WisDOT Research Program

Annual 2022 Report

WISCONSIN DEPARTMENT OF TRANSPORTATION

Foreword

It is my pleasure to present the Wisconsin Department of Transportation (WisDOT) 2022 annual report on research activities. This report highlights WisDOT's efforts to uphold our mission to provide leadership in the development and operation of a safe and efficient transportation system.

WisDOT's Research and Library Services Unit coordinates the department's research activities and provides access to information that leads to data-driven decision making. Over the last year, the team has continued its efforts to align research and the department's strategic priorities; to facilitate and track implementation of research results; to promote the use of emerging technologies; and to support the adoption of associated policies and procedures to demonstrate accountability to our transportation stakeholders and the public.

WisDOT's award-winning $4.56 million research program funded 64 research projects, completed seven Wisconsin Highway Research Program (WHRP) projects, and led three projects funded through the Transportation Pooled Fund (TPF) Program.

WisDOT continues to focus on critical transportation policy issues. In federal fiscal year 2022, three research program policy projects were completed focusing on workforce development, data cataloging and security, and streamlining design process requirements in the local bridge improvement assistance program.

Research and library staff completed four synthesis reports and 27 literature searches; responded to 280 information requests; and delivered 526 resource items. The research program also collaborated with educational institutions, organizations within the transportation industry and state and federal agencies to develop and disseminate valuable, innovative ideas of shared interest by participating in national studies and panels.

I am proud to recognize these accomplishments and would like to thank the many individuals that serve on research committees and panels at the national, state and department levels. Their expertise and guidance are critical to the success and implementation of research.

Craig Thompson, Secretary
Wisconsin Department of Transportation

This is a report of research and technology transfer activities carried out by the Wisconsin Department of Transportation through the Part B research portion of the State Planning and Research Program of the Federal Highway Administration, U.S. Department of Transportation. The report describes activities during Federal Fiscal Year 2022, covering October 1, 2021 through September 30, 2022.

Contents

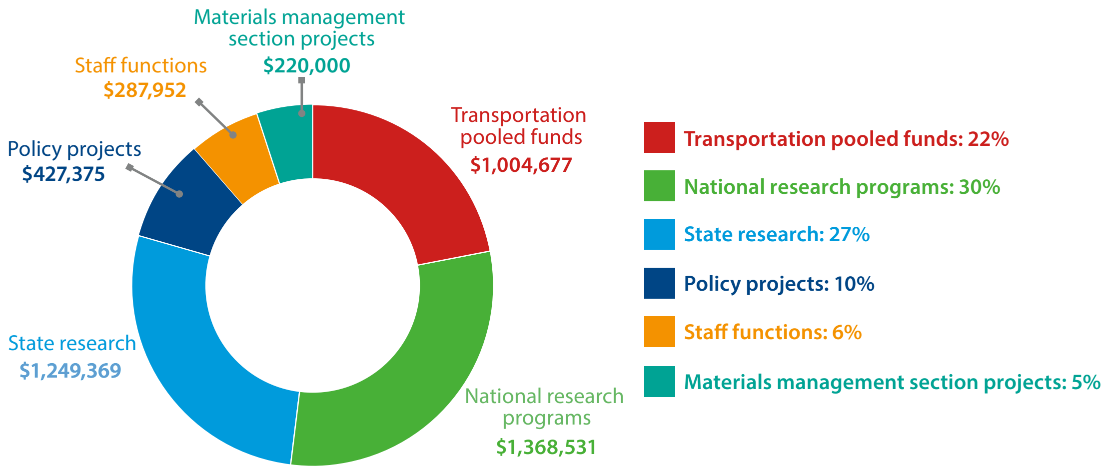
Common acronyms used in this document

AASHTO	American Association of State Highway and Transportation Officials
DBM	(WisDOT) Division of Business Management
DBSI	(WisDOT) Division of Budget and Strategic Initiatives
DMV	(WisDOT) Division of Motor Vehicles
DOT	U.S. Department of Transportation
DSP	(WisDOT) Division of State Patrol
DTIM	(WisDOT) Division of Transportation Investment Management
DTSD	(WisDOT) Division of Transportation System Development
EXEC	(WisDOT) Executive Offices
FFY	Federal Fiscal Year
IPIT	Institute for Physical Infrastructure and Transportation at University of Wisconsin – Milwaukee
FHWA	Federal Highway Administration
NCHRP	National Cooperative Highway Research Program
SPR	State Planning and Research Program
TPF	Transportation Pooled Fund
TRB	Transportation Research Board
TOPS	Traffic Operations and Safety Laboratory at University of Wisconsin - Madison
UW	University of Wisconsin
WHRP	Wisconsin Highway Research Program
WisDOT	Wisconsin Department of Transportation

Program overview

The Wisconsin Department of Transportation (WisDOT) managed a $4.56 million program for research and technology transfer services during federal fiscal year (FFY) 2022. The State Planning and Research Part B (SPR-B) federal program funded 90 percent ($4.1 million) of the program, while state funds covered the remaining ten percent ($0.46 million).

Research program funding



State research

The Wisconsin Highway Research Program (WHRP), established in 1998 by WisDOT in collaboration with the University of Wisconsin–Madison, aims to better design, build, and reconstruct the state's transportation system. The four areas of focus include geotechnics, structures, flexible and rigid pavements. See page 21 for all completed and in-progress projects.

Transportation pooled funds

The Transportation Pooled Fund (TPF) program allows federal, state and local agencies and to combine resources to support transportation research studies of common interest. In FFY 2022, WisDOT research led three pooled fund projects and participated in 42 others. These projects include advances in safety and engineering methods and materials. For a full list of pooled fund projects, see pages 23-24.

Policy projects

WisDOT partners with the University of Wisconsin–Madison's Traffic Operations and Safety (TOPS) Laboratory and the University of Wisconsin-Milwaukee's Institute for Physical Infrastructure and Transportation on research projects (IPIT)

National research programs

The department participates in national research initiatives through the Transportation Research Board (TRB), National Cooperative Highway Research Program (NCHRP) and American Association of State Highway Transportation Officials (AASHTO) Technical Services Program.

Staff functions

Efficient management of transportation knowledge and research findings contributes to continuous improvement. The Research and Library team conducts technology transfer activities and provides library services to coordinate dissemination of research recommendations to enhance operations within the department.

Materials management section projects

Funds for WisDOT's Materials Management Section (MMS) internal projects, including the investigation and implementation of new materials and methods are also included in the research program.

