Design and Development of Ten-Element Hybrid Simulator and Generalized Substructure Element For Coupled Problems

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ABSTRACT

The development at the University of Toronto of a ten-element hybrid simulator and a generalized substructure element in OpenSees are presented in this paper.

Hybrid simulation has been an active research area in the past decade which encompasses development of new integration algorithms, simulation frameworks, and applications. Yet, unless the physically tested element significantly contributes to the lateral load resisting or energy dissipation systems, the improvement in the accuracy by adopting a hybrid simulation is only marginal. In most cases, the number of physically tested elements in the hybrid simulation is limited by the availability of experimental resources such as actuators, controllers, and laboratory space. To overcome the limitation, a novel experimental apparatus is being developed at the University of Toronto with which up to ten elements, such as braces and hysteretic dampers, can be concurrently tested and integrated into a hybrid simulation. The system can test up to ten physical specimens with force capacity of 800 kN or 1,600 kN, depending on the number of tested specimens. The main design requirements, current development status, and potential applications are presented in this paper.

To integrate the physical specimens in the ten-element hybrid simulator and other potential substructure elements into hybrid simulation, a generalized substructure element is being developed for OpenSees. The main research focus in the development is to standardize the data exchange format and communication protocol such that any other potential substructure modules can be readily integrated into hybrid simulation. The data exchange format is defined such that the number of degrees of freedoms, data types, error checks, can be communicated in a flexible manner between modules. Designing a versatile data exchange format and a communication protocol is expected to facilitate simulation of coupled systems including diverse substructure modules and other loading scenarios such as thermal loading. The data exchange format and example implementations will be open to the research community in the near future. An example of numerical hybrid simulation in which a six-storey structure and braces in the structure are modelled with two analysis platforms are presented in the paper. Physical hybrid simulation of the structure using ten-element hybrid simulator is also planned.