Construction and Materials – Research

FY2025 Annual Report

Contents

Introduction

Greetings!

MoDOT's Research Section is fueled by the newest innovations in processes, products, or materials. We believe such changes lead to a safer and more efficient workforce, as well as economical choices within MoDOT.

During State Fiscal Year 2025, 14 contracted research projects were completed. Topics ranged from pedestrian safety, bridges, pavement materials, geotechnical issues, erosion control, maintenance, and multimodal transportation. A brief summary of each project is provided, along with a link to the full report, executive summary, and any appendices.

Should you want to know more about a particular topic, please contact the Research section at MoDOTResearch@modot.mo.gov.

Sincerely,

Jen Harper
Research Director

TR202206 – Friction Enhancements to Asphalt Pavement Surfaces

Research Project Manager: Brent Schulte
Principal Investigators: Missouri Center for Transportation Innovation and Missouri University of Science and Technology - Alireza Roshan and Magdy Abdelrahman

Full Report Executive Summary

Maintaining the appropriate amount of pavement friction is critical for safe driving. Missouri Department of Transportation (MoDOT) has used high friction surface treatment (HFST) since 2013 to restore pavement surface friction where traffic has worn down pavement surface aggregates and to improve wet crash locations. Conventional HFST application consists of a polymer resin layer and polish resistant aggregates. Highway agencies examine existing pavement surface conditions before determining whether HFST can be used, as it is not intended as a repair for surface distress conditions, such as rutting. The relatively high cost of constructing and removing HFST with polymer resins along with the durability concerns due to existing pavement conditions, has led state agencies to consider HFST with asphalt-based binders as an alternative. This research evaluated alternative asphalt binders for use in surface friction treatments. The research program evaluated the friction performance of HFST applications made with asphalt-based binders including newly developed modified asphalt binders. An updated Life-Cycle-Cost (LCC) Excel program was developed to conduct cost analysis based on the performance of the tested binder-aggregate combinations. The study showed acceptable asphalt-based binders for HFST applications and recommended continuing the development of asphalt-based binders to enhance the performance of HFST applications.

TR202212 – Mitigating and Preventing MoDOT Safety-Related Incidents through Root-Cause Elimination and Utilization of Leading Safety Indicators

Research Project Manager: Scott Breeding
Principal Investigators: Missouri Center for Transportation Innovation and Missouri University of Science and Technology - Bahaa Chammout and Islam El-adaway

Full Report Executive Summary

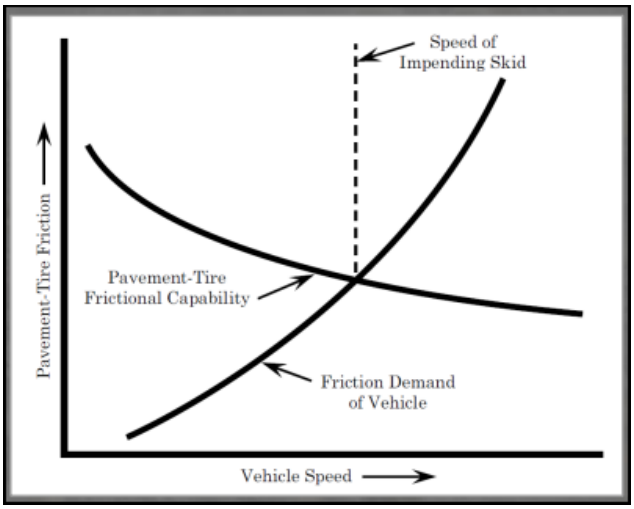
This report investigated and analyzed the factors influencing incident occurrence in work zone environments, aiming to identify areas where proactive planning can enhance incident mitigation. Drawing from an extensive review of existing literature on work zone safety, 37 factors affecting public and occupational safety were identified. Two surveys were conducted among MoDOT employees and contractors to assess the relative importance of these factors on worker safety within work zones. Survey results highlight driver-related factors, such as the driver's level of attention and unsafe driving, as the most critical to worker safety in work zones. MoDOT employees and contractors evaluated MoDOT's performance on the factors studied. While MoDOT's performance received substantial ratings overall, contractors consistently rated it lower, indicating a difference in perspectives between stakeholder groups. Both groups identified the presence of law enforcement as a critical area suggesting further improvement in Missouri work zones. MoDOT employees rated field compliance with safety policies and the overall safety culture in their workplaces. Variations in policy compliance were observed, with certain policies, such as those related to backing movements, requiring attention to improve adherence—a crucial aspect for occupational safety in work zone environments. While MoDOT employees demonstrated strong knowledge of department policies and safety procedures, they expressed lower satisfaction with the timely investigation of safety incidents and the effectiveness of subsequent improvements. This comprehensive analysis provided a benchmark for MoDOT and other stakeholders to address identified deficiencies and enhance work zone safety practices effectively.

