WisDOT Research Program

Annual Report 2018

Foreword

I am pleased to present the Wisconsin Department of Transportation (WisDOT) 2018 annual report on research activities. This report highlights WisDOT's efforts to uphold its mission to provide leadership in the development and operation of a safe and efficient transportation system.

WisDOT's award-winning, $4.09 million research program supports the department's culture of data-driven decision making and accountability to the public through the implementation of promising policies, materials and technologies. The program completed six projects through the Wisconsin Highway Research Program (WHRP), led three Transportation Pooled Fund (TPF) Program projects and participated in 39 others. The American Association of State Highway Transportation Officials (AASHTO) recognized WHRP's *Critical Factors Affecting Asphalt Concrete Durability* as one of the nation's highest-value research projects in its annual Research Makes the Difference "*Sweet 16*" publication.

The department 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. WisDOT hosted a peer exchange on research, development and technology. The event included research staff from five state DOTs, the Transportation Research Board (TRB) and Federal Highway Administration, who shared best practices for conducting research programs that effectively implement innovative ideas. Research staff completed four synthesis reports and 28 literature searches; responded to 213 customer inquiries; and delivered 480 items.

I am proud to recognize these accomplishments and would like to thank the staff that serve in at least one role on more than 200 research committees and panels at the national and state levels. Their expertise and guidance are critical to the success and implementation of research.

Dave Ross, 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 2 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 2018, covering October 1, 2017 through September 30, 2018.

Contents

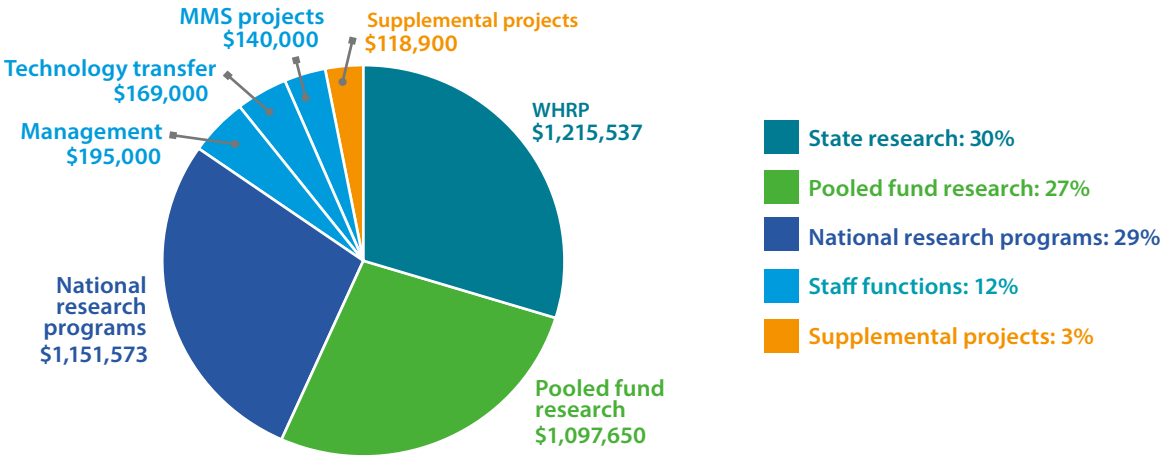
Common acronyms used in this document

AASHTO	American Association of State Highway and Transportation Officials
DBM	(WisDOT) Division of Business Management
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
FHWA	Federal Highway Administration
NCHRP	National Cooperative Highway Research Program
OMB	Office of Management and Budget
SHRP2	The Second Strategic Highway Research Program
SPR	State Planning and Research Program
TPF	Transportation Pooled Fund
TRB	Transportation Research Board
UW	University of Wisconsin
WHRP	Wisconsin Highway Research Program
WisDOT	Wisconsin Department of Transportation

Program overview

The Wisconsin Department of Transportation (WisDOT) managed a $4.09 million program for research, library and technology transfer services during federal fiscal year (FFY) 2018. The State Planning and Research Part 2 (SPR2) federal program funded 92 percent ($3.7 million) of the program, while state funds covered the remaining eight percent ($.34 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. It focuses on geotechnics, structures and flexible and rigid pavements. Policy research addresses non-engineering issues such as planning, operations and safety. See pages 7–9 for all completed and in-progress projects.

Pooled fund research

The Transportation Pooled Fund (TPF) program allows federal, state and local agencies and other organizations to combine resources to support transportation research studies of common interest. In FFY 2018, WisDOT research led three pooled fund projects and provided support for 39 others. These projects range in scope and include advances in engineering methods and materials; safety; and performance management. For a full list of pooled fund projects, see pages 10–11.

Supplemental projects

WisDOT partners with the University of Wisconsin–Madison to further transportation research through the Construction and Materials Support Center (CMSC) and Traffic Operations and Safety (TOPS) Laboratory.

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 the transportation knowledge and research findings contributes to continuous performance improvement. The research program funds technology transfer activities and library services to coordinate dissemination of research recommendations to enhance operations within the department. Funds for WisDOT's Materials Management Section (MMS) projects are also included in the research program.

