) will be monitored for performance. Each road will be rated prior to and upon placement of treatment, and then annually until the PQI returns to pretreatment score. The data will be entered into the Pavement Preservation Treatment Benefit-Cost analysis tool, which will permit the life extension and cost benefit to be calculated.

This process will be replicated until such time that sufficient data has been collected to determine the average life extension for the various treatments for both primary and secondary routes in the two geographical regions previously mentioned. The data will then be uploaded into the Department’s Pavement Management system (HPMA) to aid in life extension modeling within the HPMA software.

Lastly, this research project directly aligns and supports the 2nd Goal of the SCDOT Strategic Plan 2018-2020 for maintaining and preserving the existing transportation infrastructure. SPR-695 provides clear direction for a strategic and targeted approach to identify and place the right treatment on the right road at the right time. This process should enable SCDOT personnel in making proactive decisions when selecting treatments that will maximize the lane miles of service life added to the system within the allocated budgets.
Project Summary and Benefits

South Carolina initiated research to reduce the number of fatal and serious injury vehicular crashes by reviewing proven successful safety programs used in other states, and developing an implementation plan for the programs that have a high likelihood of success given South Carolina’s conditions. The following represent key program adoptions/changes that could bring about significant reductions in fatal crashes in SC with notable benefit/cost ratios.

1) Tree-related Fatalities (2015 - 191 Fatalities, 24.9%) - South Carolina ranked 1st in the nation for the highest fatality rate (0.32 per 100,000 population) for crashes involving trees. Researchers determined that a tree-related crash is 42 times higher if the minimum clear zone is not met. By reclaiming up to 50% or 75% of the recommended clear zone, it is expected that roadway fatal and injury crashes involving trees could be reduced from 27% to 60%, respectively. In addition, every dollar invested in tree clearing should result in $26-$38 in savings for tree removal and reduced hazards during natural disasters.

2) DUI Fatalities (2015 - 301 fatalities, 30.7%) - South Carolina has some of the weakest laws in the United States relating to DUI offenders and is one of only two states in the nation where police officers prosecute their own DUI cases. Reductions in DUI-related factors could be seen in South Carolina by implementing stricter laws for first-time offenders and repeaters by utilizing ignition interlock systems, and through other programs such as DUI courts, beverage server training, and solicitor prosecution of DUI cases. It is estimated that for every dollar invested in DUI courts, $49 will be saved.
3) Speed-related Fatalities (2015 - 361 fatalities, 36.9%) - Almost 40% of the fatalities on SC roadways were speed-related, exceeding authorized speed limit and/or driving too fast for conditions, which is the 2nd highest rate in the nation. Auto-enforcement with cameras has the potential to expand speed management programs and reduce all types of crashes. Unfortunately, in 2010, South Carolina banned the use of red light cameras and speed cameras in the state. Utilizing fixed or mobile camera speed enforcement could reduce fatal crashes, improve traffic flow with more uniform speeds, and save $13 dollars for every dollar invested.

4) Teen Driver Fatalities (2015 - 40 fatalities, 6%) - Traffic fatalities are the leading cause of death of teens and in 2015, there were 37 fatal crashes among 15-17 year-old drivers, which produced a crash cost of $347.8 million in SC. Graduated Drivers Licensing programs have reduced teen crashes by 10-40% on average in the US through a three-stage approach: supervised learning period, restricted intermediate licensing stage, and full license stage. The Insurance Institute of Highway Safety estimates that SC could reduce the rate of teen driver related fatal crashes by nearly 50% or more by adopting the strictest GDL provisions. Adopting the three stricter GDL criteria in SC could achieve a 45% reduction in SC by raising the permit age to 16 and the unrestricted licensing age to 17, raising the minimum number of practice hours to 70, and restricting teen passengers during the intermediate driving phase. For every dollar invested in adopting strict GDL provisions, $156 will be saved.

The development of this comprehensive safety program assessment, along with identification of funding sources, will enable forward movement on all fronts. Using a data driven approach to safety program selection will yield support for changes in programs, policies, and standards, and have positive impacts on safety, operational, and economic aspects of the SC roadway system. Further, the implementation of a data-driven safety management program will help to assure that the most appropriate strategies are implemented. To implement this research, the Department will work through the state’s Strategic Highway Safety Plan to explore the various areas jointly among several safety partners.

SCDOT recently began implementing a Rural Road Safety Program (RRSP) that utilized a risk based, data-driven approach to identify roads in the state with the greatest potential for eliminating traffic fatalities and reducing severe injuries. These roads will be evaluated individually and engineering countermeasures tailored to the specific issues present on each road. The overall mission of the RRSP is to first, keep vehicles on the road, and second, to provide an area for recovery should a vehicle depart the roadway. Other areas noted above will require involvement and commitment from outside agencies and the South Carolina legislature.
Integration of the Incident Command System (ICS) Protocol for Effective Coordination of Multi-Agency Response to Traffic Incidents

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**Project Summary and Benefits**

South Carolina conducted research to enhance the use of Incident Command System (ICS) protocols and incorporate Traffic Incident Management (TIM) best practices to more effectively manage day-to-day incidents on the Interstate roadway system. In recent years, there has been an increased focus on TIM and incorporating ICS to reduce traffic congestion on the nation's Interstates. Studies show that for every minute a freeway lane is blocked due to an incident, there is a corresponding time of four minutes of travel delay, and the likelihood of a secondary crash increases by 2.8% for every minute that the primary incident remains a hazard.

Severe congestion also leads to: increased response time by police, fire, and emergency medical services; lost time and a reduction in productivity; increased cost of goods and services; increased fuel consumption and vehicle maintenance costs; reduced air quality and other adverse environmental impacts; and a negative public image for agencies involved in incident management activities. Between 2012 and 2013, there were 129 fatal incidents recorded on South Carolina interstates (90 fatal incidents in 2014). Roughly half of the fatal incident recovery times (i.e., dispatch of response to incident cleared) were in excess of six hours, with maximum recovery times well over 12 hours.

