Wisconsin Department of Transportation

Wisconsin Highway Research Program

Request for Proposals

Alternative Conditioning Method to Calculate Formation Factor for Wisconsin Concrete Pavement

Questions submitted to research@dot.wi.gov regarding the content of this RFP are due no later than 04:30 PM (CST) on January 3, 2023

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 18, 2023

Proposers must submit a PDF version of their proposal by 4:30 PM (CST) on February 8, 2023 to: research@dot.wi.gov.

Proposal Preparation Guidelines can be found at Proposal Preparation Guidelines

Proposers will be notified by April 28, 2023

For more information regarding this RFP, contact the WisDOT Research Program at 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)

Rigid Pavement Technical Oversight Committee (TOC)

Request for Proposals

Alternative Conditioning Method to Calculate Formation Factor for Wisconsin Concrete Pavement

I. Background and Problem Statement

Formation factor is the concrete's electrical resistivity over its pore solution's electrical resistivity ratio. It is a measurement used for assessing concrete permeability and durability as part of the Performance Engineered Mixtures (PEM) methodology, the new standard for designing concrete mixes. Furthermore, engineers evaluate the concrete's susceptibility to chemical penetration based on formation factor measurements.

Electrical resistivity measurement of concrete pore solution is sensitive to concentration of soluble ions (e.g., Na^+ and K^+), and, therefore, the conditioning of concrete specimen including leaching and the degree of saturation is important for the formation factor measurement. There are two conditioning methods specified in AASHTO TP 119-22 – Immersion of specimens in a calcium hydroxide-saturated solution (i.e., the *default conditioning*) and sealed sample (i.e., the *alternative conditioning option*) for measuring the formation factor. For the default conditioning method specifically, it is assumed that the sample's pore solution is in equilibrium with the curing solution after the conditioning procedure, and the electrical resistivity of the simulated pore solution can be used to calculate the formation factor. However, some variations in the pore solution chemistry/electrical resistivity can still exist because materials can have different soluble ion contents, especially when alternative supplementary cementitious materials are used and conditioning may not fully reach equilibrium[1,2]. In addition, the simulated pore solution requires additional preparation, and the high pH solution is prone to carbonation. These requirements create logistic and cost challenges when implementing formation factor measurements into Wisconsin Department of Transportation (WisDOT) specifications.

This study's primary objective would be to assess the degree of variation in the pore solution chemistry/electrical resistivity in WisDOT's concrete mixtures and also the effectiveness of the conditioning method for formation factor testing. Based on the findings, alternative conditioning procedures such as limewater curing with a correction factor to account for alkali

[1] Tanesi, J., Ardani, A., & Montanari, L. (2019). *Formation factor demystified and its relationship to durability* (No. FHWA-HRT-19-030). United States. Federal Highway Administration. https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/19030/19030.pdf

[2] Spragg, R., Graybeal, B., Saladi, N., Montanari, L., & De la Varga, I. (2022). *Electrical Resistivity Testing to Rapidly Assess the Durability of UHPC-Class Materials* (No. FHWA-HRT-21-095)., https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/21095/21095.pdf

leaching may be developed. This study will involve in-depth lab testing to examine pore solutions from WisDOT concrete mixtures, testing electrical resistivity and formation factor of concrete samples with various solutions and conditioning methods. The success of this study will enhance the PEM specification and help implement PEM in Wisconsin in a timely manner.

I. Research Objectives

- Determine the degree of variability in both pore solution chemistry and electrical resistivity.
- Evaluate the effectiveness of the standard conditioning method by determining the degree of equilibration and/or the leaching kinetics.
- Identify the standard and alternative conditioning methods for Wisconsin concrete with various pore solutions to measure formation factor and compare the accuracies between the methods.
- Identify practical conditioning methods for measuring formation factors, and/or develop correction factors correlating alternative methods to standard procedures for Wisconsin concrete.

II. Scope of Work

Task 1: Extensive Literature Review and State of Practice of using Formation Factor

Conduct a comprehensive literature review to identify conditioning methods to measure formation factor in concrete. The conditioning methods should include using the conventional pore solutions (e.g., lime-water) and curing methods (e.g., fog room), and standard methods described in AASHTO TP 119-22. This task includes the survey of Departments of Transportation (DOTs) and industries in which conditioning methods are used for state pavement jobs. In addition, researchers should collect information regarding conversion factors and correlations (if any practical ways) used to convert formation factor measurements among various conditioning methods. Researchers will also identify the obstacles and hurdles for using the identified conditioning pore solutions and methods compared to the standard methods. The critical evaluation of published results should also reveal the acceptable range of formation factors when alternative solutions and conditioning methods are used.

