Status of Tsunami Building Code Adoption – Hawaii

HI-EMA Hawaii Earthquake and Tsunami Advisory Committee (HETAC)

Vertical Evacuation Committee, Final 23 February 2021

Initial version by Gary Chock - September 22, 2020

Lessons learned and data collected during post-tsunami engineering surveys of the 2009 American Samoa, 2010 Chile, and 2011 Japan tsunamis enabled the development of engineering design provisions for structures that are capable of withstanding tsunami forces and effects. Much of the work was led by structural engineers Gary Chock and Ian Robertson in Hawaii leading the Tsunami Loads and Effects Subcommittee of the American Society of Civil Engineers (ASCE). In 2016, this intensive 5-year effort produced a new Chapter 6, Tsunami Loads and Effects, to the ASCE 7-16 Standard for Minimum Design Loads and Associated Criteria for Buildings and Other Structures. The work involved a very rigorous, technically-accredited, consensus-based process requiring the resolution of thousands of independent technical review comments and the development of tsunami design mapping methods. As a result, technically-precise requirements and building codes for comprehensively designing tsunami-resilient buildings exist for the United States since 2016, and as an example for the world since the adoption of this standard in the International Building Code 2018 edition.

Milestones:

1. Since the 1990s, Waikiki has had a policy that encouraged vertical evacuation. The prior policy advised evacuation to the 3rd floor or higher in structural steel or reinforced concrete buildings six stories or taller in height, assuming tsunamis of comparable size (magnitude) as had been experienced in Hawaii during the past 100 years. After the M9.1 2004 Sumatra, Indonesia earthquake and tsunami, sole reliance on historical events for planning was questioned and additional research by the University of Hawaii was reviewed by the Hawaii Earthquake and Tsunami Advisory Committee of the Hawaii Emergency Management Agency. Subsequently, in April 2015**,** based on application of the ASCE 7 tsunami loads to prototypical Waikiki buildings calibrated to the building codes of their construction vintage, along with more prudent acknowledgement that the prior policy had not considered greater Aleutian extreme tsunami scenarios, Honolulu updated its Waikiki policy, advising for vertical evacuation to the 4th floor or higher in structural steel or reinforced concrete buildings 10 stories or taller.

2. The ASCE 7-16 Standard for Minimum Design Loads and Associated Criteria for Buildings and Other Structures, included a new Chapter 6, Tsunami Loads and Effects, which was approved on March 11, 2016, five years after the Great East Japan Earthquake and Tsunami. This new chapter in the ASCE 7 standard provides prescriptive requirements for the design of tsunami-resistant Risk Category III and IV buildings and structures, and Risk Category II buildings if enacted by a local jurisdiction. The five western states (AK, WA, OR, CA, HI) have probabilistic tsunami runups and offshore tsunami amplitude design data available in the online ASCE 7 Tsunami Design Geodatabase.

   In August 2019, FEMA updated its guidance publication, *Guidelines for Design of Structures for Vertical Evacuation from Tsunamis*, 3rd Edition. This edition provides information for

both technical and lay audiences. Planning, funding, locating, operating, and maintaining vertical evacuation refuge structures is provided in the first six chapters. Information (background, guidance, commentary) on the technical design provisions of ASCE/SEI 7-16 is provided in the last three chapters. Available at https://www.fema.gov/media-library-data/1570817928423- 55b4d3ff4789e707be5dadef163f6078/FEMAP646_ThirdEdition_508.pdf

(FEMA P-646, 2019):
Risk Category is a categorization used in the determination of loads based on the risk associated with unacceptable performance. In general, buildings and other structures that represent a low risk to human life are assigned Risk Category I; standard occupancy structures are assigned Risk Category II; hazardous or otherwise important facilities are assigned Risk Category III; and essential facilities are assigned Risk Category IV.

For the purpose of tsunami design, buildings and other structures are assigned to Tsunami Risk Categories. Tsunami design is required for all structures designated as Tsunami Risk Category IV, which includes tsunami vertical evacuation refuge structures. Tsunami design is required for Tsunami Risk Category III structures where inundation depths exceed 3 feet (0.914 m), and Tsunami Risk Category II structures only where designated by local statute.