Completed Research Brief

Wisconsin Highway Research Program
Project 0092-17-07
September 2022

Evaluating Current Wisconsin Mixes Using Performance Engineered Mixture Testing Protocols

Research Objectives

- Use performance-based testing on current WisDOT concrete mixtures
- Create a database of results on WisDOT mix designs and compare to PEM specifications
- Evaluate 1.5-inch aggregate in the Tarantula Curve and MinT consolidation versus rodding during SAM testing
- Test resistivity using multiple curing conditions

Research Benefits

- Greater flexibility in the composition of concrete mixtures that can be used for projects due to increased reliability in testing measures and understanding of mixture performance

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Background

Concrete specifications provided by state highway agencies (SHA) are typically prescriptive; that is, they describe the materials and methods that must be used to complete projects. The main concerns with this approach are that most of the risk and liability for the performance of the project is on the SHA, which limits the incentive for contractors to innovate. Performance-related specifications (PRS), those that describe expected concrete performance, offer an alternative that allows contractors flexibility and encourages innovation, leading to improved performance and lower costs. This research took place in two phases. In Phase I, the objectives were to:

- Use performance-based testing methods on current WisDOT mixtures, and
- Collect a comprehensive database of results on several WisDOT mix designs and assess how they compare to proposed Performance-Engineered Mixtures (PEM) specifications

In Phase II, the objectives were to:

- Evaluate the 1.5-inch aggregate in the Tarantula Curve and Miniature Vibration Table (MinT) consolidation compared to rodding during Super Air Meter (SAM) testing.
- Test resistivity per AASHTO TP119-21 and AASHTO T358-21 using bucket curing in pore solution, accelerated curing, lime curing, and sealed sample.
- Perform field testing on Wisconsin mixtures to verify Phase I recommendations and perform additional resistivity conditioning.

Methodology

In Phase I, the research team sampled concrete mixes used at eight construction projects sites across the state, representative of a variety of materials and methods. Samples were taken at the plant, before the paver and after the paver in the morning and afternoon of two consecutive days. Performance tests were conducted on each sample to measure strength, durability and workability properties.

Strength properties:

- Flexural vs. Compressive Strength

Workability properties:

- Box Test
- Vibrating Kelly Ball

"The results of this research will be integral in the direction of evaluating concrete performance."

–Leslie Hidde, WisDOT

Interested in finding out more?

Final report is available at: **WisDOT Research website**

Durability properties:

- Bulk resistivity
- Coefficient of thermal expansion
- Formation factor
- Hardened air voids
- Porosity
- Super Air Meter (SAM)
- Surface resistivity

Conducting a surface resistivity test

In Phase II, a large lab study was conducted to investigate performance using various aggregate sources and blends. The research team investigated the common use of 1.5-inch stone in Wisconsin as it pertains to the Tarantula Curve and performance properties. The various optimized blends were tested using slump, box test, shrinkage, and resistivity. Additionally, five more field projects were visited where testing was conducted using various consolidation methods for the SAM test, and various conditioning methods for resistivity testing.

Results

Results demonstrate the value of using the optimized gradation curve (Tarantula Curve) by increasing workability and reducing cementitious products without sacrificing performance. Even though theoretical relationships between compressive and flexural strength have been developed, the mixtures tested in this study with the highest compressive strengths did not always have the highest flexural strengths. It was also found that air content is not a good indicator of Spacing Factor as results varied widely among samples with the same air content. However, SAM numbers remained similar indicating loss of largely coarse bubbles. Resistivity increased with all curing methods tested, but the 28-day accelerated curing had the benefit of being faster than other methods with little difference in outcome. The coefficient of thermal expansion varied across the types of mixtures tested, with Dolomite showing mid-range coefficients with less variability than other materials such as gravel.

Recommendations for implementation

Although results will not be fully implemented until 2025, this research was used to pilot specifications used for the 2022 construction season

- Continued option to use 1.5-inch aggregate size in WisDOT mixtures
- Use of the Tarantula Curve with a warning band for all WisDOT mixtures where longevity is important
- Design and production targets for the SAM meter
- Using MinT for SAM consolidation and the accelerated curing method for resistivity

This brief summarizes Project 0092-17-07,
"Evaluation of Current WI Mixes Using Performance Engineered Mixture Testing Protocols"
Wisconsin Highway Research Program

Completed Research Brief

Wisconsin Highway Research Program
Project 0092-19-02
June 2022

Internal Curing of Bridge Decks and Concrete Pavement to Reduce Cracking

Research Objectives

- Evaluate materials available in Wisconsin for use in internally cured concrete
- Evaluate the performance of fresh and hardened concrete with and without internal curing
- Determine the impact of using internally cured concrete on concrete durability and sustainability of bridge deck and pavement placements

Research Benefits

- Using internally cured concrete in pavements will reduce rehabilitation costs
- Incorporating a special provision into WisDOT manuals will allow concrete producers and contractors to become familiar with internally cured concrete.

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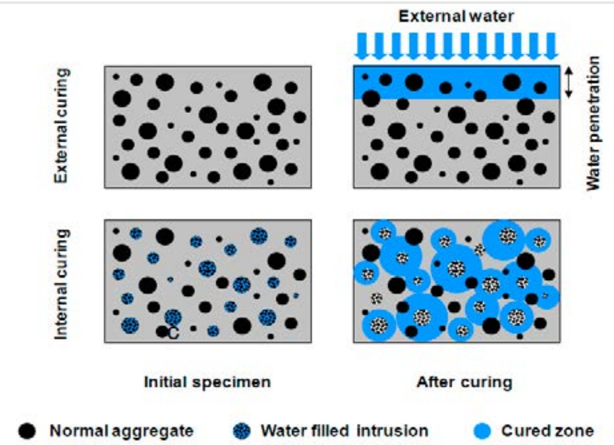
Background

Volumetric changes in concrete bridge decks and pavements can often result in cracking or warping, leading to reduced performance and durability. Changes in the moisture content of hardened concrete or the self-desiccation of cementitious materials with a relatively low water-to-cementitious materials ratio (w/cm) cause these volumetric changes.

Internal curing (IC) is a proven technology able to provide additional water to enhance the hydration of cement and pozzolans in the mixture, resulting in improved mechanical properties and improved durability. Additionally, since the IC water is not accessible during batching, distress associated with self-desiccation (autogenous shrinkage) and drying shrinkage is mitigated. IC can be achieved by utilizing lightweight fine aggregate (LWFA) or super absorbent polymers (SAP).



Internal vs. External Curing

This research project sought to evaluate different LWFA and SAP materials available in Wisconsin for use in internally cured concrete (ICC); evaluate the performance of fresh and hardened concrete with and without IC; and determine the potential impact of using ICC on the concrete durability and sustainability of bridge deck and pavement placements, respectively.

Methodology

The research team conducted two experimental phases to assess internal curing agents' influence on the properties of concrete. First, a study on mortar involved designing 17 different mortar mixtures to evaluate the effect of IC agents on autogenous shrinkage (ASTM C1698) and compressive strength (ASTM C109). Mortar mixtures were designed with w/cm ratios of 0.35 and 0.45 to investigate the efficacy of LWFA and SAP on autogenous shrinkage at different w/cm ratios. Three different replacement levels of LWFA corresponding to 80 percent, 100 percent and 120 percent of the required IC water were considered for each LWFA type.

"Internal curing of concrete has been demonstrated to reduce cracking in concrete bridge decks and pavements. This research gives the department tools to implement this technique in the future."