States which have implemented enhanced ICS and TIM procedures are consistently achieving major incident clearance times of one and a half hours or less. Quickly resolving major highway incidents involves multi-stakeholder agency emergency response and may include personnel from the state department of transportation, highway patrol and/or other law enforcement agencies, fire services, emergency medical services, towing, coroner, and hazardous-spill cleanup services. After analyzing the current state-of-practice in South Carolina and national best practices, four potential areas for improvement in incident response were identified:

1) **Towing**: South Carolina uses a rotation-based dispatch system for major incident towing where companies have 45 minutes to arrive on scene and are paid by the hour. Adopting a Towing and
Recovery Incentive Program (TRIP) similar to the one that Georgia implemented in 2008, could yield a 66% incident duration reduction with an estimated 234 minutes per major incident. Georgia’s TRIP compensates certified recovery companies to expedite incident clearance and has reduced clearance times from 216 minutes to less than 40 minutes (38 min in 2014). Additionally, in 2011, it was estimated that the program realized $456,396 (or 71%) per-incident cost savings.

2) **Hazmat:** Overestimation by on-scene response personnel may cause delays in potential HAZMAT (i.e., hazardous material releases) incidents when Department of Health and Environmental Control (DHEC) resources are requested for notification-only incidents. Accurately identifying when a HAZMAT response is needed will result in faster incident clearance times. South Carolina needs to define and develop a statewide policy, operating procedures, and interactive spill training for evaluating fuel and hazardous material cargo spills.

3) **Coroner:** Under South Carolina’s current legislation, incident responders are not allowed to disturb a deceased body in any way until the (deputy) corner or (deputy) medical examiner has completed a formal investigation and authorization. Implementing traffic fatality certification laws as Texas, Tennessee, and Louisiana, could reduce delays and increased congestion due to the response time of the coroner or medical examiner. These laws are a combination of quick clearance (i.e., temporary removal of the deceased from the roadway and/or certification of the incident fatality by EMS and qualified Fire personnel) and hold harmless acts.

4) **Crash Investigation:** The Multidisciplinary Accident Investigation Team (MAIT) conducts in-depth investigations of complex circumstance incidents (e.g., fatalities and felony cases). Incidents involving MAIT are generally the longest in duration as much of the work performed on-scene, at the time of the incident. Utilizing new technologies (e.g., 3D laser scanning and drone cameras) may reduce incident data collection and investigation time from 50% to 90% while simultaneously collecting a significant amount of additional data. Further, these technologies do not require personnel to enter hazardous areas of the scene, nor do they require traffic operations to be suspended during use. Based on the analysis of other states’ implementation of these strategies, South Carolina should expect shorter incident duration times, reduced costs, and increased efficiency for each stakeholder agency, and more effective cooperation with local responders. The motoring public should experience fewer secondary collisions, reduced congestion times, and lower vehicular operating costs. Additionally, there will be less fuel wasted and fewer emissions from idling vehicles due to reduced incident times, and a more favorable opinion by the public of the incident management agencies. Likewise, the implementation of the ICS strategies and enhanced TIM scenarios showed a return of investment range from $15 to $168 for every dollar invested which accrues from savings of travel time, fuel, and emissions.

In August 2012, through a partnership with South Carolina Department of Public Safety (SCDPS), SCDOT implemented the FHWA-SHRP-2 TIM training initiative. The training sessions were conducted in three regions of the state, Columbia, Greenville, and Charleston, and concluded in June 2013. This effort coincided with the annual SCHP In-service training cycle and facilitated TIM training for approximately 800 SCDPS personnel. In June 2014, SCDOT contracted with Parsons Corporation to continue TIM training by offering a four hour, multi-module course on clearing travel lanes in an expedited manner. To date, 4,806 (33.5%) of the first responders needing training have completed the TIM program. Providing training for all first
responders will contribute to Goal 3 of the SCDOT Strategic Plan, increasing the efficiency and reliability of our road and bridge network through a defined reduction in lane clearance times at incident scenes.

The effect of the training has been immediate. In 2018, the average clearance time has been reduced for lane blocking incidents by an average of approximately 23 minutes per incident. The SCDOT’s goal is to further reduce these times by one minute per year with a finite goal of 20 minutes per incident. In addition, TIM training reduces the probability of secondary collisions and provides enhanced safety for all first responders. Traffic Engineering, ITS TIM, and SC Highway Patrol will need to involve the partners in incident management to encourage ongoing participation in TIM Training. The SCDOT must involve the SCDOT Safety Council and stakeholder agencies to jointly promote and explore avenues for continued implementation of this research. Additionally, complete implementation may require involvement and commitment from the South Carolina legislature.
Valleybrook Archaeological Education and Curation Center, East Tennessee State University, Johnson City, Tennessee

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<td>Tennessee Department of Transportation Anne Freeman 505 Deaderick Street, Suite 900 Nashville, Tennessee 37243 615-253-2430</td>
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**Project Summary and Benefits**

The benefits of this research project were largely practical and qualitative. Practical in the sense that the implementation of this research provided a consolidated, permanent repository for the curation of legacy collections of archaeological materials recovered from TDOT projects. These materials were previously held by a variety of institutions, private contractors, and private individuals. Establishing and curating these collections in a repository meeting all applicable standards and best practices fulfills the stewardship mandate in the National Historic Preservation Act under which these materials were collected. These collections are available for education, training, and research by archaeology students and professionals alike. The collections are not limited only to ETSU students, but are instead available for research purposes to anyone who’s interested in them.

The primary change made possible by this contract was the consolidation of TDOT’s legacy archaeological collections into a single facility. Also, since this facility was established, it provides the framework for a new agreement between ETSU and TDOT to become a central repository for “point-forward” projects. It also represents a good example of a public-private partnership in that the ETSU facility is housed at the former Kodak campus in Johnson City; Kodak donated their Johnson City campus and all facilities to ETSU. The Kodak facilities provided sufficient horizontal and vertical space to accommodate shelving and storage space to support the long-term curation of these collections. The research contract addressed a single, long-standing need by providing a consolidated repository for the permanent curation of archaeological legacy collections recovered from TDOT road and bridge construction projects. These materials were collected under the authority of the National Historic Preservation Act and a state archaeological permit, but state facilities managed by the Tennessee Division of Archaeology or the Tennessee Department of Transportation were either full and unable to accept new collections or were not equipped to do so.
The lack of curation space is a nationwide issue that every state and federal agency is dealing with, so much so that the problem has a nickname within agency circles – the “curation crisis.” The crisis is that state and federal agencies are mandated to collect and curate archaeological materials, but the only the collection side of the equation is funded. Many state and federal agencies see curation as an unfunded mandate, the result of which is a hodge-podge of solutions, few of which meet the spirit of the National Historic Preservation Act or 36 CFR 79, regulations regarding curation of archaeological materials. In light of the situation in Tennessee, the implementation of this research contract “solved” the curation crisis for TDOT’s legacy collections by providing a safe, secure, and sustainable repository and by making the collections available for education, training, and research purposes.
Evaluation of Intelligent Compaction in Asphalt Pavement Construction in Tennessee