The ITIC has compiled Vertical Evacuation Practices for the United States and worldwide. A total of 117 references were found, mostly from the USA, Japan, and Indonesia. Materials available on ITIC web site.
http://itic.iocunesco.org/index.php?option=com_content&view=article&id=2070&Itemid=2927

3. The 2018 International Building Code (IBC) incorporated by reference the requirements of ASCE 7-16 that includes the tsunami-resilient design of critical and essential facilities.

4. In 2018, Hawaii approved the adoption of Chapter 6, Tsunami Loads and Effects, of ASCE 7-16 into the State Building Code. The State Building Code applies to all state government buildings. The counties and private sector follow the County Building Codes.

5. In May of 2020, the City and County of Honolulu adopted the IBC 2012 with the tsunami design requirements of ASCE 7-16, applicable to Risk Category 3 and 4 buildings and structures and taller Risk Category 2 building of certain occupancies:
   1615.1 General. The design and construction of Risk Category III and IV buildings and structures and Risk Category II buildings meeting the criteria of Section 1615.2, where located in the Tsunami Design Zones defined in the ASCE 7 Tsunami Design Geodatabase (version 2016-1.0), shall be in accordance with Chapter 6 of ASCE 7-16.
   1615.2 Criteria for Risk Category II buildings to be subject to tsunami-resilient design and construction. Risk Category II buildings and structures shall comply with Chapter 6 of ASCE 7 when meeting all of the following conditions:
   1. Are of Occupancy Classifications A, B, E, I, M, R-1, R-2, or Higher Education Laboratories, and
   2. Located where the tsunami inundation depth is greater than 3 feet (0.914m) at any location within the intended footprint of the structure, and
   3. The highest occupiable floor exceeds 45 feet above grade plane and also exceeds the tsunami inundation depth determined at the site.

6. In 2021, the State is expected to adopt the 2018 IBC amended with more detailed scope of applicability of tsunami design for taller buildings:
   SECTION 1615 TSUNAMI LOADS
   1615.1 General. The design and construction of Risk Category III and IV buildings and structures, and those Risk Category II buildings meeting the criteria of Section 1615.2, where located in the Tsunami Design Zones defined in the ASCE 7 Tsunami Design Geodatabase (version 2016-1.0), shall be in accordance with Chapter 6 of ASCE 7-16.

   1615.2 Criteria for Risk Category II Buildings to be subject to Tsunami-Resilient Design and Construction. Risk Category II buildings and structures shall comply with Chapter 6 of ASCE 7 when meeting all of the following conditions:
   1. Are of Occupancy Classifications A, B, E, I, M, R-1, R-2, or Higher Education Laboratories, and
   2. Located where the tsunami inundation depth is greater than 3ft (0.914m) at any location within the intended footprint of the structure, and
   3. The highest occupiable floor exceeds the height above grade plane specified in Figures 1615.2(a) through 1615.2(e) and also exceeds the tsunami inundation depth determined at the site.

