Assessing the Performance of Structural Systems for Response to Multi-hazard Conditions Using Real-Time Hybrid Simulation: Challenges, Solutions, Illustrations

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There is an evolving interest among stack-holders to enhance the resiliency of the community to the effects of natural hazards on the built environment. Consequently, the engineering community has been faced with the challenge to find means to effectively renovate existing structural systems as well as develop new structural system concepts that they can withstand multi-hazards with minimal damage and downtime. To meet this challenge research needs to be conducted that incorporates the various components of systems in order that their interdependency is properly accounted for, realistic loading conditions are considered, and load-rate effects in response modification devices (e.g., supplemental dampers) that may be used to enhance system performance is taken into consideration. An approach that has gained attention to meet these requirements is real-time hybrid simulation (RTHS). This presentation will present the challenges and solutions developed by the author and his colleagues at the NEES and NHERI facilities at Lehigh University in RTHS applied to multi-hazards that include earthquake and wind events. Among these challenges are: (1) the need to be able to create complex analytical substructures where a large number of DOF and members exist in the system that require modeling, and the requirement to accurately complex model material behavior; (2) need for integration algorithms that are robust, fast converging, and possess dissipative properties to alleviate the effects of noise introduced by laboratory restoring forces and change of state within a time step; and, (3) need for accurate real-time actuator control to precisely impose the target motions onto experimental substructures, requiring kinematic compensation due to geometric nonlinearities in the relationship between actuator and structural system DOF as well as delay and amplitude compensation to avoid latency in achieving targeted actuator motions. The presentation will include applications using the above solutions in order to accurately perform RTHS of complex systems subjected to extreme events, such as low-rise steel and R/C building structures outfitted with nonlinear viscous dampers subjected to strong earthquake ground motions. In addition, the presentation will include RTHS of a high-rise building with outriggers outfitted with supplemental dampers that is subjected to multi-hazard loading. The presentation will conclude the identification of needs to further develop RTHS to enable transformative research to be performed that acquires a better understanding of complex engineered systems to extreme events cause by multi-hazards.

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