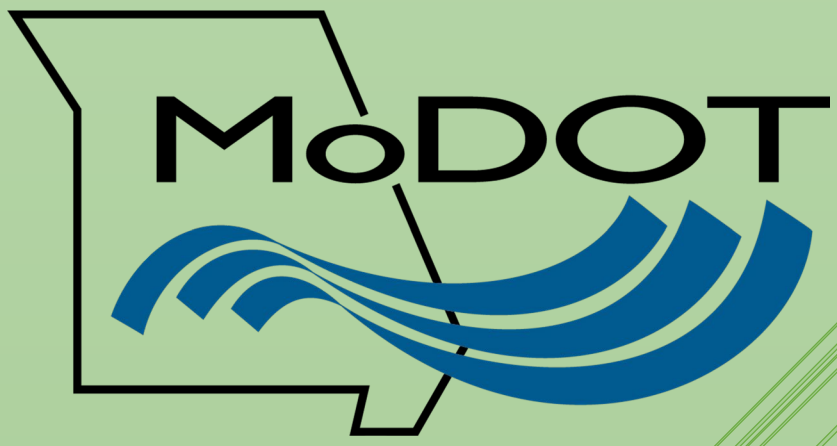


Construction and Materials – Research

FY2024 Annual Report

Contents

Introduction

Greetings!

The programs, projects and services administered by MoDOT's Research Section are for the purpose of finding more efficient ways of providing transportation services to the citizens of Missouri. The efficiencies can come in the form of new materials, improved processes, or making our transportation systems safer.

During State Fiscal Year 2024, 13 contracted research projects were completed. Topics ranged from pedestrian safety, bridges, pavement materials, geotechnical solutions, 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.

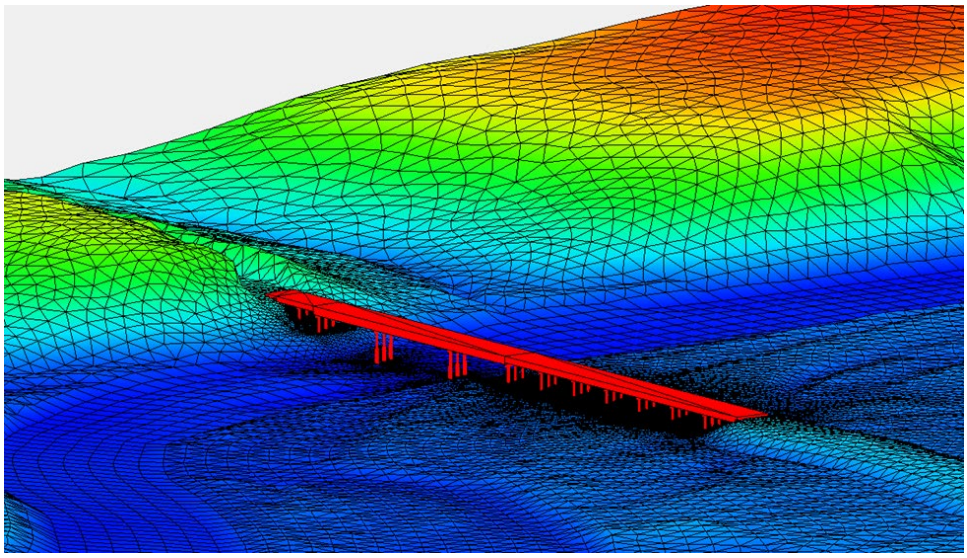
Sincerely,

Jen Harper
Research Director

TR202017 – Impacts of Hydraulic Modeling Methods on Bridge Scour Analysis at Missouri Bridges

Full Report Executive Summary

This study examined the impact of hydraulic modeling on bridge scour in Missouri. The study primarily focused on contrasting 1D vs. 2D hydraulic modeling techniques. The research team developed recommendations for sediment/soil sampling methods and conducted bridge scour risk assessments for the five bridges studied. Field data were collected at five study sites to obtain the required terrain and soil/sediment input data for hydraulic modeling and scour analyses. The recommended methods developed for soil/sediment sampling in the overbank areas are soil augers or test pits, and for overwater locations, a FISP or clamshell samplers.



