RESEARCH
Makes the Difference 2020

Award-Winning Innovations from State DOTs

ADVANCED INFRASTRUCTURE TECHNOLOGIES

CHEMICAL STABILIZATION GUIDELINES HELP STRENGTHEN MONTANA'S DIVERSE SOILS

Montana has a wide variety of subgrade soils, including problematic soils that lack strength and jeopardize pavement resilience. Previous Montana Department of Transportation (MDT) practices leaned toward geosynthetic reinforcement for stabilization, but MDT sought to understand whether chemical methods were a feasible alternative. Consequently, MDT initiated a project to test lime and cement additives on six different soils representing Montana's diverse geological conditions. After stabilizing the soils, the research team studied their physical, chemical, and mineralogical changes to assess whether they met strength requirements. Those that did were then tested for durability against freezing/thawing and wetting/drying cycles. The research team used the results to develop step-by-step guidelines, including selection criteria, strength requirements, and dosage amounts for lime and cement additives. MDT expects chemical subgrade stabilization to increase shear strength, minimize permanent deformation and fatigue cracking, and limit expansion and contraction on Montana's pavements. A life cycle cost analysis also found that *chemically treating problematic soils results in life cycle cost savings of 9.0 to 15.9 percent*. Project page.

CARBON FIBER REINFORCED POLYMER PROVIDES LONG-TERM DURABILITY FOR MICHIGAN BRIDGES

The Michigan Department of Transportation (MDOT) built the nation's first carbon fiber bridge in 2001 and has since constructed several bridges using carbon fiber reinforced polymer (CFRP), which—unlike steel—is corrosion-resistant. Although CFRP performed well in the field, its long-term durability wasn't fully understood, meaning engineers lacked the technical specifications they needed to optimize the CFRP design process. Therefore, MDOT partnered with Lawrence Technological University to test the short- and long-term performance of CFRP strands and beams under various conditions, including 300 freeze-thaw cycles, fire/loading events, and severe weather. The researchers then produced design criteria, guidelines, and detailed examples to make MDOT's CFRP design and construction process more efficient. The results of this project have already been put to good use, as engineers used them to design a new I-75 bridge in Metro Detroit in 2017. Moreover, thanks to CFRP, MDOT's goal of building a bridge with a minimum 100-year service life is even closer to becoming a reality. Final report.

The "Sweet Sixteen" state research projects

highlighted on these pages were selected by the Research Advisory Committee of the American Association of State Highway and Transportation Officials (AASHTO). They comprise four high-value research projects from each of the four AASHTO regions, funded primarily through the State Planning and Research (SPR) Program.

As the nation's cornerstone state research program, SPR provides Federal Highway Administration (FHWA) funding to the states to address top concerns and identify solutions at the state level. States further address areas of common concern through the Transportation Pooled Fund Program.

Complementing this publication are two companion pieces for 2020 focusing on research innovations in the areas of safety and maintenance, management, and preservation. All of these publications may be found at **research.transportation.org**.

AMERICAN ASSOCIATION of STATE HIGHWAY and TRANSPORTATION OFFICIALS

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Find more high-value state DOT research projects at AASHTO's research website, research.transportation.org.

ADVANCED INFRASTRUCTURE TECHNOLOGIES

IOWA'S UNMANNED HYDROGRAPHIC SURVEY SYSTEM INCREASES SAFETY AND SAVES TIME

Over the years, the Iowa Department of Transportation (DOT) has surveyed many water bodies to support transportation improvement projects. Traditional hydrographic survey methods require staff to wade into the water or use a boat to collect data. In addition to being slow, this process often captures incomplete underwater surface data and presents safety risks to surveyors. This project aimed to determine whether an advanced, remote-controlled survey system could more safely and efficiently collect hydrographic data and evaluate bridge scour. Iowa DOT had a two-person crew test the system at four sites and found that it can collect 3D underwater surface data at a greater density and with more accuracy than traditional methods. Moreover, the remote-controlled system **reduced the hydrographic survey time from roughly 15 hours to 2 to 3 hours** and eliminated safety concerns for Iowa DOT staff, who no longer have to enter the water. Iowa DOT will use the system to conduct 40 to 50 underwater surface surveys a year. Final report.

