Oregon Department of Transportation

Research Stage 1 Problem Statement

Number 26-59 – "Development of Concrete Resistivity Standards for ODOT"

1. Concisely describe the **transportation issue** (including problems, improvements, or untested solutions) that Oregon needs to research.
ODOT is seeking to develop a specification for the acceptance of concrete materials based on the use of electrical resistivity to assess the materials' resistance to permeability and other transport properties. National research has been performed (by OSU) resulting in test methods like AASHTO T402 (and T358). Research is needed to relate the results of the resistivity test to specification limits (i.e., acceptance quality limits) that should be implemented in Oregon and service life predictions. This is particularly useful as concrete binders and mixtures are projected to change dramatically over the next decade as low global warming potential mixtures are implemented in Oregon.

2. What **final product or information** needs to be produced to enable this research to be implemented?
ODOT has begun the development of a specification to provide a more cost-effective alternative to "02001.15(b)(2)(d) Permeability Tests". Documentation is needed to define the testing options for the alternatives that are in the AASHTO standard, as well as to define the acceptable quality values for materials using constituents from Oregon. Further, it is known that the current specification (02001.15(b)(2)(d) Permeability Tests) will not be able to effectively measure low GWP mixtures with binders that have low portland cement clinker contents. Information is needed to describe how to convert AASHTO T402/358 values to a more fundamental measure of fluid transport (permeability) and other transport properties (e.g., chloride diffusivity).

This project would have four deliverables:

1) clarification on options and timing of tests performed using AASHTO T402/T358 for materials qualification and acceptance,
2) performance limits for concrete made using materials native to Oregon,
3) specification language for 02001.15(b)(2)(d) Permeability Tests that permit AASHTO T402/358, and
4) a standard method to interpret AASTHO T402/T358 results for low portland cement clinker content mixtures (this may include the conversion of resistivity measurements to a form that accounts for pore solution known as the formation factor, F-factor). These binders are particularly important due to the desire to reduce the GWP potential of concrete (i.e., reducing GHG).

This work would be used by the ODOT concrete quality control office and through project specifications and testing standards. ODOT and ODOT contractors already own most of the equipment used to measure electrical resistivity (AASHTO T402/358).

This can enable ODOT to quantify the long-term durability of concrete made using low-clinker concrete that reduces the GWP of concrete. This can enable ODOT to make cost-effective solutions for material selection and acceptance.

3. (Optional) Are there any individuals in Oregon who will be instrumental to the success of implementing any solution that is identified by this research? If so, please list them below.

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4. Decision making lenses
Please complete the following three sections. Your answers to these questions will be applied on a programmatic basis to support agency decisions. Answering yes to the questions below is not required. Resolving a narrowly focused technical research problem may meet agency needs without answering yes to any of the following questions. The ODOT Research Section will seek a balanced portfolio some projects will answer yes to one of the three categories below (e.g. climate, equity, and/ or safety) and other projects in a different category.

We are looking for an overall program balance and no one project is expected to balance all categories. Generally, a research problem statement is expected to be able to answer yes with clear and verifiable information in only one of the three categories below, some projects may be able to answer yes in two or even three categories. Some projects (i.e. needs focused on specific elements of infrastructure design), may have no yes answers but may still be high value research need.

Climate
Oregon recognizes the climate crisis and makes systemic changes to reduce emissions caused by travel. Every mile driven in Oregon is powered by a clean source of fuel. We seek research that supports construction and maintenance operations are carbon neutral and investments in mobility that support travel by low and no emission modes. While every research project may not result in a reduction in emissions, transportation investments overall support emission reductions to achieve state goals. Oregon envisions a transportation system that is resilient in the face of seismic and climate events and impacts to the degradation of the natural environment are reduced. Our vision includes a transportation infrastructure is built in a way that avoids impacts on key habitat and results in better environmental conditions for wildlife and native vegetation. For definitions and details please review the equity vision, goals, and objectives of the ODOT Strategic Action Plan and Oregon Transportation Plan.

4f. Will addressing the **transportation issue** identified as a need in Question 1 develop, or validate methods for the estimation, measurement, or monitoring of transportation generated greenhouse gasses (GHG)?

