Stage 1 Research Problem Statement

Number: ***25-83***

Proposed Title: Application of nanoengineered high performance concrete (nHPC) as durable overlay for concrete bridge decks in Oregon

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

As shown in Figure 1, many bridge structures in Oregon state with ages of 50 to 70 years are in fair condition, which need repair and rehabilitation for service life extension. Meanwhile, there is an increasing number of research projects on bridge decks from 2020 as recorded in the Research in Progress (RiP) database of Transportation Research Board (TRB). For bridge deck rehabilitation, ultra-high-performance concrete (UHPC) overlay can provide both structural strengthening and protection from ingress of external deleterious substances, but UHPC is an overdesign for bridge overlay application and innovations are needed to optimize the mix design to be more constructible, cost-efficient and environmentally sustainable.

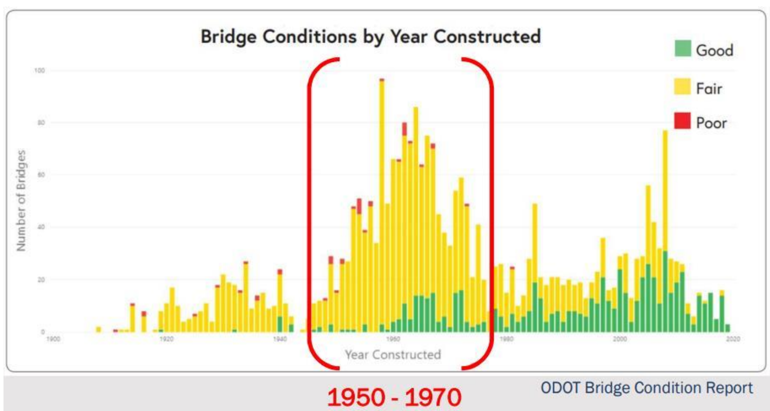

Figure 1 Oregon bridge condition (extracted from webinar "Oregon Bridge Decks and Overlays: Materials and Construction Practices" by David Dobson, PE)

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

The proposed project fits well with the ODOT's strategic goals of Economic and Community Vitality and Sustainability and Climate Action, and addresses the research focus areas of **Climate** and **Cost reductions or savings to construction, operations, or asset maintenance**. Despite the superior properties of UHPC, the SP00541 (not published in the Oregon Standard) proposes the requirement of minimum 28-day compressive strength of 20,000 psi for UHPC, which is overdesign for bridge deck overlay application. The combined use of a very low water-to-binder mass ratio (~0.2) and a high dosage of discontinuous fiber reinforcement also presents a great challenge for the construction of UHPC overlay in the field. This is an important issue to ODOT, because developing a more affordable, construction-friendly and sustainable mix design on the basis of UHPC design methodology can help reduce the construction cost and difficulty of bridge deck overlay.

The limited usage of supplementary cementitious materials (SCMs) in UHPC is a major challenge, which makes its cost and carbon footprint much higher than that of other conventional types of overlays. Although some researchers studied the mechanical properties of UHPC with higher contents of SCMs as a replacement of cement, there is a lack of in-depth investigation on the durability of such UHPC. The National UTC TriDurLE recently developed the mix design of nHPC with multiple SCMs (i.e., class C/F fly ash, silica fume, and limestone powder), a reduced fiber content, and incorporation of nanomaterials (i.e., nano montmorillonite and graphene oxide); and we will continue the study on the durability of this nHPC in this project to validate its feasibility of being the overlay for repairing and protecting the deteriorated bridge decks in Oregon state. The resistance of nHPC to freeze-thaw attacks, chloride ingress, and deicing chemical attack in the lab and field will be investigated. It is expected that the high replacement level of cement can not only reduce the initial construction cost (lower than 4$/m^3$/MPa) but also enhance the durability of nHPC overlay in the field. Additionally, the overall CO_2 emission of the rehabilitated bridge deck throughout the service life can be significantly decreased, based on our preliminary life cycle assessment (LCA).

3. What **final product or information** needs to be produced to enable this research to be implemented?
This project will generate an eco-efficient and durable mix design of nHPC using less amount of cement (<50 wt.%), a lower content of fiber (<1.0 vol.%), and trace amount of nanomaterials (~0.6 wt.%). The nHPC prepared with the mix design in this project features good workability (self-consolidating), low material cost, and good mechanical properties and durability performance for adoption by ODOT for the application of overlays on bridge decks that need protection and rehabilitation. In addition, the LCA can show the decrease of overall CO_2 emission throughout the service life of the bridge deck. To sum up, the results and findings will reduce the construction cost and carbon footprint of concrete bridge deck overlay for use by highway agencies and potentially others.

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.