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| Submitter  | Tennessee Department of Transportation  
Anne Freeman  
505 Deaderick Street, Suite 900  
Nashville, Tennessee 37243  
615-253-2430 |
| Links      | https://www.youtube.com/watch?v=0oYX0o2gbyw |

Project Summary and Benefits

Starting with the 2018 paving season TDOT has implemented wide use of Intelligent Compaction (IC) on many paving projects. The research project that was used as a trial prior to this helped pave the way for the development of the specification and let TDOT know what information should be considered essential to the process and which parts of the technology are not ready for implementation. The IC research project fulfilled its need to prove the concept could be used and gave TDOT The confidence to move forward with wide spread adoption of the technology. Based on this TDOT built our spec to around “IC Lite” which incorporates the two pieces of IC that were proven to be beneficial while not requiring the contractors to purchase equipment that will not provide useful data to TDOT. The use of IC technology has proven through the TDOT IC Research Project as well as parallel studies to dramatically improve consistency of rolling operations as well as increase in place densities of asphalt pavements, which in turn has a demonstrated benefit on the longevity of pavements. TDOT will additionally be participating in FHWA’s increased density research program (phase 3) in conjunction with our new IC specification.
Local Calibration of Mechanistic - Empirical Pavement Design Guide in Tennessee

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| Submitter     | Tennessee Department of Transportation  
Anne Freeman  
505 Deaderick Street, Suite 900  
Nashville, Tennessee 37243  
615-253-2430 |

**Project Summary and Benefits**

The purpose of the research is to conduct local calibration of pavement performance (distress) model in the AASHTOWare Pavement ME Design software so that improved accuracy can be achieved for the pavement performance modeling. The calibrated Pavement ME design models aim to help TDOT transition from the current AASHTO 93 Pavement Design to Pavement ME Design. The concept of Pavement ME Design is to use engineering mechanics and real world observations of pavement performance to determine the pavement thickness that best matches anticipated loads, localized material properties and site specific climatic conditions. The implementation of the results make it possible to predict during the design phase the distresses and untimely deformations of the pavement structure based on Tennessee climatic conditions, Tennessee materials, and Tennessee traffic loadings. Such untimely failure can be corrected during the design phase. This approach will lead to significant savings for Tennessee taxpayer. There will be savings in frequent maintenance strategies, operational cost, and materials.

The implementation would provide precise pavement designs that are better tailored to site specific conditions which should lead to more efficient designs and more effective use of available funding. Pavement ME Design is predicted on the understanding that it yields a more cost effective pavement structure. The design methodology will reduce pavement thickness, extend the service life of pavement and minimize maintenance frequency based on predicted results.

Since materials vary across the country, it is considered critical to adjust the calibrated coefficients to reflect agency specific or local conditions, materials, policies, and experience that may not have been included in the initial global calibration-validation process for Pavement ME Design. Local calibration will maximize the benefit since it will minimize the biases between the predicted output values and the field observed distresses.
These procedures and changes can be replicated in agencies, states and even at the federal level. Some agencies that have implemented Pavement ME Design are experiencing thinner pavements with reduced distresses and improved performance. Several States in the United States and provinces in Canada have transitioned from the AASHTO 1993 pavement design guide to the Pavement Mechanistic-Empirical Design Guide MEPDG, now known as Pavement ME Design. A majority of the states use the LTPP database and data stored in the pavement management system (PMS) as the main source of data for calibration. Most of the states that provided responses reported the transfer function of alligator cracking is the most difficult to calibrate, followed by longitudinal cracking and transverse function.

In TDOT’s subsequent implementation phase, the results of the local calibration are being used as the necessary input parameters needed to run Pavement ME Design for site specific projects. The Pavement ME design does not provide a design thickness as the end product. Instead, it provides the pavement performance throughout its design life. The design thickness can be determined by modifying the design inputs and obtaining the best performance with an iterative procedure. The performance models used in Pavement ME Design are nationally calibrated using design inputs and performance data largely from the national Long-Term Pavement Performance (LTPP) database.

The Pavement ME Design implementation plan in Tennessee recommended local calibration of Pavement ME Design performance prediction models for Tennessee conditions. It was imperative that the results of the research should be used to calibrate the input parameters for Pavement ME Design performance models for Tennessee implementation by taking into account local materials from Tennessee, traffic information for Tennessee, and Tennessee environmental conditions.
## Develop Typical Material Input Values for Mechanistic-Empirical Pavement Design in Tennessee

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<tr>
<td>Submitter</td>
<td>Tennessee Department of Transportation Anne Freeman 505 Deaderick Street, Suite 900 Nashville, Tennessee 37243 615-253-2430</td>
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### Project Summary and Benefits

Mechanistic-Empirical Pavement Design Guide (MEPDG) is a new pavement design concept that uses engineering mechanics and real world observations of pavement performance to determine pavement thicknesses that best match anticipated loads, material properties, and climatic conditions. MEPDG as a more theoretically detailed pavement design method than the current AASHTO 93 method offers long-term financial benefits to each adopting agency in terms of better pavement designs. With the current limited financial dispensation, it is not wise to base pavement design technique solely on sound engineering principles. It must be cost-effective in implementation and in practice. The purpose of the research is to develop typical material input values necessary for the implementation of AASHTO MEPDG in Tennessee and to validate and calibrate MEPDG input based on local weather, local material and local traffic conditions.

The research resulted in the establishment of material data base for MEPDG input level 1 and 2 utilizing the triaxle cyclic test results of thirteen soils in Tennessee. Utilizing the PMS database in Tennessee, the national calibrated transfer function in MEPDG was verified. It was found that the national default MEPDG over predicts total rutting in asphalt pavements. Also traffic was found to be an important factor affect predicted pavement roughness in MEPDG. This research exposed the lapses in the national default which led TDOT to work towards localizing the input parameters.