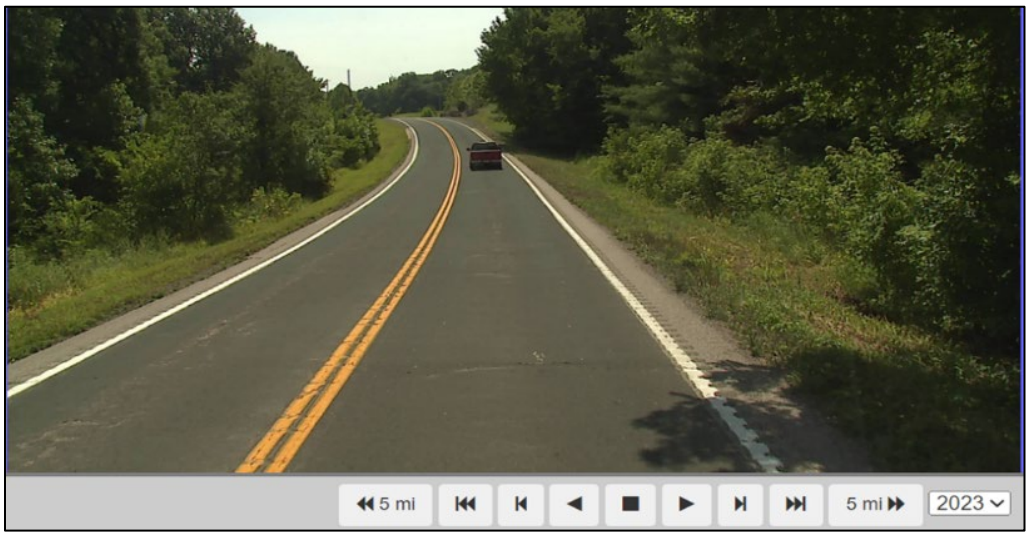
TR202219 – High Friction Surface Treatment Review

Research Project Manager: Scott Breeding
Principal Investigator: Applied Research Associates - Zafrul Khan, Jay F. Bledsoe, Ahmad Alhasan, and Hyung S. Lee

Full Report Executive Summary

MoDOT has implemented HFST in various locations across the state to reduce roadway departure crashes by improving pavement friction. To prevent premature failure and to ensure that the HFST performs adequately throughout the design life, this study evaluated the pavement distress and condition before and after the application of HFST. Along with pavement distress and condition data, this study also evaluated the crash data of the HFST sections. Although analysis of data showed higher distress in some sections, it was the reflection of underlying distress, not the 'failure' of HFST, as observed from the Automatic Road Analyzer (ARAN) images. Statistical analysis of the safety data revealed that HFST is around 66% effective in reducing crashes in wet conditions. Based on the evaluation of pavement condition and safety analysis, this study provided guidance on the selection of future locations for HFST applications.

