SPR RESEARCH PROGRAM
SECOND-STAGE PROPOSAL SUMMARY

PROBLEM NUMBER AND TITLE

25-05 Reducing carbon footprint of PCC transportation infrastructure through use of local materials and mixture design optimization.

PROBLEM SUMMARY

The concrete industry is pushing toward lower carbon footprint systems. However, research is needed to elucidate the local materials in Oregon (and surrounding areas) that can be used to produce low carbon concrete while still achieving the desired mechanical and durability properties necessary for implementation. Local materials in combination with modern mix design methods can result in significantly reduced carbon footprint of Portland cement concretes used in transportation infrastructure.

ODOT OBJECTIVES

Primary agency objective is to understand the availability and readiness of locally sourced materials that can be successfully used as supplementary cementitious materials in concrete mixes. This includes understanding the durability of these mixes as well as the market readiness of these materials.

BENEFITS

Low-carbon blended concrete optimized using locally available materials will help ODOT to meet one goal of the ODOT Strategic plan to reduce carbon emissions. Further, increasing the use of local materials also helps in economic competitiveness in the State of Oregon and should provide lower cost materials for ODOT and even the broader transportation infrastructure sector in the state. This research project thus addresses several key strategic directions in the RAC Priorities Plan for 2023 including: economic and community vitality, stewardship of public resources, and sustainability and climate action.

SCHEDULE, BUDGET AND AGENCY SUPPORT

Estimated Project Length: 36 months.
Estimated Project Budget: $375,000
ODOT Support:

Jeff Shambaugh – State Pavement Engineer
Dean Chess – Product Evaluation Coordinator

FOR MORE INFORMATION

For additional detail, please see the complete STAGE 2 RESEARCH PROBLEM STATEMENT online at:

https://www.oregon.gov/odot/Programs/ResearchDocuments/25-05.pdf

SPR RESEARCH PROGRAM
SECOND-STAGE PROBLEM STATEMENT
FY 2025

PROBLEM NUMBER AND TITLE

25-05 REDUCING CARBON FOOTPRINT OF PCC TRANSPORTATION INFRASTRUCTURE THROUGH USE OF LOCAL MATERIALS AND MIXTURE DESIGN OPTIMIZATION

RESEARCH PROBLEM STATEMENT

The concrete industry is pushing toward lower carbon footprint systems. However, research is needed to elucidate the local materials in Oregon (and surrounding areas) that can be used to produce low carbon concrete while still achieving the desired mechanical and durability properties necessary for implementation. CO_{2eq} emissions from cement production account for approximately 8% of the world's CO_{2eq} contribution. In mid-2022 most U.S. cement suppliers made a significant change by increasing the substitution of finely ground limestone from less than 5% to 10-15%. In combination with replacements by supplementary cementitious materials (SCMs), CO_{2eq} emissions can be lowered by as much as 50% or more. A recent approach that is gaining significant traction in the U.S. are LC^3 systems (limestone calcined clay cement). These cementitious blends have been proven to reduce CO_2 emissions without compromising design strength and durability. Several challenges exist for full-scale implementation. Locally available SCMs may be able to be used in place of the calcined clay portion of LC^3 where kaolinitic clays are not available. Ensuring that these are available at scale for PCC production is required. In addition to changing the cementitious materials, SPR-823 reported that the cementitious materials content can be reduced by almost 20% if the aggregate is first characterized. However, the research noted the need for better dimensional stability (e.g., shrinkage) and abrasion testing. Further, while later age strength is retained, or even exceeded compared to 100% OPC systems, the early-age strength (e.g., prior to 7 days) can be reduced when compared with systems with high cement replacements. Such blended cements must be carefully designed to maximize the synergistic benefits while obtaining desired mechanical and durability properties. Several different acceleration techniques to overcome the early-age strength impacts are possible, and merit investigation in this proposed project.

RESEARCH OBJECTIVES

The objective of this research is to develop low-carbon blended cement using material that can be readily produced in Oregon per ODOT requirements for paving and for structural applications, including High Performance Concrete (HPC). This will involve replacing up to 20% of the Portland cement with finely ground limestone and another 20-40% with a supplementary cementitious material such as natural pozzolan, slag, calcined clay, or others to be identified. Assessing the market readiness of local available SCMs (e.g. natural pozzolans) is also key.