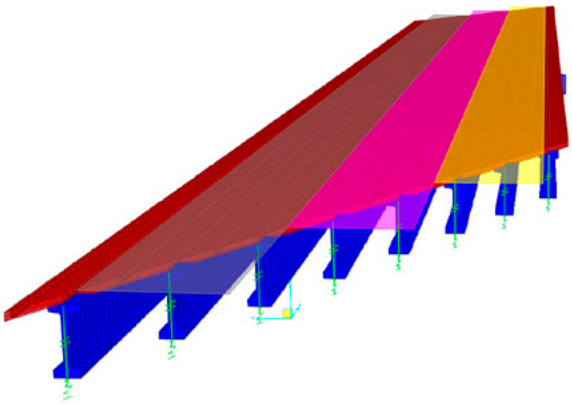
Featured research

Examples of research that contribute to achieving the department's strategic mission are listed below. The realized or anticipated impacts to the state of practice are included for each project, to reaffirm the department's commitment to data-driven decision making through implementation of applied research recommendations.

Design & Performance of Highly Skewed Deck Girder Bridges

WHRP 0092-16-05

Project Brief and Final Report:
wisconsindot.gov/Pages/about-wisdot/research/structures.aspx



Highly skewed bridges are more complex and pose more challenges than bridges that pass perpendicularly over the road or other features below it. However, as infrastructure demands increase and the amount of undeveloped land decreases, skew is becoming more commonplace in bridge construction.

The goal of this project was to investigate the performance of high-skew bridges and recommend strategies to mitigate negative impacts of skew.

Results of the research showed that skew angle of a bridge correlates positively with deck cracking and that shrinkage is the main cause. High skew also caused larger superstructure in-plane displacements compared to bridges with no skew, particularly in the transverse direction.

The research team recommended complementing girder line analysis with accurate and computationally-efficient two-dimensional bridge analysis to increase safety margins in designing high-skew bridges.

This project yielded superstructure and bearing design recommendations that will improve the highly skewed bridges' resistance to deck cracking and racking and expansion joint displacements.

Evaluation of Protocols for Determining Asphalt Binder Content and PG Characteristics

WHRP 0092-16-02

Project Brief and Final Report:
wisconsindot.gov/Pages/about-wisdot/research/flex-pave.aspx

AASHTO solvent extraction and ignition tests are well established methods for determining asphalt content and ensuring quality mixes. However, test accuracy is sensitive to variations in materials and high recycled binder content mixes commonly used in Wisconsin.

The main objectives of this research were to evaluate solvent extraction, ignition and asphalt analyzer test procedures; determine tolerances between methods; and modify WisDOT material and mix standards.

The within-lab and between-lab standard deviations and acceptable ranges of the asphalt analyzer, centrifuge extraction and reflux extraction tests met AASHTO T 164 requirements. The ignition method's within-lab and between-lab standard deviations and acceptable ranges exceeded AASHTO T 308 specifications.

The research team recommended WisDOT also allow asphalt analyzer and ignition.

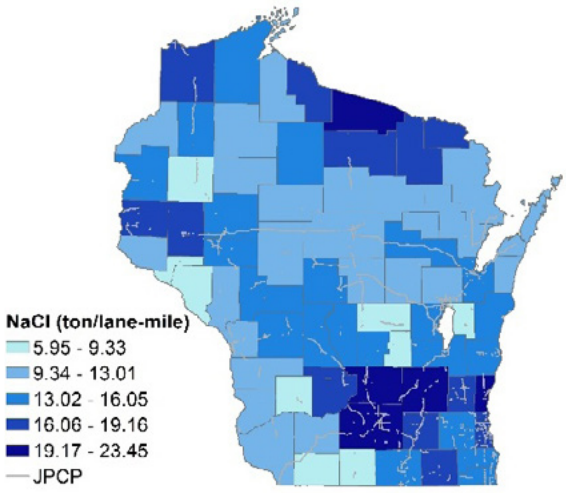
The project advanced both WisDOT's and its contractors' ability to verify the asphalt binder content in mixtures, which will ensure more durable pavements.

Featured research (continued)

Evaluation of the Effects of Deicers on Concrete Durability

WHRP 0092-17-03

Project Brief and Final Report:
wisconsindot.gov/Pages/about-wisdot/research/rigid-pave.aspx



Wisconsin experiences approximately 13 to 55 winter events per year, with annual snowfall ranging from 15 to 132 inches. Anti-icing and deicing materials can mitigate the dangers of winter road conditions, but rock salt and other chemicals may cause pavement damage.

The goal of this research was to identify what deicing and anti-icing materials are used in Wisconsin and their effects on concrete pavement durability.

Survey results and WisDOT data analysis confirmed that rock salt and salt brine are the primary anti-icing and deicing materials used in Wisconsin. Accelerated deterioration near joints and bridge decks were the main durability concerns.

The research team recommend rock salt and salt brine remain the primary materials for deicing and anti-icing, limiting harsher treatments such as calcium chloride and magnesium chloride to winter events with temperatures below the effective limit of rock salt.