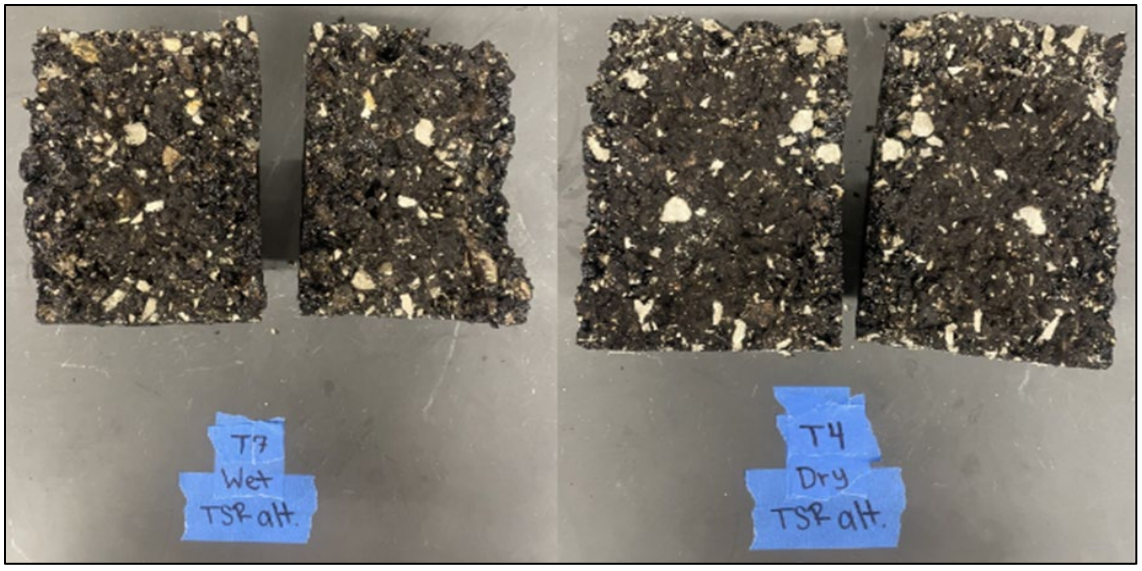




TR202306 – Evaluation of Stripping Tests for Asphalt Mixtures to Replace AASHTO T283 Method in Missouri

Research Project Manager: Scott Breeding
Principal Investigator: University of Missouri, Columbia - Bill Buttlar, Punyaslok Rath, Jim Meister, and Katie Distelrath

Full Report Executive Summary



Many paving agencies in the U.S. including MoDOT use the AASHTO T283 method (Tensile Strength Ratio (TSR) test) to determine the moisture damage susceptibility of asphalt mixtures. However, the TSR test has shown to have a poor correlation with field results based on a review of literature and MoDOT observations. In addition, the TSR test is time consuming and may be redundant in light of current requirements to conduct the Hamburg Wheel Tracking Test (HWTT) as part of balanced mix design. For this research, five asphalt mixtures were investigated. The mixtures were subjected to the TSR test and HWTT. The Stripping Inflection Point (SIP) parameter was computed from HWTT using the Iowa method. The SIP parameter was found to be superior to the TSR test in correlating to field performance. Comparison of the Rutting Test-Index results with the SIP parameter suggested that the RT index is likely a weak indicator of moisture damage in asphalt mixtures. Based on the results obtained in this limited study, a framework was proposed to replace the TSR method.

TR202311 – Asset Characterization Using Automated Methods

Research Project Manager: Brent Schulte
Principal Investigator: Missouri Center for Transportation Innovation and the University of Missouri, Kansas City - Sungyop Kim, Donald Baker, Jejung Lee, Aaron Sprague, and Charles Mwaipopo

Final Report Executive Summary

Increasing and intensifying flood events pose serious challenges to highway agencies in maintaining water crossing assets and assessing potential flood hazards. This project aimed to develop an automated flood risk assessment program for small water crossing assets, focusing on culverts with less than a 20-foot span not listed in the 2023 National Bridge Inventory (NBI). Information on such small assets is often limited and not readily available. Using a Geographic Information System (GIS), the project identified potential non-NBI water crossing sites and conducted field surveys to collect the asset information on Missouri's highways. Based on the field survey data, the project developed a GIS-based flood risk assessment tool for small water crossing assets using publicly available high-resolution Light Detection and Ranging (LiDAR) data. The tool was built with Python scripts that process four sequential steps on the Quantum Geographic Information System (QGIS), the most popular nonproprietary open-source GIS software program. The project conducted a pilot study of culverts in Cass County, Missouri. The plugin hydraulic results were compared to HEC-RAS 2D modeling results. The hydraulic results indicated that the tool has the potential to identify small water crossing assets and predict flood overtopping effectively.

TR202316 – Truck Mounted Attenuators Truck Safety

Research Project Manager: Scott Breeding
Principal Investigator: University of Missouri, Columbia - Praveen Edara, Zhu Qing, Carlos Sun, Henry Brown, Trent Guess, and Johnathan Stokes

