Briefing on the Basis for the Tsunami Hazard Criteria in ASCE 7
Oregon Seismic Safety Policy Advisory Commission Meeting of September 12 2019

Background to the ASCE 7-16 Chapter 6, Tsunami Loads & Effects- a Standard of Practice

In the ASCE 7 Standard, Minimum Design Loads and Associated Criteria for Buildings and Other Structures, tsunami design provisions are contained in the new Chapter 6, Tsunami Loads and Effects. Chapter 6 of ASCE 7-16 wasdeveloped over a five year period from 2011 to 2016. These are the first comprehensive tsunami design provisions for buildings in the world, although Japan has had limited tsunami design guidelines for vertical evacuation structures for some time. Development of these Tsunami Loads and Effects provisions was conducted in strict accordance with the ASCE consensus process that is accredited by ANSI, similar to what is used for the development of most engineering standards for use in building codes. The Tsunami Loads and Effects Subcommittee, consisting of 16 members and 14 associate members, spent four years and more than 12 in-person meetings to develop the 26 pages of code and 42 pages of commentary relating to tsunami design. These provisions were then subjected to scrutiny by over 50 members of the ASCE 7 Main Committee, through 8 consensus ballots, involving over 1500 review comments that had to be addressed by the subcommittee. Finally a 3 month public review period was given. The entire process was then independently audited by ASCE upper management and then by the Board of ASCE to verify by documentation that every one of the over 1500 comments had been resolved in accordance with its governing rules. The final Chapter 6, Tsunami Loads and Effects, was officially approved for inclusion in ASCE 7-16 on March 11, 2016. Subsequently, through its public hearing and voting process, the International Code Council adopted these tsunami design requirements by reference into the International Building Code, IBC 2018, without alteration. Chapter 6 of ASCE 7-16 is therefore an engineering standard practice for design of buildings and other structures. It has also been adopted by amendment into the Hawaii State Building Code in November, 2018, and it has been adopted in State of California effective January 2020.

ASCE 7-16 Tsunami Design Zones and Tsunami Flow Parameters for Engineering Applications

In the ASCE 7 Standard, Minimum Design Loads and Associated Criteria for Buildings and Other Structures, the natural hazards with extraordinary consequences, that is, earthquakes, tsunamis, high wind and tropical cyclones, are determined through probabilistic hazard analysis. Probabilistic hazard analysis has been the basis for engineering design in the U.S. for over 30 years. The hazard criteria for design are not based on deterministic scenarios.

ASCE 7-16 includes an electronic geodatabase of Runup points that defines the inundation limits of the ASCE Tsunami Design Zone established for the ASCE Maximum Considered Tsunami. The Maximum Considered Tsunami is a strictly defined term in the ASCE 7 Standard, which is given in the mapping provided by the ASCE Tsunami Design Geodatabase. This probabilistic inundation zone has an approximate recurrence interval of 2500 years with an additional allowance to account for the inherent uncertainties in source characterization and tsunami modeling results. To avoid overconfidence in a few postulated scenarios, the probabilistic tsunami hazard analysis method accommodates many thousands of seismically-plausible tsunamigenic events from sources around the Pacific Basin, including 372 scenarios from the Cascadia Subduction Zone, adapted from the seismicity model used for the 2014 USGS National Seismic Hazard Maps (Figures 1 and 2).

The ASCE 7 modeling includes terrain roughness effects due to land use/cover and the density of development in establishing the inundation limit. The modeling used by DOGAMI does not account for any ground surface friction effects on the inland flow, so its mapped extents of inundation will artificially extend further inland than the ASCE mapping that does include the effect of surface roughness. However, due to the lack of friction, DOGAMI models would underpredict the inundation depth that a structure needs to withstand, so they are not appropriate for engineering design. In order to reduce the possibility of inadequate design forces, the geodatabase does not provide any output of tsunami modeling of inundation depth and flow velocity. It is well known that present-day tsunami models have not been validated for flow velocities over land, and large variation occurs between models even for predicting currents in offshore waters and within harbors, etc. Therefore, ASCE 7 has procedures to derive flow velocities that have been statistically calibrated to be more conservative, and safer for engineering use, than the raw modeling data.