This research will help WisDOT reduce concrete deterioration by optimizing deicing and anti-icing material blends, application rates and technology.

Technology transfer and library activities

The Office of Management and Budget (OMB) Research and Library Services Unit provides information services for WisDOT staff and supports implementation of research results. Services provided in FFY 2018 include:

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. Four synthesis reports were completed in FFY 2018 on topics ranging from geogrid test methods to parklets.

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. Twenty-six literature searches were completed in FFY 2018. Topics included: cold-in-place recycling; winter brining recipes; pavement buckling; and freeze-thaw testing.

Library services

Library staff handled 213 customer inquiries, delivered 480 items (books, reports, standards and journal articles) and added 381 digital titles to the Wisconsin Digital Archives.

Library digitization

WisDOT is digitizing its physical collection of items published or sponsored by the department. Staff will organize and catalog all digitized items, leading to greater access for the department and item permanency through its partnership with the Wisconsin Digital Archives. Staff may borrow physical copies of materials through the library's participation in interlibrary loan and other resource sharing networks.

Completed research projects

PROGRAM	PROJECT ID	PERFORMING ORGANIZATION	PRINCIPAL INVESTIGATOR	PROJECT BUDGET	WISDOT PROJECT MANAGER	PROJECT TITLE	COMPLETION DATE
WHRP–Geotech	0092-15-06	University of Wisconsin–Milwaukee	Hani Titi	$119,997	Andrew Zimmer	Evaluation of the Long-Term Degradation and Strength Characteristics of In-situ Wisconsin Virgin Base Aggregates under HMA Pavements	6/2018
WHRP–Flexible Pavement	0092-16-02	NCAT at Auburn University	Carolina Rodezno	$150,000	Andrew Hanz	Asphalt Binder Extraction Protocol for Determining Amount & PG Characteristics of Asphaltic Mixtures	1/2018
WHRP–Structures	0092-16-05	University at Buffalo	Pinar Okumus	$150,000	Philip Meinel	Design & Performance of Highly Skewed Deck Girder Bridges	5/2018
WHRP–Flexible Pavement	0092-16-06	NCAT at Auburn University	Randy West	$150,000	Steven Hefel	Regressing Air Voids for Balanced HMA Mix Design Study	9/2018
WHRP–Rigid Pavement	0092-17-03	University of Wisconsin–Platteville	Danny Xiao	$60,000	Chad Hayes	Evaluation of the Effects of Deicers on Concrete Durability	6/2018
WHRP–Flexible Pavement	0092-17-04	University of Wisconsin–Madison	Hussain Bahia	$150,000	Stacy Glidden	Field Aging and Moisture Sensitivity Study	9/2018

Ongoing research projects

PROGRAM	PROJECT ID	PERFORMING ORGANIZATION	PRINCIPAL INVESTIGATOR	PROJECT BUDGET	WISDOT PROJECT MANAGER	PROJECT TITLE
WHRP–Rigid Pavement	0092-14-05	University of Wisconsin–Madison	Steven Cramer	$ 249,918	Kevin McMullen	Comparison of Fresh Concrete Air Content Test Methods & Analysis of Hardened Air Content in Wisconsin Pavements - Phase I and II
WHRP–Flexible Pavement	0092-15-05	Temple University	Ahmed Faheem	$ 100,000	Erv Dukatz	Evaluation of WisDOT Quality Management Program (QMP) Activities and Impacts on Pavement Performance
WHRP–Rigid Pavement	0092-16-01	Marquette University	James Crovetti	$ 199,825	Myungook Kang	Joint Sawing Practices and Effects on Durability Phase I and II
WHRP–Geotech	0092-16-03	Clemson University	Amir Poursaee	$ 149,938	Jeff Horsfall	Evaluation of H-pile Corrosion Rates for WI Bridges Located in Aggressive Subsurface Environments
WHRP–Structures	0092-16-04	University of Wisconsin–Madison	Gustavo Parra-Montesinos	$ 140,000	William Oliva	Staged Concrete Bridge Deck & Overlay Pours Adjacent to Live Traffic
WHRP–Geotech	0092-16-07	University of Missouri	Andrew Boeckmann	$ 110,000	Andrew Zimmer	Thermal Integrity Profiling for Detecting Flaws in Drilled Shafts
WHRP–Geotech	0092-17-01	University of Wisconsin–Milwaukee	Hani Titi	$ 99,990	Andrew Zimmer	Evaluation of Recycled Base Aggregates
WHRP–Structures	0092-17-02	University of Wisconsin–Milwaukee	Habib Tabatabai	$ 111,265	Aaron Bonk	Strength & Serviceability of Damaged Prestressed Girders
WHRP–Structures	0092-17-05	Simpson Gumpertz & Heger Inc.	Jesse Beaver	$ 100,000	Steve Neary	Performance and Policy Related to Aluminum Box Culverts and Pipe Culverts in Wisconsin
WHRP–Flexible Pavement	0092-17-06	University of Wisconsin–Madison	Hussain Bahia	$ 100,000	Steven Hefel	Investigation of Tack Coat Materials on Tracking Performance
WHRP–Rigid Pavement	0092-17-07	Behnke Materials Engineering, L.L.C.	Signe Reichelt	$ 124,962	Chad Hayes	Evaluation of Current WI Mixes Using Performance Engineered Mixtures Testing Protocols

