USA Efforts: Consideration of the Requirements for Vertical Evacuation: Engineering Design and Construction Guidance

Under the US NTHMP, FEMA, NOAA, and the western US States have focused in the last few years on the consideration of requirements necessary to permit safe vertical evacuation in areas where the shortness of evacuation time prevents safe evacuation inland. The project is being driven by the fact that there are several coastal communities along the West Coast of the United States that are vulnerable to tsunami, which could potentially be generated within minutes of an earthquake on the Cascadia Subduction Zone. Communities in Alaska, Hawaii, and the East Coast are subject to similar tsunami hazards. Given that many of these coastal communities are located in areas that would be impossible to evacuate quickly, a large tsunami could result in a significant loss of life, and NOAA/NTHMP and FEMA are looking for alternatives. One alternative would be vertical evacuation structures, if such structures could be constructed to resist tsunami loads.

Under Phase I of the NTHMP project, the State of Washington managed a study using Oregon State University and the University of Hawaii to collect potential data regarding tsunamis and the forces they impart on structures. The study, *Development of Design Guidelines for Structures that Serve as Tsunami Vertical Evacuation Sites*, was published in 2005.

Under Phase II, the NTHMP project will build on the work started in Phase I and develop a technical design and construction guidance document for special facilities that would allow for vertical evacuation from tsunami conditions. This work includes the involvement of the engineering and design communities and the States. Its goal is to research and produce construction design guidance for a tsunami shelter structure capable of withstanding both the severe ground shaking expected during a design earthquake and specific velocities and water pressure from a tsunami that would impact structures. This is a significant challenge since current design practice takes into account earthquake or coastal storm surge but does not address stronger forces that a tsunami would generate.

The Phase 2 project started in 2004, with the Task 4 Contract to the Applied Technology Council (ATC) for the "*Development of Design and Construction Guidance for Special Facilities for Vertical Evacuation from Tsunami*." The objective of the project is to determine whether it is possible to build a structure that would be capable of resisting the extreme forces of a tsunami, and if so, to develop a technical design and construction guidance document for special facilities that would allow for vertical evacuation from tsunami conditions.

While a design and construction guidance document for vertical evacuation facilities does not presently exist, there are resources available and ongoing efforts that will support the development of such a document. One existing resource is the FEMA 55 *Coastal Construction Manual*, which provides information on the causes, nature, and effects of the tsunami hazard faced by the United States, but does not provide guidance on how to design critical structures to resist the effects of tsunamis.

At the same time within the engineering research and modeling community, there are efforts to develop performance-based design guidance. The *Performance Based Tsunami Engineering (PBTE) Project* is a 4-year Research Project by the University of Hawaii, Oregon State University, and Princeton University with funding from the US National Science Foundation under the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) Programme. The main concept of performance-based engineering is to adopt a broader scope of design that yields more predictable tsunami performance within established levels of risk over a range of tsunami demands. The Project brings together experts in structural, ocean, and coastal engineering, hydrodynamics and computational mechanics, tsunami, fluid-transport and scour, and experimental modeling, tsunami and seismic hazard analysis, disaster management and preparedness, and tsunami and seismic community response and social science to develop and disseminate methodology and tools for implementation of site specific PBTE for use in the analysis, evaluation, design and retrofit of coastal structures and facilities. These include guidelines for performing a site specific probabilistic tsunami hazard analysis (PTHA), simulating coastal inundation, scour modeling, simulation of tsunami-structure interaction, development of structural loading time histories, and non-linear structural analysis.

Finally, the NTHMP is planning a Phase III project under the US NTHMP to develop a companion document to the Vertical Evacuation Tsunami Shelter Guidelines. This companion document will provide planning information for States and local communities on how this tsunami shelter design guidance can be utilized at the local level. This information will especially be critical for low-lying communities that lack evacuation access to high ground following a local earthquake and that may have to rely on vertical evacuation.

Given the significant level of risk that exists for the residents of the applicable coastal communities in the Pacific Northwest, Alaska, and Hawaii, the development of a document will significantly improve the protection of the residents of these communities. The objective of this project will be to develop a technical design and construction guidance document for special facilities that would be able to withstand both seismic loads and tsunami loads and remain functional to allow for vertical evacuation of the public from tsunami conditions.