TR202020 - Evaluation of Recycled Components in Stone Matrix Asphalt Mixes

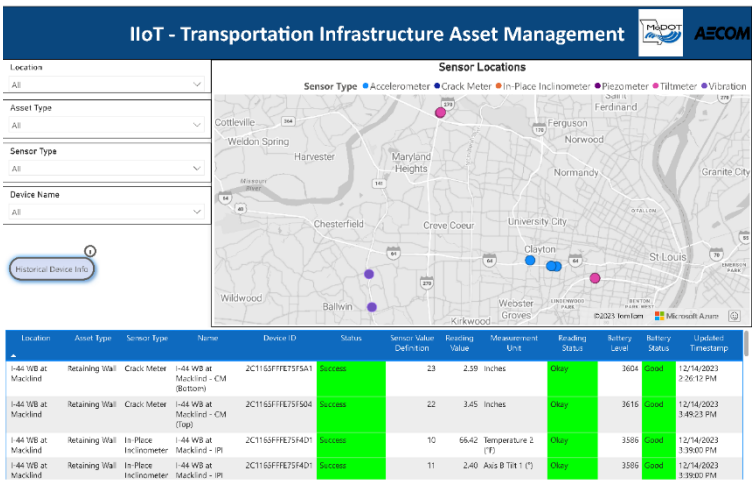
Full Report Executive Summary

Currently, Missouri DOT (MoDOT) does not allow use of recycled materials in SMAs. MoDOT commissioned this study to investigate the effect of incorporation of recycled materials such as RAP and GTR in SMAs. In Phase 1, plant-produced mixtures were collected, and recreated under BMD methodology to determine acceptable upper-limit on RAP for initial implementation. In Phase 2, friction properties of mixtures were obtained by testing aggregates, lab and plant produced mixtures, and a field section containing GTR. Based on the results, the following conclusions were drawn: 1) The current use of conglomerate, unfractionated RAP stockpiles poses practical limitations in achieving passing BMD thresholds at higher levels of RAP, 2) Suitable frictional characteristics were achieved at lower levels of RAP but results indicated that the softer aggregates present in current RAP stockpiles tended to reduce skid resistance, and 3) Use of GTR appears to be promising option for incorporating recycled materials into Missouri pavements, based on lab BMD and skid resistance results in the lab and field. Based on the findings, the following

recommendations were made: 1) MoDOT should consider allowing RAP in SMA mixtures but, an upper limit of 15% asphalt binder replacement (ABR) from RAP is recommended at this time, 2) If greater than 15% ABR by RAP is considered, a value engineering proposal should be provided, accompanied with BMD tests, and 3) The research supports the continued and increased usage of GTR as a possible approach towards achieving good mixture durability, skid resistance, and mixture sustainability.

TR202110 – Transportation Infrastructure Asset Monitoring Through the Industrial Internet-of-Things

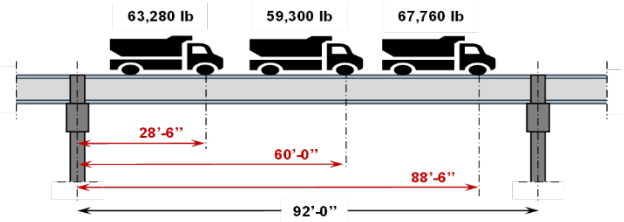
Full Report Executive Summary



This project explored the current status and viability of Industrial Internet-of-Things (IIoT) technology for the purpose of asset management of transportation infrastructure in Missouri. The project was framed in two phases. Phase 1 focused on preliminary research to assess the readiness of IIoT for initial implementation on the transportation highway system (such as: bridges, pavements, retaining walls, signs, etc.). This project implemented Phase 2, a pilot project deployed on a limited number of assets to evaluate the technology.

TR202203 – Intermediate Bents – Calculation of Restraint Factor

Full Report Executive Summary



MoDOT uses a k-factor of 2.1 to evaluate the buckling resistance of non-integral intermediate bent columns in prestressed concrete superstructures (assuming a fixed-free condition). However, the restraint provided by longitudinal girders at the top of a column provides additional resistance to the buckling of the column and may allow a reduction in the k-factor to as low as 1.2 (for a fixed – rotationally restrained condition). This project determined the actual level of restraint at the top of the columns so that more accurate values of k-factors can be used. The project developed detailed Finite Element (FE) models using ANSYS workbench. The detailed FE models considered the standard design details including the shear keys, dowel bars, roofing felt bond breaker between

the diaphragm and bent cap, and joint filler at the edge of the diaphragm. The main source of rotational movement was found to be the connection between the bent cap and diaphragm.