Ongoing research projects (continued)

PROGRAM	PROJECT ID	PERFORMING ORGANIZATION	PRINCIPAL INVESTIGATOR	PROJECT BUDGET	WISDOT PROJECT MANAGER	PROJECT TITLE
WHRP–Geotech	0092-17-08	Geocomp Corporation	Allen Marr	$ 149,971	Andrew Zimmer	Monitoring of Lateral Earth Pressure and Movements of Cut Retaining Walls
WHR–Rigid Pavement	0092-18-01	University of Wisconsin–Platteville	Danny Xiao	$ 125,000	Kevin McMullen	Evaluation of Penetrating Sealers Applied to Saw Cut Faces in Concrete Pavement Joints
WHRP–Rigid Pavement	0092-18-02	Applied Pavement Technology, Inc.	Prashant Ram	$ 80,000	Jed Peters	Non-Cementious Repair Materials
WHRP–Structures	0092-18-03	Iowa State University	Basak Aldemir Bektas	$ 140,000	Ryan Bowers	Protocols for Concrete Bridge Deck Protections and Treatments
WHRP–Structures	0092-18-04	University of Wisconsin–Milwaukee	Konstantin Sobolev	$ 60,000	John Sendor	Concrete Underwater Placement Literature and Synthesis
WHRP–Flexible Pavement	0092-18-06	Pennsylvania State University	Mansour Solaimanian	$ 150,000	Erik Lyngdal	Enhanced Moisture Sensitivity Study
WHRP–Geotech	0092-18-07	University of Wisconsin–Madison	William Likos	$ 150,000	Jeff Horsfall	Mechanically Stabilized Earth (MSE) Wall Backfill Water Infiltration
WHRP–Flexible Pavement	0092-19-05	Behnke Materials Engineering, L.L.C.	Signe Reichelt	$ 165,000	Daniel Kopacz	Rubber Asphalt Study for Wisconsin

Pooled fund participation

PROJECT NUMBER	TITLE	FFY 2018 FUNDING AMOUNT	WISDOT TECHNICAL REPRESENTATIVE	LEAD AGENCY/ STATE
TPF-5(176)	Traffic Analysis and Simulation	N/A	Vicki Haskell, DTSD	FHWA
TPF-5(183)	Improving the Foundation Layers for Concrete Pavements	N/A	Jeff Horsfall, DTSD	Iowa
TPF-5(193)	Midwest States Pooled Fund Crash Test Program	$66,000	Erik Emerson, DTSD	Nebraska
TPF-5(206)	Research Program to Support the Research, Development, and Deployment of System Operations Applications of Vehicle Infrastructure Integration	$50,000	Anne Reshadi, DTSD	Virginia
TPF-5(219)	Structural Health Monitoring System	N/A	Scot Becker, DTSD	Minnesota
TPF-5(238)	Design and Fabrication Standards to Eliminate Fracture Critical Concerns in Two Girder Bridge Systems	N/A	Alex Pence, DTSD	Indiana
TPF-5(253)	Member-Level Redundancy in Built-up Steel Members	N/A	Alex Pence, DTSD	Indiana
TPF-5(255)	Highway Safety Manual Implementation	N/A	Brian Porter, DTSD	FHWA
TPF-5(264)	Passive Forced Displacement Relationships for Skewed Abutments	N/A	James Luebke, DTSD	Utah
TPF-5(267)	Accelerated Performance Testing for the NCAT Pavement Test Track	N/A	Steve Krebs, DTSD Barry Paye, DTSD	Alabama
TPF-5(281)	Center for the Aging Infrastructure: Steel Bridge Research, Inspection, Training and Education	$50,000	Scot Becker, DTSD	Indiana
TPF-5(283)	The Influence of Vehicular Live Loads on Bridge Performance	$50,000	Alex Pence, DTSD	FHWA
TPF-5(290)	Aurora Program	$25,000	Mike Adams, DTSD	Iowa
TPF-5(295)	Smart Work Zone Deployment Initiative	$50,0000	Erin Schoon, DTSD	Iowa
TPF-5(297)	Improving Specification to Resist Frost Damage in Modern Concrete Mixtures	$17,500	Chad Hayes, DTSD	Oklahoma
TPF-5(301)	Research, Development and Technology Peer Exchange Facilitation Support Services	$27,888	Lynn Hanus, OMB	Oregon
TPF-5(302)	PG+/Modified Binder Quality Control Criteria	N/A	Barry Paye, DTSD	WisDOT
TPF-5(305)	Regional and National Implementation and Coordination of ME Design	$10,000	Laura Fenley, DTSD	FHWA
TPF-5(308)	The Use of Bridge Management Software in the Network Analysis of Big Bridges	N/A	Josh Dietsche, DTSD	Michigan
TPF-5(313)	Technology Transfer Concrete Consortium	$8,000	Chad Hayes, DTSD	Iowa
TPF-5(316)	Traffic Control Device (TCD) Consortium	$20,000	Erin Schoon, DTSD	FHWA
TPF-5(317)	Evaluation of Low Cost Safety Improvements	$15,000	Brian Porter, DTSD	FHWA