NOVEL DIFFUSER TECHNOLOGY IMPROVES STREAM FLOW OF MAINE CULVERTS

As infrastructure ages and weather patterns change, existing highway culverts struggle to handle higher flows from more intense rainfall and land use development. Replacement is expensive, but less costly rehabilitation methods like slip-lining can reduce a culvert's capacity by increasing outlet velocities and losses. So, the Maine Department of Transportation (Maine DOT) investigated a novel solution: culvert outlet diffusers. Mounted on the outlet of an existing culvert, diffusers reduce outlet losses and increase the culvert's efficiency, allowing it to operate at a lower inlet water level even when full. Maine DOT built, installed, and tested a fiberglass diffuser in Thorndike, Maine, and found that the technology can **increase hydraulic capacity by up to 40 percent**. Moreover, diffusers are cost-effective, simple to install, and can be used in conjunction with slip-lining to increase flow rates. Maine DOT holds a patent for the diffuser system and hopes to continue its deployment on highway culverts. Final report.

SAFER ROADS

PEDESTRIAN HYBRID BEACONS INCREASE SAFETY ON ARIZONA HIGHWAYS

Arizona has successfully reduced pedestrian crashes at crosswalks using pedestrian hybrid beacons (PHBs), which are traffic control devices that increase driver yielding behavior. However, Arizona Department of Transportation (ADOT) guidelines did not recommend installing PHBs on higher-speed roads, where their effectiveness was not documented. To better understand their safety and operational impacts—particularly in comparison to signalized/unsignalized intersections and lower-speed PHB sites—ADOT analyzed crash data for 186 PHB sites and studied video data at 10 PHBs on higher-speed roads. With 40 hours of video data showing 1,214 pedestrian or bicyclist crossings, researchers found that **driver yielding behavior at the high-speed PHB sites averaged 97 percent**, a value similar to prior findings for lower-speed roads. Moreover, the **PHBs reduced severe total crashes by 25 percent, pedestrian-involved crashes by 46 percent, and severe rear-end crashes by 29 percent**. Based on these findings, the study team suggested that ADOT revise its PHB guidelines and develop uniform design specifications to encourage their wider use. Final report.

CALIFORNIA REDUCES WRONG-WAY DRIVING COLLISIONS

Though rare, wrong-way driving (WWD) collisions are often fatal, as the Sacramento and San Diego areas experienced firsthand in 2015. To mitigate WWD risks, the California Department of Transportation (Caltrans) installed enhancements on several exit ramps in these areas, including active radar-based monitoring systems, flashing beacons, and two-way white/red and yellow/red reflective markers. These enhancements warn drivers and notify authorities when vehicles enter from the wrong direction. Caltrans evaluated their effectiveness by installing zone-triggered video image processing systems that automatically detected and recorded a short video clip of each WWD event. Researchers reviewed the clips to quantify the WWD problem, the effectiveness of the enhancements, and the accuracy of the active monitoring and warning systems. For the Sacramento exit ramps, **the WWD collision rate dropped 53 percent, and 85 percent of drivers recognized their WWD error** and turned around before entering the freeway. Caltrans will use these results to make informed, data-driven decisions regarding future WWD detection and mitigation strategies. Final report.

PENNSYLVANIA METHOD ASSESSES THE SAFETY OF COLLECTOR ROADS

Transportation professionals across the country rely on the safety performance function (SPF) equations in AASHTO's *Highway Safety Manual* to predict crash frequencies based on anticipated traffic volumes, geometric characteristics, and other roadway and roadside features. For the Pennsylvania Department of Transportation (PennDOT), however, the manual's SPFs lacked the level of localization necessary to accurately evaluate the safety of its 3,400 miles of urban–suburban collector roadways, which experienced about 6,500 crashes from 2013 to 2017. Using electronic crash data from PennDOT, panoramic images, and satellite imagery, researchers developed statewide, district-level, and county-level SPFs that are consistent with the *Highway Safety Manual* but also account for Pennsylvania-specific driving conditions and regional differences. PennDOT added the new SPFs to its network screening and will use them to analyze 2019 crash data. The department also updated the *Pennsylvania Safety Predictive Analysis Methods Manual* to make the SPFs easily available. Pennsylvania is now the only state that has SPFs for urban–suburban collector roads. Final report.

SMART CONSTRUCTION AND OPERATIONS

DIGITAL INSPECTION PROGRAM ENHANCES INDIANA'S INFRASTRUCTURE

Faced with the retirement of experienced inspectors, increasingly complex infrastructure construction, and emerging technologies, the Indiana Department of Transportation (INDOT) decided to develop a construction inspection program to ensure the near- and long-term performance of its critical construction elements. Specifically, INDOT wanted to allocate resources to the riskiest areas and provide the tools inspectors need to perform their jobs effectively and efficiently. To develop the program, researchers compiled a list of INDOT's core inspection activities and used expert surveys and advanced data analytics to assess their risks based on the probability of failure and the resulting consequences on cost, time, quality, and safety. They then prioritized the activities based on a composite index risk score. This information was fed into a digital, risk-based inspection program that provides real-time information about inspection priorities and requirements, inspection forms, and access to training materials. In a pilot study, the program *reduced inspection time up to 50 percent*, and it is expected to provide near- and long-term cost savings by resulting in higher-quality infrastructure. Final report.