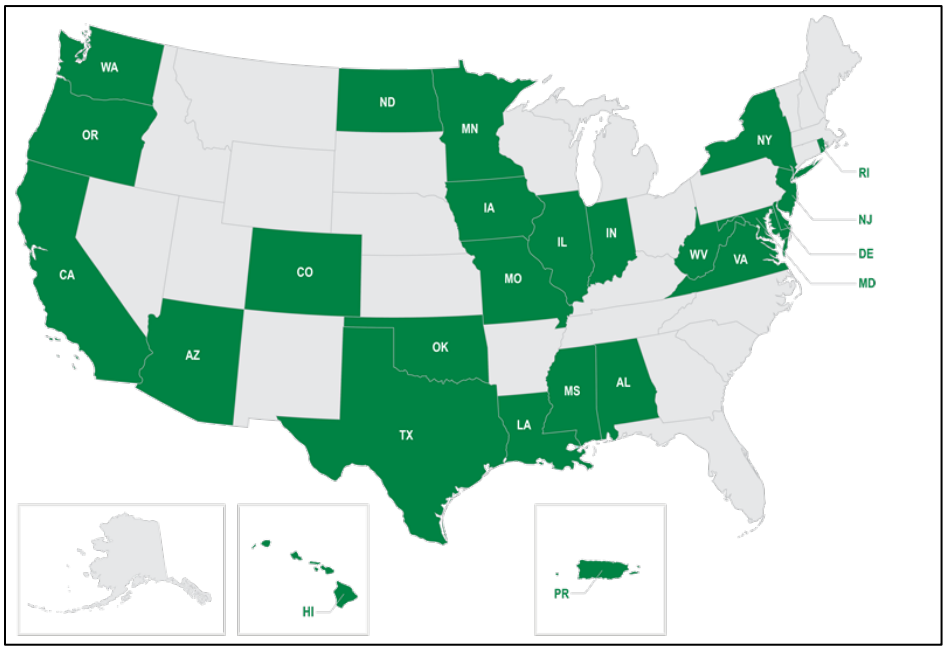
Final Report Executive Summary

This study evaluated the effectiveness of in-vehicle safety countermeasures in reducing injury risk for Truck Mounted Attenuator (TMA) truck occupants during collisions. With increasing incidents involving TMAs in work zones, understanding the protective impact of advanced safety features has become crucial. A review of historical TMA crash reports revealed that rear-end collisions are the primary issue, with whiplash injuries being the most common type of injury among drivers. Current in-vehicle safety countermeasures were examined, including active headrests, reactive seatbacks, and anti-whiplash systems, which were tested across six simulated collision scenarios incorporating varying vehicle weights, speeds, and impact angles. Using a biomechanical simulation model and telematic data, results indicated that active headrests, particularly with 40 mm travel level, consistently reduced injury criteria values, effectively lowering head and neck injury risks in both straight and angled collisions. In contrast, the reactive seatback and anti-whiplash systems demonstrated mixed efficacy, performing well in low-impact conditions but poorly in high-impact scenarios. Limited high-impact telematic data, particularly with 80,000-pound vehicles, highlight the need for further validation for high-impact collision scenarios. Findings suggested that integrating advanced head restraint systems could significantly enhance TMA truck driver safety.

TR202324 – A Roadmap for Missouri: Assessing Needs an Implementation Framework for Incorporating Environmental Product Declarations

Research Project Manager: Jenni Hosey
Principal Investigators: Missouri Center for Transportation Innovation and the University of Missouri, Kansas City - John Kevern, Bill Buttlar, and Punyaslok Rath

Final Report Executive Summary



This report details MoDOT's activities within FHWA's Climate Challenge program. The purpose of the program was three-fold, 1) to increase knowledge of environmental product declarations (EPDs) within the Missouri asphalt and concrete industry, 2) to assess the current state of Missouri EPDs and compare with appropriate regional and national benchmarks, and 3) to provide recommendations for lowering the global warming potential (GWP) of asphalt and concrete mixtures. The ultimate goal of this process is to assess the state-of-the practice in Missouri, to support future informed decision-making. Per phase GWP benchmarks for Missouri's asphalt EPDs were determined by the National Asphalt Pavement Association's benchmarking system for asphalt mixtures; however, limited data from Missouri asphalt plants was available. The asphalt mixtures were also assessed to identify carbon-intensive mixture types and processes. Based on the findings, recommendations were made to lower the GWP of the asphalt mixtures to conform to the benchmarks. Very few concrete EPDs currently exist in Missouri and none have been specifically created for MoDOT concrete mixtures. The existing EPDs are consistent with regional benchmarks. With relatively small allowable increases to the Supplementary Cementitious Materials (SCM) content within the specifications or adoption of pavement Performance Engineered Mixtures (PEM), all concrete mixtures could achieve the US General Services Administration's GWP benchmarks.