Pooled fund participation (continued)

PROJECT NUMBER	TITLE	FFY 2018 FUNDING AMOUNT	WISDOT TECHNICAL REPRESENTATIVE	LEAD AGENCY/ STATE
TPF-5(319)	Transportation Management Center Pooled Fund Study	$50,000	Stacey Pierce, DTSD	FHWA
TPF-5(326)	Develop and Support Transportation Performance Management Capacity Development Needs for State DOTs	$10,000	Jacquelyn Irving, OMB	Rhode Island
TPF-5(330)	No Boundaries Roadway Maintenance Practices	$10,000	Scott Bush, DTSD	Ohio
TPF-5(335)	2016 through 2020 Biennial Asset Management Conference and Training on Implementation Strategies	N/A	Scot Becker, DTSD, Justin Shel, DTIM	Iowa
TPF-5(340)	Axle and Length Classification Factor Analysis and Effects on Annual Average Daily Traffic (AADT)	N/A	Russell Lewis, DTIM	WisDOT
TPF-5(341)	National Road Research Alliance (NRRA)	N/A	Barry Paye, DTSD	Minnesota
TPF-5(346)	Regional Roadside Turfgrass Performance Testing	$20,000	Leif Hubbard, DTSD	Minnesota
TPF-5(347)	Development of Maintenance Decision Support System Pooled Fund and Operations	$350,149	Mike Adams, DTSD	South Dakota
TPF-5(351)	Self De-icing LED Signals	$20,000	Don Schell, DTSD	Kansas
TPF-5(352)	Recycled Materials Resource Center	$40,000	Barry Paye, DTSD	WisDOT
TPF-5(353)	Clear Roads Phase II	$25,000	Allan Johnson, DTSD	Minnesota
TPF-5(354)	Improving the Quality of Highway Profile Measurement	$20,000	Mike Wolf, DTIM	South Dakota
TPF-5(368)	Performance Engineered Concrete Paving Mixtures	$15,000	Chad Hayes, DTSD	Iowa
TPF-5(370)	Fostering Innovation in Pedestrian and Bicycle Transportation Pooled Fund Study	$25,000	Jill Mrotek-Glenzinski, DTIM	FHWA
TPF-5(372)	Building Information Modeling (BIM) for Bridges and Structures	$20,000	Scot Becker, DTSD	Iowa
TPF-5(374)	Accelerated Performance Testing on the 2018 NCAT Pavement Test Track with MnROAD Research	$100,000	Barry Paye, DTSD	Alabama
TPF-5(375)	National Partnership to Determine the Life Extending Benefit Curves of Pavement Preservation Techniques (MnROAD/NCAT Joint Study Phase II)	$50,000	Barry Paye, DTSD	Minnesota
TPF-5(377)	Enhanced Traffic Signal Measures	$ 30,000	Jeremy Iwen, DTSD	Indiana
TPF-5(379)	Technology Exchange on Low Volume Road Design, Construction and Maintenance	$10,000	Rodney Taylor, DTSD, Justin Shell, DTIM	Iowa
TPF-5(381)	Evaluation of Lateral Pile Resistance Near MSE Walls at a Dedicated Wall Site Phase II	$20,000	Jeff Horsfall, DTSD	Utah

Committees and contacts

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Wisconsin Highway Research Program
Project 0092-16-05
October 2018

Research Brief

Design and Performance of Highly Skewed Deck Girder Bridges

Research Objectives

- Identify the effects of large skew on bridge analysis, design and service performance
- Develop design strategies to analyze bridges with skew and control performance issues

Research Benefits

- Improved WisDOT's understanding of the behaviors and challenges of skewed bridge decks
- Provided design recommendations to improve performance of skewed bridges and improve deck lifespan

Principal Investigator

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Project Manager

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Background

Bridge skew is the angle between a line perpendicular to a superstructure and its supports. Highly skewed bridges are more complex and pose more challenges than bridges that pass perpendicularly over the road or other features below it. Skew alters distribution of loads from deck to girders. It can cause large deformations at girder ends or create stresses in the superstructure. However, as infrastructure demands increase and the amount of undeveloped land decreases, skew is becoming more commonplace in bridge construction. Thirty percent of Wisconsin bridges built between 1995 and 2014 are skewed between 20° and 60°. The goal of this project was to investigate the performance of high-skew bridges in Wisconsin to identify limits for simplified analysis methods, and to evaluate and recommend design details and practices that can mitigate negative impacts of skew on decks and bearings.

I-94's B-40-870 bridge, skewed 64° over Hank Aaron State Trail, was load tested and monitored for one year.

Methodology

The research team reviewed inspection reports of Wisconsin bridges, interviewed maintenance engineers and inspected four bridges with skew ranging from 0° to 52° to document visible performance factors. The team performed load testing on a steel girder bridge skewed 47° and load testing with one-year monitoring on a prestressed concrete girder bridge skewed 64° to collect data on live-load and long-term response.