TRANSPORTATION SYSTEMS MANAGEMENT AND OPERATIONS OPTIMIZE SAFETY AND MOBILITY IN FLORIDA

The Florida Department of Transportation (FDOT) has adopted six transportation systems management and operations (TSM&O) strategies to alleviate congestion and reduce crashes: ramp metering systems, dynamic message signs, road rangers, express lanes, transit signal priority, and adaptive signal control technology. Yet FDOT staff lacked the tools they needed to quantify their potential mobility and safety benefits. To fill this gap, researchers developed mobility enhancement factors and crash modification factors and incorporated these factors into a decision support tool that enables FDOT staff to quantify each strategy's benefits. For the first time, project planners can easily select the best strategy to optimize safety and mobility and accurately calculate the operational and safety benefits for TSM&O deployments. The tool could save FDOT $3,000 per project and *reduce total fatalities by 5 percent, crashes by 15 percent, and travel time by 20 to 50 percent*. Final report.

SAFER ROADS

VIRGINIA DEVELOPS SUCCESSFUL INCENTIVE PROGRAM TO REDUCE CRASH CLEARANCE TIMES

A towing and recovery incentive program (TRIP) is a traffic incident management tool for clearing severe, long-duration, heavy-vehicle incidents through improved towing standards, procedures, and training. In 2017, the Virginia Department of Transportation's (VDOT's) Richmond District piloted a TRIP on its interstate highways with a goal of filling significant gaps in the literature about how to evaluate such programs. The study focused on how to select appropriate incidents in the "before" period, quantify confidence in the results, and capture the regional benefits of overall traffic incident management culture. To create the TRIP evaluation methodology, VDOT developed and applied evaluation metrics to analyze the performance of the Richmond pilot based on incident data. VDOT also performed a qualitative assessment to gauge success. The research showed that over a 10-year operational period, *TRIP benefits will outweigh costs by a factor of between 9.2 and 12*. As a result, VDOT will continue conducting TRIP operations in the Richmond District and is exploring opportunities to expand them along I-81 in the Bristol, Salem, and Staunton Districts. Final report.

LOUISIANA INCREASES FIELD INSPECTION PRODUCTIVITY WITH NEW E-CONSTRUCTION TOOL

Project inspectors at the Louisiana Department of Transportation and Development (DOTD) must collect vast amounts of field data and information, and they've traditionally done so using a resource-intensive, paper-based process. But the release of a cloud-based, e-construction inspection technology called HeadLight presented an opportunity for DOTD to eliminate this inefficiency altogether. Over 18 months, 182 field inspectors and staff from four DOTD districts field-tested HeadLight on more than 50 pilot projects statewide. Researchers then used metrics—such as time savings and data volume, variety, timeliness, and availability—to compare how HeadLight performed versus the traditional inspection process. Ultimately, inspectors who used HeadLight experienced a *28 percent increase in productivity exceeding 117,000 hours per year*. HeadLight also increased the number of inspector observations (including photos and other media), improved the timeliness of daily work report submissions, provided a central and easily searchable data repository, and improved communication among project teams. Final report.

STAINLESS STEEL PROTECTS VIRGINIA'S BRIDGES FROM CORROSION

The original Route 340 Bridge in Waynesboro, Virginia, was constructed in 1934. By 2012, the bridge had significantly corroded and needed to be replaced. However, the commonly used material of uncoated weathering steel wasn't feasible for the new bridge because of its location near a plant that produces corrosive chemicals and its vulnerability to 10-year storm events. Instead, VDOT chose to build the Route 340 Bridge superstructure with a corrosion-resistant, cost-effective stainless steel known as ASTM A1010. In addition to using A1010 steel cross-frames and stainless-steel fastener assemblies on bolted splices, VDOT identified a new welding consumable to use with A1010. VDOT expects that the new Route 340 Bridge will have a *100-year service life*, require low maintenance, and result in significant long-term cost savings. These promising results led the department to develop guidance on using A1010 steel for future bridge designs and repairs, and VDOT is currently exploring ways to reduce its initial costs. Final report.
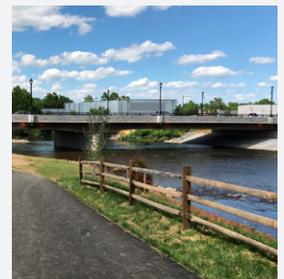
STRATEGIC PLANNING AND MAINTENANCE