– William Oliva, WisDOT

Interested in finding out more?

Final report is available at: [WisDOT Research website]

The second phase evaluated 12 different concrete mixtures to investigate the effects of IC agents on concrete performance: six were designed for pavement applications (PA mixtures) and the remaining six were designed for bridge deck applications (BD mixtures). Two control mixtures, two LWFA mixtures and two superabsorbent polymer (SAP) mixtures were considered for both pavement and bridge deck uses. Data from LWFA and SAP mixtures were compared to control mixtures at each w/cm level for both pavement and BD categories.

Results

All mixtures in the study on mortar exhibited an initial expansion in the early ages (less than one day); the control mixture exhibited an initial expansion that was followed by significant autogenous shrinkage that increased monotonically with time. The 28-day shrinkage strain was found to be dependent on the LWFA replacement level. All SAP mixtures exhibited expansion at early ages, but it was significantly lower compared to the control mixture. This study indicated that SAP desorbs fluid faster than LWFA, and using SAP with a higher absorption capacity will likely further reduce autogenous shrinkage. In the concrete study, incorporating LWFA resulted in a slightly lower compressive strength, which is more pronounced at higher w/cm. Hardened concrete properties showed a general improvement when IC was incorporated. The use of ICC resulted in a substantial increase in the resistance against cracking of bridge deck concrete mixtures under restrained conditions. In non-restrained conditions, shrinkage was comparable to the control concrete mixtures. The life cycle cost analysis (LCCA) showed that the service life of bridge decks can be extended by using ICC, and that the LCCA of an ICC pavement can be reduced compared to a control scenario.

Recommendations for implementation

WisDOT manuals should incorporate a special provision to allow for concrete producers and contractors to become familiar with ICC in Wisconsin. The special provision provides sufficient flexibility to the producer and contractor to place ICC successfully while providing sufficient performance assurance to WisDOT.

To ensure that cracking in bridge decks is significantly mitigated, the researchers recommend that in addition to ICC, project specifications consider evaluating the potential for cracking using the restrained shrinkage method.

The benefit of ICC in pavements correlates with reduced rehabilitation costs during service. The monitoring of the ICC concrete performance should be conducted once ICC is incorporated and successfully executed in various pavement projects. Since this project recently closed, an implementation plan is still being created.

This brief summarizes Project 0092-19-02,
"Internal Curing of Bridge Decks and Concrete Pavement to Reduce Cracking"
Wisconsin Highway Research Program

Completed Research Brief

Wisconsin Highway Research Program
Project 0092-20-01
June 2022

Rating Longitudinal Laminated Timber Slab Bridges

Research Objectives

- Develop updated wheel load distribution width equations
- Investigate retrofit techniques to potentially increase live load capacity
- Reduce the number of timber slab bridges with over-conservative load postings

Research Benefits

- The equations developed within this project better define the behavior of longitudinal timber slab bridges
- Retrofits on bridges improved the transverse load distribution and the equivalent strip width

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Background

The Wisconsin Department of Transportation (WisDOT) recognizes that there are many challenges in assessing bridge condition and performance, and, as a result, has been updating its bridge load-rating program to include more data analytics, especially for its timber bridge inventory. Of the 571 timber bridges in Wisconsin, 450 are timber slab bridges.

Current methods of load rating use equations that were first developed in the late 1980s and early 1990s for determining the equivalent strip width: these equations often yield results that unnecessarily penalize the bridge by requiring a posted weight limit. Research shows that inspecting, load testing and modeling representative bridge structures provides a means to more accurately create analytical bridge models for purposes such as load ratings. Additionally, once a baseline performance metric is attained from the live load testing, various retrofit techniques can be implemented into the analytical model to evaluate their efficacy at improving load distribution. The combination of experimental and analytical research results in more accurate load ratings and effective selection of strengthening options.

Methodology

Through a program of bridge live load tests and analytical modeling, the research team measured and modeled bridge behavior. The selection of bridges for field testing considered bridge type, year built, main span length, deck width, and posting information. The researchers identified 10 timber slab bridges from three counties (Barron, La Crosse and Monroe) with a span length of 23 to 31 feet and a width of 25.5 to 32 feet. They tested three bridges in La Crosse County twice, both before and after the strengthening measures, to study the effect of the transverse spreader deck retrofit method. Seven bridges in Barron and Monroe Counties were tested once each.

The researchers used trucks of three different sizes for the tests. For each bridge, a truck was driven across the bridge in specific transverse postioins to study the distribution of the loads.

Truck parked at position of maximum strain response for survey data collection

“Timber slab bridges account for only three percent of Wisconsin’s bridge inventory, but 16 percent of its posted bridges. This research provides the knowledge we need to alleviate weight limit restrictions by improved analysis, load testing, or retrofit methods.”

– Alex Pence, WisDOT

Interested in finding out more?

Final report is available at: [WisDOT Research website]

Data were collected in two different ways, and the data collected from the first approach was used to validate the data from the second approach:

1. A conventional approach of using strain gages and deflection transducers connected to a data acquisition system to help the research team gain a comprehensive understanding of the timber deck behavior.
2. Using surveying equipment to obtain the same or similar deflection data as obtained from the first method but reduced to only the longitudinal truck position where the maximum load response was realized.

Results

The research team confirmed the original speculation that the current equivalent strip width calculation methodologies are conservative. The equivalent strip width is a function of the ratio of longitudinal and transverse stiffness of the timber slab deck; where bridge strengthening or rehabilitation are being considered, it is to the benefit of the structural capacity to be mindful of this relationship.

Load testing proved to be extremely beneficial in developing models and recommendations. The resulting equation for calculating equivalent strip width is a good representation of actual structural behavior.

This research project presented the opportunity to test three bridges in La Crosse County before and after strengthening retrofits were completed. In these tests, it was evident that the retrofit improved the transverse load distribution and, accordingly, the equivalent strip width.

Recommendations for implementation

Experimental and analytical results support using less conservative, modified live load distribution equations for timber slab bridges in Wisconsin. Further, the use of transverse spreader decks is an effective retrofit method to further improve load distribution. This project focused on bridges constructed with nail-and-spike-laminated panels, and the research team recommends that the load test method should be conducted in the same way for timber bridges constructed differently, such as with glue-laminated panels. In the final report, the research team provides the full steps required to complete the additional live load testing so that other bridges can be tested in the future. Pending FHWA approval of the revised specification, these results will be implemented in 2023.

