ASCE 7 Tsunami Loads and Effects Subcommittee

Gary Chock, ASCE 7 TLESC Chair

Tohoku Tsunami photograph at Minami Soma by Sadatsugu Tomizawa

The Code Development Process

Hierarchial Lexicon of Hazard Information from an Engineering (and Code Development) Perspective

- Hypothetical Hazards
- Historical and Paleo Hazards
- Hazard Assessment
- **Probabilistic Hazard Analysis**
- Vulnerability and Exposure Assessment
- **Vulnerability Analysis**
- **Engineering Risk Analysis**

USA Codes and Standards

- International Building Code (IBC)
- ASCE 7 Minimum Design Loads for Buildings and Other Structures (ASCE 7) developed in an ANSI-accredited consensus process

- Other Standards:
  - Material specific design specifications
  - Non-structural installation standards
  - Testing and qualification standards

Design Codes

- National Codes and Standards are *updated* every 3 to 5 years:
  - International Building Code augments and adopts by reference the load and public safety requirements of
    - American Society of Civil Engineers / Structural Engineering Institute ASCE 7 Standard, Minimum Design Loads for Buildings and Other Structures
- Model Building Codes are mandatory *when adopted* by the local jurisdiction as a regulatory ordinance.
- Guidelines have no force of law. Many FEMA documents (such as FEMA P646) are of this type but may represent a path towards a "pre-standard" that may later be converted into a standard referenced by the code.

Background Information
Objective of the ASCE Tsunami Standards Activity

- A national standard for engineering design for tsunami effects written in mandatory language does not exist. As a result, tsunami risk to coastal zone construction is not explicitly and comprehensively addressed in design codes.
- The Tsunami Loads and Effects Subcommittee of the ASCE/SEI 7 Standards Committee shall develop a proposed new Chapter 6 - Tsunami Loads and Effects, with Commentary for the 2016 edition of the ASCE 7 Standard. ASCE 7-2016 proposed to be adopted in the IBC in January 2016.
- ASCE 7-2016 Chapter 6 would provide prescriptive loads for tsunami and its effects, and it will also incorporate aspects of Performance Based Tsunami Engineering.
- ASCE TLESC was proposed in 2010, established in February 2011, and has formally met in July & October 2011; March, 2012; next meeting in July 2012, etc.

Risk categories of buildings and other structures per ASCE 7

Risk Category I	**Buildings and other structures that represent a low risk to humans**
Risk Category II	**All buildings and other structures except those listed in Risk Categories I, III, IV**
Risk Category III	**Buildings and other structures with potential to cause a substantial economic impact and/or mass disruption of day-to-day civilian life in the event of failure.**
Risk Category IV	**Buildings and other structures designated as essential facilities**

