Oregon Department of Transportation

Stage 1 Research Problem Statement

Number*: 25-40*

Proposed Title: High Performance Concrete Mixtures with Reduced Global Warming Potential

1. Concisely describe the **transportation issue** (including problems, improvements, or untested solutions) that Oregon needs to research.

Concrete materials and mixture proportions are changing to reduce the global warming potential (GWP) associated with concrete production. ODOT currently has a specification for a prescriptive high-performance concrete (HPC) mixture. This HPC mixture consists of 66% Type I/II cement 30% fly ash or slag and 4% silica fume. To reduce the GWP of concrete the industry is moving to replace Type I/II cement with Type IL cement, and it is assumed that at some point in the future Type I/II will cease to be available. As such work is needed to develop/replace ODOTs prescriptive HPC mixture.

Further, there is a potential to further reduce the GWP of ODOT mixtures as compared to the historical average values. The potential exists to use alternative supplementary cements (SCM, e.g., natural pozzolans, recycled glass, industrial by products, or carbonated cement fines) that are emerging to reduce the GWP of concrete mixtures. This also increases sustainability by utilizing recycled materials. This project seeks to develop a prescriptive HPC capable of reaching the required strength and service life requirements with a reduced GWP. The prescriptive mixture(s) will be compared with the NRMCA benchmark LCA environmental product declaration (EPD) GWP limits for the Northwest Region. This will aid ODOT in implementing new federal initiatives that "Reduce the Cradle-to-Gate Embodied Carbon Content of Concrete". This can potentially provide access to increased federal monies for infrastructure development.

2. Document how this **transportation issue** is important to Oregon and will meet the Oregon Research Advisory Committee Priorities

This proposal aligns with two of the research activity committee's (RAC) priorities in that it addresses 1) sustainability and climate action and 2) stewardship of public resources. It directly supports ODOT's commitment to innovative technologies and systems, and cost reductions in construction, operations, and maintenance.

The concrete industry has been actively working to reducing the carbon footprint (GWP) of concrete. One approach widely studied to reduce embodied carbon content is to replace the Ordinary Portland Cement (OPC, ASTM C150 Type I/II) used with portland limestone cement (PLC, ASTM C595 IL cement). A complementary approach is to replace a portion of the cement (either Type I/II or IL) with SCMs. While some SCMs have always been used, the use of higher volumes and their combination with IL requires more examination.

This project will utilize materials specific to Oregon (i.e., local materials and materials that are imported into the region) to develop a prescriptive mixture design that has both high performance (strength and durability) and low global warming potential. This work will increase ODOT's and local industries' understanding of solutions to reduce the GWP of concrete mixtures. Further this will provide the ability to implement these solutions on a commercial scale. Further, by developing prescriptive mixtures this will provide off-the-shelf solutions that do not require unique solutions with extensive testing to be performed if not needed. This will provide new mixtures that can be implemented by ODOT and other agencies.

This project is consistent with ODOT focus on timely, intellectually robust, and industrially relevant research that supports the ongoing delivery of transportation infrastructure and services in Oregon. The project will document computations focused on achieving the optimal cementitious mixture compositions, and experimental results for

strength and durability properties (AASHTO R101 will be used as applicable). The project will also demonstrate how the experimental results can be used for service life computations that feed LCA estimations. This can improve the discussion of GWP taking it from the current focus on the A1 to A3 stages (cradle to gate) to the more meaningful A1 to D stages (cradle to grave). This will enable both the initial GWP reduction and the long life to be considered in sustainable long-term solutions. For example, a material that lasts 75 years rather than 25 years has improved GWP in the A1 to D analysis that may not be immediately evident in the A1 to A3 analysis.

Specifically, ODOT is interested in examining IL cements with ternary blends of fly ash, silica fume, and natural pozzolans. The team will utilize reactivity testing developed at Oregon State University to characterize these materials. The work will address concerns that have historically persisted in the industry around SCM dosage limits, such as those imposed by ACI 301 for samples exposed to deicing salts. These concerns were introduced for SCM with lower qc/qa procedures than procedures currently used, and this was primarily introduced for residential/commercial flatwork that are typically finished differently than ODOT mixtures. As such, many of the scaling concerns associated with over finishing do not apply for ODOT.

It is proposed that the project will consist of eight tasks:

- Task 1: Survey of available cements, SCMS, and alternative SCMS for Oregon
- Task 2: Chemical, physical and reactivity characterization of cements and SCMS for Oregon
- Task 3: Pozzolanic reactivity characterization
- Task 4: Identification of exposure classes
- Task 5: Identification of the most promising mixtures
- Task 6: Laboratory trials
- Task 7: Field trials and testing
- Task 8: Development of potential specification language

3. What **final product or information** needs to be produced to enable this research to be implemented?

ODOT focuses on applied research that will develop knowledge with a specific practical application of developing a prescriptive mixture design for high-performance concrete with a reduced GWP as compared to the current concrete system. It is anticipated that the new proportions will have between a 10 and 30% reduction in the GWP. The results will also form a 'generic' EPD based on Oregon industry values that compares the conventional and new HPC prescriptive mixture that can be used in lieu of a product specific EPD.

The deliverables of this project will be a report that outlines the chemical and physical properties of local cementitious materials. Further, strength and durability properties of high-performance concrete will be documented. This will enable ODOT to have a prescriptive (or a few prescriptive) options for mixture proportions that are known to satisfy strength, durability, and GWP criteria without extensive testing thereby saving time and money for the ODOT on project delivery.

4. (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.

The project that is proposed would benefit from incorporation of local industry both in terms of cement, SCM, and concrete suppliers. This can help to make sure the research is using representative materials that as well as to develop a unified platform of the mixture proportioning and testing approach being used. As such, the following table is an initial suggestion of interested parties.

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5. Other comments:
NA

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