



# WHRP

## Wisconsin Department of Transportation Wisconsin Highway Research Program

Request for Proposals

### ***Hydraulic Conductivity of Base Course Materials, Pavement Drainage, and Relation to Pavement Buckling***

Questions submitted to [research@dot.wi.gov](mailto:research@dot.wi.gov) regarding the content of this RFP are due no later than 04:30 PM (CST) on January 4, 2024

Responses to questions will be posted to the WisDOT Research and Library website <http://wisdotresearch.wi.gov/rfps-and-proposals> by 04:30 PM (CST) on January 19, 2024

Proposers must submit a PDF version of their proposal by 4:30 PM (CST) on February 9, 2024 to [research@dot.wi.gov](mailto:research@dot.wi.gov).

Proposal Preparation Guidelines can be found at the Proposal Preparation Guidelines at <https://wisconsin.gov/Pages/about-wisdot/research/researchers.aspx>

Proposers will be notified by April 26, 2024

For more information regarding this RFP, contact the WisDOT Research Program at [research@dot.wi.gov](mailto:research@dot.wi.gov).

This RFP has been posted to the Internet at: <http://wisdotresearch.wi.gov/rfps-and-proposals>

**Wisconsin Highway Research Program (WHRP)  
Geotechnics Technical Oversight Committee (TOC)  
Request for Proposals**

***Hydraulic Conductivity of Base Course Materials, Pavement Drainage,  
and Relation to Pavement Buckling***

**I. Background and Problem Statement**

Poor drainage of base course materials can potentially jeopardize the structural integrity of pavement foundations. This is mainly attributed to the stiffness softening and shear strength reduction behavior of unbound aggregate systems due to moisture intrusion, causing a reduction in capillary forces and effective stress. Another primary concern associated with excessive moisture in base courses is the buckling potential of concrete pavements, particularly during hot weather. The buckling of concrete pavements is a severe problem affecting the traveling public due to potential safety concerns, so buckled pavements require immediate repair, which is expensive and can be difficult.

The literature search found several studies that have researched the properties of pavement base materials, including hydraulic conductivity, water retention curves, drainability, and resilient modulus. However, much less research studies the relationship between elevated base course moisture and pavement buckling. For example, the Wisconsin Highway Research Program (WHRP) Project 0092-20-02, completed in February 2022, indicated that drainage design was one of the critical differences between pavement design in Wisconsin, which has relatively high occurrences of pavement buckling, compared to neighboring states that have relatively lower occurrences of pavement buckling. In addition, a National Road Research Alliance (NRRRA) study (Drainability of Aggregate and Sand, 2021) characterized the drainability of 1¼ in. dense graded base and breaker run from Wisconsin sources as “poor.”

This research project aims to study the effects of excessive moisture in base courses, focusing on the potential contributions of base course drainability and water retention to pavement buckling and investigate adjustments to base course gradations and drainage details and strategies to improve drainability, control sensitivity to moisture changes, and reduce buckling potential while maintaining adequate pavement support. The proposed project will include sampling and testing of base courses around the state to characterize the index properties, hydraulic conductivity, water retention curves, drainage properties, and resilient modulus. Base course samples from pavement buckling occurrences will also be collected to assess if commonalities exist in the base courses where pavement buckling occurs. Current pavement drainage strategies employed in Wisconsin will also be reviewed. Base course gradations, water retention properties, and pavement drainage strategies of surrounding states will also be reviewed. The culmination of reviewing current WisDOT base course gradations and drainage details and those of surrounding

states will be the development of updated base course gradations and drainage strategies to improve moisture management while maintaining adequate pavement support.

## II. Research Objectives

The project objectives include:

1. Characterize the gradation, hydraulic conductivity, water retention, and drainability of base course materials and their potential contributions to pavement buckling occurrences.
2. Review the current drainage practices in Wisconsin's transportation practices.
3. Critically assess whether moisture accumulation below the pavement, particularly when combined with elevated temperature and humidity in warm seasons, contributes to pavement buckling issues in Wisconsin DOT (WisDOT) roads.
4. Develop updated base course gradations that improve hydraulic conductivity and water retention properties while maintaining current strength and stiffness characteristics.
5. Recommend adjustments to base course gradations and drainage systems currently employed in the State of Wisconsin to enhance drainage systems and reduce buckling potential while maintaining adequate pavement support under traffic loads.