Risk Category of Buildings and Other Structures for Tsunami Loads

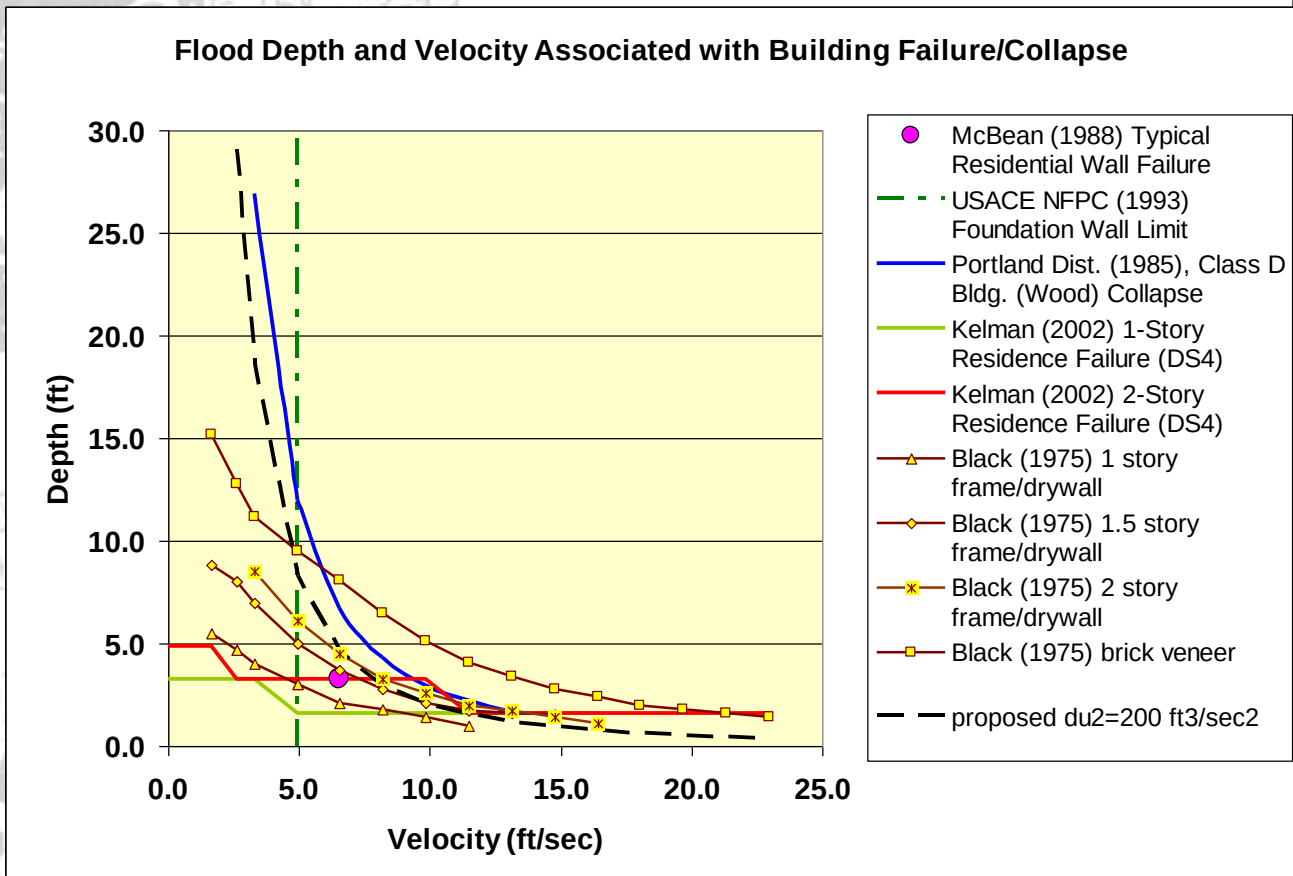
Use or Occupancy of Buildings and Structures	Risk Category for Tsunami
Buildings and other structures that represent a low hazard to human life in the event of failure	I
All buildings and other structures except those listed in Risk Categories I, III, and IV	II
Buildings and other structures , the failure of which could pose a substantial risk to human life*, including, but not limited to:* • ***Buildings and other structures where more than 300 people congregate in one area*** • ***Buildings and other structures with daycare facilities with a capacity greater than 150*** • ***Buildings and other structures with elementary school or secondary school facilities with a capacity greater than 250*** • ***Buildings and other structures with a capacity greater than 500 for colleges or adult education facilities*** • ***Any other occupancy with an occupant load greater than 5,000 based on net floor area.*** Buildings and other structures, not included in Risk Category IV, with potential to cause a substantial economic impact and/or mass disruption of day-to-day civilian life in the event of failure. Buildings and other structures not included in Risk Category IV (including, but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, hazardous waste, or explosives) containing sufficient quantities of toxic or explosive substances where the quantity of the material exceeds a threshold quantity established by the authority having jurisdiction and is sufficient to pose a threat to the public if released.	III
Buildings and other structures designated as essential facilities*, including, but not limited to:* • ***Health care facilities with a capacity of 50 or more resident patients*** • ***Hospitals and other health care facilities having surgery or emergency treatment facilities*** • ***Fire, rescue, ambulance, and police stations*** • ***Designated tsunami vertical evacuation refuges*** • ***Designated emergency preparedness, communication, and operation centers and other facilities required for emergency response*** • ***Power generating stations and other public utility facilities required in an emergency*** • ***Aviation control towers and air traffic control centers*** • ***Telecommunication centers*** Buildings and other structures, the failure of which could pose a substantial hazard to the community Buildings and other structures (including, but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, or hazardous waste) containing sufficient quantities of highly toxic substances where the quantity of the material exceeds a threshold quantity established by the authority having jurisdiction and is sufficient ot pose a threat to the public if released. Buildings and other structures required to maintain the functionality of other Risk Category IV structures.	IV

Overview of Tsunami Design Code Scope

- Applicable only to states and territories with quantifiable probabilistic hazard: Alaska, Washington, Oregon, California, Hawaii, and Guam, American Samoa, and Puerto Rico, USVI
- Not applicable to any buildings within the scope of the International Residential Code,
- Not applicable to any Risk Category II structures up to ~65 feet in height, nor any Risk Category I structures
- Applicable to Risk Category III and IV buildings and structures, and Risk Category II buildings of height sufficient for reliable life safety and reasonable economy