Task 2: Select, Collect, and Deliver the Material to Researchers

Researchers will work with the Project Oversight Committee (POC) members to identify different sources of coarse aggregate, commonly used cement, and supplementary cementitious materials (SCMs) for concrete pavement. Sources of coarse aggregate should include, at a minimum, mixed aggregate from south-central Wisconsin, crushed limestone from the Milwaukee area, igneous gravel from northwest Wisconsin, and igneous quarry material from north-central Wisconsin. In addition, the research team will consult with POC members about the types of SCM and their contents for this study. Researchers will be responsible for collecting and shipping the materials for lab testing.

Task 3: Measure the Pore Solution Electrical Resistivity of Concrete, and Test Effectiveness of the Conditioning Methods

Pore solutions should be extracted from concrete (preferred) or mortar/paste samples and characterized for solution chemistry and electrical resistivity to calculate accurate formation

factors. Conditioning of samples with different pore solutions will be conducted in this task. The effectiveness of the conditioning methods should be evaluated based on the final condition of the sample or experimentally measured leaching kinetics. This task will explore typical WisDOT concrete mixtures and develop the pore solution electrical resistivity database of them. The database should further include the duration for concrete samples to reach the equilibrium in various solutions. The results of the Task will be utilized in Task 4 to calculate the formation factors from pore solutions and conditioning methods.

Task 4: Conduct Lab Testing with Various Pore Solutions and Conditioning Methods to Calculate the Formation Factors

Using both bulk and surface resistivity tests, researchers will conduct laboratory tests to calculate formation factors. The tests should cover (1) standard pore solutions and conditioning methods specified in AASHTO TP 119-22 (both defaulting and alternative conditioning options) and (2) conventional and other alternative pore solutions and conditioning methods identified in Tasks 1 and 3. The research team may consider comparing electrical resistivity measurements to permeability tests (e.g., Rapid Chloride Permeability Test -RCPT) to verify the lab results.

Task 5: Data Analyses and Interpretations

Researchers will conduct analyses to interpret the testing results from Task 3 and 4. The goal is to compare all calculated formation factors and to establish correlations between measurements using different conditions, solutions, and methods. The experimental correction factors will be developed so that formation factors can be corrected and implemented immediately. Before drafting the project report, the results will be presented and discussed with POC members.

Task 6: Final Report and Closeout Presentation

The research team will prepare and submit a draft final report that will include project background, lab data analysis and interpretation, and recommendations for alternative curing methods for measuring formation factors. As part of this report, the research team will include any data files collected from lab and field testing for future use, analysis, and interpretation.

III. Required Testing/Equipment

- Pore solution extracting apparatus, using procedures such as those recommended by Montanari et al.[3]
- Analytical equipment for solution chemistry analysis, such as Inductively Coupled Plasma–Optical Emission Spectroscopy (ICP-OES), and aqueous electrical resistivity
- Standard Method of Test for Rapid Determination of the Chloride Permeability of Concrete (AASHTO T277)
- Super Air Meter (SAM) (AASHTO TP 118)
- Electrical Resistivity of a Concrete Cylinder Tested in a Uniaxial Resistance Test (AASHTO TP 119-22) Both Surface and Bulk resistivity test

IV. WisDOT/TOC Contribution

[3] Montanari, L., Tanesi, J., Kim, H., & Ardani, A. (2020). Influence of loading pressure and sample preparation on ionic concentration and resistivity of pore solution expressed from concrete samples. *Journal of Testing and Evaluation*, *49*(5).

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

A. The POC will work with the research team for the shipment of materials. The budget developed should include the costs associated with material transportation.
B. The research team will not assume the availability of WisDOT staff or equipment in the proposal. If WisDOT or another entity donates equipment or staff time, a commitment letter must be included in the proposal.
C. The Technical Oversight Committee (TOC) and POC will coordinate access to WisDOT aggregates used in laboratory test programs. In addition, the research team must arrange and cover the transport of aggregates and materials to their laboratory test facilities as needed.
D. 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 the 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 for this project, including traffic flagging, signage, barricades, etc., and the duration (hours/day/location). WisDOT will not fund the traffic control apart from the research project budget.

V. Required for Travel to Fulfill TOC Obligations

The principal investigator will deliver the final presentation during the last three months of the project.

VI. Deliverables

A. Quarterly Progress Reports
   a. WHRP contracts require quarterly technical progress reports that serve both 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 Closeout Presentation (BCOP) Report
   a. A BCOP report is required to 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 is required to give a presentation to the TOC.
   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 after 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 Closeout 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.

VII. Schedule and Budget

A. The project budget shall not exceed $200,000
B. The proposed project duration is 24 months, starting around 10/01/2023
C. The deadline for submittal of the BCOP is three months before the contract end date to allow for report review activities.

VIII. Implementation

A. Develop a database of electrical resistivity with various practical pore solutions that can be used to calculate the Formation Factor in Wisconsin.
B. Identify the correlations between Formation Factors obtained from various conditioning methods, including conventional and standard condition procedures.
C. Identify practical pore solutions and conditioning methods to calculate Formation Factor for Wisconsin's Concrete Pavement.
D. Recommend and refine specification for acceptance of using Formation Factors calculated from various conditioning methods to prevent early failure.