## III. Scope of Work

### Task 1: Literature Review

The research team will perform a comprehensive literature review regarding the state of practice across northern Departments of Transportation (DOTs) in the United States and Ministries of Transportation in Canada. Emphasis should be placed on the complete review and evaluation of gradation, hydraulic conductivity, water retention, and drainability of the base course materials and pavement system from surrounding states to identify differences between WisDOT design standards/specifications and those of other agencies. The research team must document procedures used by different entities to design efficient moisture management systems that resulted in higher drainage capacity and decreased incidences of buckling in rigid pavements under the combined effect of temperature and moisture. Successful examples of functioning drainage layers, including geosynthetics and other methods, should also be documented. The role of road shoulders and their characteristics on the drainage capacity of highway infrastructure should also be explored. The observations and findings obtained from the review of current practices will be synthesized to serve as the basis for formulating the work plan and can be used as the precursor for recommending adjustments to WisDOT standard details and specifications.

The literature review results will be documented and presented to the Project Oversight Committee (POC) in an interim report.

#### *Supporting Documents:*

- Rao, S. et al. (2022). "Evaluation of Concrete Pavement Buckling in Wisconsin." Wisconsin Highway Research Program. URL: <https://wisconsindot.gov/documents2/research/0092-20-02-final-report.pdf>

- Oh, H. et al. (2021). “Drainability of Base Aggregate and Sand.” National Road Research Alliance (MNDOT). URL: <https://rosap.nrl.bts.gov/view/dot/58397>

### **Task 2: Sampling and Laboratory Testing**

The research team will develop a sampling matrix to characterize the hydraulic conductivity, water retention, and physical properties [e.g., index properties, particle-size distribution, fines content, particle shape, Atterberg limits, moisture content, specific gravity and Proctor (optimum moisture content and maximum dry unit weight)], and stiffness properties (e.g., resilient modulus) of various base course materials in Wisconsin. The sampling matrix should ensure an appropriate representation of predominant aggregate and source materials used to construct dense graded base layers in different WisDOT regions. At a minimum, the research team will collect between 25 and 30 samples of production-dense graded base course materials (about 5 to 6 samples per region) to account for different sources and gradations of base course materials used in Wisconsin. The sampling should focus on sampling sources of 1 ¼ inch dense grade base (WisDOT Standard Specification 305), including virgin aggregate, crushed stone, crushed gravel, crushed concrete, reclaimed asphalt, reprocessed material, and blended material. Additionally, at least one sample of Open Graded Base (WisDOT Standard Specification 310) shall be collected from each region.

The proposed sampling matrix will be presented to the POC for final approval.

### **Task 3: Experimental Investigation of Buckling Sites**

The laboratory testing program for base course samples will characterize the index properties, hydraulic conductivity, water retention, and resilient modulus of base materials to investigate if commonalities exist in the base courses where pavement buckling occurs during warm seasons. The research team will also perform experimental investigations, including field surveys, sampling, and laboratory testing in buckling areas across the state to assess whether moisture accumulation below the pavement contributes to pavement buckling issues. The experimental investigations should focus on finding the controlling parameters for buckling incidents in Wisconsin environments as they relate to the water retention properties and drainage characteristics of base course materials. The field survey will evaluate pavement surface conditions, road shoulder characteristics, subsurface drainage systems, and the saturation state of subsurface layers subjected to heat-induced pavement buckling. As it will be difficult for the research team to mobilize to collect samples during pavement buckling repair work, the research team will coordinate with the POC and Region Maintenance Staff to ensure WisDOT and county maintenance staff collect base course samples from below buckled concrete pavement sections.