Exemption for light frame residential

- Subject to mandatory evacuation
- Categorical infeasibility of light-frame design for most tsunamis



Chris Jones

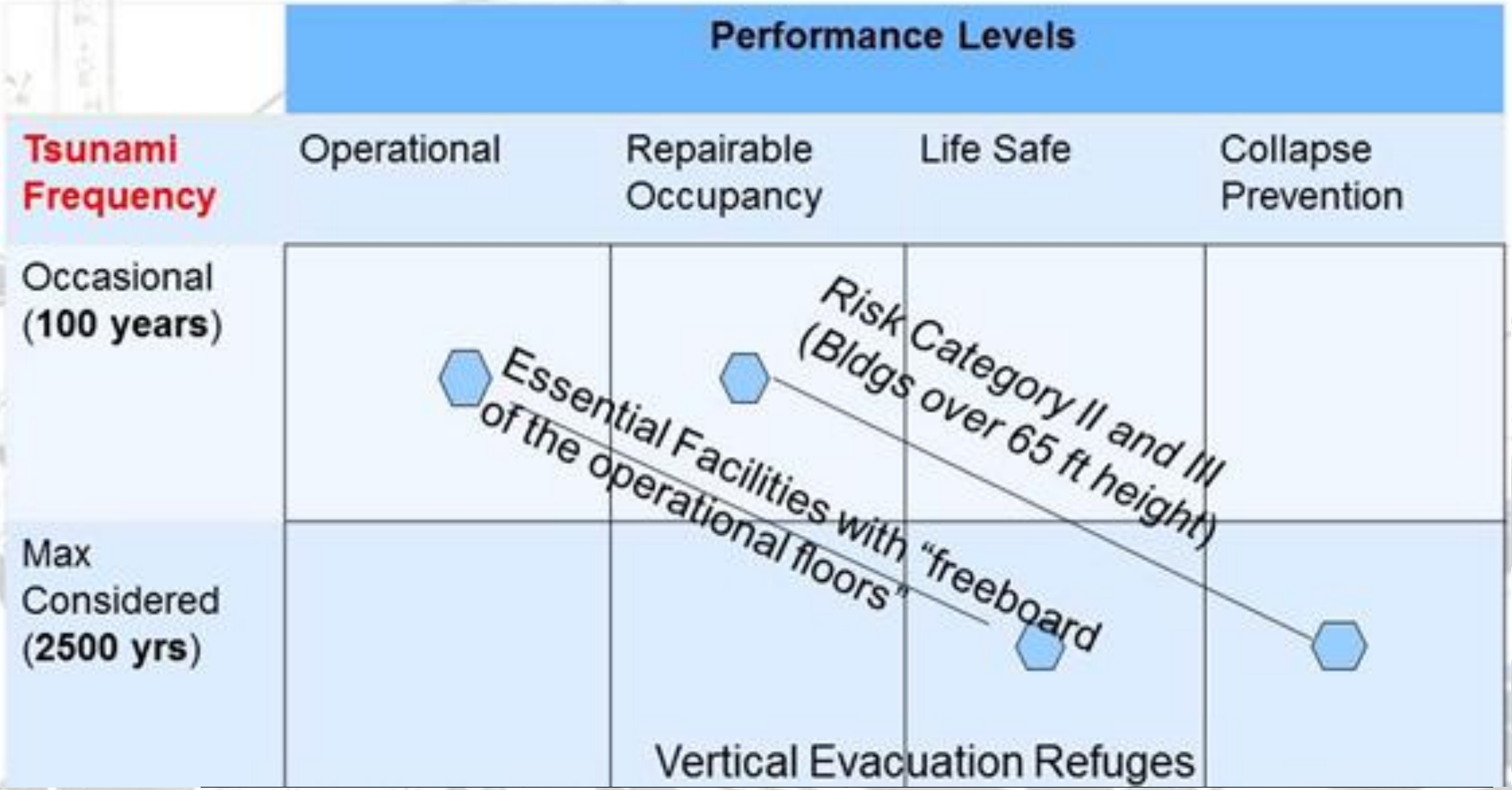
Seismic Performance-Based Design Objectives (Concept)

	Performance Levels				
Earthquake Frequency	Operational	Immediate Occupancy	Life Safe	Collapse Prevention	*Collapse Possible*
Occasional (**100 years**)					
Rare (500 years)					
Max Considered (2500 yrs)					