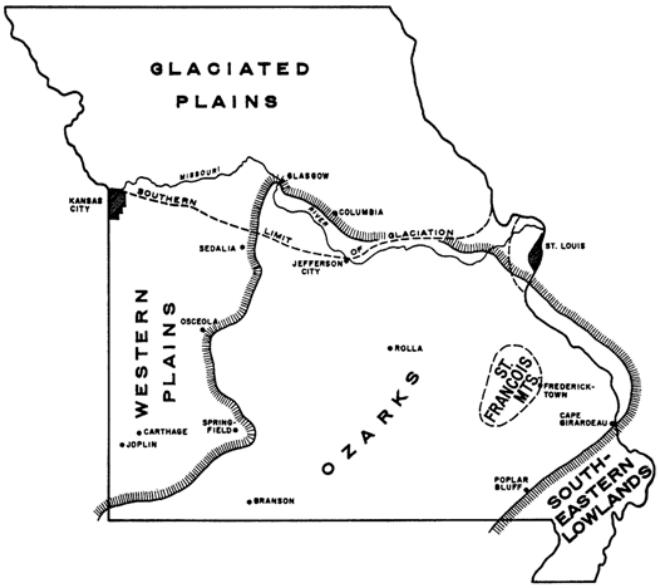
TR202204 – Design Coefficients of Friction for MoDOT PTFE Bearings

Full Report Executive Summary

MoDOT specifies filled or unfilled flat polytetrafluoroethylene (PTFE) bearings per section 1038.4.4 for expansion bearings. The design friction coefficients are in EPG section 751.50. MoDOT believes that if designers follow our specifications, then the filled PTFE and/or cold values may be conservatively used but that it leads to friction forces that are sizable. The dynamic friction force is often larger than the forces that would be applied to a fixed bent due to temperature, wind, or braking. This nullifies the benefits of using the expansion bearing. This research looked at what design coefficients of friction should be used when distributing forces for substructure design. The research also determined if dimpled lubricated pads are an effective alternate and if so, what should be added to the specifications to address maintenance issues with this type of bearing.

TR202207 – Pile Setup and Restrike Procedures

Full Report Executive Summary



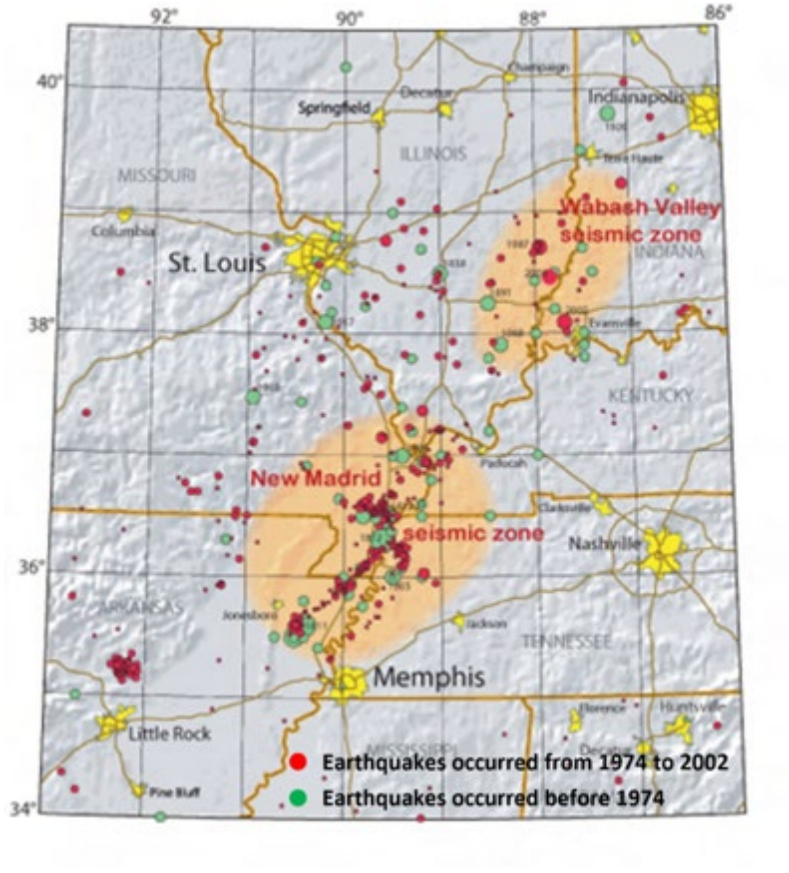
The objective of this research was to provide MoDOT with rational procedures and guidelines to incorporate pile setup in MoDOT pile design. Pile setup refers to the time-dependent increase in the capacity of driven piles that occurs after the end of piledriving. High-strain dynamic load test data from end of driving (EOD) and beginning of restrike (BOR) were compiled from sites in Northern Missouri and Southeast Missouri to develop models of pile setup in these regions where the use of friction piles is common. Reliability analysis was performed using the model developed from Northern Missouri data to probabilistically calibrate resistance factors that can be applied to the expected pile setup without the need for