TR202403 – Shear Wave Velocity Measurements

Research Project Manager: Jenni Hosey
Principal Investigator: SCI Engineering, Inc. - Evgeniy Torgashov, Neil Anderson, and Thomas J. Casey

Final Report Executive Summary

MoDOT commissioned SCI Engineering, Inc. to investigate cost-effective, nonintrusive geophysical methods for determining time-averaged shear wave velocity profiles to a depth of 100 feet, based on anticipated updates to AASHTO seismic site classification specifications. Following a comprehensive literature review, eight candidate methods were identified. Of these, four methods were selected for field testing based on their practicality and effectiveness. Field evaluations were conducted at three sites: the SCI Office in O'Fallon, Illinois; the I-270 Chain of Rocks Bridge; and the Martin Luther King, Jr. Connector in Illinois. The sites were selected based on access, availability of existing ground truth subsurface soil information, and a variety of subsurface profiles. Various geophone spacings and array configurations were tested. Performance metrics included depth of investigation, ease of deployment, data quality, and interpretability. Results demonstrated that combining Active and Passive analysis methods offered the most reliable and practical solution, providing consistent results, minimal operational complexity, and shared equipment and software requirements. SCI Engineering developed a comprehensive user manual and conducted field demonstrations to train MoDOT personnel in the acquisition, processing, and interpretation of data. Adoption of these methods will streamline MoDOT's seismic site classification processes, align practices with forthcoming AASHTO requirements, and enhance MoDOT's internal technical capacity.

TR202410 – Effective Methods to Safely Communicate with Commercial Motor Vehicles

Research Project Manager: Jenni Hosey
Principal Investigator: University of Missouri, Columbia and George L. Crawford and Associates - Praveen Edara, Yaw Adu-Gyamfi, Henry Brown, Mark Amo-Boateng, Shawn Leight, and Joanne Stackpole

Final Report Executive Summary

One critical aspect to improving the safety of commercial motor vehicles (CMVs) involves how to communicate with CMV drivers safely and effectively through an electronic notification system (ENS). The objectives of this project were: 1) conduct a review of existing ENS methods in use by CMV drivers, trucking companies, and the freight industry; 2) conduct a survey of selected state departments of transportation (DOTs) regarding their current practice in ENS for communicating with CMV drivers; 3) conduct a needs assessment brainstorming workshop with MoDOT and stakeholders; and, 4) develop standards and specifications for data feeds consisting of traveler information critical for CMV operators. Results from the literature review indicate that several communication technologies have a wide range of applications for communication with CMV drivers. In their survey responses, all 18 responding DOTs indicated that they have not developed any data standards or policies for communicating information electronically to CMV drivers. Based on the discussion at the stakeholder workshop, the research team developed a matrix of the types of information and technology used to convey information to CMV drivers. To address the challenges of diverse data streams for CMV drivers, a unified application programming interface (API) was developed to consolidate all relevant data into a single, cohesive platform, providing CMVs with seamless access to critical information. The API, which was demonstrated through a web interface, ensures that CMVs and their operators can make well-informed, safe, and timely routing decisions. The API's modular and scalable design offers flexibility to add additional features in the future.

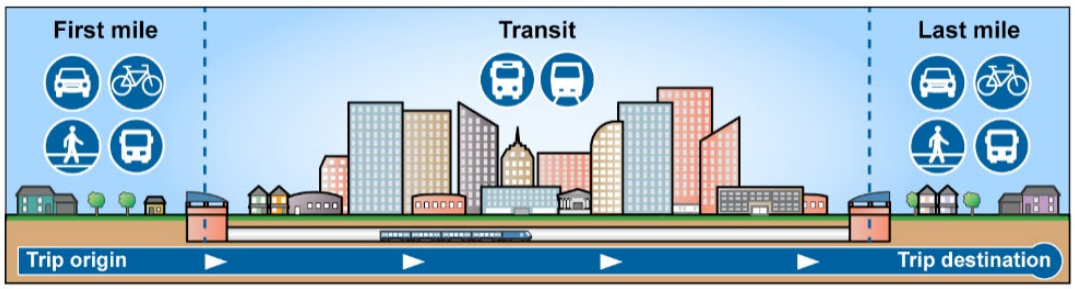
TR202412 – First and Last Mile Connectivity for Missourians

