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Ph.D. DISSERTATION DEFENSE

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Date:	Friday, April 28th, 2023
Time/Location:	2:00 pm– 3:30 pm / Gateway North, Room 213
Title:	Challenges and Opportunities of Developing Ultra-High-Performance Concrete (UHPC) for Bridge Deck Overlay Applications

Chairperson:	Dr. Weina Meng, Department of Civil, Environmental and Ocean Engineering, School of Engineering and Science
Committee Members:	Dr. Yi Bao, Department of Civil, Environmental and Ocean Engineering, School of Engineering and Science Dr. Christos Christodoulatos, Department of Civil, Environmental and Ocean Engineering, School of Engineering and Science Dr. Chang-Hwan Choi, Department of Mechanical Engineering, School of Engineering and Science

ABSTRACT

This research aims to address the key challenges of using UHPC as the bridge deck overlay: (1) Two types of low-shrinkage UHPC mixtures with reduced cracking potentials are developed: (i) prewet expansive agents' method; (ii) UHPC with proper combination of pre-saturated lightweight sand, expansive agent, and shrinkage-reducing agent. (2) A water-based nanoclay suspension is utilized to enhance the thixotropy of UHPC, which improves the shape stability of UHPC on the sloped bridge deck. (3) Cellulose nanocrystal is utilized to coat and modify the surface of steel fibers, thus improving the flexural/tensile properties of UHPC mixture. (4) Two high-carbon waste materials (e.g., off-specification fly ash (OSFA) and used biochar) are utilized in producing UHPC, which reduces the materials cost and carbon footprint. (5) The mixing kinetics of UHPC during the mixing process is revealed and an efficient multi-batching method is proposed to ease the large-scale UHPC production on job sites. Experimental results indicated that: (1) the optimal prewet time and content for expansive agent is 45 min before the mixing process and 4% by mass of binder, which reduces the cracking potentials of UHPC by 30%. (2) the optimal combination of lightweight sand, expansive agent, and shrinkage-reducing agent in UHPC is 50%, 2%, and 2%, which reduces the cracking potentials of UHPC by 60%. (3) the water-based nanoclay addition efficiently increases the thixotropy of UHPC overlay, which results in the reduction of bond strength between overlay and substrate. To address this issue, the proper vibration can be applied to partially recover the bond strength. (4) the threshold concentration of CNCs coating suspension is 1.0%, which increases the flexural strength and toughness of UHPC by 15% and 20% at 28 days. (5) the proper combination of 20% OSFA and 40% slag or the addition of 1% pre-saturated biochar in UHPC achieves satisfying mechanical strength, low autogenous shrinkage, as well as low cost and carbon footprint. (6) the mixing kinetics of UHPC are affected by the mixing volume, mixing temperature, and mixing method. A mathematical model is designed and validated to describe the mixing kinetics of UHPC, which helps to guide the mixing method design for large-scale UHPC production.