This brief summarizes Project 0092-20-01,
“Analytical and Testing Methods for Rating Longitudinal Laminated Timber Slab Bridges”
Wisconsin Highway Research Program

Completed Research Brief

Wisconsin Highway Research Program
Project 0092-20-02
April 2022

Concrete Pavement Buckling in Wisconsin

Research Objectives

- Investigate buckling of concrete pavements in Wisconsin roadways
- Reveal the key mechanisms for buckling in Wisconsin with forensic studies
- Identify innovative methods to mitigate buckling incidents and associated costs

Research Benefits

- This study led to the development of a set of key recommendations to address buckling in Wisconsin
- This project's key recommendations reveal possible changes to address buckling and can be applied to reduce buckling in the future

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Background

Buckling (also known as blowup) in Portland cement concrete (PCC) pavement is a localized upward movement or shattering of concrete slabs. Buckling typically starts with the cracking of a construction joint due to shrinkage: pavement contracts during cold winter months and expands during warm summer months. Over time, incompressibles infiltrate into the joints, causing high growth rate of yearly maximum compressive stress. The probability of buckling increases due to a variety of risk factors such as those that affect pavement's neutral temperature, the magnitude of temperature and increase in moisture, and the accumulation of compressive stresses over time.

Wisconsin has had over 100 blowups each year since 2019, with the rate of buckling generally increasing over the last decade. Most blowup incidents occurred in jointed plain concrete pavement (JPCP), with a few incidents occurring in resurfaced concrete pavement and continuously reinforced concrete pavements (CRCP).

Blowup on Hwy 14 in Rock County

The goal of this research study was to investigate buckling of concrete pavements, reveal key mechanisms and factors that impact buckling, and identify methods to reduce the risk of buckling.

Methodology

To conduct this research, the team:

- Performed a thorough literature review
- Interviewed personnel from other highway agencies and industry representatives about their experiences with buckling in their jurisdiction
- Reviewed standards and specifications of six highway agencies neighboring Wisconsin
- Performed a field investigation and analyzed the data of eight buckling sites and three control sites in Wisconsin

"This project allows WisDOT to identify the main reasons for buckling incidents and mitigate future incidents with feasible solutions. WisDOT takes full advantage of these findings to enhance our concrete pavement practices by updating design specifications and maintenance guidance."

– Myungook (MK) Kang, WisDOT

Interested in finding out more?

Final report is available at: **WisDOT Research website**

- Simulated the risk of buckling using analytical modeling

Results

The research indicated that buckling is a phenomenon that develops over time, with many potential contributing factors and mechanisms. Key factors that contribute to Wisconsin's higher incidence of buckling relative to other midwestern and northeastern states, and much higher incidence of buckling relative to southern and northwestern states, include hot and humid summers with rainfall; concrete pavement operations performed during winter months, leaving joints unfilled or unsealed throughout the pavement's life; using an unbound aggregate base course beneath the concrete slab; and using salt, sand and grit to treat snowy and icy roads. Additional durability issues stem from using less durable concrete mixes in the past that contribute to moisture and salt damage of the hardened concrete, and the use of asphalt patches to repair spalling.

Significant differences between Wisconsin practices and those of neighboring agencies with fewer occurrences and a smaller probability of buckled joints involve the design of joints and drainage, and in maintenance and rehabilitation treatments and practices. Most of the agencies whose practices the research team reviewed seal or fill their JPCP transverse joints; Wisconsin's practice since 1990 has been to use a single saw cut for the JPCP transverse joint that is left unsealed or unfilled throughout the pavement's life. The literature suggests that leaving the transverse joint unsealed or unfilled throughout the pavement's life results in incompressibles collecting in the joints.

Recommendations for implementation

To reduce the occurrences of buckling in Wisconsin, the research team recommends using a single saw cut and filling transverse joints with a low-modulus sealant; reviewing and updating cold weather practices; optimizing concrete mixtures for strength and durability; using concrete with lower CTE; repairing spalled joints with concrete full- or partial-depth patches as soon as practical; providing positive drainage in areas susceptible to water; using a stabilized base course; using wider paved shoulders and vegetation beyond shoulders; experimenting with forcing joints to activate; and using pressure relief expansion joints as a last resort. WisDOT will evaluate the impact of executing one or more of these recommendations in terms of initial costs, bid prices, life cycle costs, pavement maintenance and rehabilitation costs, etc., and analyze the costs in view of the benefits, such as reduced buckling and improved pavement performance. The research results are guiding a new specification which will be implemented by 2025.

This brief summarizes Project 0092-20-02,
"Evaluation of Concrete Pavement Buckling in Wisconsin"
Wisconsin Highway Research Program

Expansion of AASHTOWare Mechanistic-Empirical (ME) Design Inputs

Research Objectives

- Expand the current PMED material library using asphalt mixtures being paved in Wisconsin
- Estimate the empirical asphalt structural layer coefficient to represent the current asphalt mixtures being placed in Wisconsin
- Understand how material/construction specification changes influence PMED changes

Research Benefits

- Expanding the materials library supports efforts to implement the PMED software in Wisconsin
- Provided an update to the structural layer coefficients required by the AASHTO Interim Design Guide to represent current asphalt mixtures being placed in Wisconsin
- Updated XML files for use in the PMED software to avoid input errors

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Background

The Wisconsin Department of Transportation (WisDOT) has supported several research studies in the past decades to measure the mechanical or performance properties of asphalt mixtures in support of the AASHTOWare Pavement ME Design (PMED) software to design pavement structures in Wisconsin. The outcome of those studies was to prepare a library or catalog of the asphalt materials inputs that can be integrated into the WisDOT pavement design practice for using the AASHTOWare PMED. The material properties required for the AASHTOWare PMED software are tied to a hierarchical input approach: Level 1 inputs represent project-specific mixture properties derived from comprehensive laboratory and/or field testing; Level 2 inputs are calculated from volumetric properties or other variables using regression equations embedded in the PMED software; and Level 3 inputs represent “best-guessed” material properties.

The primary objective of this study was to expand the existing PMED software’s material library by testing asphalt mixtures being paved in Wisconsin. Additionally, the research team aimed to estimate the empirical asphalt structural layer coefficient needed by the AASHTO 1972 Interim Design Guide to represent current asphalt mixtures being placed in Wisconsin and understand how material specification changes influence the PMED inputs for Levels 1, 2 and 3. The study’s outcomes will also help WisDOT understand how frequently the PMED inputs library needs to be updated and expanded.

Methodology

The outcome of WHRP 0092-08-06 and WHRP 0092-10-17 research studies provided the mechanical properties for WisDOT asphalt mixtures with a complete Level 1 library of asphalt mixtures.