Numerous state DOTs have fully implemented or partially implementing the MEPDG. InDOT implemented theirs last year and VDOT was the latest agency to announce its implementation last month. The project addresses the need for a cost effective, long lasting pavement. The idea of modeling for performance indicates predicting anticipated distresses within the design years and averting such distresses either by substituting materials (Alternates), increasing or decreasing the pavement thickness or strengthening the base by adding a booster (Geosynthetic material) or treating the subgrade with lime.
The objective of the project was to develop typical material input values for Tennessee necessary for the implementation of AASHTO MEPDG and to validate and/or calibrate MEPDG based on local weather and material conditions for its complementation in Tennessee. The local materials were identified and the objective was fulfilled. The research results were valid in the sense that the input materials developed were the necessary input parameters needed for the implementation of MEPDG in Tennessee.
Innovative Strategies for Public Involvement for TDOT

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Project Summary and Benefits

Looking at TDOT before this project was implemented and what has occurred since has changed the perception of TDOT within the state. Communication is critical to success from a state perspective. Departments of transportation typically have a negative perception among constituents with road construction, potholes, delays, congestion, etc. (not a lot of positive items). If you look at this project at that timeframe and fast forward to today, you will see remarkable improvement with constant communication between the Office of Community Transportation and the community, talking to various stakeholders and listening to concerns, issues, and problems. This has resulted in a noticeable improvement in relationships between communities and TDOT (based on customer survey results). There are many examples of positive results from this project but probably the most notable is the passage of the IMPROVE Act from last year (increase annualized around $300 million per year when fully implemented) which increased fuel taxes to the state. If the legislators, who represented the constituents, were not satisfied with TDOT’s job and work, it would have never passed. Another example includes work on the Freight Advisory Committees which also has represented the [freight] industry and businesses on projects within TDOT.
Enhanced Cost Estimating and Project Development Procedures for MPOs

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| Submitter  | Texas Department of Transportation  
Wade Odell  
200 E. Riverside Drive  
Austin, Texas 78705  
512-416-4737 |

Links: [https://library.ctr.utexas.edu/Presto/content/Detail.aspx?cld=M2UxNzg5YmEtYzMyZS00ZjBlLWVlODctYzljMzQ3ZmVmOWFl&rid=NTYx&qrs=RmFsc2U=&q=KGNhdGFsb2cuQWxsVGV4dDooNjkyOSkpIE9SIChycC5BbGxUZXhOOk2OTI5KSk=&ph=VHJ1ZQ==&bckToL=VHJ1ZQ==&rrtc=VHJ1ZQ](https://library.ctr.utexas.edu/Presto/content/Detail.aspx?cld=M2UxNzg5YmEtYzMyZS00ZjBlLWVlODctYzljMzQ3ZmVmOWFl&rid=NTYx&qrs=RmFsc2U=&q=KGNhdGFsb2cuQWxsVGV4dDooNjkyOSkpIE9SIChycC5BbGxUZXhOOk2OTI5KSk=&ph=VHJ1ZQ==&bckToL=VHJ1ZQ==&rrtc=VHJ1ZQ)

Project Summary and Benefits

One of the major challenges for Metropolitan Planning Organizations (MPOs) is that their transportation plans and programs can be readily undermined by unrealistically low preliminary cost estimates and unachievable optimistic project letting dates. This can lead to significant negative repercussions, including delays or cancellations of anticipated improvements, losing out on available federal or state funds, and even the cascading effect of preventing other qualified projects from being implemented.

Researchers developed a new procedural guidebook, entitled “Project Scoping Guidebook for Metropolitan Planning Organization Transportation Projects,” to enhance the quality of the scope of work, cost estimate, and anticipated construction start date for projects proposed by local governments for inclusion in MPO transportation planning documents. This guidebook is based on a rigorous analysis of best practices in MPOs and DOTs from across the nation. It includes guidance and recommendations from Texas and throughout the nation that have proven to be successful in developing project proposals that meet targeted costs and achieve planned letting dates. Furthermore, enhancements to this guidebook ensure its applicability and ease of use. A thorough and consistent approach to project scoping can greatly assist local governments in developing realistic project costs and schedules. It also provides guidance to MPOs on evaluating proposed projects and comparing them with competing projects to identify those more likely to be implemented when planned for the requested funding.

The guidebook has been distributed electronically to all Texas MPOs, and is mentioned in project development workshops hosted by MPOs and TxDOT districts throughout the state. The guidebook is also discussed in Local...
Government Project Procedures Qualification training classes conducted by TxDOT for local governments who undertake designing and constructing transportation improvement projects which include FHWA and/or TxDOT funds.
The objectives of this research project were to develop and validate procedural guidance, business practices and workflows through field and laboratory evaluations of specific pavement forensics and railway operations data collection and processing tasks. A three-university consortium research team led by The University of Texas at Arlington (UTA) was engaged in research works for TxDOT to establish unmanned aerial vehicles (UAV) related guidance on operational policies, procedures and guidelines, and a UAV Flight Operations Manual (FOM) for implementing UAVs for DOT applications in the infrastructure management area. All the objectives were successfully accomplished with the FOM prepared for implementation of infrastructure surveys. The research study results from field surveys also showed that the photogrammetry approach using the UAV platform has demonstrated and provided very good preliminary solutions to bridge studies, pavement forensics, railway corridor surveys, and estimating stockpile volumes.
Using a Safety Forecast Model to Calculate Future Safety Metrics

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| Submitter           | Utah Department of Transportation  
|                     | David Stevens  
|                     | P.O. Box 148410  
|                     | Salt Lake City, Utah 84114  
|                     | 801-589-8340 |

**Project Summary and Benefits**

Several years ago, the UDOT Planning Division, with the assistance of the UDOT Traffic and Safety Division, developed a Safety Index to add a safety metric to the project prioritization process for the long-range plan. The Safety Index was a relatively simple formula based on historical crash data. This was a significant step forward, but the index could only focus on areas that needed attention from a historical safety perspective and could not capture the potential benefits related to projected future traffic conditions. This research sought to identify a process to improve long-range planning prioritization by using forecasted safety metrics in place of the existing UDOT Safety Index.

The research team for this project developed a Safety Forecast Model using Highway Safety Manual (HSM) Safety Performance Functions (SPFs) and Crash Modification Factors (CMFs). The research team obtained existing roadway characteristics from UPlan, UDOT’s online map center, that served as inputs for the Safety Forecast Model. The research team also collected condition data, such as forecasted volumes and lanes, from the Utah Statewide Travel Model (USTM), a travel demand forecasting model. Existing crash data (obtained from UDOT) were used to assess the base-year crash predictions of the Safety Forecast Model. The model was used to compare crashes predicted based on the current 2015-2040 UDOT long-range plan Build scenario to crashes predicted based on the No-Build scenario.

