WisDOT Research Program

Annual 2019 Report

Foreword

I am pleased to present the Wisconsin Department of Transportation's (WisDOT) 2019 annual report on research activities. This report highlights WisDOT's mission to provide leadership in the development and operation of a safe and efficient transportation system.

This year, a structural reorganization brought WisDOT's Research and Library Services Unit into the newly formed Division of Budget and Strategic Initiatives. The Research and Library Services Unit facilitates the department's research activities and provides access to information that fosters data-driven decision making. By aligning research with the department's strategic priorities, we aim to accelerate implementation of research results; the application of promising materials and technologies; and the adoption of associated policies and procedures to demonstrate accountability to our transportation stakeholders and the public.

WisDOT's $4.09 million (FFY 2019) research program completed 12 projects through the Wisconsin Highway Research Program (WHRP) and Policy Research Program; it led four multi-state Transportation Pooled Fund (TPF) Program projects and participated in 42 others. 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. Research and library staff completed nine synthesis reports and 20 literature searches; responded to 362 information requests; and delivered 576 resource items.

I am proud to recognize these accomplishments and would like to thank the many staff that serve on research committees and panels at the national and state levels. I would also like to thank the many industry and academic experts that partnered with us on these projects. 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 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 2019, covering October 1, 2018 through September 30, 2019.

Contents

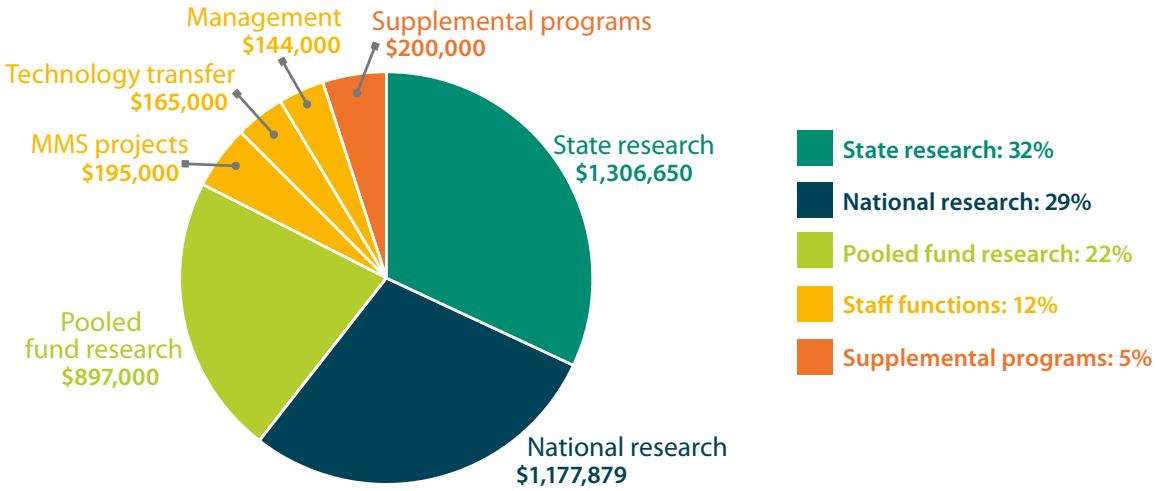
Common acronyms used in this document

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
FHWA	Federal Highway Administration
NCHRP	National Cooperative Highway Research Program
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) 2019. The State Planning and Research Part 2 (SPR2) federal program funded 90 percent ($3.69 million) of the program, while state funds covered the remaining 10 percent ($0.4 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. The Policy Research Program 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 2019, WisDOT's research team led four pooled fund projects and provided support for 42 others. These projects 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's Research and Library team 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 transportation knowledge and research findings contributes to continuous performance improvement. The Research and Library team 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) internal projects, including the investigation and implementation of new materials and methods, 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.