Two-dimensional analyses, validated with test data, were compared to American Association of State Highway Transportation (AASHTO) Load and Resistance Factor Design (LRFD) girder-line analyses on a selection of Wisconsin bridges with varying skew angles, secondary elements, bridge geometry and deck-concrete composite action. Finite element analysis was also used to study long-term displacements and stresses created by restraint against deformations.

"Appropriate usage of the mixed bearing design will help improve the durability of our highly skewed structures throughout the state."

– Philip Meinel, WisDOT

Interested in finding out more?

Final report is available at: WisDOT Research website.

Results

Finite element models revealed that maximum shear in girders increases and moment decreases as skew increases. Two-dimensional modeling is accurate enough to study moment and shear distribution of prestressed concrete bridges and steel bridges. AASHTO specifications with WisDOT exceptions can predict load distribution, but with a small safety margin in some cases.

The skew angle of a bridge correlated positively with deck cracking. Shrinkage was the main cause of typical diagonal cracking on high skew bridge decks; temperature changes alone did not create deck cracking. High skew also caused larger superstructure in-plane displacements compared to bridges with no skew, particularly in the transverse direction. Field monitoring and modeling showed that using mixed bearing arrangements over the same pier is an efficient method to limit superstructure in-plane rotation or racking. For the bridge with mixed bearings monitored over one year, the transverse displacements remained small; longitudinal displacements were larger and correlated highly with temperature changes.

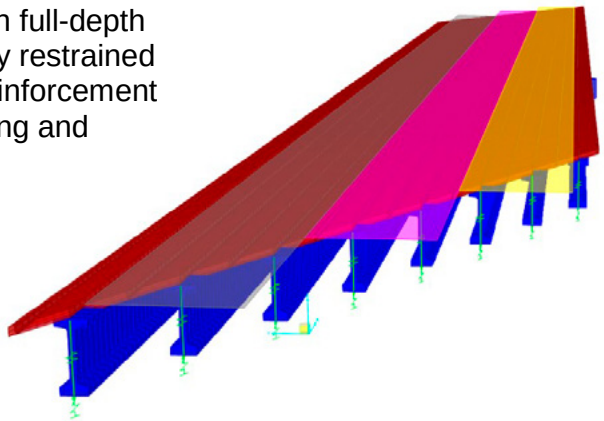
Models revealed that bridge end details affect deck cracking behavior. Reducing deck restraint limited cracking, and full-depth concrete end diaphragms and laterally restrained abutment bearings created the highest deck strains. Increasing deck reinforcement or orienting it along the skew did not reduce deck strains.

Recommendations for Implementation

The research team offered several recommendations for the design and analysis of skewed bridges. Two-dimensional bridge analysis' accuracy and computational efficiency should complement girder line analyses to increase safety margins in designing high-skew bridges. These analyses can also be used to estimate expansion joint displacements and fixed bearing forces.

Superstructures and bearings should be designed to accommodate for racking and expansion joint displacements. Shrinkage-controlled concrete mixtures and construction practices should be employed to reduce cracking. Mixed bearings can reduce in-plane displacements and control deck cracking, and is recommended for large skews.

Restraint of deck through full-depth end diaphragms, laterally restrained bearings or additional reinforcement may worsen deck cracking and should be avoided.



This brief summarizes Project 0092-16-05,
"Design and Performance of Highly Skewed Deck Girder Bridges"
Wisconsin Highway Research Program

Research Brief

Wisconsin Highway Research Program
Project 0092-16-02
March 2018

Evaluation of Protocols for Determining Asphalt Binder Content and PG Characteristics

Research Objectives

- Determine within-lab and between-lab variability of solvent extraction, ignition and asphalt analyzer procedures used to quantify asphalt content.
- Evaluate the variability in PG properties of extracted binder after recovery.
- Provide recommendations for improving WisDOT material and mix design standards.

Research Benefits

- Determined within-lab and between-lab variability of each asphalt content test.
- Recommended including ignition and asphalt analyzer tests in WisDOT specifications.
- Offered correction factors for ignition testing and tolerance adjustments to extraction testing to improve accuracy.

Principal Investigator

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Technical Oversight Committee Chair

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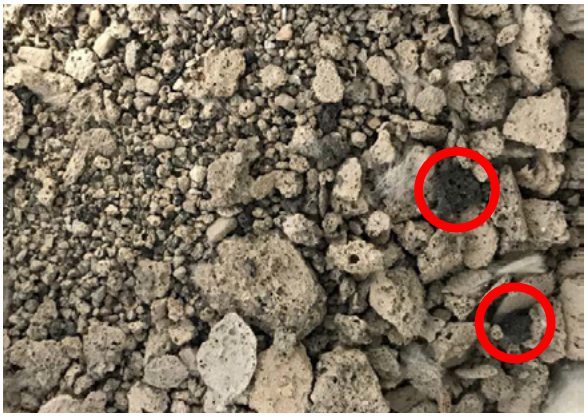
Background

Accurate determination of asphalt content is critical to ensuring the quality of asphalt mixes used in Wisconsin's road projects. The two most-common methods for determining asphalt content are the American Association of State Highway and Transportation Officials (AASHTO) solvent extraction and ignition tests. These procedures are well established; however, their accuracies are sensitive to variations in materials and high recycled binder content mixes commonly used in Wisconsin. Therefore, an evaluation is needed to assess within-lab and between-lab testing variability.