The research team determined, through a case study of 15 long-range plan widening projects, that the project prioritization ranking changes if the ranking considers future safety impacts rather than relying solely on historical crash data. All else being equal, the new process examined as part of this research gives road segments that are most likely to experience an improvement in safety a higher prioritization ranking than segments that would not experience an increase in safety. The research team also determined that the Safety Forecast Model could be used to recommend safety projects or for other applications such as systemic safety analyses. Systemic safety analysis looks at roadway and crash attributes to identify common conditions across the state (as opposed to looking at spot aggregations of crashes) that lead to fatal and serious-injury crashes. For example, the Safety Forecast Model was used to identify road segments with the highest reduction in fatal and
injury (FI) crashes if lane widths and shoulder widths are improved on rural two-lane, two-way roads. The results of the project were not realized in time for the new Safety Forecast Model to be incorporated into the development of UDOT’s 2019 statewide long-range plan and the Utah Unified Transportation Plan, but will be incorporated into the future plans.
Quantifying the Vulnerability of Vermont Bridges to Seismic Loading

**Project ID**  
RSCH020-737

**Cost**  
$214,150

**Duration**  
51 months

**Submitter**  
Vermont Agency of Transportation  
Emily Parkany  
1 National Life Drive, 5th Floor  
Montpelier, Vermont 05633  
802-272-6862

**Project Summary and Benefits**

This project has developed a spreadsheet with a number for each bridge on the Vermont state system quantifying the seismic risk for each bridge. There is a lot of interest among our structures, bridge preservation, asset management, programming, and scoping staff to understand which bridges have greater seismic risk. It is anticipated that once bridges are identified for rehabilitation, then the information from this project can be used to mitigate seismic risk going forward. The inputs to the quantification can be modified. For example, we plan to substitute the network criticality values obtained with a resilience project to determine if the seismic rankings would change. We anticipate modifying the tool when we have better/explicit geotechnical information about footings, etc. The number of staff interested in this work and the ways that we can use the tool to improve our projects make the research exciting and valuable.
Low Cracking Concretes for the Closure Pours and Overlays of the Dunlap Creek Bridge

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**Project Summary and Benefits**

This project involved the construction and evaluation of the closure pours used to replace the joints and the overlays used to provide deck protection for two, five span bridges on I-64 over Dunlap Creek in Alleghany County, Virginia. Closure pours consisted of low permeability fiber-reinforced concretes resistant to wide cracking. Three different fibers, polyvinyl alcohol, polypropylene, and steel were used. Latex-modified concrete with Rapid Set cement but without fibers was also included as a control since it is commonly used for closure pours in Virginia.

Overlays consisted of concretes with a low cracking potential and low permeability. Five different materials were used for the overlays: (1) latex-modified concrete with Rapid Set cement, (2) silica fume concrete (SFC) alone, (3) SFC with shrinkage reducing admixture, (4) SFC with lightweight coarse aggregate, and (5) SFC with lightweight fine aggregate. The concrete in the closure pours achieved the specified compressive strength of 3,000 psi in less than 24 hours and low permeability (< 1000 coulombs) at 28 days. The concrete in the overlays also achieved the specified compressive strength of 3000 psi in less than three days and low permeability at 28 days.

The surveys after two to three winters indicated mostly tight, leak resistant cracks (<0.1 mm [0.004 in] in width) in the fiber reinforced concretes. The study recommends that fiber-reinforced concretes be used when tight cracks and high early strengths are needed. Also, SFC overlays with shrinkage reducing admixture, with lightweight coarse aggregate, or with lightweight fine aggregate are ready for implementation. Installation of the crack resistant overlays will extend the life of the decks by 50 years or more. Joint replacement using closure pours will prevent further deterioration of the substructure elements and extend the life by 50 years or more. Implementation is continuing with construction of these overlays and closure pours.
Optimizing Short Duration Bicycle and Pedestrian Counting in Washington State

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**Project Summary and Benefits**

Across the United States, jurisdictions are investing more in bicycle and pedestrian infrastructure, which requires non-motorized traffic volume data. While some agencies use automated counters to collect continuous and short duration counts, the most common type of bicycle and pedestrian counting is still performed manually. The objective of this research is to identify the optimal times of day to conduct manual counts for the purposes of estimating annual average daily non-motorized traffic (AADNT) accurately.

This study used continuous bicycle and pedestrian counts from six U.S. cities, including three in the Pacific Northwest, to analyze AADNT estimation errors for multiple short duration count scenarios. Using two permanent counters per factor group reduces error substantially (>50%) compared to using just one; afternoon counts seem to be best for reducing error (2 p.m. - 6 p.m.). While Monday is associated with high error, Friday is comparable to other weekdays. Error on Sunday is often as good, if not better than Saturday, contrary to what others have found. Arlington had the lowest AADNT estimation error (mean absolute percent error) likely due to better data quality and higher non-motorized traffic volumes and Mt. Vernon, Washington had the highest. Average AADNT estimation errors for the studied short duration count scenarios ranged from 30% to 50%. Error is lower for the commute factor group, bicycle-only counts, scenarios in which more peak hours are counted, and when more than one permanent counter was available to estimate adjustment factors.

To minimize error, this study recommends increasing the number of permanent bicycle and pedestrian count sites, validating and calibrating the equipment, and increasing the length of time counted at each count site to at least 8 hours (7-9 p.m., 11 a.m. - 1 p.m., 4-6 p.m. Tuesdays, Wednesdays, or Thursdays, and 12-2 p.m. Saturdays), but preferably counting a whole week using calibrated automated equipment.
## Improved Methodology for Benefit Estimation of Preservation Projects

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| **Submitter**        | Washington State Department of Transportation  
Doug Brodin  
P.O. Box 47372  
Olympia, Washington 98504  
360-705-7972 |

### Links

### Project Summary and Benefits

The Washington State Department of Transportation (WSDOT) currently incorporates the investment cost associated with highway project improvements, in addition to those user and maintenance costs derived from the Highway Economic Requirements System - State Version (HERS-ST), into the REMI-TranSight model to quantify the regional economic benefits associated with transportation investment projects. The focus for the WSDOT is primarily on larger projects such as new road construction but can also include highway preservation and maintenance.