Joint Sawing Practices and Effects on Durability

WHRP 0092-16-01

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

Wisconsin and other northern states often experience premature deterioration in pavement joints. Pavement joints are saw cuts made in hours-old concrete to control cracking. WisDOT has traced the causes of premature joint deterioration to damage incurred by improper sawing equipment, methods and timing. The objectives of this research were to evaluate which sawing factors most impact the durability of near-joint concrete and recommend best practices to mitigate damage.

Results showed that sawing early in the timing window using early-entry equipment can cause physical damage to the aggregate and concrete. Saw blades that are old, worn or used interchangeably between concretes with different coarse aggregate types produce higher absorption and more variability in joint quality.

This research will help WisDOT improve the long-term performance of concrete joints through optimized saw-cut practices and application of penetrating sealers. These improvements are estimated to reduce repair costs by $18,000 per mile of a four-lane highway.

Performance and Policy Related to Aluminum Box Culverts and Pipe Culverts in Wisconsin

WHRP 0092-17-05

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

Failure of an aluminum culvert due to pitting corrosion from deicing salts in 1993 prompted WisDOT to investigate and subsequently restrict its use of aluminum drainage structures, such as pipe and box culverts. The objectives of this research were to evaluate WisDOT's current policies restricting the use of aluminum culverts and provide guidelines for how to best administer culverts in transportation projects.

Results of the research showed that aluminum culverts proved to be resistant to general corrosion when installed at sites with soil and water pH levels between 4.5 and 9 and resistivity of more than 500 Ω-cm. Resulting recommendations include updating WisDOT's manuals and specifications to allow aluminum culverts at sites meeting these conditions and strategies for mitigating the corrosion and abrasion.

This project identified potential pathways for aluminum culvert corrosion and methodology to prevent its occurrence. The results will be used to guide future WisDOT culvert policy.

Featured research *(continued)*

Thermal Integrity Profiling for Detecting Flaws in Drilled Shafts

WHRP 0092-16-07

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

Thermal Integrity Profiling (TIP) measures the temperature of concrete along the length of drilled-shaft reinforcing cages to identify potential defects. The heat generated from hydration of cement within the drilled shaft is captured by wired sensors affixed to the cage and recorded by small data loggers at the ground surface. This research was conducted to evaluate the effectiveness of TIP and its potential to serve as a more reliable and comprehensive alternative to Crosshole Sonic Logging (CSL).

TIP and CSL were performed on three test shafts with intentionally fabricated defects. Results showed that TIP and CSL each excel in detecting certain defects and fail to adequately detect others; when used complementarily, the tests are well suited to detect all significant defects.

This research provides better insight for WisDOT engineers on how to interpret and make use of the results of CSL and TIP as complementary tests.

Technology transfer and library activities

The Division of Budget and Strategic Initiatives Research and Library Services Unit provides information services for WisDOT staff and supports implementation of research results.

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. Nine synthesis reports were completed in FFY 2019 on topics ranging from transportation revenue-generation methods to sandbag alternatives.

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 literature searches were completed in FFY 2019. Topics included: innovative flood monitoring systems; rebar testing; asphalt rejuvenators; and alternatives to riprap fabrics.

WisDOT library services

Library staff handled 362 information requests, delivered 576 digital items (books, reports, periodicals and articles) and added 744 digital items to the Wisconsin Digital Archives.

Intranet library resources

As part of the department's conversion to a new intranet platform, the library revamped its portal to electronic documents such as AASHTO ePublications. Increasing digitization and copyright protection by publishers of transportation information materials necessitates the library serve as a facilitator within the department to instruct staff on how to access and use these resources. This central hub of information helps staff locate and acquire the resources they need to make informed decisions.

