Ph.D. DISSERTATION DEFENSE

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Date: Monday, May 1st, 2023
Time/Location: 2:30 pm - 4:00 pm; ABS 301
Title: CO_2 sequestration and waste utilization for low-carbon concrete

Chairperson: Dr. Weina Meng, Department of Civil, Environmental and Ocean Engineering, School of Engineering &Sciences

Committee Members: Dr. Xiaoguang Meng, Department of Civil, Environmental and Ocean Engineering, School of Engineering &Sciences
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ABSTRACT

This research focuses on waste utilization and CO_2 sequestration technologies for reducing concrete carbon emission: (1) off-specification fly ash (OSFA), a type of high-carbon waste fly ash, is utilized in concrete by using it to tailor strain-hardening cementitious composite (SHCC); (2) OSFA is utilized in concrete by coating it with nano-$CaCO_3$ to improve its physical and chemical properties and thus enhance the key properties of concrete; (3) CO_2 is sequestered in concrete before mixing by pre-carbonation of ground granulated blast-furnace slag (GGBS) that is further used in ultra-high performance concrete; (4) CO_2 is sequestered in concrete during mixing by injecting it to produce a nano-$CaCO_3$ suspension that is uniformly dispersed and used to prepare concrete; (6) Waste glass is recycled in concrete with mitigation of alkali-silica reaction by using carbonation curing.
Experimental results and analysis revealed that: (1) With a fiber content of 2%, water-to-binder ratio of 0.26, and sand-to-binder ratio of 0.36, using the OSFA to replace 20% Portland cement can increase the flexural strength by 13% and the ultimate deflection by 29% while retaining a reasonable compressive strength (66 MPa) and desired strain-hardening behaviors with dense microcracks. (2) coating of OSFA with nano-$CaCO_3$ transformed OSFA from a harmful additive to a beneficial one for concrete regarding the mechanical properties. (3) By replacing the original slag with the carbonated slag, UHPC mixture requires higher HRWR content to reach the same flowability, has shorter setting time, gains more compressive strength, generates slightly higher autogenous shrinkage, and produces more hydration products. (4) by the CO_2 injection process, high-level dispersion of nano-$CaCO_3$ suspension is obtained, which leads to the 16% increase 28-day compressive strength of concrete and 15% reduction in life-cycle carbon footprint. (5) with optimized carbonation curing, the 28-day compressive strength was improved by up to 40%, and the ASR-induced expansions were significantly reduced by up to 85%. This study provides a synergistic pathway for development of low-carbon concrete for a wide range of concrete applications.