Research Project Manager: Jenni Hosey
Principal Investigator: Shared Use Mobility Center - Alvaro Villagran, Peter Hauer, Hani Shamat, Luba Guzei, and Nicky Althoff

Final Report Executive Summary

By closing gaps in transit systems or by complementing transportation services, first-last mile transportation services are integral in enabling access to employment opportunities as well as other key destinations. This study examined first-last mile service programs across the United States and assessed existing conditions in Missouri to learn about the challenges and opportunities in providing first-last mile options supporting access to employment. This study showed that first-last mile services can address gaps in transportation systems, that different modes of transportation offer first-last mile service options to match local contexts and needs, and that partnerships between public agencies, mobility providers and local employers are key to developing first-last mile services supporting access to employment.

To inform how first-last mile services can support Missourians' access to employment, the team conducted a scan of over 50 first-last mile services across the United States, produced 15 case studies, and conducted 5 in-depth interviews with mobility providers. To understand what current conditions are affecting first-last mile issues in Missouri, the team developed an existing conditions analysis mapping transit and mobility services in Missouri, conducted in-depth interviews with 2 local transit agencies, and hosted a virtual forum with Missouri's transportation stakeholders. The team summarized the findings from these research activities, and presented recommendations to inform how MoDOT, local governments, and transit agencies can support first-last mile services for Missourians.

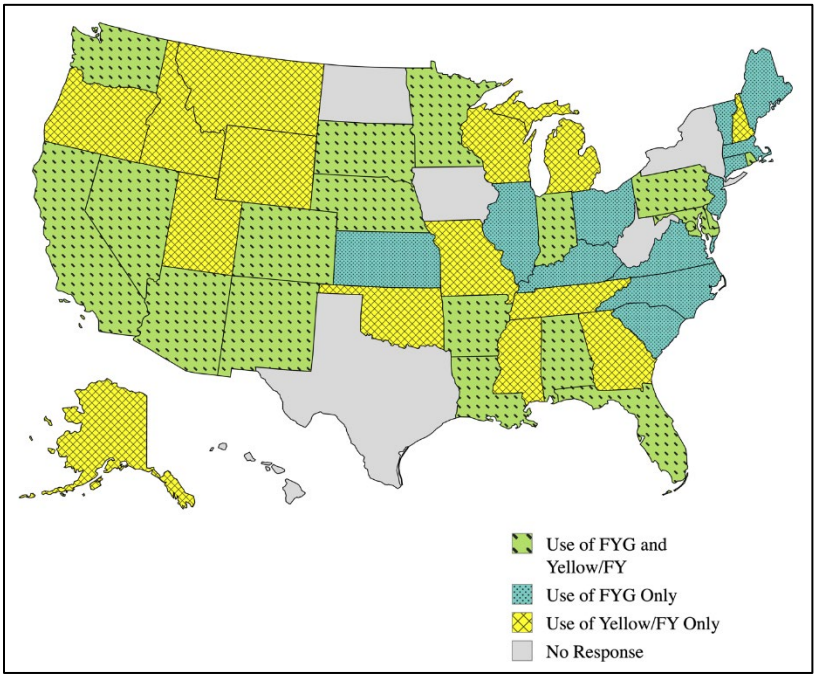


TR202416 – Safety Impacts of Fluorescent Yellow-Green Signs on Pedestrians

Research Project Manager: Jenni Hosey

Principal Investigator: University of Missouri, Columbia and Arora and Associates - Henry Brown, Praveen Edara, Carlos Sun, Daeyeol Chang, Zhu Qing, Priscilla Tobias, Jerrid Dinnen, and Melissa Jiang