FULL-DEPTH RECLAMATION TECHNOLOGIES SAVE ROADWAYS AND COSTS IN TEXAS

Rural roadways across Texas experience heavy-haul traffic that causes the subbase and base materials to fail. In response, the Texas Department of Transportation (TxDOT) conducted a project to renew approximately 38 lane miles of pavement in 10 different TxDOT districts using full-depth reclamation (FDR) technologies. TxDOT determined that using foamed asphalt or asphalt emulsion FDR is a cost-effective rehabilitation method. TxDOT also treated one-half to three-quarters of a lane mile per day, and the results showed that asphalt-based FDR provided a high-stiffness, moisture-resistant base that is less prone to shrinkage cracking and to fatigue damage under heavy loads. Furthermore, FDR *reduced project duration by up to 70 percent* and produced average *savings of approximately $220,000 per lane mile* compared to traditional pavement methods. Based on this project's success, 20 TxDOT districts will rehabilitate an average of 30 lane miles of roadway per year using FDR as part of a 10-year plan. TxDOT expects FDR to *save at least $132 million in the first year and $1.32 billion over 10 years*. Project site.

MINNESOTA PROVIDES PRACTITIONER-READY GUIDANCE TO ADDRESS SEVERELY DISTRESSED PAVED ROADS

Aging, low-volume paved roads from the 1970s and 1980s have deteriorated significantly across Minnesota, and many local transportation agencies lack the resurfacing and labor budgets necessary to repair them. In 2015, the Transportation Research Board's National Cooperative Highway Research Program (NCHRP) Synthesis 485 documented different practices and conditions of converting paved roads to unpaved. The Minnesota Department of Transportation (MnDOT) worked with researchers, who were members of the original NCHRP 485 study cohort, to develop a comprehensive guide on how to convert severely distressed paved roads into unpaved gravel surfaces—which are easy to maintain and far more economical than pavement resurfacing. This study defines a low-volume road as having an average daily vehicle count of fewer than 150 per day. In addition to providing methods for determining if a road is a good candidate for conversion, the guide provides design, construction, and maintenance specifications for unpaving, as well as life cycle cost analysis tools, public communications tools, and safety information. Graphics, flowcharts, photographs, and additional references make the guide especially user-friendly. MnDOT also developed a complementary video presentation to serve as a webinar and training tool. This practitioner-ready guide is the first of its kind available for local agencies. Project page.

DEMAND-BASED PRICING REDUCES CONGESTION IN WASHINGTON, D.C.

With limited curbside parking in Washington, D.C., streets become congested with drivers simply searching—and circling—for spaces. The increasing population and endless number of visitors creates even more demand for parking. In response, the District Department of Transportation (DDOT) launched the parkDC: Penn Quarter/Chinatown Parking Pricing Pilot. DDOT's goal was to create a demand-based parking system that integrates cost-effective, asset-lite parking management solutions to increase parking availability, ease congestion, and reduce pollution. During the pilot, DDOT changed prices depending on whether a space was in a high- or low-demand location and adjusted time limits based on the time of day. The project also used two mobile apps, parkDC and VoicePark, to provide real-time information about parking availability and pricing, and it tested new signage to reduce clutter and more clearly communicate on-street parking regulations. Ultimately, *circling time decreased 7 to 15 percent* and weekday *congestion decreased 5 percent* in Penn Quarter/Chinatown. Thanks to these successes, DDOT is working to expand demand-based pricing to other neighborhoods. Project site.

MASSACHUSETTS IMPROVES PEDESTRIAN INFRASTRUCTURE INVENTORY WITH MOBILE LIDAR

To ensure pedestrians and wheelchair users have access to reliable, safe sidewalks and curb ramps, the Massachusetts Department of Transportation (MassDOT) regularly upgrades its inventory of pedestrian infrastructure. But a previous effort to survey and catalog 26,000 curb ramps took almost 2 years, so MassDOT had to find a more efficient solution. The answer lies in mobile LiDAR-based computer visioning technology. This project developed a methodology consisting of three key algorithms to 1) automatically segment a LiDAR point cloud, 2) extract sidewalks and curb ramps, and 3) assess their conditions. MassDOT successfully tested the methodology along the 271-mile State Route 9 Corridor by extracting 85 miles of sidewalk and 1,297 curb ramps in less than 40 hours. The data were also seamlessly integrated with MassDOT's existing road inventory file. MassDOT will use this information to make timely decisions about maintenance and upgrades and *could save up to $7.8 million in operational costs* if it applies the proven methodology to the entire state road network. The department is now investigating similar methods for other critical assets, including pavement markings, signage, and guardrails. Final report.

Photos courtesy of: MDT, MDOT, Iowa DOT, Maine DOT, ADOT, Caltrans, FDOT, VDOT, TxDOT, MnDOT, DDOT