restrikes. The application of these resistance factors is shown to produce significant cost benefits over the current common practice of ignoring pile setup. In addition, pile setup factors within the first 24 hrs. of the EOD were examined to provide information on the likelihood of successful restrikes for various levels of required capacity. Data from sites in Southeast Missouri were insufficient to develop a meaningful model of pile setup and associated resistance factors. The limited data that were used showed moderate levels of pile setup, indicating the use of restrike analysis in Southeast Missouri may be cost effective. Additional data collection at sites in Southeast Missouri is recommended.

TR202213 – Identification of a Response and Rescue Network for the St. Louis Region

Full Report Executive Summary

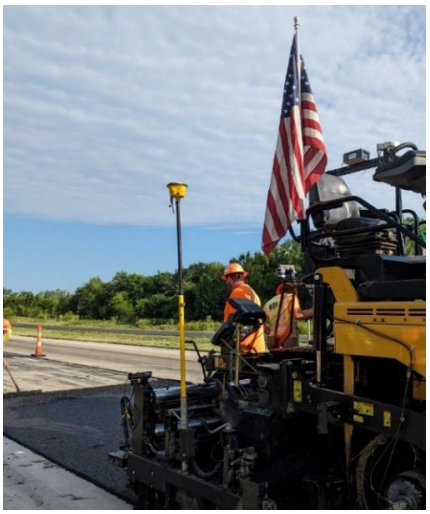
Emergency preparedness and response are crucial for mitigating the impact of natural disasters such as earthquakes. The St. Louis metropolitan region is vulnerable to earthquakes in the New Madrid and Wabash Valley Seismic Zones. This study focused on understanding and addressing transportation impacts of an earthquake in the St. Louis region. An online survey conducted across eight counties in the St. Louis region gathered data on citizen preferences, travel patterns, and vehicle usage during an evacuation. The research team employed transportation simulation tools, including macroscopic and mesoscopic approaches, to assess regional traffic impacts. The research evaluated the effects of a magnitude 6.7 earthquake, considering infrastructure damage estimates from the USGS ShakeCast model. Performance measures such as average vehicle speed and operating speed-to-speed limit ratio were gathered from the simulation to determine congestion across the road network. Twelve evacuation scenarios were assessed using simulation. The scenarios varied based on the level of damage to the road network, evacuation demand, and timing of the earthquake. Results showed that morning earthquakes resulted in the worst traffic impacts. Mesoscopic models confirmed severe congestion on MO 100 and



identified bottlenecks on I-170 and US 67. A tabletop exercise was conducted with key emergency response stakeholders in the St. Louis region to better understand coordination and communication needs during an earthquake response. This study equipped stakeholders with tools for effective response, aiding emergency responders, urban planners, and policymakers in minimizing the impact of earthquakes.

TR202221 – Consultant Support for Intelligent Compaction and Paver-Mounted Thermal Profiling Projects