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Chris Duman	State Pavement Quality & Materials Engineer	christopher.l.duman@odot.oregon.gov	503-559-4994
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5. Other comments:
This effort will demonstrate the methodology of developing an eco-efficient mix design for nHPC overlay as shown in Figure 2. We aim to provide an alternative mix design with lower cement and fiber content while maintaining good mechanical properties and comparable durability performance (Figure 3). With the incorporation of multiple SCMs and affordable nanomaterials available from Pacific Northwest, the nHPC should have the dense microstructure that comparable to UHPC while a less content of calcium hydroxide which can easily react with external deleterious species such as magnesium chloride-based deicers. These outcomes can be readily evaluated. Next phase would be field demonstration of nHPC to show case the feasibility of being applied on bridge decks as overlay and thus promote the adoption of nHPC overlay by various agencies.

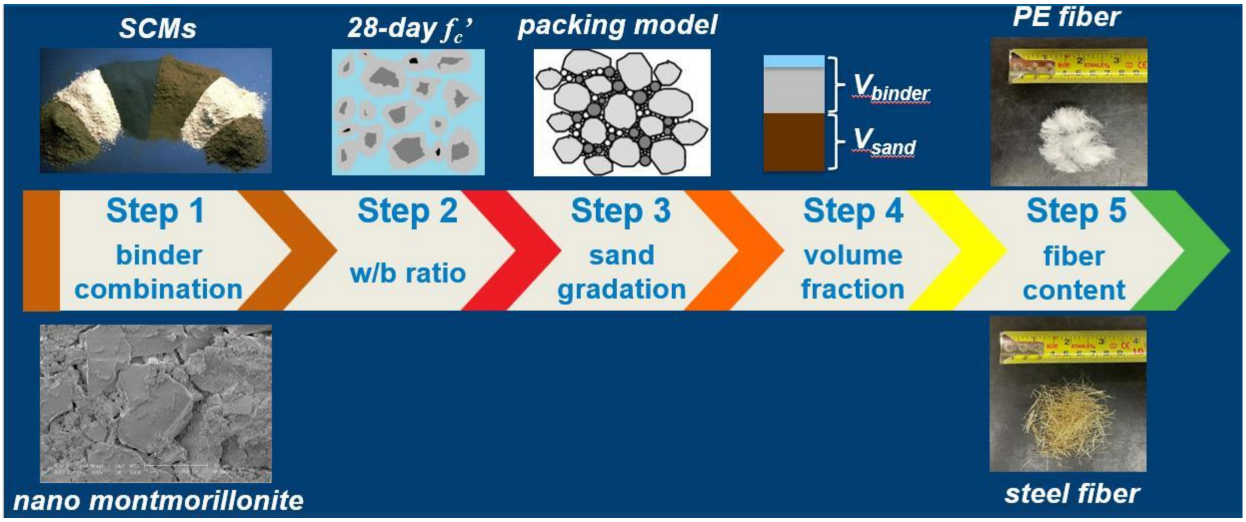
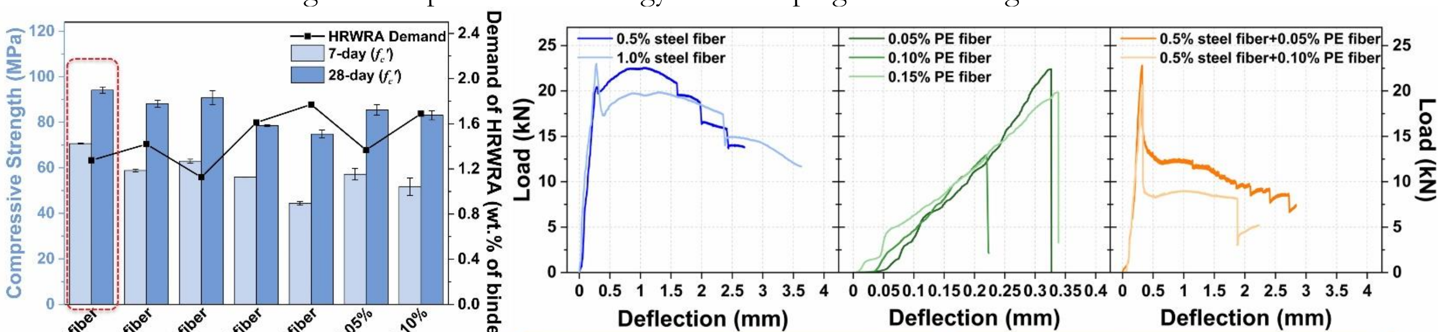


Figure 2 Stepwise methodology of developing the mix design of nHPC



Group	f_c' (MPa)	HRWRA (wt%)	f_1 (MPa)	δ_1 (mm)	f_p (MPa)	δ_p (mm)	f_{600}^D (MPa)	T150 (J)
0.5% steel fiber	94.1	1.28	5.94	0.29	6.56	1.08	6.15	39.7

Figure 3 Preliminary results of compressive strength and flexural performance of nHPC

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