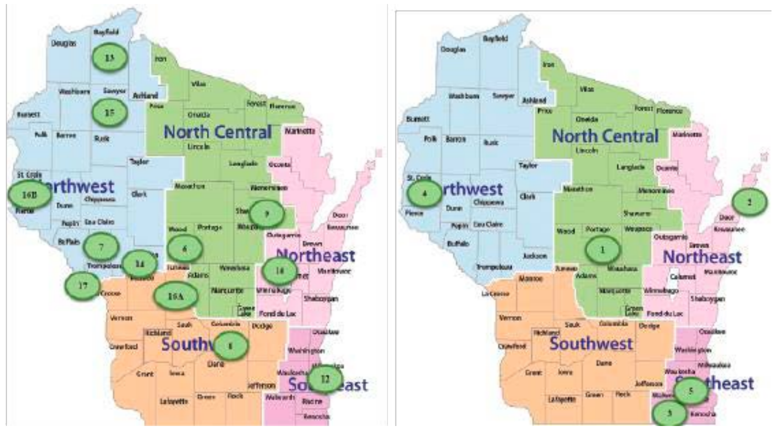
This study tested asphalt binders and mixtures with the following tests: dynamic modulus, IDT creep compliance and strength, repeated load plastic strain, bending beam fatigue strength and IDT strain at failure. Six binder grades have been used in Wisconsin construction projects since 2019; the final test plan included all six from two sources, for 12 total asphalt binder samples. Five base mixtures were sampled throughout the state; a total of 17 combinations of binders and bases were tested. The map (below, left) shows the sample sites for the 12 asphalt binders; the map on the right shows the sample sites for the five base mixtures.

“Results from this study are going to improve WisDOT’s pavement design process.”

– Erik Lyngdal, WisDOT

Interested in finding out more?

Final report is available at:
[WisDOT Research website]



Maps of procurement sites for asphalt surface and base mixtures

To determine the 1993 AASHTO structural layer coefficients from laboratory test results, the research team calculated the structural layer coefficient from the asphalt mixture modulus using the 1993 AASHTO regression equation and back-calculated the structural layer coefficient from the distress predictions of the PMED software.

Results

This research study expanded the PMED software’s material library by testing asphalt mixtures that are being paved in Wisconsin. The catalog includes the Level 1 material inputs selected by pavement designers in Wisconsin to reflect the mixtures used in day-to-day practice. The input Level 1 measured asphalt properties were found to be consistently different from the input Level 3 default properties included in the PMED software. The asphalt mixtures that exhibited poor rut depth resistance did exhibit better resistance to bottom-up fatigue cracks; the dynamic modulus between the different mixtures, however, was not significantly different.

Recommendations for implementation

This study resulted in the creation of XML files of asphalt binders and mixtures, and of subgrade soils that can be input into the PMED software to simplify the inputs and reduce the potential for input errors. WisDOT should consider and use both previous and new asphalt and soil XML files in future calibration efforts to verify global calibration coefficients. The research team also recommends a new structural coefficient for hot material asphalt (HMA) materials, if warranted, as well as a sampling strategy to verify and update HMA materials inputs with time. These research results were implemented by creating a new design method and were completed in 2021.

This brief summarizes Project 0092-20-03,
“Expansion of the AASHTOWare ME Design Inputs for Asphalt Layers”
Wisconsin Highway Research Program

Completed Research Brief

Wisconsin Highway Research Program
Project 0092-21-01
December 2022

Development of Design Procedures for Concrete Adhesive Anchors

Research Objectives

- Provide simplified design guidance for adhesive anchor use on WisDOT projects
- Provide design guidance and examples for adhesive anchors used for concrete parapet replacement on WisDOT projects

Research Benefits

- New guidance on the use of adhesive anchors in multiple applications that allows for increased use in WisDOT projects

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Background

Concrete adhesive anchors are used in new and retrofitted transportation structures by WisDOT and other departments of transportation (DOTs). Adhesive anchors can be reinforcing bars or threaded rods installed in holes drilled in concrete and anchored with a polymeric adhesive. Current applications of adhesive anchors by WisDOT include backwall, pacing block and wing replacements (upper and lower sections), and abutment and pier extensions. The use of adhesive anchors for sustained loads in overhead applications has been prohibited by many state DOTs, including WisDOT. This project focused on providing simplified design guidance for adhesive anchor use on WisDOT projects. The project also resulted in providing design guidance and examples for adhesive anchors used for concrete parapet replacement on WisDOT projects, which is currently not allowed for wingwall replacement and for abutment extension.

Methodology

The project consisted of a literature review, written survey of state DOTs, design examples for adhesive anchors in three different applications, laboratory testing of wingwalls simulating an upper wingwall replacement, review of WisDOT policy, and recommendations based on findings.

Results

The literature review found the American Association of State Transportation Officials (AASHTO) and the American Concrete Institute (ACI) specify that adhesive anchors must be designed, detailed and installed using the provisions of ACI 318-14, Ch. 17, except for two modifications regarding adhesive anchors under impact loading and sustained tension. Sustained tensile loading is addressed in both ACI 318 and AASHTO specifications by including a sustained load factor. State DOTs specify if and when adhesive anchors can be used in sustained load applications.

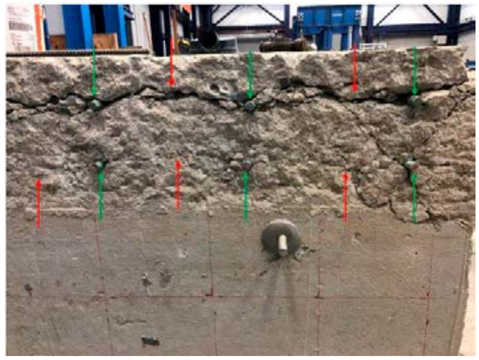
Few adhesive manufacturers have information regarding bond strength of coated reinforcing bars. ACI 318 provides lower-bound default values for anchors meeting the qualification requirements of ACI 355.4 where the product-specific characteristic bond stress is not known. These default values are much smaller than those of products in the WisDOT-approved product list; therefore, using them would generally result in designs that are too conservative.

"This research provides current guidance and recommendations for improving WisDOT's utilization of concrete adhesive anchors in transportation structures."

– James Luebke, WisDOT

Interested in finding out more?

Final report is available at:
WisDOT Research website



Test Sample B2. Green arrows point to the reinforcement anchors. Red arrows point to cracks between a row of anchors.

Testing was conducted to simulate an upper wingwall replacement on top of an existing lower wingwall to determine performance of epoxy coated reinforcing bars adhesively anchored into the lower wingwall and cast into the upper wingwall. A total of two test samples were fabricated to represent an upper wingwall replacement on a lower wingwall. The performance of both walls was similar in that the ultimate load values and cold-joint opening displacement and load reinforcing bar strain characteristics were similar. Calculations were made based on ACI design equations to determine the anticipated failure mode of the adhesively anchored reinforcement in the lower wingwall. The failure modes considered were concrete breakout, reinforcing steel yield and fracture, and adhesive bond failure. The controlling calculated design strength failure mode was concrete breakout. The tests of the wingwalls indicated the ACI design procedure results in a design that is conservative for this application.

Recommendations for implementation

The researchers recommended WisDOT consider the following changes. Pending FHWA approval of the revised specification, these results will be implemented in 2024:

- Allow adhesive anchors in parapets with strict adherence to manufacturer installation instructions and design procedures following AASHTO and ACI specifications with AASHTO- designed anchor capacity limited by anchor spacing.
- Allow adhesive anchor use in sustained tensile loading applications.
- Allow adhesive anchors in overhead or upwardly inclined installation applications.
- Allow alternative design approaches to utilize high bond strength products.
- Change installation procedure requirements in the WisDOT Standard Specification to follow the manufacturers' published installation instructions and allow adhesive anchors in abutment wingwall replacement.
- Allow adhesive anchors for concrete parapet replacement.