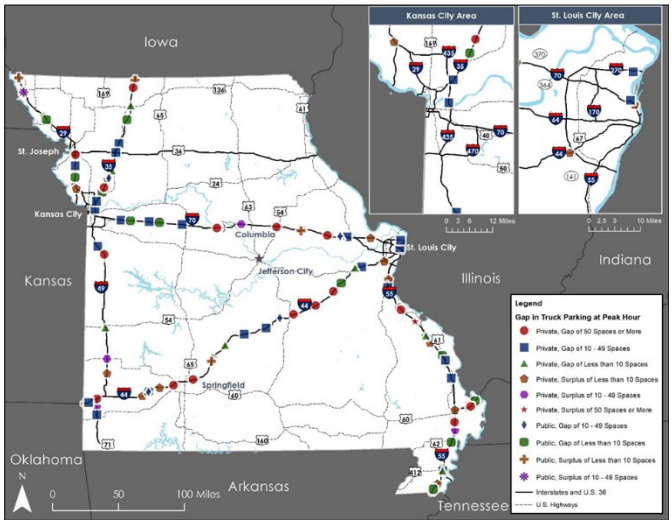
Full Report Executive Summary



MoDOT's Intelligent Compaction (IC) and Paver-Mounted Thermal Profiling (PMTP) projects (full report, executive summary) from 2017 to 2021 showed improvements in paving quality, leading to an extension of these projects into 2022 and 2023. The aim was to procure consulting services to maintain the success of IC-PMTP projects. The project spanned 26 months, from March 2022 to April 2024, with this report summarizing the progress in 2023. Key trends since 2017 include increased IC pass count coverage, reduced temperature segregation, and consistent compaction temperatures, indicating enhanced construction practices and pavement quality. MoDOT is dedicated to further developing the IC-PMTP program, focusing on statewide implementation, evolving specifications, comprehensive training, and employing innovative technologies. The 2023 highlights include the adoption of automated boundary collection methods, evolving IC and PMTP specifications with new classifications and price adjustments, a detailed training program, and plans to address cellular or GPS coverage issues in future projects.

TR202313 – Truck Parking Investments for Missouri

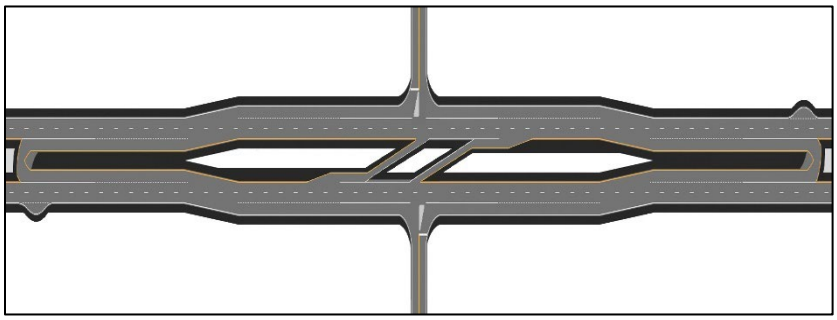
Full Report Executive Summary



Missouri's multimodal freight system is critical to the health of both the state and national economy, and as the economy and population grow, goods movement activity is expected to increase. This growing demand for goods will likely mean more trucks on the road, leading to a greater need to enhance the infrastructure necessary for trucks to improve safety for both truck drivers and the traveling public. MoDOT commissioned this study to develop a prioritized list of truck parking locations and immediate actions for near- and long-term changes in truck parking availability in Missouri. The key objectives of this study were to identify an initial list of locations for possible investment, develop a methodology to prioritize locations in Missouri for potential truck parking investments via truck parking demand and truck parking safety metrics, assign a prioritization score for the 18 most promising sites, and conduct an analysis of benefits and costs for each shortlisted site. The shortlist of 18 public truck parking facilities was prioritized by their benefit-cost ratio effectiveness. As Missouri considers strategies and policies to produce a lasting impact in the availability of truck parking, investment in these identified facilities will yield the highest positive impact with the lowest cost. However, given limited funding to develop all the facilities, the 12 with a benefit-cost ratio (BCR) effectiveness score greater than one should be considered first. For the development of these sites, next steps will involve more detailed engineering and design assessments to further understand the local costs and impacts. Overall, with a projected increase in truck traffic throughout Missouri, this study reaffirms the need for increased funding for truck parking investment and the increase of truck parking capacity. This study was included in MoDOT's successful $92.8 million INFRA grant application for Interstate 70.

TR202320 – Safety Evaluation of J-turn Intersections in Missouri

Full Report Executive Summary



MoDOT has implemented J-turn intersections to improve road safety on rural highways since 2007. Traditional two-way stop-controlled intersections present significant risks for severe crashes. J-turns, by design, mitigate these risks by

directing vehicles to turn right and then perform a U-turn at a designated median opening. The primary objective of this study was to evaluate the safety performance of J-turn intersections in Missouri. The safety analysis of Missouri's J-turn installations provided robust evidence of a significant reduction in crashes. The CMFs and collision diagrams generated from this research report will help MoDOT select sites and improve design criteria for future J-turn installations in the state.

