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Harnessing AI for Sustainable Design and Seismic Resilience of UHPC Structures

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Abstract:

This keynote talk introduces an innovative framework for sustainable design as well as performance-based seismic design (PBSD) and fragility assessment of ultra-high-performance concrete (UHPC) elements, utilizing artificial intelligence (AI) techniques. It begins with a novel framework for developing environmentally sustainable and cost-effective UHPC that can be tailored to specific project requirements using advanced machine learning (ML) and multi-objective optimization algorithms. This optimization balances cost, strength, and 17 environmental impact metrics to ensure structural efficiency and sustainability. The focus then shifts to developing an accurate stress-strain constitutive model for confined UHPC. A hybrid ML model combined with a conditional tabular generative adversarial network was developed to predict the peak and ultimate stress-strain responses for UHPC confined with normal-strength steel (NSS) or high-strength steel (HSS) spirals.

Further, hybrid ML-based complete stress-strain response prediction models for UHPC confined with NSS or HSS spirals are presented alongside analytical equations for peak and ultimate responses. The talk then introduces explainable ML-powered drift capacity limit states for UHPC columns across four damage states, considering different sources of uncertainties. These drift limit states are applied in the PBSD of UHPC columns, and a design example is provided, demonstrating enhanced seismic resilience. Finally, a multivariate bridge-specific seismic fragility assessment approach for UHPC bridges is presented, using hybrid ML models to evaluate the seismic vulnerability of such bridges. In conclusion, this talk demonstrates how AI-driven optimization and predictive modeling can significantly advance infrastructure sustainability and resilience to extreme events such as earthquakes.