The research team will critically assess at least five to ten representative pavement buckling sites by evaluating the collected samples. At a minimum, the research team (in coordination with WisDOT and county maintenance staff) will aim to collect three samples (mid-panel and at the joints) from each buckling site. Most samples should be collected from jointed plain concrete pavement (JPCP) sections. The selection of representative JPCP sections will be determined considering the geographical locations across Wisconsin, functional roadway

classification, historical records, frequency of buckling incidences, base aggregate materials, pavement structure design, drainage design, and ability to provide traffic lane closure.

For reference, the geographic distribution of buckling incidences in Wisconsin between 2013 and 2019 indicates that most buckling occurred in the central and southern parts of the state (Figure 1).

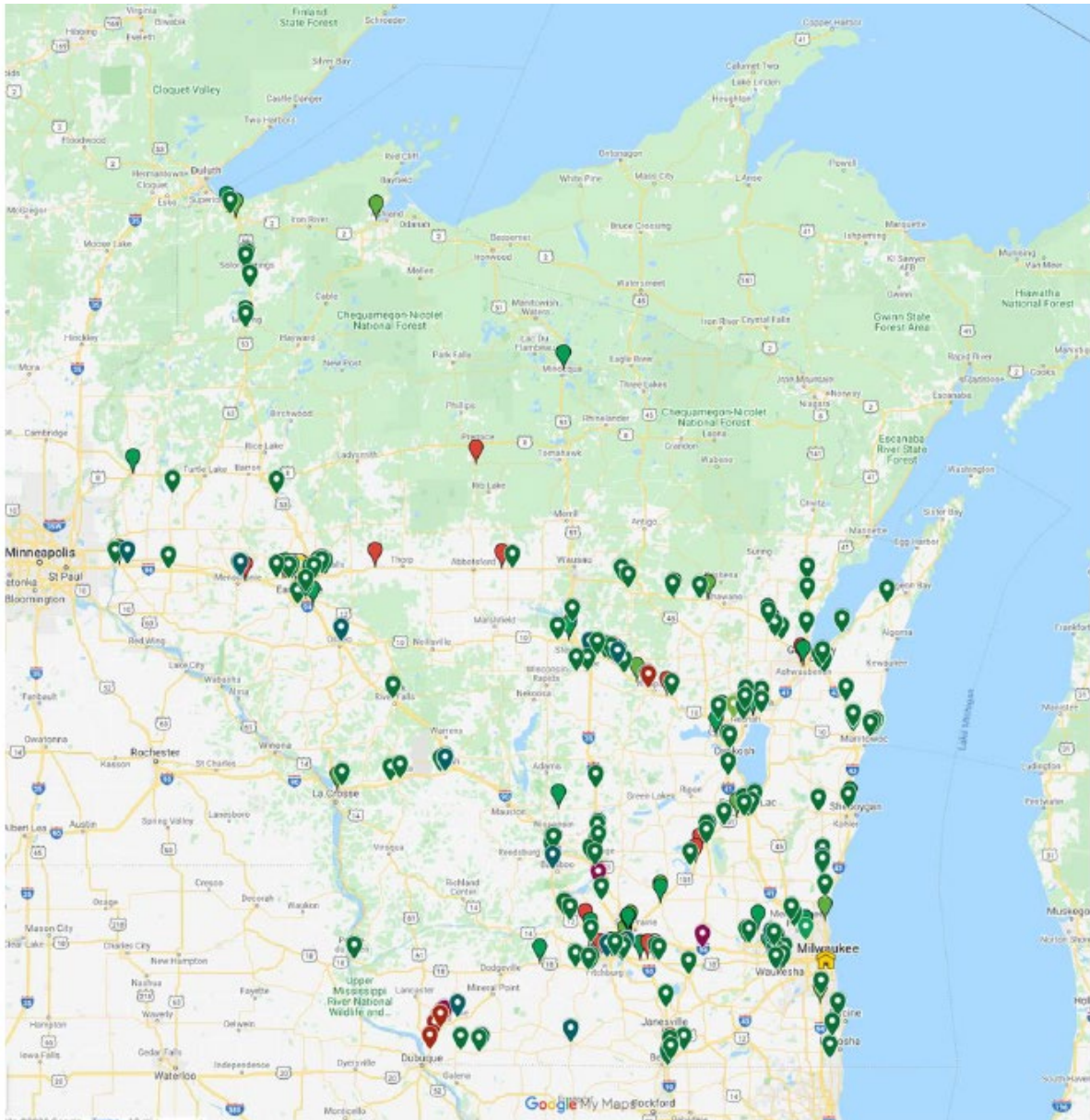


Figure 1 – Geographic distribution of pavement blowups in Wisconsin between 2013 and 2019 (Rao et al., 2022).

#### **Task 4: Assessment of Pavement Buckling Potential based on Base Course Water Retention and Drainability**

The data collected in Tasks 2 and 3 will be compiled and critically assessed to identify the role of road drainage design and hydraulic conductivity and water retention of base course materials in the pavement buckling mechanisms when the concrete expands during demanding environmental conditions of increased temperature and moisture in Wisconsin. The research team will adopt data-driven and analytical/statistical approaches to develop further predictive models for estimating pavement buckling potential based on the drainage characteristics of base courses and drainage systems in the State of Wisconsin.

#### **Task 5: Develop Updated Base Course Gradation**

An earlier NRRRA study characterized the drain ability of 1¼ in. dense graded base and breaker run from Wisconsin sources as “poor,” and poor drain ability may be correlated to increased incidences of pavement buckling. Therefore, the goal of this task is to develop updated base course gradations that improve the hydraulic conductivity and water retention of the current dense grade base course while maintaining its strength and stiffness characteristics. Information from Task 2 should be used as baseline hydraulic conductivity and resilient moduli values for existing dense graded base course materials. In addition, constructability should be considered in developing updated gradations. For example, an open-graded base gradation (Standard Specification 310) is generally not a preferred substitute for a dense graded base from a constructability standpoint since wheeled construction equipment may have difficulty traversing and turning on an open-graded base.

