UNIVERSITY TRANSPORTATION CENTER

RESEARCH BRIEF

Real-Time Hybrid Experimental-Numerical Simulation of Bridge Infrastructure Subject to Cascading Earthquake-Tsunami Hazards

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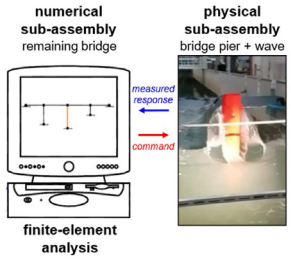
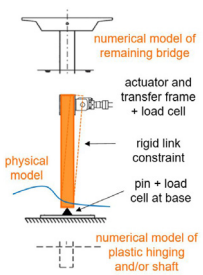
Background

Bridges in the Pacific Northwest are vulnerable to cascading earthquake-tsunami hazards. These bridges are critical to maintaining mobility for post-event emergency response, repair, and recovery of coastal communities after extreme events. Although bridge strength can be significantly compromised when the bridge is subjected to cascading earthquake-tsunami scenarios, little data exists to support the simulation of bridges to both earthquake and tsunami loading. Test data under individual earthquake and tsunami hazards is available, but space is limited in wave facilities, necessitating small-scale structural models. Scaling laws then make it difficult to incorporate structural damage from previous seismic loading into hydrodynamic experiments. Although numerical models can be analyzed using full-scale bridge properties, few software can apply both seismic and tsunami loading (with structural damage) in a single analysis.

Real-time hybrid simulation (RTHS) – a testing technique that combines physical experiments and numerical models – can alleviate the aforementioned constraints and provide data to validate computational FSI models. In hybrid simulation, physical and numerical models interact through actuators and sensors, i.e., actuators impose interface conditions on a physical model and sensor measurements are fed back to inform a numerical model. As such, RTHS virtually extends the Large Wave Flume at OSU, enabling holistic testing of a complete bridge subjected to numerical earthquakes and physical waves.





Research Project

Following the Tohoku earthquake, many Japanese bridges experienced uplift of the deck off the bridge piers due to the subsequent tsunami loading. However, if the connection between the pier and deck was retrofitted to resist deck uplift, then the bridge instead experienced significant damage to the pier during the tsunami, because the pier was already damaged from the earthquake (piers are usually designed to exhibit inelastic response for seismic design).

The research proposed would be the first application of hybrid simulation to tsunami hazards, including previous damage from earthquake loading. To study bridge pier response to cascading earthquake-tsunami loading, the proposed RTHS approach partitions a bridge assembly such that the physical waves and bridge pier reside in a physical sub-assembly and the remaining bridge, including damage from seismic loads, resides in a numerical sub-assembly. The hybrid physical-numerical sub-assemblies then represent a complete bridge assembly, which is impossible to test experimentally due to the capacity of existing wave facilities.

ABOUT THE AUTHORS

The research team consisted of Barbara Simpson and Minjie Zhu of Oregon State University.

ABOUT THE FUNDERS

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EXPECTED DATE OF COMPLETION

August 2022

FOR MORE INFORMATION

http://depts.washington.edu/pactrans/research/projects/real-time-hybrid-experimental-numerical-simulation-of-bridge-infrastructure-subject-to-cascading-earthquake-tsunami-hazards/