Completed research projects

PROGRAM	PROJECT ID	PERFORMING ORGANIZATION	PRINCIPAL INVESTIGATOR	PROJECT BUDGET	WISDOT PROJECT MANAGER	PROJECT TITLE	COMPLETION DATE
WHRP–Flexible Pavements	0092-15-05	Temple University	Ahmed Faheem	$100,000	Erv Dukatz	Evaluation of WisDOT Quality Management Program (QMP) Activities and Impacts on Pavement Performance	10/2018
WHRP–Geotechnics	0092-15-06	University of Wisconsin–Milwaukee	Hani Titi	$119,997	Andrew Zimmer	Evaluation of the Long-Term Degradation & Strength Characteristics of In-situ WI Virgin Base Aggregates under HMA Pavements	11/2018
Policy	0092-15-11	University of Wisconsin–Madison	Andrea Bill	$77,000	Sarah Buzzell	Motorcycle Licensing and Safety	12/2018
WHRP–Rigid Pavements	0092-16-01	Marquette University	James Crovetti	$203,825	Myungook Kang	Joint Sawing Practices and Effects on Durability	8/2019
WHRP–Geotechnics	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	12/2018
WHRP–Geotechnics	0092-16-07	University of Missouri	Andrew Boeckmann	$110,000	Andrew Zimmer	Thermal Integrity Profiling for Detecting Flaws in Drilled Shafts	11/2018
Policy	0092-16-11	University of Wisconsin–Milwaukee	Xiao Qin	$100,000	Evan Moorman	Identifying Highly Correlated Variables Relating to the Potential Causes of Reportable Wisconsin Traffic Crashes	7/2019
WHRP–Geotechnics	0092-17-01	University of Wisconsin–Milwaukee	Hani Titi	$99,990	Andrew Zimmer	Evaluation of Recycled Base Aggregates	2/2019
WHRP–Structures	0092-17-02	University of Wisconsin–Milwaukee	Habib Tabatabai	$167,218	Aaron Bonk	Strength & Serviceability of Damaged Prestressed Girders	10/2018
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	2/2019
WHRP–Flexible Pavements	0092-17-06	University of Wisconsin–Madison	Hussain Bahia	$100,000	Steven Hefel	Investigation of Tack Coat Materials on Tracking Performance	3/2019
WHRP–Rigid Pavements	0092-18-02	Applied Pavement Technology, Inc.	Prashant Ram	$80,000	Jed Peters	Non-Cementitious Repair Materials	6/2019

Ongoing research projects

PROGRAM	PROJECT ID	PERFORMING ORGANIZATION	PRINCIPAL INVESTIGATOR	PROJECT BUDGET	WISDOT PROJECT MANAGER	PROJECT TITLE
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
WHRP–Geotech	0092-17-08	Geocomp Corporation	Allen Marr	$149,971	Andrew Zimmer	Monitoring of Lateral Earth Pressure and Movements of Cut Retaining Walls
WHRP–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–Structures	0092-18-03	Iowa State University	Basak Aldemir Bektas	$140,000	Ryan Bowers	Protocols for Concrete Bridge Deck Protections and Treatments
WHRP–Flexible Pavement	0092-18-05	Temple University	Ahmed Faheem	$165,000	Stacy Glidden	Investigation of In-Service Pavement Performance
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–Structures	0092-19-01	Clemson University	Brandon Ross	$180,000	David Kiekbusch	Textured Epoxy Coated and Galvanized Reinforcement to Reduce Cracking in Concrete Bridge Decks and Components
WHRP–Structures	0092-19-02	CTL Group–Materials & Mechanics	Jose Pacheco	$194,555	Oliva William	Internal Curing of Bridge Decks and Concrete Pavement to Reduce Cracking
WHRP–Rigid Pavement	0092-19-03	University of Wisconsin–Madison	Pavana Prabhakar	$150,000	Myungook Kang	Roadway Concrete Barrier Design and Performance – Material Durability Issue
WHRP–Flexible Pavement	0092-19-04	NCAT at Auburn University	Carolina Rodezno	$40,000	Erik Lyngdal	Recycled Asphalt Binder Study
WHRP–Flexible Pavement	0092-19-05	Behnke Materials Engineering, L.L.C.	Signe Reichelt	$165,000	Daniel Kopacz	Rubber Asphalt Study for Wisconsin
WHRP–Geotech	0092-19-06	University of Wisconsin–Milwaukee	Rani, Elhajjar	$100,000	Andrew Zimmer	Comparison of ASTM Standards for the Evaluation of Geogrid Strength