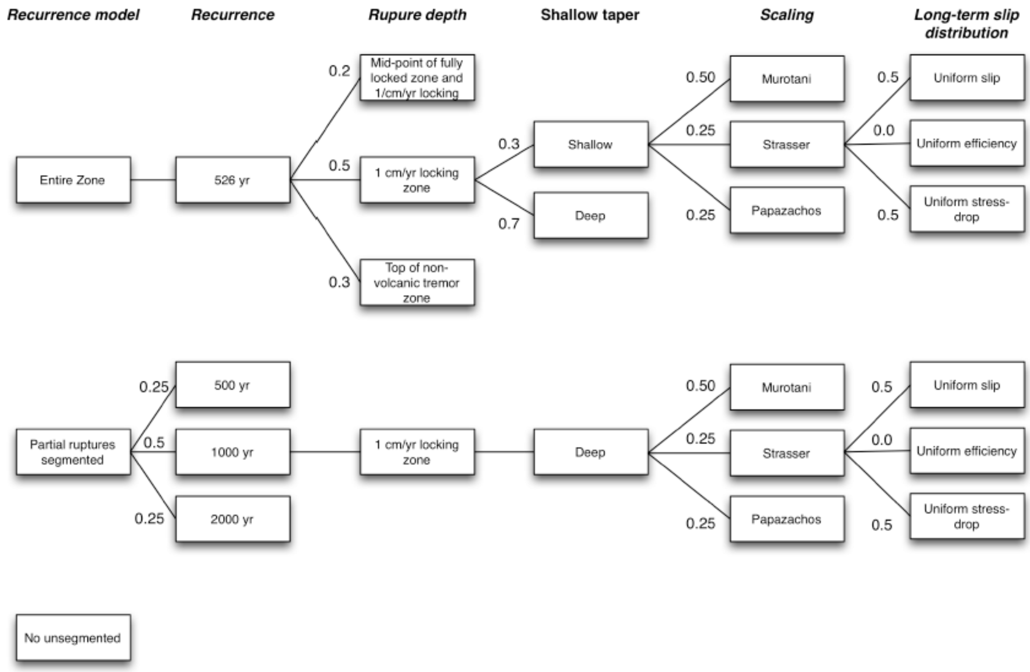

Figure 1. Logic tree model for the Cascadia subduction zone, based on the model used for the 2014 US National Seismic Hazard Maps (resulting in 372 events)

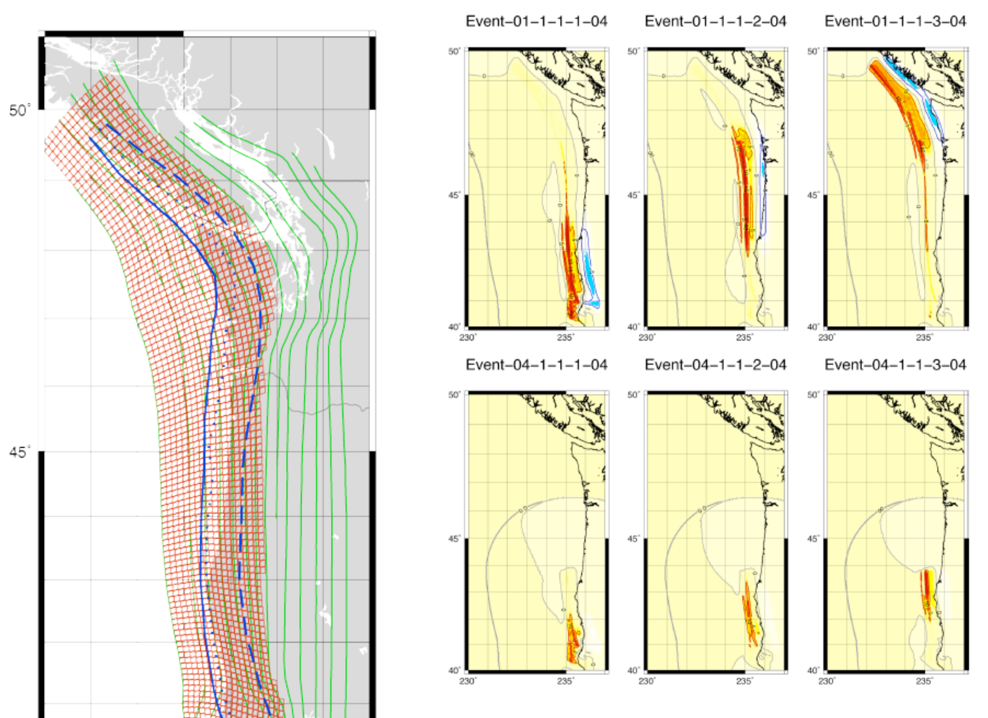

Figure 1. a – model of the Cascadia subduction zone interface (red grid), the subduction contours (green) and different rupture termination depths (epistemic). b – slip distributions for two scenarios, each of which has three instances for the slip distribution (aleatory).

Figure 2. Examples of vertical displacement field (red = uplift) for two of CSZ probabilistic scenarios: top is a full-rupture earthquake, bottom is a partial rupture, with each shown three times with different asperity locations.

Site-Specific Probabilistic Tsunami Hazard Analysis is Required for Critical and Essential Facilities

When seeking greater accuracy of flow characteristics for special structures of high risk, a Probabilistic Site-Specific Inundation Analysis is performed in accordance with ASCE 7 Section 6.7, using high-resolution digital terrain models. Nevertheless, even these more sophisticated modeling procedures are required to demonstrate parity with the ASCE 7 Offshore Tsunami Amplitudes given in the geodatabase, so that the tsunami wave is consistent with the Maximum Considered Tsunami. In addition, minimum flow velocities are given to prohibit the use of model output of flow speed that would be inconsistent with the flow speeds calculated from videos of actual tsunamis. Regional seismic subsidence and sea level rise are also considered. Note that probabilistic subsidence maps per definition show subsidence everywhere, never uplift, and they cannot be compared directly with tectonic movements of a single scenario. The ASCE Tsunami Loads and Effects Subcommittee is presently working on an update to the spatial resolution of its seismic subsidence maps to make smoother interpolations, since the objective is to show conservatively safe subsidence values for engineering design.

Conclusion

In summary, the ASCE tsunami design geodatabase runups that define a probabilistic inundation, the Offshore Tsunami Amplitudes that define a probabilistically rare wave height, and the seismic subsidence maps that define a probabilistic subsidence, together with specified engineering parameter limits and analysis procedures, are statistically established using reliability engineering analysis, into a fully integrated methodology to design engineered structures for a low probability of failure. They do not have the purpose to replicate any particular scientific state of the art tsunami inundation model per se, because that would not serve the ultimate purpose of public safety when the uncertainty of the tsunami phenomenon itself is heeded. When the ASCE tsunami Geodatabase is used in conjunction with the ASCE 7 tsunami design parameters and analysis methods, target reliabilities for structural safety stipulated in the ASCE 7 Standard are achieved in design.

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