Essential Facilities

Risk Category II

Tsunami Design based on Risk Category



Evacuation procedures for emergency response are still necessary

Overview of Scope

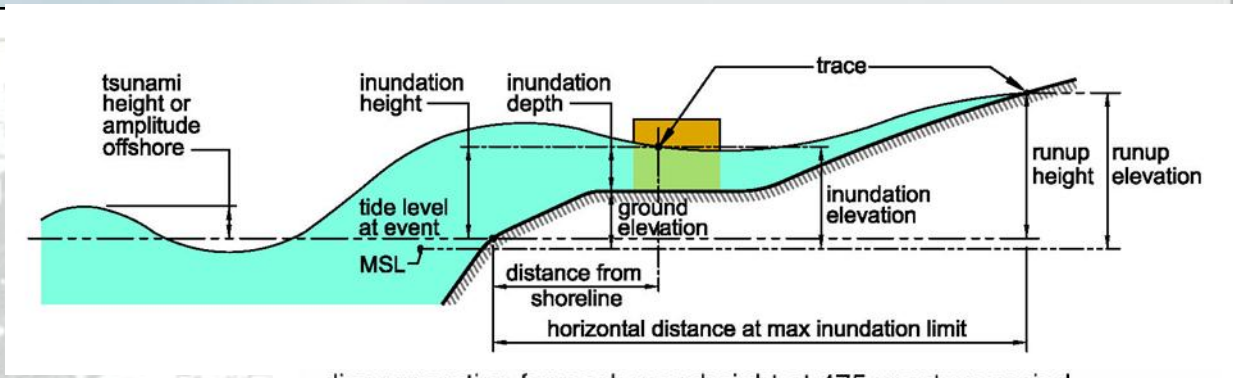
- Performance criteria to be based on 2,500-year hazard level Maximum Considered Tsunami for consistency with ASCE 7 seismic hazard criteria with tsunami as a coseismic effect.
- A probabilistic Hazard Map of offshore tsunami height is being developed and will be incorporated in the Standard.
- The tsunami hazard inland inundation limiting zone affected at the 2,500-year level would be identified.
- Criteria will identify where ground shaking and subsidence from a preceeding local offshore Maximum Considered Earthquake needs to be considered prior to tsunami arrival (for Alaska and the regions directly affected by the Cascadia Subduction Zone).

Special Considerations for Tsunami Design

- For Pacific NW regions governed by nearby offshore earthquakes, structure will need to resist earthquake prior to onset of tsunami.
- Need for local tsunami inundation mapping of hydrodynamic loading parameters, based on probabilistic regional offshore tsunami heights
- Tsunami wave height not proportional to EQ magnitude
- Include possible earthquake-induced subsidence affecting tsunami inundation
- Flow acceleration in urban landscapes
- Analyze the key loading phases of depth and velocity in momentum flux pairs
- Tsunami forces not proportional to building mass
- Inflow and outflow characteristics will be different
- Debris accumulation and low-speed debris impacts
- Scouring at the perimeter of the building

Probabilistic Tsunami Hazard Analysis

- To include a national map of 2,500-year tsunami offshore wave height to use as the initial condition benchmark for local inundation maps or prescriptive inundation calculation, where the specified offshore wave height is attributed to the disaggregated governing seismic sources.