Pooled fund participation

PROJECT NUMBER	TITLE	FFY 2019 FUNDING AMOUNT	WISDOT TECHNICAL REPRESENTATIVE	LEAD AGENCY/ STATE
TPF-5(176)	Traffic Analysis and Simulation	$10,000	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(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 Engineering Center–SBRITE	N/A	Scot Becker DTSD	Indiana
TPF-5(283)	The Influence of Vehicular Live Loads on Bridge Performance	N/A	Alex Pence DTSD	FHWA
TPF-5(290)	Aurora Program	$25,000	Mike Adams DTSD	Iowa
TPF-5(295)	Smart Work Zone Deployment Initiative	$50,000	Erin Schoon DTSD	Iowa
TPF-5(297)	Improving Specification to Resist Frost Damage in Modern Concrete Mixtures	N/A	Chad Hayes DTSD	Oklahoma
TPF-5(305)	Regional and National Implementation and Coordination of ME Design	N/A	Amy Brooks DTSD	FHWA
TPF-5(313)	Technology Transfer Concrete Consortium	N/A	Chad Hayes DTSD	Iowa

Pooled fund participation *(continued)*

PROJECT NUMBER	TITLE	FFY 2019 FUNDING AMOUNT	WISDOT TECHNICAL REPRESENTATIVE	LEAD AGENCY/ STATE
TPF-5(316)	Traffic Control Device Consortium	N/A	Jay Hille DTSD	FHWA
TPF-5(317)	Evaluation of Low Cost Safety Improvements	N/A	Brian Porter DTSD	FHWA
TPF-5(319)	Transportation Management Center Pooled Fund Study	N/A	Stacey Pierce DTSD	FHWA
TPF-5(326)	Develop and Support Transportation Performance Management Capacity Development Needs for State DOTs	N/A	Jacquelyn Irving DBSI	Rhode Island
TPF-5(330)	No Boundaries Roadway Maintenance Practices	$10,000	Chris Ohm DTSD	Ohio
TPF-5(335)	2016-2020 Biennial Asset Management Conference and Training on Implementation Strategies	N/A	Scot Becker DTSD, Justin Shell DTIM	Iowa
TPF-5(340)	Axle and Length Classification Factor Analysis and Effects on Annual Average Daily Traffic (AADT)	N/A	Russell Lewis DTIM	Wisconsin
TPF-5(341)	National Road Research Alliance (NRRA)	$150,000	Barry Paye DTSD	Minnesota
TPF-5(346)	Regional Roadside Turfgrass Performance Testing	N/A	Leif Hubbard DTSD	Minnesota
TPF-5(347)	Development of Maintenance Decision Support System Pooled Fund and Operations	$130,000	Mike Adams DTSD	South Dakota
TPF-5(351)	Self De-icing LED Signals	N/A	Donald Schell DTSD	Kansas
TPF-5(352)	Recycled Materials Resource Center – 4th Generation	N/A	Barry Paye DTSD	Wisconsin
TPF-5(353)	Clear Roads Phase II	$25,000	Allan Johnson DTSD	Minnesota
TPF-5(354)	Improving the Quality of Highway Profile Measurement	N/A	Mike Wolf DTIM	South Dakota
TPF-5(359)	Evaluating New Technologies for Roads Program Initiatives in Safety and Efficiency (ENTERPRISE) Phase 2	$30,000	David Karnes DTSD	Michigan
TPF-5(368)	Performance Engineered Concrete Paving Mixtures	N/A	Chad Hayes DTSD	Iowa