There is a need for a systematic method to estimate the transportation benefits of highway improvement projects. This would provide necessary data inputs for an economic impact analysis process in order to accurately quantify the long-term economic benefits of highway improvement projects. This research project evaluates and analyzes the current process for calculating pavement improvement benefits and then develops an improved approach for measuring the benefits of these highway preservation projects. In order to better understand how other state transportation departments evaluate different improvement alternatives and to gauge to what extent they utilize the HERS-ST software, a comprehensive national survey of state DOTs was conducted.

The results enhanced the understanding of current practices of pavement program analysis across the country as to whether and how HERS-ST is being utilized by state transportation agencies. The survey results revealed that few states still utilize the HERS-ST software and vary widely on how they evaluate pavement projects. Increased utilization of HERS-ST and the application tool developed in this project has the potential to increase consistency across states and improve the benefit calculation method.
Based on the survey results, the Excel-based HERS-ST Benefit Application Tool (HERS-ST-BAT) was developed. This was created to supplement HERS-ST for benefit and cost estimation processes. It improves the existing process in three primary aspects:

1) Greater control of data inputs used by HERS-ST for simulations;

2) Ability to compare unimproved and improved scenarios at different time periods;

3) Modification of regional input parameters instead of utilizing national averages.

Combining this developed tool, HERS-ST-BAT, with HERS-ST, a transportation agency is better equipped to estimate the changes of agency and user costs from a proposed pavement project with accuracy and flexibility. The HERS-ST-BAT is applied to three past highway projects from WSDOT and the results are reported in the case studies within this report. The measurable user costs and maintenance costs are estimated and used in different scenarios. Compared with the scenario without any improvement, the scenarios with improvements at the appropriate time can reduce total costs by 0.25% to 1.09% at the county level. In addition, Hot Mix Asphalt (HMA) projects can save total costs by $6 to $35 million dollars more than Portland Cement Concrete (PCC) projects. The more specific improvements are delayed, the less total cost savings are realized. In the worst case, an improvement even increases total costs by 0.15% because implementation is too late to offset the high initial construction costs within the analysis period.

The national survey revealed that individual states evaluate pavement projects differently and do not always utilize consistent approaches. The tool developed here, in conjunction with the HERS-ST software, provides an improved method for consistent and systematic pavement project evaluation. The findings generally confirmed that early pavement improvements can significantly extend pavement life and save total costs. The overall results in this report indicate that the improved method is applicable to various pavement improvement projects. Regional transportation agencies, especially for those without a statewide travel demand model, can incorporate this method for evaluating highway improvement decisions.
Rapid Road Rehab (R3): Web-Based Road Rehabilitation Planning, Design and Construction Decision Support Tool

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| Submitter  | Washington State Department of Transportation  
             Lu Saechao  
             310 Maple Park Avenue, SE  
             Olympia, Washington 98504  
             360-705-7260 |
| Links      | http://www.wsdot.wa.gov/ |

**Project Summary and Benefits**

The use of the R3 tool will benefit departments of transportation (DOTs) by saving project costs and shortening construction schedules, which will lead to funding more projects. The use of R3 is especially beneficial for transportation agencies when it is implemented during the planning and design stages of highway project development in order to balance schedule (construction production), inconvenience (traffic delay), and affordability (agency budget). R3 provides meaningful performance indicators that allow engineers to integrate a holistic analysis framework to the design and selection of pavement rehabilitation projects. Ideally, R3 is intended for deployment in the planning and development stages of a highway project and can be used as a design and scoping tool prior to contractor selection. These results help state DOTs facilitate the selection of cost-effective construction strategies and transportation management plans (TMP) for highway paving projects. Additionally, the software is beneficial as a post-construction verification tool that provides reasonable expectations for contractor productivity.

The software's scheduling module estimates highway project duration (total number of closures), incorporating alternative strategies for pavement designs, lane-closure tactics, and contractor logistics. R3’s traffic module (using the Highway Capacity Manual demand capacity model) quantifies the impact of construction work zone closures on the traveling public in terms of road user cost and time spent in queue. For the current web application there are access/support fees for states to use. Many case studies in California and other states have proven the capabilities and benefits of this tool. FHWA formally endorsed CA4PRS as a “Priority, Market ready Technologies and Innovations” product in 2008 for nationwide deployment.

Most recently, a prototype version of R3 was used for the I-15 Devore Project in California with traffic simulation models to select the most economical rehabilitation scenario. The 4.5 kilometer concrete reconstruction project, which would have taken 10 months using traditional nighttime closures, was completed over two 9-day periods using one-roadbed continuous closures and around-the-clock construction. Implementing continuous closures...
rather than repeated nighttime closures in this project resulted in significant savings: $6 million in agency costs and $2 million in road user costs.
Critical Factors Affecting Asphalt Concrete Durability

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| Submitter        | Wisconsin Department of Transportation  
Andy Eiter  
4802 Sheboygan Avenue, Room 104  
Madison, Wisconsin 53707 |

Project Summary and Benefits

Raveling and surface-initiated cracking are the primary forms of deterioration suffered by aging asphalt pavement. Asphalt durability is a pavement’s resistance to such deterioration and has traditionally been addressed in mixture design and construction through a combination of: asphalt binder specifications; aggregate specifications; limits on volumetric properties; testing and requirements to minimize moisture sensitivity; and in-place compaction requirements. While these requirements have been largely successful, changes to mixture composition and the use of performance-related mixture testing may further improve asphalt concrete durability.

The objective of this project was to evaluate the current Wisconsin Department of Transportation (WisDOT) mixture criteria relative to best practices associated with durability and recommend practices to increase durability. A synthesis of current practice was conducted to identify mixture compositional factors affecting asphalt mixture durability and promising methods for improving pavement durability, and two experiments were conducted. The first experiment developed relationships among four compositional factors affecting asphalt mixture durability, cracking resistance, and age hardening. Effective binder volume, recycled binder content, polymer modification and virgin-binder, low-temperature grade were evaluated at three levels to address possible non-linear effects and the interaction among factors. The second experiment used plant mixtures to verify estimates of cracking resistance obtained from the regression equations developed from the laboratory-prepared mixtures experiment.

The findings of this research have helped WisDOT make several improvements to its asphalt concrete design criteria. Results showed that 9.5 millimeter overlay mixtures with higher design volume of effective binder have greater resistance to cracking compared to 12.5 millimeter mixtures. This has led to a greater use of 9.5 millimeter overlays throughout Wisconsin.
The project also helped refine WisDOT specifications by reaffirming the use of: increased virgin binder by regressing air voids; increased design voids in mineral aggregate; polymer modified binder in surface mixtures; and proper low-temperature grades of virgin binder by eliminating -22. WisDOT expects these improved mixture specifications to add two or more years of life to an average pavement, a 10% or greater increase that will reduce pressure on WisDOT’s letting program and could save the agency more than $25 million annually, by conservative estimates.