☒Yes ☐No ☐Unsure

The proposed research can be used in a life cycle assessment (LCA) to quantify the environmental impacts of construction following international norms, specifically focusing on the entire life (A1-D).

4g. If climate or GHG is not the focus of this **transportation issue** identified in this problem statement, will the research apply a GHG analysis to transportation infrastructure, planning, operations, maintenance, or materials?

☐Yes ☐No ☒Unsure

4h. Will the addressing the **transportation issue** include development or testing of construction practices, methods, or materials to establish potential reductions in greenhouse gas emissions?

☒Yes ☐No ☐Unsure

The proposed research can provide specification limits and methods to quantify the GWP of concrete based on long term durability (assessed using the permeability measures). This work will establish technical limits and be extended to work for low clinker binders specifically focused on reducing the GWP/GHG of concrete mixtures.

4i. Will the solving the **transportation issue** in question 1 study or support the reduction of vehicle miles traveled and single occupancy vehicle travel or support transition to electric vehicles (or other types of zero emission vehicles) or low-carbon alternative fuels?

☐Yes ☒No ☐Unsure

4j. Will the solving the **transportation issue** in question 1 lead to work that will support, measure, monitor, transportation system resilience in response to expected climate events, effects, or natural disasters in general?

☒Yes ☐No ☐Unsure

The proposed research can provide specification limits (i.e., resistivity or formation factors) that are used to establish long-term durability and resistance to environmental changes.

4k. Will the solving the **transportation issue** in question 1 lead to work that may result in better environmental conditions for wildlife and native vegetation ?

☐Yes ☐No ☒Unsure

4l. If you answered yes to any of the climate questions above or can provide alternative details related to climate, please provide additional information:

These results are provided in the sections above.

Equity

Equity can have many dimensions and impacts relating to communities, and transportation. It is important that problem statement proposals clearly explain in what capacities are equity dimensions or impacts being examined within problem statements. It is a goal of the OTP to "Improve access to safe and affordable transportation for all, recognizing the unmet mobility needs of people who have been systemically excluded and underserved. Create an equitable and transparent engagement and communications decision-making structure that builds public trust". Proposed research may have the intent of studying elements of this goal or apply analysis to specific transportation topics to ensure the resulting research recommendations is consistent with our equity goals. For definitions and details please review the equity vision, goals, and objectives of the ODOT Strategic Action Plan and Oregon Transportation Plan.

4a Is the **transportation issue** identified as a need in Question 1 specifically focused on transportation equity?

☐Yes ☒No ☐Unsure

4b If the **transportation issue** is not focused on transportation equity, will the primary topic be assessed for equity benefits or impacts within the research project?

☐Yes ☐No ☒Unsure

4c Is the implementation of potential findings from this research likely to directly involve participation from an identified group that would benefit from an equitable process or outcome?

☐Yes ☐No ☒Unsure

4d Is the intended final product or information expected to support ODOT's equity efforts (Including but not limited to supporting one of the equity related objectives of the ODOT's Strategic Action Plan or Oregon Transportation Plan) ?

☐Yes ☐No ☒Unsure

4e If you answered yes to any of the equity questions above or can provide alternative details related to equity, please provide additional information:

While the project is not focused on equity the process can be used by all and provides a level platform for evaluating material solutions.

Safety

Research outcomes may include interventions and countermeasures to prevent or reduce the frequency of crashes or other causes of transportation-related injury or death; or may include measures to reduce severity of injury (including prevention of death) after a crash or other injurious event. For definitions and details please review the equity vision, goals, and objectives of the ODOT Strategic Action Plan, Oregon Transportation Safety Action Plan and Oregon Transportation Plan.

4m. Will solving the **transportation issue** in question 1 support improving **safety culture** for either transportation workers or the traveling public?

☒Yes ☐No ☐Unsure

Establishing practices for quantifying and specifying long-term durability reduces the number of construction cycles removing construction workers from dangerous situations. This also reduces traffic at construction sites which have been known to result in a substantial increase in accidents and fatalities.

4n. Will the solving the **transportation issue** support improving safety through **healthy and livable communities**?

☐Yes ☒No ☐Unsure

4o. Will solving the **transportation issue** support improving safety through using **best available technologies**?

☐Yes ☐No ☒Unsure

4p. Will solving the **transportation issue** support improving safety through **communication and collaboration**?