Pooled fund participation *(continued)*

PROJECT NUMBER	TITLE	FFY 2019 FUNDING AMOUNT	WISDOT TECHNICAL REPRESENTATIVE	LEAD AGENCY/ STATE
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	N/A	Scot Becker DTSD	Iowa
TPF-5(374)	Accelerated Performance Testing on the 2018 NCAT Pavement Test Track with MnROAD Research	$50,000	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 2)	$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	N/A	Rodney Taylor DTSD, Justin Shell DTIM	Iowa
TPF-5(381)	Evaluation of Lateral Pile Resistance Near MSE Walls at a Dedicated Wall Site Phase 2+3	N/A	Jeff Horsfall DTSD	Utah
TPF-5(382)	Drivers Failing to Yield at Multi-Lane Roundabout Exits	$50,000	Rebecca Szymkowski DTSD	FHWA
TPF-5(383)	2019 Innovations in Freight Data Workshop	$14,000	Matt Umhoefer DTIM Dan Thyes DTIM	Iowa
TPF-5(388)	Developing Implementation Strategies for Risk Based Inspection (RBI)	$50,000	Scot Becker DTSD	Missouri
TPF-5(389)	Connected Vehicle Pooled Fund Study	$50,000	Anne Reshadi DTSD	Virginia
TPF-5(395)	Traffic Disruption-Free Bridge Inspection Initiative with Robotic Systems	$25,000	Rick Marz DTSD	Missouri
TPF-5(396)	Mid-America Freight Coalition Phase 3 (MAFC-3)	$37,000	Matt Umhoefer DTIM	Wisconsin
TPF-5(432)	Midwest Bridge Preservation Partnership	$20,000	Bill Oliva DTSD	Wisconsin

Committees and contacts

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Research Brief

Wisconsin Highway Research Program
Project 0092-16-01
January 2019

Concrete Joint Sawing Practices and Impacts on Durability

Research Objectives

- Investigate concrete joint sawing techniques currently used in Wisconsin
- Assess impacts of these techniques on the durability of the constructed pavement joints
- Recommend best practices for joint sawing to improve durability and performance

Research Benefits

- Determined causes for premature deterioration of joints in young concrete pavements
- Recommended strategies to mitigate joint deterioration and improve joint performance through better sawing timing, technique and equipment

Background

Wisconsin and other northern states have recently seen premature deterioration in concrete pavement joints. The Wisconsin Department of Transportation (WisDOT) has traced the causes of deterioration to the construction of the joints. Joints are sawn into hours-old concrete pavement to control random cracking. Improper saw timing, equipment and methods can damage the pavement and require high levels of maintenance. The objectives of this research were to evaluate which sawing factors most impact the durability of near-joint concrete and recommend best practices.

Methodology

The researchers inspected and joint-cored five sites to identify the relationship between sawing practices and durability. Two concrete pavement test sections were constructed to assess the impacts of: saw type (conventional versus early-entry); timing of sawing operations; type and quality of the saw blade and equipment; depth of the saw cut; adherence to matching saw blade type with predominant coarse aggregate (northern igneous gravels versus southern limestones); and the application of penetrating sealers to the sawn face.

Laboratory tests were conducted on samples recovered from the joints of each constructed test section, including water absorption, freeze-thaw durability and deicer scaling resistance.

Performing an early-entry saw cut

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"This research will help WisDOT improve the long-term performance of concrete joints through optimized saw-cut practices and application of penetrating sealers."

– Myungook (MK) Kang, WisDOT

Interested in finding out more?

Final report is available at:
WisDOT Research website

Results

Sawing early in the timing window using early-entry equipment can cause physical damage to the aggregate and concrete. For limestone mixtures, the damage occurred directly underneath the sawing shoe while, for gravel mixtures, cracks formed immediately outside the shoe.