This project has been presented through a National Road Research Alliance webinar and at the 2017 Mid-Continent Transportation Research Symposium as a joint presentation by the researcher and WisDOT. It also won the Walter J. Emmons Award for best paper presented at the 2017 Association of Asphalt Paving Technologists Annual Meeting.
Wisconsin Department of Transportation

Better Concrete Mixes for Rapid Repair

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| Submitter  | Wisconsin Department of Transportation  
Andrew Eiter  
4802 Sheboygan Avenue, Room 104  
Madison, Wisconsin 53707 |

Links

Project Summary and Benefits

Increasing demands on Wisconsin’s highway system impact the lifespan of roadways, resulting in more frequent lane closures for maintenance and repairs, in turn, creating more user delay. Rapid-repair strategies such as precast and cast-in-place (CIP) concrete patches aim to minimize the duration of traffic disruptions and lower costs.

The Wisconsin Department of Transportation (WisDOT) uses high early strength portland cement concrete in its rapid-repair CIP operations. The mix has a high cement content, accelerators, superplasticizers, air entraining admixtures, and other mixture constituents that give it high strength gain and a fast curing time but also makes it more susceptible to high shrinkage and inadequate air void systems. This repair strategy costs less up front than precast patches but may suffer a shorter service life if the CIP is not optimal. The goal of this research was to evaluate the performance of rapid-repair pavements used in Wisconsin and identify high-quality mixtures with longer service lives capable of withstanding the Midwest’s harsh freeze-thaw cycles.

The researchers performed strength, air-dry shrinkage, and freeze-thaw testing on 13 rapid-repair mixtures, according to AASHTO and ASTM standards. Results showed significant durability issues in only one project, suggesting that durability issues that occur in rapid-repair pavements are more likely due to difficulties associated with construction or mix procedures, rather than mix design. Even though this shows Wisconsin’s current CIP rapid-repair concretes perform adequately, the findings suggest that they can still be made more durable and workable than higher water-cement ratio concretes if dry calcium is added to the mix or upper slump limits are raised to six inches. Allowing contractors more flexibility regarding slump limits and the use of dry calcium chloride could increase the durability of rapid-repair concretes and cut facility maintenance and rehabilitation costs. Less-frequent and shorter lane closures could also reduce crash and fatality risks for
motorists and contractors during maintenance periods. WisDOT is currently reviewing its specifications to incorporate appropriate changes.
Viability of Vehicle Length in Estimating Vehicle Classification and Axle Factors

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| Submitter   | Wisconsin Department of Transportation  
              Andrew Eiter  
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              Madison, Wisconsin 53707 |

### Project Summary and Benefits

The timely delivery of high-quality traffic data is critical to effective decision making in planning, pavement engineering, freight, safety, and cost allocation and to a comprehensive performance measurement system. Vehicle classification is a key traffic parameter, and while most classification in traffic monitoring is based on the number of axles a vehicle has, a simpler, lower-cost method of classifying by length is emerging.

The primary objectives of this WisDOT-led pooled fund were to understand the accuracy of axle factors determined from vehicle length and to develop and evaluate methods for converting length data to axle-based classifications. Twelve other departments of transportation supported the project: Georgia, Iowa, Idaho, Illinois, Kansas, Minnesota, North Dakota, New York, Ohio, Pennsylvania, Texas and Utah.

Two sets of data analysis tests were conducted by the principal investigators at SRF Consulting Group. The first test compared the accuracy of eight proposed methods to estimate axle factors. From this data set, two were selected for a second round of analysis. A robust evaluation of accuracy considered factors such as season, facility type, and whether the site was urban or rural. The research team assembled a multistate dataset using Wisconsin and Long-Term Pavement Performance (LTPP) data for comprehensive performance tests of the methods. The performance of the two recommended methods (see Final Report, Methods 1 and 5) were found to be within the accepted limits of performance, within 2 percent error. Axle factor accuracy did not vary significantly with changes in road character, facility type, or number of lanes. Not only do length-classification sites report highly-accurate data, they are less expensive to install, rarely need repair, and have a comparatively-long sensor life. For a typical site covering four lanes, an axle-classification setup costs upward of $45,000 to install and $28,000 to maintain over a six-year period, while a length-classification setup only costs $18,000 to install and $300 to maintain over a six-year period, a cost reduction of approximately $55,000 per site. In addition to the 75% cost reduction of monitor sites, improved data collection will reduce costs for road design
and improve efficiency of the broader transportation network. This project has been selected for presentation at the National Travel Monitoring Exposition and Conference in June 2018.

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| Submitter  | Wyoming Department of Transportation  
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Project Summary and Benefits

This study is considered a first step towards validating the applicability of the Highway Safety Manual (HSM) Part D to Wyoming conditions. The HSM Part D provides a quantitative measure of safety for various countermeasures known as crash modification factors (CMF). These CMFs are provided for four distinct groups of treatments: roadway segments (e.g., rumble strips, passing lanes, etc.), intersections (e.g., flashing yellow arrows), special facilities (e.g., Highway-rail crossings, and interchanges), and road networks. CMFs provided in the HSM Part D are calibrated based on data collected from a few states in the US, which may not represent the same safety efficacy of countermeasures implemented in Wyoming.

The objectives of this study are (1) to validate the applicability of the HSM Part D to Wyoming conditions, (2) to calibrate CMFs for various countermeasures in Wyoming, and (3) to provide recommendations in terms of data requirements, how to mitigate data shortcoming, and applicability of alternative analytical methodologies to evaluate the safety effectiveness of specific countermeasures. Depending on data availability, various observational before-after and cross-sectional techniques were adopted in this study to calibrate CMFs for six countermeasures applied to roadway segments, intersections, and special facilities. The results indicated that the majority of these countermeasures are statistically significant in reducing crash frequencies and severity.
Mitigation Strategies to Reduce Truck Crash Rates on Wyoming Highways

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Project Summary and Benefits

Wyoming has one of the highest large truck crash rates in the country. This is due to a variety of reasons which include: the significant amount of through truck traffic on I-80, adverse weather conditions, and the challenging geometric conditions. The main objective of this study is to develop mitigation strategies to reduce these high truck crash rates and provide recommendations to the agencies that can help enhance truck-related safety. These agencies include: the Wyoming Highway Patrol (WHP), Wyoming Department of Transportation (WYDOT), and the trucking industry in Wyoming.