☐Yes ☐No ☒Unsure

4q. Will the solving the **transportation issue** support improving safety through **investing strategically**?

☒Yes ☐No ☐Unsure

4r. If you answered yes to any of the safety questions above or can provide alternative details related to safety, please provide additional information:

These results are provided in the sections above.

5. Other comments:
Proposed Title – Development of Concrete Resistivity Standards for ODOT

Electrical resistivity is increasingly used as a test method to assess the transport properties (permeability) of concrete. Recently, standards have been developed to measure the resistivity of concrete AASHTO T 358-22 and AASHTO T 402-23 and precision and bias statements have been developed for these methods [Chopperla et al. 2024]. Electrical resistivity testing of concrete is relatively easy to perform, inexpensive, rapid, and non-destructive [Spragg et al. 2011, Rupnow and Icenogle 2012]. Specifications have been developed to use resistivity to assess concrete performance [AASHTO R101], which is particularly important as there is a desire to reduce the global warming potential (GWP) of concrete with new mixtures and materials and ensure that durability is maintained.

This study will quantify the timing at which tests should be performed as well as the sample curing and conditioning option from the testing standard for specification by ODOT. This will be useful for the development of specification language to provide an alternative to ODOT's current practice (02001.15(b)(2)(d) Permeability Tests) that permit AASHTO T402/358. It is currently thought that ODOT will benefit from assessing sealed samples that lend themselves to embedded sensors; however, the pros and cons of this approach will be discussed with the SAC. Implementing the resistivity testing would save ODOT time and money as it has done for other DOTs [Rupnow and Icenogle 2012].

This study will develop a baseline of tested ODOT mixtures to determine the current performance for existing materials. This information will be used to establish performance limits for concrete made using materials native to Oregon. This will enable confidence in the values established for acceptance and allow pay factors to be developed. This will reduce risk to ODOT and contractors.

Further, a standard method to interpret AASTHO T402/T358 results for low-clinker content mixtures will be developed. These binders are particularly important due to the desire to reduce the GWP potential of concrete (i.e., reducing GHG). The proposed approach will measure the resistivity; however, testing/calculation will be performed to determine the formation factor (an approach that corrects the resistivity by accounting for the pore solution resistivity). To account for the pore solution composition, a test method will be adopted using cold water extraction [Tuinukuafe et al. 2022] or estimation based on constituents [Biever et al. 2023]. The formation factor has the benefit that it is independent of material chemistry and is particularly useful for mixtures that have a lower cement clinker content or mixtures made using binders that are made using alternative materials which are becoming increasingly popular for reducing the GHG (GWP) of concrete. While resistivity data will be used to establish the limits, the belief is that a specification based on the formation factor (along with procedures to obtain it for ODOT) will be of the greatest long-term value. This can help ODOT ensure that long-term durability can be achieved even with low GWP mixtures.

References

AASHTO-R101. Standard Practice for Developing Performance Engineered Concrete Pavement Mixtures. American Association of State and Highway Transportation Officials; 2022. p. 14.

AASHTO-T358. Standard Method of Test for Surface Resistivity Indication of Concrete's Ability to Resist Chloride Ion Penetration. American Association of State Highway and Transportation Officials (AASHTO); 2022. p. 14.

AASHTO-T402. Standard Method of Test for Electrical Resistivity of a Concrete Cylinder Tested in a Uniaxial Resistance Test. American Association of State and Highway Transportation Officials; 2023. p. 17.

Biever, JH, Chopperla, K., Isgor, OB, Weiss, WJ (2023) "Practical Measurement of Pore Solution Resistivity in Fresh Mixtures," ACI Materials Journal 120 (5)

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Rupnow TD, Icenogle PJ. (2012) Surface resistivity measurements evaluated as alternative to rapid chloride permeability test for quality assurance and acceptance. Transportation research record. 2290(1):30-7.

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Tuinukuafe, A.; Chopperla, K. S. T.; Weiss, J.; Ideker, J.; Isgor, B. "Estimating Na+ and K+ Concentrations of the Pore Solution Based on Ex-Situ Leaching Tests and Thermodynamic Modeling." RILEM Tech Lett 2022, 7, 88-97.

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