#### **Task 6: Provide Recommended Adjustments to the Current State of Practice**

The research team will provide recommended adjustments to WisDOT standard details and specifications regarding base course gradations and drainage practices to (1) enhance subsurface moisture drainage under prolonged inundation conditions and elevated groundwater table, (2) improve the long-term performance of the pavement structure by removing the excessive moisture, (3) reduce buckling potential, and (4) maintain adequate pavement support. Practical implementations, as well as limitations in terms of constructability and stiffness capacity, should be considered when proposing adjustments to base course gradation and drainage design to ensure sufficient pavement support is achieved. The research team will assess effective mitigation strategies for reducing buckling incidents related to drainage design. The potential use of various functioning drainage layers/materials, including geosynthetics and other techniques to improve performance (e.g., enhance moisture management, reduce buckling potential, and maintain stiffness) should also be investigated.

The research team will develop recommendations and guidelines with updated base course gradations and pavement drainage details in a format consistent with Wisconsin Standard Specifications, Construction and Material Manual (CMM), Facility Development Manual (FDM), and Highway Maintenance Manual.

### **Task 7: Final Report and Closeout Presentation**

The research team will prepare and submit a draft final report that will include the literature review and synthesis, design of the sampling matrix and laboratory testing, data analysis, interpretation, assessment of pavement buckling potential, updated course gradations, and recommended adjustments to WisDOT standard details and specifications for enhancing roadway drainage capacity and reducing buckling potential. As part of this report, the research team will include Excel files with curated testing data for future use, analysis, and interpretation.

A closeout presentation (COP) will be scheduled within three months before the end of the contract. At least one representative from the research team is expected to present the results and recommendations from the project.