TR202322 – Vulnerable Road User Safety Assessment

Full Report Executive Summary

Vulnerable Road Users (VRUs) are nonmotorized road users, such as pedestrians and bicyclists, who do not have the protection of a vehicle shell. VRU injuries and fatalities have been increasing, leading to various efforts to assess and improve VRU safety. One such state-level effort was the development of a Missouri VRU safety assessment plan. This plan included a systemic analysis of intersections and segments, high-crash analysis of statewide facilities, examination of various contributory factors such as equity, unhoused pedestrians, transit, and lighting, and review of low-cost proven VRU countermeasures. Certain facilities stand out from the crash analysis such as urbanized three-legged and four-legged intersections, rural two-lane undivided highways, urbanized roadways, and controlled access roadways because of secondary crashes. Stakeholders reviewed the data-driven results and were engaged via two meetings as well as an electronic survey. For the near term, there are various low-cost countermeasures that could be deployed over intersections and entire corridors in Missouri, such as beacons and leading signal intervals. For the long term, technological solutions could help to reduce or eliminate human error of both drivers and VRUs. The information gathered from this report was included into the MoDOT Highway Safety Improvement Program.

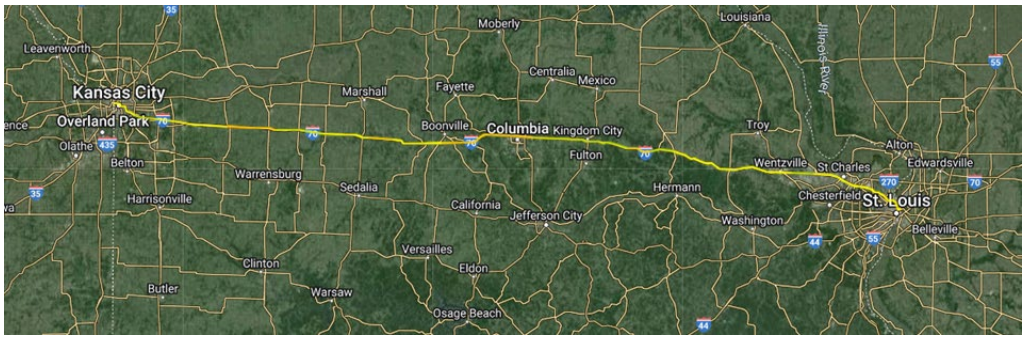
TR202417 – Comprehensive Data Analysis for Asphalt Mixture Performance Tester Tests on MO 740 and US 54

Full Report Executive Summary

The Missouri S&T research team conducted comprehensive data analysis from the Asphalt Mixture Performance Tester (AMPT) samples collected from the Highway 54 and MO 740 projects. The MO 740 project in Boone County contained test sections with five mix designs, i.e., control mix, ground tire rubber (GTR)-modified mixture, and three mixtures containing recycled plastic. The US 54 project had ten samples collected at different times during the production of the surface mix. The data were analyzed on both roadway projects examining the material and structural scales. For the MO 740 project, field performance was also used to verify the research findings. The fatigue performance index Sapp and the Rutting Strain Index (RSI) were calculated, and the mixture performance in pavement structures with realistic traffic loads and climate was predicted. The research found that the mixture performance in the Highway 54 project has a good correlation with the mixture volumetric properties. In terms of the different mix designs in the MO 740 project, the AMPT tests suggested that the GTR-modified mixture had the lowest modulus but had the highest cracking resistance. However, the mixture might have a higher rutting susceptibility than the other mixtures. On the other hand, the addition of plastic increased the mixture stiffness and did not have a great impact on the fatigue and rutting performance compared with the control mixture.

TR202419 – I-70 Pavement Structure Evaluation

Full Report



Roadway structural properties on 463 lane-miles of Interstate 70 between Kansas City and St. Louis were determined using deflection, surface condition, and three-dimensional ground penetrating radar (3DGPR) data collected with the ARRB iPAVE Traffic Speed Deflectometer (TSD). Data was collected in the right wheel path of the travel lane in both the eastbound and westbound directions. The TSD data were collected at the posted speed limit (typically, no more than 70 mph) and results are averaged and reported at 0.01-mile intervals. The 3DGPR data was analyzed to determine the thickness of the pavement layers at each reported TSD test point. The data was analyzed to determine pavement structural properties, to evaluate the load transfer of the underlying transverse joints and cracks, and to identify areas of potential asphalt stripping.