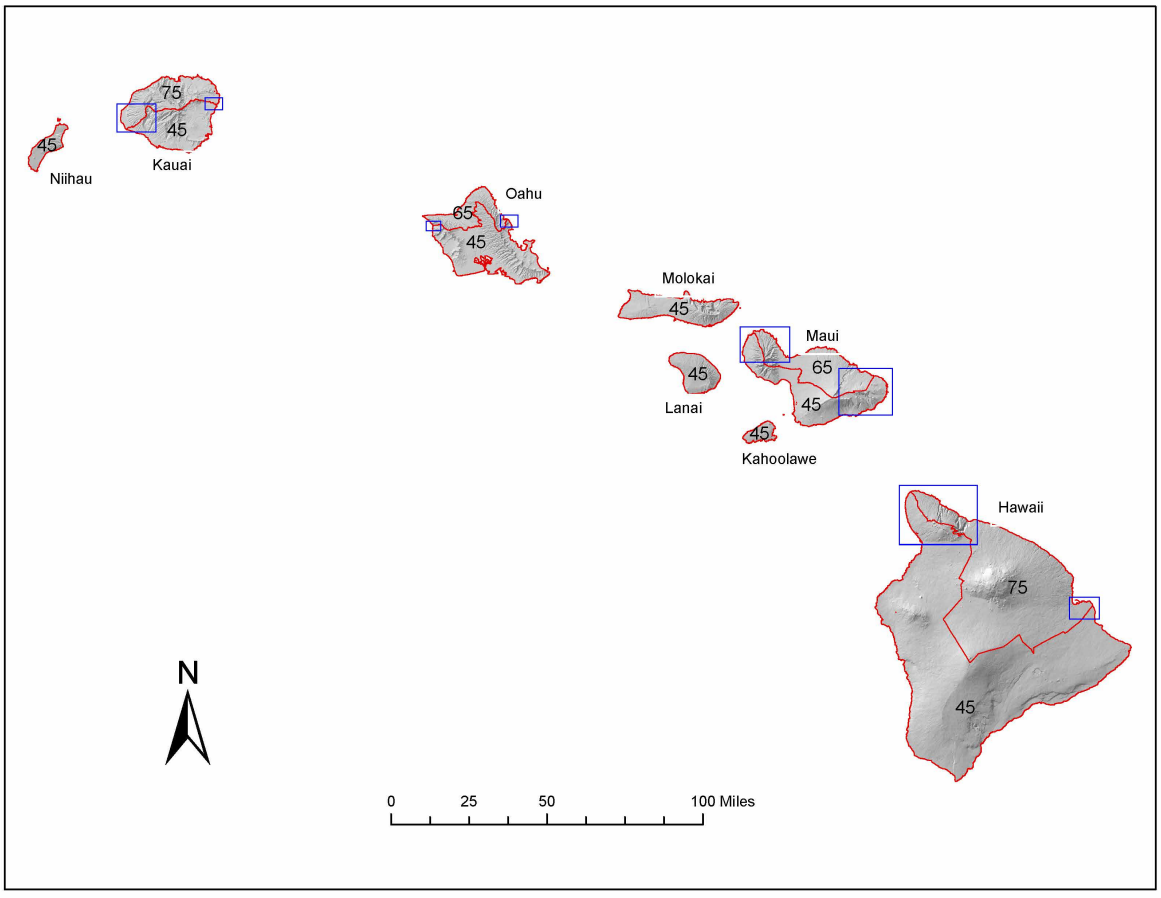

Figure 1615.2(a)
Minimum Height of Highest Occupiable Floor for Risk Category II Buildings to Require Tsunami Design – State of Hawaii.

7. To improve upon the ASCE 7 Tsunami Design Zone Geodatabase, more detailed inundation modeling using higher resolution bathymetric and topographic digital elevation data was undertaken by Ian Robertson, Applied Research International and the University of Washington under contract with DBEDT's Office of Planning Coastal Zone Management Program. Higher resolution Tsunami Design Zone mapping for Oahu was completed in 2019 and is being incorporated into the ASCE 7-22 Tsunami Design Geodatabase. The ASCE 7-22 Geodatabase will also include a revised Tsunami Design Zone for Hawaii Island incorporating higher resolution mapping performed by University of Washington for the high population areas of Hilo and Kailua-Kona. Current high resolution Tsunami Design Zone inundation analysis is ongoing for Maui island, followed by Kauai over the next two years.

8. To improve upon the ASCE 7 Tsunami Design Zone Geodatabase, the California Geological Survey and the State of Washington also developed more detailed inundation modeling of its more populated coastlines using higher resolution bathymetric and topographic digital elevation data. These mapping updates are also being incorporated into the ASCE 7-22 Tsunami Design Geodatabase.

9. The US Department of Defense now incorporates the ASCE 7-16 tsunami design requirements in its Unified Facilities Criteria for Structural Engineering, and developed tsunami design zone mapping for its Pacific Ocean naval ports.
    - The design and construction of buildings and structures located in a Tsunami Design Zone, as defined by the Tsunami Design Geodatabase or by DoD tsunami mapping for at risk OCONUS installations, must be in accordance with Chapter 6 of ASCE 7.

10. To model losses before, during or after a tsunami, high hazard states and territories in the U.S. are able to use FEMA's Hazus Tsunami Model for initial loss estimations to the built environment and to broadly estimate social and economic impacts. The tsunami loss estimation module evaluates overall structure losses according to their building code vintages and structural system types.