### **IV. Required Testing**

At a minimum, the following laboratory tests should be performed on the collected base course samples where applicable:

- Hydraulic conductivity (ASTM D5084-16)
- Soil-water characteristics curve (SWCC) tests (ASTM D6836-16)
- Resilient modulus (AASHTO T 307)
- Grain size distribution (AASHTO T 27)
- Atterberg limits (AASHTO T89-22/AASHTO T90-22)
- Moisture content (ASTM D2216)
- Specific gravity (AASHTO T84-22/ AASHTO T85-22)
- Proctor (AASHTO T180)
- Particle Shape

The final list of tests will be defined in consultation with the POC.

### **V. WisDOT/TOC Contribution**

WisDOT will provide the following support through the POC to support the successful completion of the project.

- A. The TOC and POC will coordinate access to WisDOT aggregates used in laboratory test programs. The POC will work with the research team to ship materials. However, the research team will be responsible for aggregate sampling at the buckling sites (Task 3) and must arrange for and cover the cost of aggregate and material transport to their laboratory test facilities as needed or for other samples or materials anticipated by the researcher.
- B. If fieldwork on or around in-service facilities is anticipated, the proposal will describe the nature and extent of traffic control and support assistance required. The research team will coordinate with WisDOT regional personnel and possibly county personnel where project fieldwork is being conducted. For WisDOT planning purposes, the research team shall specify in the proposal, as practical, traffic control measures needed for this project, including traffic flagging, signage, barricades, etc., and the duration

(hours/day/location). WisDOT will only fund the traffic control with the research project budget.

- C. The research team will not assume the availability of WisDOT staff or equipment in the proposal (beyond what was described in section V.A). If WisDOT or another entity donates equipment or staff time, a commitment letter must be included in the proposal.
- D. Researchers should refrain from assuming the availability of contractors for sampling and testing.

## **VI. Required Travel**

This project will require travel to the project sites across Wisconsin for sampling, field inspection, documentation, measurement, and information collection.

## **VII. Deliverables**

- A. Quarterly Progress Reports
  - a. WHRP contracts require quarterly technical progress reports for technical and administrative functions.
  - b. Detailed information regarding the content of the progress report can be found at [Quarterly Progress Reports Guidelines](#)
- B. Invoices
  - a. Invoices shall be submitted quarterly for partial payments on the project for authorized services completed to date. Four invoices per year are expected, one partial invoice for each specified quarter.
  - b. Detailed information regarding invoicing can be found at [Invoicing Requirements](#)
- C. Before Close-Out Presentation (BCOP) Report
  - a. A BCOP report must be submitted three months before the contract end date to allow time for review and revision of the BCOP before the presentation.
  - b. Reports are expected to have quality technical writing and proper grammar. It is acceptable to dedicate funds in the project budget for the services of a technical editor to ensure these requirements are met.
  - c. The required elements of the BCOP report can be found at [Before Closeout Presentation Requirements](#)
- D. Project Closeout Presentation (COP)
  - a. The Principal Investigator on the research team must give a presentation to the TOC during the last three months of the project.
  - b. Presentation and formatting requirements can be found at [Closeout Presentation Requirements](#)
- E. After Closeout Presentation (ACOP) Report
  - a. The ACOP report is due within three weeks of the Closeout Presentation for review and comments.
  - b. This report details the results of the research project. The final report should be as concise as possible (e.g., a maximum of 50 pages plus supporting appendices) and follow the report guidelines and submission requirements: [After Close-Out Presentation Report Requirements](#)



- c. After revision(s) and oversight committee chair approval, an electronic copy of the Publication-Ready Report must be delivered to WisDOT by the contract end date.

**VIII. Schedule and Budget**

- A. The project budget shall be at most \$225,000.
- B. The proposed project duration is 24 months, starting around 10/01/2024.
- C. The deadline for submittal of the BCOP is three months before the contract end date to allow for report review activities.

**IX. Implementation**

- A. Provide recommended adjustments to WisDOT standard details and specifications regarding the base course gradations and drainage practices to enhance drainage capacity and reduce buckling potential while maintaining adequate pavement support.
- B. Provide recommendations to update Wisconsin Standard Specifications, Construction and Material Manual (CMM), Facility Development Manual (FDM), and Highway Maintenance Manual.