Absorption was affected by differences in sawing timing, technique and equipment. Old and worn blades produced higher absorption and more variability in all cases than the corresponding joint sawn at the same time with a new blade. The mixture containing igneous gravels had lower absorption than the limestone mixture. Silane treatment of the joints provided significant reduction in absorption.

The test sections showed no significant freeze-thaw deterioration after 300 cycles. Physical damage from early sawing only became distinguishable beyond 500 freeze-thaw cycles.

Surface deicer scaling was not influenced by sawing factors except for some minor raveling at the intersection of the joint face and surface. The gravel mixture performed better than the limestone mixture. The application of a topical silane sealer significantly improved the performance of both. Chloride penetration for the limestone samples was inconclusive, as the limestone aggregate absorbed the deicer salt. However, silane reduced chloride penetration of the granite mixture by 50 percent.

Recommendations for Implementation

Research results indicated that conventional sawing was substantially less sensitive to the variables tested. Results also indicated that the softer (limestone) mixture was more sensitive to sawing variables. The research team recommends discouraging sawing early in the early-entry sawing window. Early-entry sawing equipment should only be allowed on mixtures containing predominantly gravel coarse aggregates and should commence only when the concrete is sufficiently hard enough to prevent marring the surface tining/brooming and minimize raveling, chipping, spalling and other pavement damage.

Early-entry saws should have diamond blades with functioning blade guards and be equipped with guides or other devices to control cut alignment and depth. It is not acceptable or appropriate to use one type of saw blade for all cuts. Blades should be selected for the coarse aggregate present and used accordingly, especially for limestone aggregate. Worn blades cause measurable impact to concrete. Contractors should be required to maintain a blade log documenting blade type, depth and distance sawn.

This brief summarizes Project 0092-16-01,
"Joint Sawing Practices and Effects on Durability"
Wisconsin Highway Research Program

Research Brief

Wisconsin Highway Research Program
Project 0092-16-07
April 2019

Thermal Integrity Profiling for Detecting Flaws in Drilled Shafts

Research Objective

- Evaluate the effectiveness of Thermal Integrity Profiling and its potential to serve as an alternative to Crosshole Sonic Logging

Research Benefits

- Determined Thermal Integrity Profiling is suitable to replace or complement Crosshole Sonic Logging, depending on project considerations
- Provided guidance for improving Thermal Integrity Profiling accuracy and data-driven quality assurance

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Background

Thermal Integrity Profiling (TIP) measures the temperature of concrete along the length of drilled-shaft reinforcing cages to identify potential defects. The heat generated from hydration of cement within the drilled shaft is captured by wired sensors affixed to the cage and recorded by small data loggers at the ground surface. Areas of lower temperature indicate potential concrete defects within the drilled shaft.

TIP's sensitivity to defects outside the reinforcing cage make it an appealing alternative to Crosshole Sonic Logging (CSL), whose geophysical measurements only capture defects within the cage and often return false positives. This research was conducted to evaluate the effectiveness of TIP and its potential to serve as an alternative to CSL.

Methodology

Three drilled shafts, each measuring four feet in diameter and 30 feet long, were constructed to evaluate the ability of TIP and CSL methods to detect 10 intentionally fabricated defects. Nine defects were simulated by affixing 70-pound sandbags to various parts of the cage. Four were included to evaluate the effect of defect location within the cross-section, particularly how the sensitivity of TIP compares for defects outside the reinforcing cage and defects inside the reinforcing cage; two to evaluate sensitivity to soft bottom conditions; two to evaluate zones of weak concrete; and one to evaluate tremie breach. The final defect, debonding of the access tubes, was simulated by applying wheel bearing grease over the tubes. Debonding of access tubes can lead to false-positive CSL anomalies. Both TIP and CSL were performed on all three shafts.

Reinforcing cages prepped with sensors and sandbags

"This research provides better insight for WisDOT engineers on how to interpret and make use of the results of TIP testing."
– Andrew Zimmer, WisDOT

Interested in finding out more?