All interstates in Wyoming (I-80, I-25, and I-90 totaling 910 miles) and three state highways (US 26, US 30 and Wy 59 totaling 337 miles) were included in this study. A variety of datasets including: crash data, traffic volumes, traffic citations, roadway geometry, and enforcement data were investigated. Various statistical modeling techniques were successfully implemented to identify factors behind truck-related crashes. A crash and citation hot spot analysis was conducted to develop a strategy to shift enforcement resources. In addition, an enforcement analysis was conducted to estimate the effectiveness of highway patrol resources by comparing the highway patrol personnel, budget, and percent time patrolling from seven surrounded states of Wyoming.

Finally, this study provided recommendations to the three different agencies mentioned above. The recommendations to WHP focused on where and when to provide more enforcement and which type of enforcement is more effective in reducing truck-related crashes. The recommendations to WYDOT included safety countermeasures to help reduce truck-related crashes. The recommendations to the trucking industry concentrated on information that should be included in the safety training to educate truck drivers in reducing truck-related crashes.
Characterization of Crushed Base Materials in Wyoming

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| Submitter  | Wyoming Department of Transportation  
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**Project Summary and Benefits**

To improve the pavement design and construction in Wyoming, the Wyoming Department of Transportation (WYDOT) is adopting the Mechanistic-Empirical Pavement Design Guide (MEPDG). A full implementation of MEPDG requires the characterization of local crushed base materials. In this research, laboratory experiments on resilient modulus were performed to characterize the local crushed base materials in Wyoming. A comprehensive resilient modulus test program was completed by following the WYDOT modified AASHTO T 307, which incorporates WYDOT design and testing practices. The cyclic triaxial testing chamber for confining load application, two axial load sensors, and two spring-loaded linear variable transducers (LVDTs) to measure the recoverable axial strain of an aggregate specimen were used in determining the laboratory resilient modulus. Effects of moisture content, percent fine, stress, gradation, and fractured face on base resilient modulus were assessed, and estimation models were developed using statistical methods. The coefficients of constitutive models developed by NCHRP (2004) and Hicks and Monismith (1971) were calibrated for the locally available crushed base materials. Finally, a design table and chart for the estimation of base resilient modulus was developed to facilitate the full implementation of the MEPDG in Wyoming.
Evaluation of Wetland Mitigation in the Greater Yellowstone Ecosystem: Wildlife Population & Community Response

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| Submitter  | Wyoming Department of Transportation  
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Cheyenne, Wyoming 82009  
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Project Summary and Benefits

The 2006-2013 reconstruction of US Highway 26/287 over Togwotee Pass, Wyoming, impacted or caused the loss of natural wetlands. To comply with U.S. Army Corps of Engineers permit conditions, the Wyoming Department of Transportation (WYDOT) recently completed construction or restoration of 38 mitigation wetlands along the Highway 26/287 corridor and at the aggregate pit site at the U.S. Forest Service Blackrock Ranger Station. This study provides WYDOT information on differences among wetlands created to mitigate for wetland loss (n=10), wetlands impacted but not destroyed (n=7), and natural wetlands (n=16) relative to various aspects of wildlife that use these habitats.

We compared characteristics of amphibians, a pathogenic fungus, invertebrates, and birds. Created wetlands in this study area were significantly shallower than natural and impacted wetlands and had shorter hydroperiods; but impacted wetlands were similar in physical habitat characteristics to natural wetlands. Boreal toads (Anaxyrus boreas) rapidly colonized newly created wetlands and annual survival and recruitment rates were similar in created and natural wetlands. Boreal chorus frogs (Pseudacris maculata) were less than half as likely to occupy created wetlands as natural and impacted wetlands but population sizes were high in at least one created wetland. Barred tiger salamanders (Ambystoma mavortium) occurred in natural and impacted wetlands at similar levels. While Columbia spotted frogs (Rana luteiventris) are common in natural and impacted wetlands, we observed reproduction by Columbia spotted frogs at only one created wetland. There was no difference in the prevalence of the pathogenic fungus between created and natural wetlands. Species richness of invertebrates was lower in created wetlands than in natural and impacted wetlands, and the community composition of invertebrates differed among wetland types.
Communities in created wetlands were more likely to be dominated by flying species than compared to communities in natural wetlands that had more passive dispersers such as snails and clams. We recorded bird calls in two created and two natural wetlands; species richness was similar in both wetland types but some riparian specialists (e.g., willow flycatcher, Wilson’s warbler) were not detected at either created wetland. Our results suggest that wetland creation can be an important tool for conserving wetland-dependent wildlife. Understanding how animals use created wetlands sites is a critical component to understanding the efficacy of mitigation efforts and determining alternative (e.g., earlier) “endpoints.”

This report highlights characteristics in created sites that are advantageous to species that are perhaps “non-focal” but important members of the natural community. The data presented in this study provide support for earlier endpoints for determining success in created wetlands and a baseline for continued monitoring of these or other created sites.
Evaluation of the WYDOT Research Center (Phase III)

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</table>
| Submitter   | Wyoming Department of Transportation  
             Enid White  
             5300 Bishop Boulevard  
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             307-777-4182 |

Links

Project Summary and Benefits

An effective research center within a transportation organization can be a valuable asset to accomplish the goals of the overall mission. It is important to measure the benefits of a transportation research center on a regular basis to determine if research budgets have been used effectively, and to maintain the support of management. The purpose of this study was to evaluate the effectiveness of the Wyoming Department of Transportation (WYDOT) Research Center.

This study performed a detail analysis on the proposals submitted to Wyoming Department of Transportation (WYDOT) from 2011 to 2017 to evaluate the effectiveness of the WYDOT Research Center. The analysis included the investigation of performance measures, and compared that to the Phase II Study completed in 2012. These performance measures are quantifiable, meaning they are designed to place a score or value on the accomplishments of the WYDOT Research Center which can then be used to make managerial decisions for the Research Center. As a part of the study, feedback and performance evaluation surveys were conducted from the Principal Investigators and the WYDOT Project Champions. In addition, a methodology for benefit-to-cost analysis was developed to be included as a future performance measure. This report summarized the analysis, and provided the conclusions and recommendations. Specific recommendations and conclusions for the WYDOT Research Center are presented in the final chapter of this report.