WORK TASKS, COST ESTIMATE AND DURATION

Task 1 - Literature Review and Materials Availability Review

Literature review focusing on low-carbon blended cement. This review will identify available local materials for evaluation. Locally available clays, natural pozzolans and traditional SCMs will be the focus. This literature review will include an evaluation of market availability of these materials.

Task 2 – Materials Characterization

Materials identified in Task 1 will be characterized for physical and chemical properties (including fineness, bulk chemical composition, mineralogical composition, reactivity, etc.)

Task 3 - Impact of Portland Limestone Cement (PLC) Type

The synergy between PLC with SCMs will be investigated in detail by following the hydration characteristics of

blended cement. One OPC blended with various levels of commercially available limestone will also be considered as a reference to study the effect of limestone purity and replacement levels. The experimental study will include the hydration behavior, strength development and the evolution of microstructure and mechanical properties over time.

Task 4 – Laboratory Investigations: Fresh Properties, Strength Gain, Transport Properties, Shrinkage and Abrasion Resistance

Low carbon concrete mixtures will be developed and the strength and durability properties for pavement and high-performance concrete applications will be investigated. Testing will include mechanical, thermal, and environmental loading and will be determined jointly between ODOT's Technical Advisory Panel and the research team. Other metrics including workability characteristics, rate of strength gain, and change in electrical properties will also be investigated. The volumetric change (shrinkage and/or expansion) and abrasion resistance, two key properties critical for ODOT concrete, will be quantified. The water demand, influence of admixtures such as air entrainers, water reducers and superplasticizers will be evaluated. Further the impact of de-icing materials and change in design-strength criteria from the current 28-day to 56-day will be investigated for these low carbon mixtures.

Task 5 – Recommendations to Specifications and Procedures for ODOT

Based on the performance of different PLC and SCM combinations, cost and desired properties, this study will establish recommendations for developing pavement and high-performance concretes with low-carbon blended cement including updates to existing specifications and/or new specification (s) as appropriate.

Key Deliverables:

A final report that summarizes all project findings and recommendations will be produced. Additionally, a Final Research Note, per ODOT specifications will be generated at the conclusion of the project. The generation of new and/or updates to current materials specifications will be made based on the outcomes of this research project. The eventual result is anticipated to be the commoditization of low-carbon concrete using local Oregon materials and reduced overall carbon footprint of concretes used in transportation infrastructure applications.

Estimated Project Length: 36 months.
Estimated Project Budget: $375,000

IMPLEMENTATION

Implementation of research findings in this project will take place primarily by incorporating the locally sourced materials as an option for supplementary cementitious materials in Portland cement construction projects. Update recommendations to construction specification and tests specifications will be provided as part of this research.

POTENTIAL BENEFITS

Low-carbon blended concrete optimized using locally available materials will help ODOT to meet one goal of the ODOT Strategic plan to reduce carbon emissions. Further, increasing the use of local materials also helps in economic competitiveness in the State of Oregon and should provide lower cost materials for ODOT and even the broader transportation infrastructure sector in the state. This research project thus addresses several key strategic directions in the RAC Priorities Plan for 2023 including: economic and community vitality, stewardship of public resources, and sustainability and climate action. The goals outlined in this project also help to provide innovative technologies and systems and will further establish ODOT as a national leader in meeting economic and environmental sustainability goals.

PEOPLE

ODOT champion(s):

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	Coordinator		
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Problem Statement Contributors:

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STAFF REVIEW PAGE

Literature Check

TRID&RIP

☒ A review of TRID & RIP databases found no existing research that answers the research question.

Technology & Data assessment

☒ No Identified T&D output

☐ At the end of this project, the implementing unit(s) within ODOT will need to coordinate the adoption of new technology or data in order to realize the full potential of this research.

Cross-agency stakeholders

- List ODOT partners or impacted units.
    - Pavement Services

- Identify any issues of concern raised by an ODOT partners. Note expected mitigation that addresses these concerns.
    - None