Structural Testing in a Wave Flume: An Experimental Perspective and Research Needs

D. Lehman[1] , M. Motley[2], and C. Roeder[3]

Research Impetus

In extreme events, such as major earthquake or tsunamis, public safety is a primary concern. An article in July 2015 of the periodical The New Yorker entitled "The Big One" proclaimed that a major subduction zone earthquake could cause a major tsunami, which would render infrastructure well beyond the coast "useless". In coastal regions at low elevation, it can be impossible to quickly get to higher ground in the short time between the initial ground shaking and arrival of a tsunami from a subduction earthquake. Vertical evacuation structures (VES) can provide refuge to people in these areas. To protect the community during tsunamis on the upper floors, VESs are designed to: (1) have "sacrificial" lower stories below the inundation depth of the wave and (2) provide seismic resistance with minimal damage while providing resistance to large gravity and tsunami forces. Although evacuation structures have been built in tsunami-prone regions in Japan and the U.S., they are typically low-rise structures with limited shelter capacity. A tall structure could serve other purposes, such as a hotel with lower stories housing retail or conference rooms, rather than only a shelter. Although tempting, is not wise to simply adopt a structural system used in seismic regions for VESs, because the design criteria are different. In earthquake engineering, the structure is designed to sustain damage in the maximum credible event and, unless specific to the site, soil-structure interaction is neglected. This design philosophy does not fit VESs. VESs must be designed to: (1) remain damage-free during the maximum credible earthquake, (2) sustain the maximum considered tsunami at the lower floors, including horizontal and vertical forces, where initial research shows that these tsunami force demands can be 2 to 5 times the design earthquake forces, and (3) account for changes in the stiffness and strength of the soil due to liquefaction and scour.

Research Needs

Design of structures to meet earthquake demand has advanced significantly over the past three decades. It is tempting to utilize seismic structural systems to meet tsunami demands, yet this is not wise since the response required in a tsunami is elastic, whereas the response expected in the maximum earthquake is nonlinear, and therefore deformation capacity is a priority with earthquake resisting systems and strength and stiffness are priorities in tsunami resisting systems.

To meet the needs of the structural engineering community in the design of vertical evacuation and other structural systems in tsunami prone regions, the following research is required:

1. Development of new structural systems to meet tsunami demands
2. Evaluation of the response of the system, including the sub-structure, soil-fluid-structure interaction (as well as scour, etc).
3. Testing of structural and structural and geotechnical systems in large-scale wave flumes using

[1] Professor, Department of Civil and Environmental Engineering, University of Washington, Seattle WA (delehman@uw.edu)
[2] Associate Professor, Department of Civil and Environmental Engineering, University of Washington, Seattle WA (motley@uw.edu)
[3] Professor Emeritus, Department of Civil and Environmental Engineering, University of Washington, Seattle WA (croeder@uw.edu)

state-of-the-art, large-scale testing methods including instrumentation, imaging.
4. Enhancement of or building new large-scale, wave flumes to more accurately simulate tsunami demands including the impact of bathometry.

Collaboration Opportunities

There is a need for testing including new structural systems (both the superstructure and the sub-structure) as well as impact of the geotechnical system (where scour is a critical issues) in flumes capable of simulating tsunami-level forces and bathometry. This requires a multi-investigator team with diverse expertise including (1) structural system development and testing, (2) soil-structure interaction and scour, (3) testing in wave-flume facilities, (4) numerical simulation of soil-structure-fluid interaction. From the PIs perspective the critical need is the wave flume capable of simulating a tsunami and test setup with the wave flume that: (1) simulates the boundary condition of the structure, (2) allows larger scale testing (ideally 1/3 scale), (3) simulates the demands, and (4) supports high-resolution and accurate measurement of soil and structure response.