The main objectives of this research were to evaluate solvent extraction, ignition and asphalt analyzer test procedures; determine tolerances between methods; and modify WisDOT material and mix standards. The research team also evaluated the variability of the performance grade (PG) properties of extracted binder after recovery.

Methodology

The National Center for Asphalt Technology (NCAT) and several Wisconsin labs evaluated asphalt analyzer, AASHTO T 164 method A (centrifuge extraction) and method B (reflux extraction) and AASHTO T 308 ignition tests. The labs performed each of these tests on eight mixes, including virgin mixes and mixes with various recycled binder contents, containing four Wisconsin aggregates to quantify the variability in the determination of their asphalt content. NCAT also conducted centrifuge, reflux, and ignition tests on two sources of reclaimed asphalt pavement (RAP) and one source of reclaimed asphalt shingles (RAS).



Unburned asphalt remains after an ignition test performed at 800°F for RAS material.

Test results were analyzed per ASTM E 691 and ASTM C 802. Within-lab and between-lab variability for each test procedure was developed for Wisconsin materials and compared to the current AASHTO standards.

"This study advances both WisDOT's and our contractor's ability to verify the asphalt binder content in our mixtures, which will ensure more durable pavements."
– Dan Kopacz, WisDOT

Interested in finding out more?

Final report is available at: WisDOT Research website.

Results

The differences between actual and measured asphalt content were: 0.21% for centrifuge extraction; 0.17% for the asphalt analyzer; 0.14% for reflux extraction; and 0.05% for ignition, when correction factors were used. Asphalt analyzer and centrifuge extraction results indicate that solvents may be unable to remove all binder from mixes.

The within-lab and between-lab standard deviations and acceptable ranges of the asphalt analyzer, centrifuge extraction and reflux extraction tests met AASHTO T 164 requirements. The ignition method's within-lab and between-lab standard deviations and acceptable ranges exceeded AASHTO T 308 specifications. RAP did not affect the results of any test, and RAS only affected ignition results.

Ignition test results showed that most aggregates included in the study had high mass loss. Tests conducted at 800°F proved to be effective in reducing the variability in measured asphalt content. The lower temperature resulted in less loss due to aggregate burning and thus reduced the asphalt correction factors for asphalt mixes. However, for RAS material, when tests were conducted at 800°F, there was some unburned asphalt left in the residue that was not observed when tests were conducted at 900°F.

For the materials used in this study, extraction method and solvent type did not have a significant effect on the PG properties of recovered binders. Further research is needed to quantify interactions between solvents and modified binders.

Recommendations for Implementation

WisDOT specifications for testing recovered asphaltic binder currently only allow for the AASHTO T 164 centrifuge extraction method. The research team recommends WisDOT also allow asphalt analyzer and ignition tests. The asphalt analyzer results showed the lowest standard deviations of all test procedures and were similar to the centrifuge extraction results. The ignition test also yielded accurate asphalt content results when correction factors were applied.

If ignition testing is incorporated, it should be conducted at the proper temperature dependent on aggregate-mass loss rather than the standard 1,000°F.

This brief summarizes Project 0092-16-02,
"Asphalt Binder Extraction Protocol for Determining Amount & PG Characteristics of Binders Recovered from Asphalt Mixtures"
Wisconsin Highway Research Program

Research Brief

Wisconsin Highway Research Program
Project 0092-17-03
July 2018

Evaluation of the Effects of Deicers on Concrete Durability

Research Objectives

- Identify the use of various deicing and anti-icing materials in Wisconsin
- Investigate the effects of various deicing and anti-icing materials on concrete pavement durability

Research Benefits

- Broadened WisDOT's knowledge of deicing and anti-icing materials and applications in Wisconsin
- Revealed a faster rate of concrete deterioration in counties with higher NaCl, $CaCl_2$ and $MgCl_2$ application
- Integrated winter maintenance database with pavement performance data and provided suggestions to better utilize the data in the future

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Background

Wisconsin experiences approximately 13 to 55 winter events per year, with annual snowfall ranging from 15 to 132 inches. Wisconsin has traditionally used solid rock salt (NaCl) as the primary deicing chemical in winter maintenance. However, recent changes regarding the use of liquid anti-icing solutions and newer deicing chemicals have raised concerns about the potential impacts on concrete pavement durability. Previous laboratory studies indicated that these new chemicals, especially calcium chloride ($CaCl_2$) and magnesium chloride ($MgCl_2$), cause more damage to concrete than rock salt does. Anti-icing prior to winter events causes much more rapid ingress of the deicing chemicals because the dry concrete surface absorbs the anti-icing solution very readily. The objectives of this research were to investigate the use of deicing and anti-icing materials in Wisconsin and the effects they have on concrete pavement durability.