Final Report Executive Summary



The Manual on Uniform Traffic Control Devices (MUTCD) specifies the use of yellow sheeting for pedestrian or bicycle signs and fluorescent yellow-green (FYG) for school signs, with an option for the use of FYG sheeting for pedestrian or bicycle warning signs. However, switching from yellow or fluorescent yellow (FY) to FYG for pedestrian and bicyclist signage could involve significant cost and effort for government agencies. The objective of this research study was to synthesize existing research and review the state of the practice regarding the use of FYG for pedestrian and bicyclist signs. The research methodology to meet these objectives includes a literature review, survey of DOTs and metropolitan planning organizations (MPOs), and follow up interviews with a subset of DOTs and MPOs. Findings indicate that the results from previous research studies are inconclusive regarding the safety benefits of FYG (compared to yellow or FY) for pedestrian and bicyclist signs and may be outdated. There is a wide range of agency practices for FYG signs for pedestrians and bicyclists among responding DOTs and MPOs, and many agencies allow FYG for pedestrians and bicyclists to some extent. Responding agencies have primarily switched to FYG for pedestrian and bicyclist signs based on a belief that the color stands out better and as part of other safety initiatives. None of the agencies that responded to the surveys indicated that they have performed any research studies to evaluate the safety performance of FYG signs for pedestrians and bicyclists. While a limited number of respondents saw improved safety performance with the use of FYG, the research did not identify significant and conclusive evidence regarding potential safety benefits associated with the use of FYG for pedestrian and bicyclist signs.

TR202418 – Implementation of Balanced Mix Design in Missouri Test Sections with Modifiers

Research Project Manager: Scott Breeding
Principal Investigator: Missouri Center for Transportation Innovation - Bill Buttlar, Punyaslok Rath, Jim Meister, Ahmed I.H. Mohamed, Helmut Leodarta, and Katie Distelrath
Final Report Executive Summary

The overarching goal of this study was to advance the deployment of innovative pavement technologies prevalent in the state of Missouri. In this study, the focus was on evaluating recycled polymers for use in asphalt mixtures and Balanced Mixture Design (BMD) implementation. Nine test sections were constructed on I-155 near Hayti, MO. Six sections were constructed with Superpave dense graded mixtures and the other three with Stone Matrix Asphalt mixtures. These sections were modified with recycled polymers such as ground tire rubber and different kinds of waste plastics, and with virgin polymers such as Styrene-Butadiene-Styrene and Polyphosphoric Acid. A Job Special Provision was utilized for this project, which recommended the BMD thresholds for CT-Index to be 45.0 for dense-graded mixtures and 160.0 for SMA mixtures. The Hamburg rutting criteria was 12.5 mm at 15,000 passes. Additionally, an elevated BMD criteria of CT-Index = 80.0 was imposed for two of the six dense graded mixtures. The team conducted cracking, rutting, and moisture damage tests on the specimens produced in the lab and in the plant. The results indicate that the mixtures incorporating recycled polymers perform equivalently or better than the virgin polymer mixtures.

TR202420 – Testing Survey Methods for Detecting Bats Roosting in Bridges

Research Project Manager: Brent Schulte
Principal Investigator: Copperhead Environmental Consulting, Inc. - Piper Roby, Crystal Birdsall, and Timothy Divoll

Final Report Executive Summary

Bats are a critical component of our natural world, and many species are at risk. Protecting roosting habitat is one way to help conserve a variety of species. Although many bats use natural roosts, a growing number are adapting to anthropogenic structures due to habitat encroachment. This study tested methods for detecting bats using bridges as roosts. Twenty bridges were visited four times each to test six daytime methods and three evening emergence methods to detect bats. Occupancy modeling revealed that the most effective way to document bat use at bridges is with an acoustic detector during evening emergence. This was followed by the use of thermal cameras during evening emergence, and the third best model was the use of thermal cameras during the day. Surveying longer did not increase detectability in any of the top models. Based on the findings and suggestions in guidance documents for detecting bats in bridges, the first step is to survey a bridge with a spotlight, listening for bat vocalizations, and noting smell. If bats are not detected during the day, using acoustic detectors and thermal cameras during emergence will determine if bats are using bridges and can provide additional data if they are documented using them during the day.

TR202421 – Consultant Support for Intelligent Compaction (IC) and Paver-Mounted Thermal Profiling (PMTP) Projects in 2024-2025

Research Project Manager: Scott Breeding
Principal Investigator: Transtec Group - George Chang, Amanda Gilliland, and S. Subramanian
Final Report

The 2024 MoDOT IC-PMTP Annual Report highlights achievements and challenges in implementing Intelligent Compaction (IC) and Paver-Mounted Thermal Profiling (PMTP) technologies. Key updates included aligning data validation tools with updated PMTP specifications and addressing challenges such as contractor's paving boundary data manipulation and data loss. Improved PMTP thermal segregation trends were noted, though IC coverage declined due to data loss issues. Feedback meetings emphasized the preconstruction Global Navigation Satellite System and cellular surveys, stricter paving boundary validation, and updated PMTP specifications. The final report for the 2025 construction season will be published in March 2026.