This brief summarizes Project 0092-21-01,
"Development of Design Procedures for Concrete Adhesive Anchors"
Wisconsin Highway Research Program

Wisconsin Highway Research Program
Project 0092-21-05
April 2022

Material Specifications for Longitudinal Joint Construction, Remediation and Maintenance

Research Objectives

- Identify and compare materials, processes, and experiences to improve longitudinal joint performance during and after construction
- Recommend best practices for selected materials and processes relative to Wisconsin standard practice
- Summarize quality assurance requirements for each selected alternative

Research Benefits

- Recommends WisDOT continue current standard practice regarding joint geometry and testing of joint density
- Recommends implementing Void Reducing Asphalt Membrane (VRAM) during construction on a trial basis
- Recommends using penetrating asphalt emulsions as a preventative and remedial treatment for longitudinal joints

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Background

Asphalt pavement density at and near longitudinal construction joints is often significantly lower than density in the mainline areas of the pavement: this can manifest in premature deterioration of the joint area relative to the mainline. This project's objective is to synthesize the most probable solutions to deliver better longitudinal joints in Wisconsin. Distress associated with longitudinal joints is not confined to a single mix type or geographical area.

The research team identified causal mechanisms of premature longitudinal joint failure, ranging from inability to achieve sufficient density at the joint location, infiltration and subsequent damage from water at the joint, mixture segregation, aggregate bridging, and others.

Many states have enhanced or created joint performance specifications over the last decade. WisDOT's WHRP Project 0092-15-09 investigated the influence of construction practice, mix design type, and joint type on the density achieved at the joint location. Since the time of that report, WisDOT has further modified its mixture design and production specification, harmonized joint construction technique among regions, refined the longitudinal joint density specification, and built a more robust data set of paving jobs on which longitudinal joint density was a pay item for contractors. Joint improvement should focus on reducing permeability of water and air both at and near the joint directly or indirectly.

Methodology

The research team used information and data extracted from a literature review, a review of state agencies' standard practices, a review of WisDOT pavement annual distress survey data, and interviews of several pavement experts to define the most probable practices to further improve joint performance based on understanding the causes of distress. In addition to reviewing state DOT standard practices in the U.S., the research team conducted a limited review of practices in Germany, United Kingdom, Sweden, and China. Methods like cutting or milling back of joints is more popular internationally than in the U.S., but much of the same methodology practiced in the U.S. is used overseas, like overlap and pinching of the joint, and use of tack or paving asphalt to coat the joint face. From this review of methods and materials, the research team developed a framework for identifying and comparing the effectiveness of various joint materials, methods and experiences that have shown good results.

> *"This research helps to confirm the direction the department has taken with recent changes to longitudinal joint specifications."*
>
> *– Project Manager Dan Kopacz, WisDOT*

Interested in finding out more?

Final report is available at: [**WisDOT Research website**]

Results

Reducing mixture permeability at and near the joint is identified as the most promising method to improve joint performance. Based on findings, the research team proposes an organizational structure comprised of three categories for joint improvement materials and methods: Construction and Design (CD) are considerations that include specifying joint geometry, paving methods, and plans for testing of joint density that can be specified before construction; Methods and Materials During Construction (MDC) includes supplementary processes and materials during construction, such as using joint adhesive on the cold face of the joint, or applying a strip of special membrane; Methods and Materials Post-Construction (MPC**)** includes processes and materials used immediately following construction, before joint deterioration requires extensive structural repair or replacement, such as fog sealing and spraying penetrating asphalt emulsions on the joint following construction.

Categories of joint improvement materials and methods

Recommendations for implementation

The research team recommends that WisDOT continue its current standard practice regarding joint geometry and testing of joint density, but also consider evaluation of other alternatives that show significant promise in reducing risk of premature joint failures and minimizing the risk of accepting lower density at the joints relative to mainline of pavements. Based on published data and review of case studies, implementing and evaluating Void Reducing Asphalt Membrane (VRAM) during the construction process on a trial basis is recommended. Post-construction, it is recommended to use penetrating asphalt emulsions as a preventative and remedial treatment for longitudinal joints. In addition, the team recommends a more focused look at collecting and analyzing the Pavement Condition Index (PCI) database, which is an invaluable tool for understanding costs associated with joint performance. The team recommends refining this project-specific database and more accurately developing the longitudinal joint distress collection procedure to help justify the use of more costly processes or materials shown to improve joint performance. Pending FHWA approval of the revised specifications, these results will be implemented in 2025.

This brief summarizes Project 0092-21-05,
"Material Specifications for Longitudinal Joint Construction, Remediation and Maintenance"
Wisconsin Highway Research Program

Policy research projects

Funding included in the Research Federal Work Plan from State Planning & Research-Part B is being used to conduct several policy research projects in partnership with IPIT. Three projects were completed in Federal Fiscal Year 2022

Workforce Development Initiative, Phase 1

(IPIT 0092-21-62)

Project Brief and Final Report:

https://wisconsindot.gov/documents2/research/0092-21-62-final-report.pdf

WisDOT Division and Project Lead:

Jerry Mentzel, DTSD

Research Team:

Dr. Romila Singh, Associate Professor Lubar School of Business; Dr. Xiao Qin, IPIT Director; and Mark Gottlieb, IPIT Associate Director

Research Objectives:

The purpose of this project was to understand and analyze the nature of personnel gaps in WisDOT's Division of Transportation System Development (DTSD) and offer recommendations on how best to address these gaps.

Research Findings:

Three broad recommendations were offered based on analysis conducted by the UWM-IPIT team: (1) establish a team of workforce planning professionals to engage in annual/biennial workforce planning activities that are coordinated with the strategic planning process and engage multiple layers of leadership; (2) develop succession planning and knowledge management programs that are aligned with strategic workforce planning and development plans; (3) re-envision retention practices that are aligned with strategic workforce planning and development needs and focus on core competency training, establishing communities of practice, and career development programs.

Evaluation of the Local Bridge Improvement Assistance Program – Low-Risk Pilot

(IPIT 0092-21-63)

Project Brief and Final Report:

https://wisconsindot.gov/documents2/research/0092-21-63-final-report.pdf

WisDOT Division and Project Lead:
Brandon Lamers, DTSD

Research Team:

Dr. Habib Tabatabai, Professor Civil and Environmental Engineering and Dr. Xiao Qin, IPIT Director

Summary:

In 2019, a pilot program was initiated by WisDOT in consultation with the Wisconsin County Highway Association (WCHA) to streamline the delivery and oversight of low-risk local bridge projects. The goal of this research project was to evaluate the low-risk local bridge pilot program and make recommendations before its implementation on a larger scale. Analysis shows the pilot program provides significant improvements with regards to time saved and budget, but the influence over project quality was not conclusive. The research team recommends training programs for both WisDOT and local government staff. This training should be focused on three aspects: (1) The goals of the program and ways to successfully achieve them should be clarified. (2) The reduced oversight requirements of the low-risk pilot program (when compared with traditional projects) should be understood by all, and expectations of all parties should be clarified. (3) Local officials who want to participate in the program should be trained to meet a minimum set of technical qualifications. The research team further recommends modifications to some of WisDOT's performance measures related to project quality metrics.