Final report is available at:
WisDOT Research website

Results

TIP measurements produced temperature decreases greater than five degrees Fahrenheit for four defects, decreases between three degrees and five degrees Fahrenheit for two defects, and no discernable temperature decrease for the other three defects. The greatest decreases were observed for weak-concrete defects and defects outside the reinforcing cage, while limited temperature decreases were observed for inclusions within the reinforcing cage and the tremie breach defect. No temperature decrease was observed for the soft bottom defects or the smaller inside-cage inclusion. Defects are significantly more detectable with TIP methods when the evaluation temperatures are taken near the halfway time to peak temperature development, rather than at the peak time.

CSL measurements indicated arrival time increases of at least ten percent and relative energy decreases of at least five decibels for five of the intentional defects, with no discernable increase in arrival time or decrease in relative energy for the other four defects. Successfully identified defects were within the reinforcing cage, including a soft bottom defect and the tremie breach defect. CSL measurements did not produce significant indications for defects outside the reinforcing cage or for weak concrete. The tendency for false positive CSL results due to tube debonding was demonstrated with significantly delayed arrival times and decreased relative energy for CSL measurements. Evaluation of relative energy for CSL test results can be used to identify defects that are not apparent in CSL arrival time results for the same shaft.

Recommendations for Implementation

TIP and CSL each excel in detecting certain defects and fail to adequately detect others; when used complementarily, the tests are well suited to detect all significant defects. The research team recommends allowing TIP as an alternative or, when warranted, as a complement to CSL, depending on project considerations, such as predominant loading type. Both test methods should be used for technique shafts, shafts installed prior to the installation of production shafts to evaluate a contractor's proposed means and methods.

TIP testing should be performed using sacrificial wires, rather than probes, as wires' continuous time records greatly improve the likelihood of detecting defects. Interpretation should include evaluation of temperature versus time plots and be based on raw temperature measurements only, not analyses of effective radius. Any significant temperature deviations should be identified in a TIP report and trigger evaluation by the design engineer of the shaft, who should then determine whether the deviation is permissible or requires further investigation or remediation.

This brief summarizes Project 0092-16-07,
"Thermal Integrity Profiling for Detecting Flaws in Drilled Shafts"
Wisconsin Highway Research Program

Research Brief

Wisconsin Highway Research Program
Project 0092-17-05
August 2019

Performance and Policy Related to Aluminum Culverts in Wisconsin

Research Objectives

- Evaluate the performance of aluminum drainage structures in Wisconsin
- Examine recent changes to materials and specification for use of aluminum drainage structures
- Establish best practices for aluminum culvert use and formulate recommendations for updated aluminum culvert policy in Wisconsin

Research Benefits

- Determined causes and processes of corrosion
- Identified optimal soil and water conditions for aluminum culverts
- Recommended strategies for protecting culverts from chloride-induced corrosion
- Revised contemporary policies on the use of aluminum drainage structures

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Background

Corrosion and abrasion are the two primary factors that affect aluminum culvert durability. Corrosion manifests in two ways: general corrosion and localized pitting corrosion. The failure of an aluminum culvert due to pitting corrosion from deicing salts in 1993 prompted WisDOT to reevaluate its use of aluminum drainage structures, such as pipe and box culverts. Field investigations of other aluminum culverts revealed widespread corrosion at the tops of the structures, likely initiated by soil-side contact with infiltrating deicing salts. The results of this investigation lead WisDOT to severely limit its use of aluminum drainage culverts.

Corroded aluminum pipe removed from WIS 32

The objectives of this research were to evaluate WisDOT's current policies restricting the use of aluminum culverts and provide guidelines for how to best administer culverts in transportation projects.