Methodology

Researchers surveyed winter operation managers in Wisconsin's counties and major cities to determine which materials are being used and to gather anecdotal evidence of durability issues. Nearly 90,000 Storm Report records and over 6,000 Automatic Vehicle Location (AVL) records from the Wisconsin Department of Transportation's (WisDOT) winter maintenance database were analyzed and compared to historical pavement performance data. Seven sites were then selected for visual inspection to identify any relationships between concrete condition and the use of deicing and anti-icing materials.

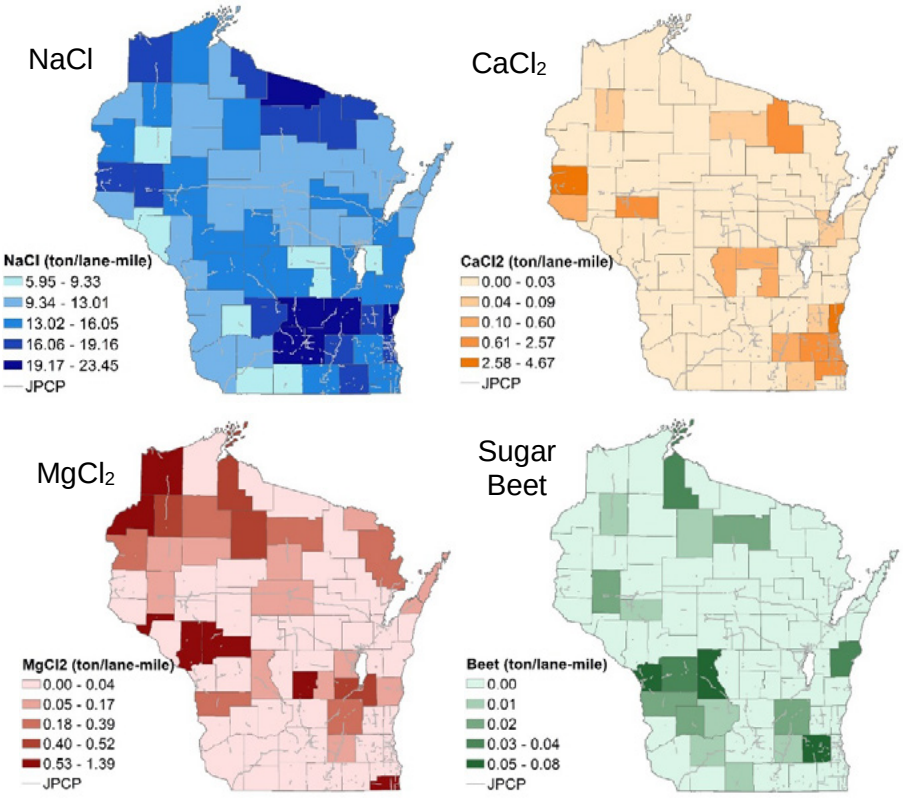
Results

Survey results and WisDOT data analysis confirmed that rock salt and salt brine are still the primary materials used in Wisconsin winter maintenance. For each lane mile in each winter event in Wisconsin, 200-400 pounds of deicing materials and 20-50 gallons of anti-icing materials are applied. This is consistent with WisDOT's Winter Maintenance Guidelines. Storm Report data, which is manually entered by county engineers, show each lane mile of roadway received an average of 13.78 tons of NaCl, 0.31 tons of $CaCl_2$ and 0.16 tons of $MgCl_2$ over the course of a winter, while the AVL database reported 9.9 tons of rock salt and 39.3 gallons of salt brine per lane mile. The application rate distribution for the various chemicals is shown on the following page.

"The findings of this research will help WisDOT reduce concrete deterioration by optimizing deicing and anti-icing material blends, application rates and technology."
– Chad Hayes, WisDOT

Interested in finding out more?

Final report is available at:
WisDOT Research website



The survey identified two problems with deicing and anti-icing materials: accelerated deterioration near joints and bridge decks. There was no statistical difference of impacts on concrete durability between solid salt and liquid brine or between different application rates. This was likely due to other factors beyond the scope of this study. However, field visits to selected locations revealed a faster rate of deterioration in counties with a higher amount of NaCl, $CaCl_2$ and $MgCl_2$ application. Joint spalling at adjoining counties in three of the seven sites was statistically different.

Recommendations for Implementation

It is recommended that rock salt and salt brine remain the primary materials for deicing and anti-icing. $CaCl_2$ and $MgCl_2$ use should be limited to winter events with temperatures below the effective limit of rock salt. Agencies should blend products to optimize deicing/anti-icing effectiveness, and should consider revising application rate guidelines to reflect material and technological advancements.

Expanding AVL coverage, providing more details of material application and making it compatible with other transportation information databases would help WisDOT continue refining its deicing and anti-icing practices to respond to safety, environment and infrastructure durability issues.

This brief summarizes Project 0092-17-03,
"Evaluation of the Effects of Deicers on Concrete Durability"
Wisconsin Highway Research Program

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