Data Inventory/Catalog

(IPIT 0092-21-65)

Project Brief and Final Report

https://wisconsindot.gov/documents2/research/0092-21-65-final-report.pdf

WisDOT Division and Project Lead:

Michael Kessenich, DBM

Research Team:

Dr. Andrew Graettinger, Associate Dean for Research and Professor Civil and Environmental Engineering; Dr. Xiao Qin, IPIT Director; and Mark Gottlieb, IPIT Associate Director

Research Objectives:

As WisDOT increasingly strives to make data-driven decisions, it is crucial to maintain centralized and consistent information about datasets throughout the entire enterprise. The WisDOT Data Inventory Catalog research project focused on finding digital datasets and pertinent information about those datasets throughout WisDOT.

Research Findings:

From the analysis and variety of survey results, the researchers recommend that WisDOT establish enterprise-wide data governance and data cataloging which will harmonize data sources, properly control access, document ownership, and create both technical and descriptive information about the who, what, where, when, and why of enterprise data.

Technology transfer and library activities

The WisDOT Research and Library Services provides information services for WisDOT staff and supports implementation of research results. Through services including synthesis reports and literature searches, we connect WisDOT employees with the most up-to-date research and industry trends.

Synthesis reports

A synthesis report is an evaluation of other state transportation agencies' policies and procedures made by comparing, contrasting, and combining information gathered from agencies' websites or through electronic surveys. Three synthesis reports were completed in FFY 2022 on the topics of transportation equity; diversifying workforce recruitment; and traffic-demand modeling.

Literature searches

A literature search is a systematic and thorough search of all types of published literature to identify a breadth of quality references relevant to a specific topic. Customers apply the collected information to decision making for funding and crafting research efforts and for general policy improvement. 27 literature searches were completed in FFY 2022. Topics included: national safety trends during the pandemic, supply chain challenges for Wisconsin companies, attitudes and perceptions related to electric and autonomous vehicles, and local program utility coordination.

WisDOT library services

Library staff handled 280 information requests, and delivered 526 digital items (books, reports, periodicals, and articles).

Historical Wisconsin Highway Maps

The WisDOT Library was a key participant in a project spearheaded by the Division of Transportation System Development's (DTSD) Cartography Unit to digitize historic Wisconsin highway maps for public access. The library donated several historic maps to the project, including maps from the 1920s and 1930s. These digitized maps, dating as far back as 1916, can be found on WisDOT's official Wisconsin Highway Map web page.

Completed research projects

PROGRAM	PROJECT ID	PERFORMING ORGANIZATION	PRINCIPAL INVESTIGATOR	PROJECT BUDGET	WISDOT PROJECT MANAGER	PROJECT TITLE	IMPLEMENTATION METHOD	COMPLE-TION DATE
WHRP – Rigid – Pavement	0092-17-07	Behnke Materials Engineering, L.L.C.	Signe Reichelt	$275,000	Myungook Kang, Leslie Hidde	Evaluation of Current WI Mixes Using Performance Engineered Mixtures Testing Protocols	New design method or guidance	7/2022
WHRP – Structures	0092-19-02	CTL Group - Materials & Mechanics	Jose Pacheco	$194,555	William Oliva	Internal Curing of Bridge Decks and Concrete Pavement to Reduce Cracking	Revise a specification	10/2021
WHRP – Structures	0092-20-01	Iowa State University	Brent Phares	$220,000	Alex Pence	Analytical and Testing Methods for Rating Longitudinal Laminated Timber Slab Bridges	Revise a specification	12/2021
WHRP – Rigid Pavement	0092-20-02	Applied Research Associates, Inc.	Shreenath Rao	$200,000	Myungook Kang	Evaluation of Concrete Pavement Buckling in Wisconsin	New design method or guidance	2/2022
WHRP – Flexible Pavement	0092-20-03	Applied Research Associates, Inc.	Harold Von Quintus	$215,000	Erik Lyngdal	Expansion of AASHTOWare ME Design Inputs	New design method or guidance	3/2022
WHRP – Structures	0092-21-01	Wiss, Janey, Elstner Associates Inc.	John Pearson	$150,000	Adam Swierczek	Development of Design Procedures for Concrete Adhe-sive Anchors	New design method or guidance	9/2022
WHRP – Flexible Pavement	0092-21-05	University of Wisconsin – Madison	Hussain Bahia	$80,000	Daniel Kopacz	Material Specifi-cations for Lon-gitudinal Joint Construction, Remediation, and Maintenance	Revise a specification	12/2021

Ongoing research projects

PROGRAM	PROJECT ID	PERFORMING ORGANIZATION	PRINCIPAL INVESTIGATOR	PROJECT BUDGET	WISDOT PROJECT MANAGER	PROJECT TITLE	ANTICIPATED IMPLEMENTATION STATUS
WHRP – Geotech	0092-20-05	University of Wisconsin – Milwaukee	Hani Titi	$175,000	Erik Lyngdal	Quality Testing of Wisconsin Aggregates	Revise a specification
WHRP – Structures	0092-21-02	Northwestern University	James Hambleton	$80,000	Steve Neary	Optimizing Bridge Abutment Slope Protection at Stream Crossings	Revise a specification, new product implementation
WHRP – Rigid Pavement	0092-21-03	University of Wisconsin – Platteville	Danny Xiao	$150,000	Kevin McMullen	Evaluating the Impact of Anti-Icing Solutions on Concrete Durability	Revise a specification, new product implementation
WHRP – Flexible Pavement	0092-21-04	Advanced Asphalt Technologies, LLC	Donald Christensen	$175,000	Tirupan Mandal	Interlayer Mixture Design	Develop an alternative testing method
WHRP - Geotech	0092-21-06	BGC Engineering USA, Inc.	Scott Anderson	$140,868	Dave Staab	Geotechnical Asset Management for Slopes	Develop a model
WHRP - Structures	0092-22-01	University of Wisconsin – Milwaukee	Habib Tabatabai	$150,000	James Luebke	Improving Bridge Concrete Overlay Performance	Revise a specification
WHRP – Rigid Pavement	0092-22-02	Applied Research Associates, Inc.	Shreenath Rao	$130,000	Leslie Hidde	Field Investigation of Dowel and Tie Bar Placement	Revise a specification
WHRP – Rigid Pavement	0092-22-03	University of Missouri – Kansas City	John Kevern	$130,000	Mark Finnell	Timely and Uniform Application of Curing Materials	Revise a specification
WHRP – Flexible Pavement	0092-22-04	NCAT at Auburn University	Randy West	$250,000	Tirupan Mandal	Balanced Mixture Design Pilot and Field Test Sections	Recommended future studies
WHRP – Geotech	0092-22-05	Michigan State University	Bora Cetin	$125,000	Andrew Zimmer	Weight-Volume Relationships and Conversion Factors for Soils and Aggregates of Wisconsin	Develop a model
WHRP – Rigid Geotech	0092-22-06	Iowa State University	Alice Alipour	$200,000	Jeffrey Horsfall	Wind-Loaded Structures	Develop a model, Revise a specification