Methodology

The research team identified 53 aluminum culverts, most five feet or greater in diameter, in WisDOT's Highway Structures Information System (HSIS) database. Photos from each culvert's most recent inspection were used to assign it one of three corrosion grades: no corrosion, minor corrosion and significant corrosion. The team inspected three in-service aluminum culverts (one corrugated pipe and two corrugated structural plate pipe arches) in accordance with the National Cooperative Highway Research Program's Culvert and Storm Drain System Inspection Manual. Each culvert was evaluated for signs of distress, such as general and localized pitting corrosion and abrasion. Soil, water and aluminum culvert samples were taken from each site and subjected to laboratory testing to determine environmental conditions and material properties.

"This research identified potential pathways for aluminum culvert corrosion and methodology to prevent its occurrence. The results will be used to guide future WisDOT culvert policy."

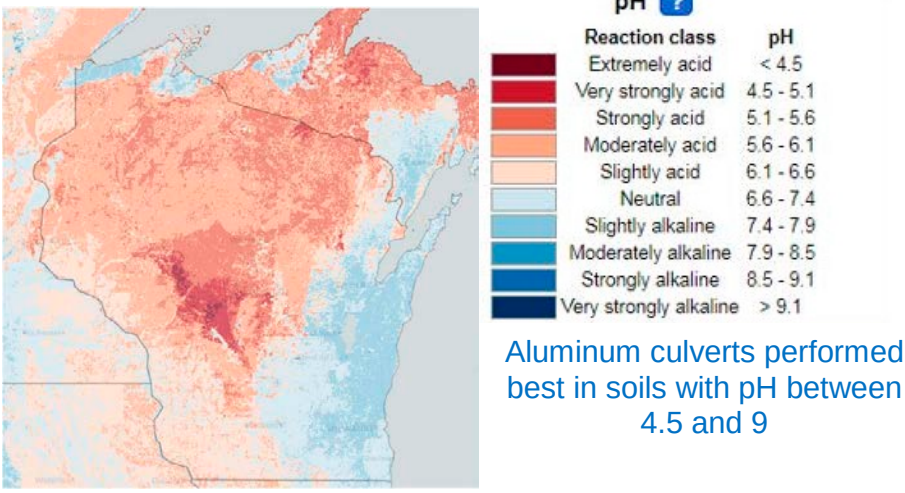
– Steve Neary, WisDOT

Interested in finding out more?

Final report is available at:
WisDOT Research website

Results

No corrosion was noted in 39 of the 53 culverts; minor corrosion appeared in eight; and significant corrosion in two, which had the lowest National Bridge Inventory (NBI) ratings. Aluminum culverts proved to be very resistant to general corrosion when installed at sites with soil and water pH between 4.5 and 9 and resistivity of more than 500 Ω-cm. Corrosion levels correlated with culvert age, pavement cracking and heavy road salt usage; they did not correlate significantly with average daily traffic, geographic location, culvert length, span or fill depth.



Aluminum culverts performed best in soils with pH between 4.5 and 9

Recommendations for implementation

Laboratory testing of soil and water samples from sites of potential culverts should be performed prior to design to determine suitability of environmental conditions. To ensure corrosion does not initiate on culverts in regions that use deicing chemicals, aluminum should be isolated from contact with chloride-containing salts that can migrate vertically from the roadway surface through cracked pavement and soil fill and through unpaved shoulders and embankments. Abrasion classifications should be made for each new culvert to determine if any additional protective measures should be taken.

The research team recommended the following updates to WisDOT's manuals and specifications regarding aluminum culverts:

- Allow use of aluminum culverts (pipe, structural plate structures, box culverts) at sites where soil and water pH ranges from 4.5 to 9 and resistivity is greater than 500 Ω-cm
- Specify use of an impermeable isolation membrane in the backfill envelope extending at least 10 feet from edges of pavement or to the end of the culvert
- Specify free-draining backfill with limited chloride ion content (< 100 ppm) below the isolation membrane

This brief summarizes Project 0092-17-05,
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