Pooled fund participation

PROJECT NUMBER	TITLE	FFY 2022 FUNDING AMOUNT	WISDOT TECHNICAL REPRESENTATIVE	LEAD AGENCY/ STATE
TPF-5(255)	Highway Safety Manual Implementation	N/A	Kevin Scopoline	FHWA
TPF-5(283)	The Influence of Vehicular Live Loads and Bridge Performance	N/A	Alex Pence	FHWA
TPF-5(305)	Regional and National Implementation and Coordination of ME Design	N/A	Tirupan Mandal	FHWA
TPF-5(317)	Evaluation of Low-Cost Safety Improvements	N/A	Kevin Scopoline	FHWA
TPF-5(326)	Develop and Support Transportation Performance Management Capacity Development Needs for State DOTs	N/A	JoAnn Prange	Rhode Island
TPF-5(335)	2016-2020 Biennial Asset Management Conference and Training on Implementation Strategies	N/A	Scot Becker	Iowa
TPF-5(347)	Development of Maintenance Decision Support System	$30,000	Mike Adams	South Dakota
TPF-5(351)	Self-De-Icing LED Signals	N/A	Brian Klipstien	Kansas
TPF-5(352)	Recycled Materials Resource Center, 4th Generation	N/A	Barry Paye	Wisconsin
TPF-5(368)	Performance Engineered Concrete Paving Mixtures	N/A	James Parry	Iowa TPF-5(370)
TPF-5(370)	Fostering Innovation in Pedestrian and Bicycle Transportation Pooled Fund	N/A	Christopher Squires	FHWA
TPF-5(372)	Building Information Modeling (BIM) for Bridges and Structures	$20,000	Scot Becker	Iowa
TPF-5(374)	Accelerating Performance Testing on the 2018 NCAT Pavement Test Track with MnROAD Research	N/A	Steve Hefel	Alabama
TPF-5(375)	National Partnership to Determine the Life Extending Benefit Curves of Pavement Preservation Techniques (MnROAD/NCAT Joint Study Phase 2)	$100,000	Ali Morovatdar	Minnesota
TPF-5(377)	Enhanced Traffic Signal Performance Measures	N/A	Jeremy Iwen	Indiana
TPF-5(381)	Evaluation of Lateral Pile Resistance Near MSE Walls at a Dedicated Wall Site Phase 2	N/A	Jeff Horsfall	Utah
TPF-5(382)	Drivers Failing to Yield at Multi-Lane Roundabout Exits	N/A	Rebeca Szymkowski	FHWA
TPF-5(385)	Pavement Structural Evaluation with Traffic Speed Deflection Devices (TSDDs)	$154,000	Ali Morovatdar	Virginia
TPF-5(388)	Developing Implementation Strategies for Risk Based Inspection (RBI)	N/A	Steve Doocy	Missouri
TPF-5(389)	Connected Vehicle Pooled Fund Study	$100,000	Anne Reshadi	Virginia
TPF-5(395)	Traffic Disruption-Free Bridge Inspection Initiative with Robotic Systems	$50,000	David Bohnsack	Missouri
TPF-5(396)	Mid-America Freight Coalition, Phase 3	$37,000	Matt Umhoefer	Wisconsin

Pooled fund participation *(continued)*

PROJECT NUMBER	TITLE	FFY 2022 FUNDING AMOUNT	WISDOT TECHNICAL REPRESENTATIVE	LEAD AGENCY/ STATE
TPF-5(399)	Improve Pavement Surface Distress and Transverse Profile Data Collection and Analysis, Phase 2	$20,000	Andrew Schilling	FHWA
TPF-5(430)	Midwest Roadside Safety Pooled Fund Program	$65,000	Erik Emerson	Nebraska
TPF-5(432)	Bridge Element Deterioration for Midwest States	$20,077	Philip Meinel	Wisconsin
TPF-5(435)	Aurora Program (FY20-FY24)	$50,000	Mike Adams	Iowa
TPF-5(437)	Technology Transfer Concrete Consortium (FY20-FY24)	$8,000	James Parry	Iowa
TPF-5(438)	Smart Work Zone Deployment Initiative (FY20-FY24)	$50,000	Erik Schwark	Iowa
TPF-5(441)	No Boundaries Transportation Maintenance Innovations	$20,000	Chris Ohm	Colorado
TPF-5(442)	Transportation Research and Connectivity	$15,000	John Cherney	Oklahoma
TPF-5(443)	Continuous Asphalt Mixture Compaction Assessment using Density Profiling System (DPS)	$25,000	James Parry	Minnesota
TPF-5(447)	Traffic Control Device (TCD) Consortium (3)	$10,000	Matt Rauch	FHWA
TPF-5(448)	Integrating Construction Practices and Weather into Freeze Thaw Specifications	$20,000	James Parry	Oklahoma
TPF-5(458)	Traffic Analysis, Modeling, and Simulation	$20,000	Vicki Haskell	FHWA
TPF-5(460)	Flood-Frequency Analysis in the Midwest: Addressing Potential Nonstationary Annual Peak-Flow Records	$55,600	Steve Neary	South Dakota
TPF-5(465)	Consortium for Asphalt Pavement Research and Implementation (CAPRI)	$20,000	Daniel Kopacz	Alabama
TPF-5(466)	NRRA - Phase II	$150,000	Barry Paye	Minnesota
TPF-5(467)	Research Project Tracking System	N/A	Diane Gurtner	Kentucky
TPF-5(472)	2021 Innovations in Freight Data Workshop	N/A	Dan Thyes	Iowa
TPF-5(478)	Demonstration to Advance New Pavement Technologies Pooled Fund	$10,000	Erik Lyngdal	FHWA
TPF-5(479)	Clear Roads Winter Highway Operations Phase 3 Pooled Fund	$25,000	Emil Juni	Minnesota
TPF-5(480)	Building Information Modeling (BIM) for Infrastructure	$30,000	Drew Kottke	Iowa
TPF-5(486)	Steel Bridge Research, Inspection, Training and Education Engineering Center (SBRITE)	$30,000	Travis McDaniel	Indiana
TPF-5(487)	Transportation Management Centers Pooled Fund Study Phase 2	$50,000	Randall Hoyt	FHWA
TPF-5(490)	Enterprise- Phase 3 (Phase 2 Continuation)	$30,000	Elizabeth Lloyd-Weis	Michigan

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