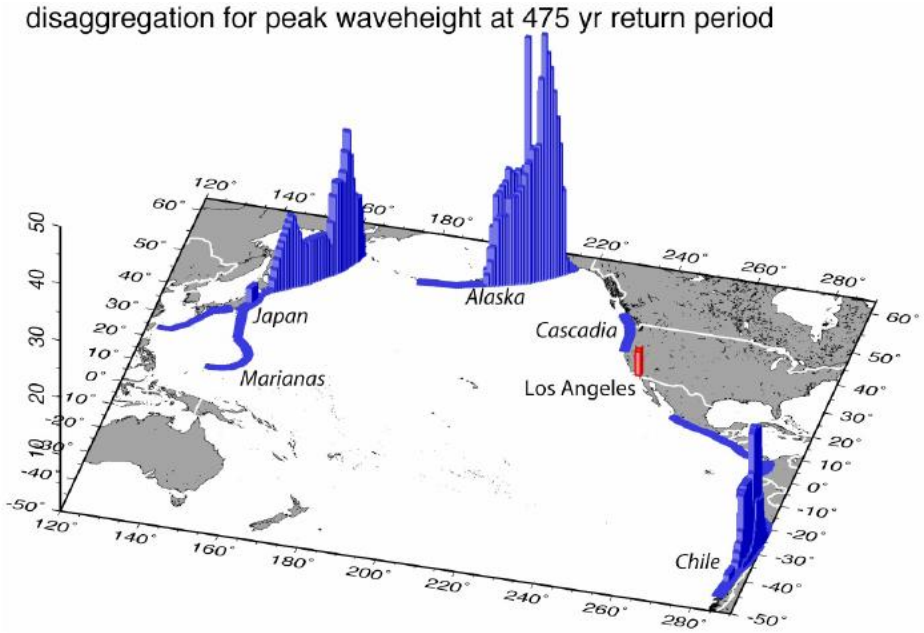
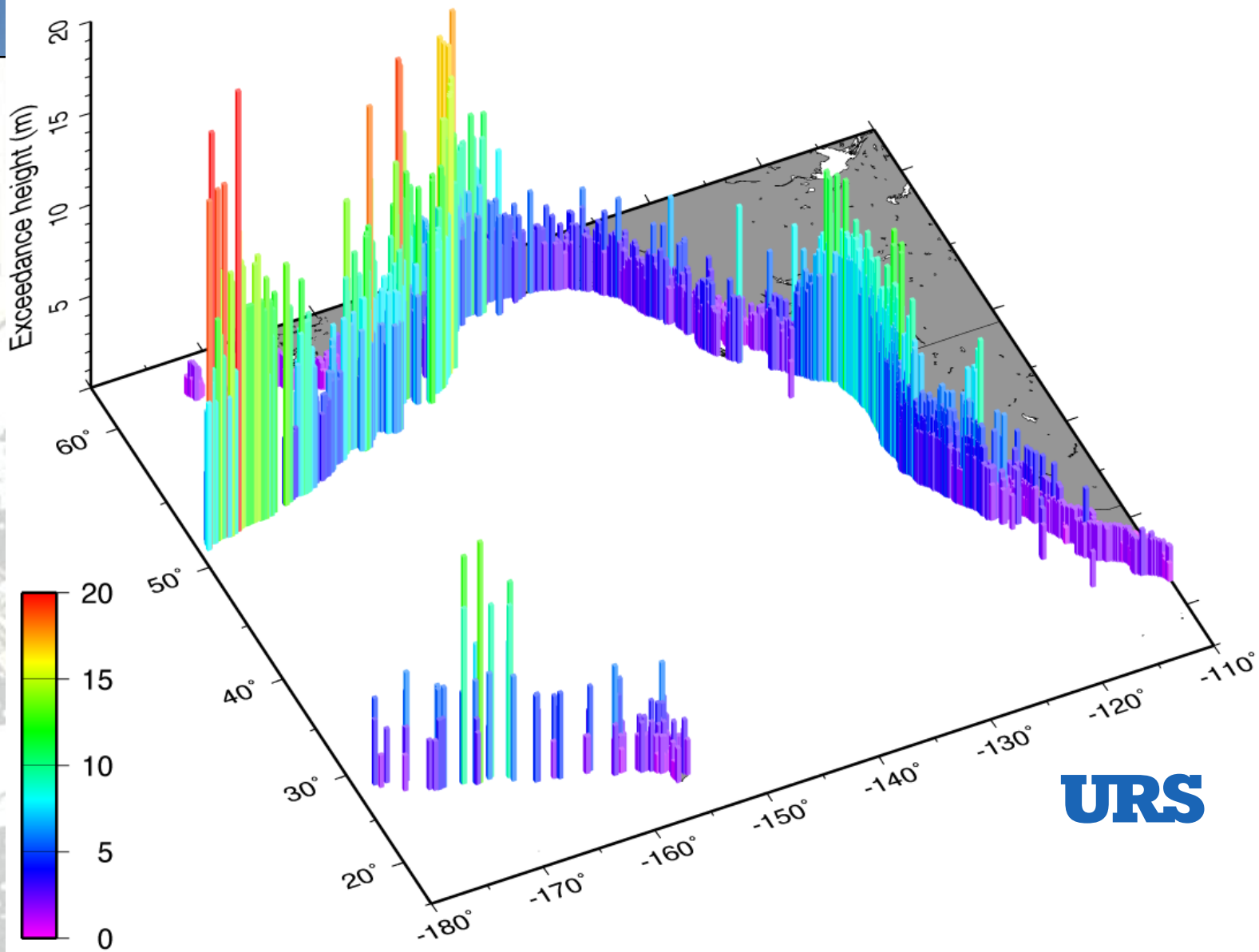


Figure 3 Source disaggregation for the tsunami hazard in the Los Angeles area for peak waveheight. The blue bars represent the relative contribution of each element towards the tsunami hazard (red bar) in the target area

Exceedance waveheights: 2500 yr



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Overview of Scope (continued)

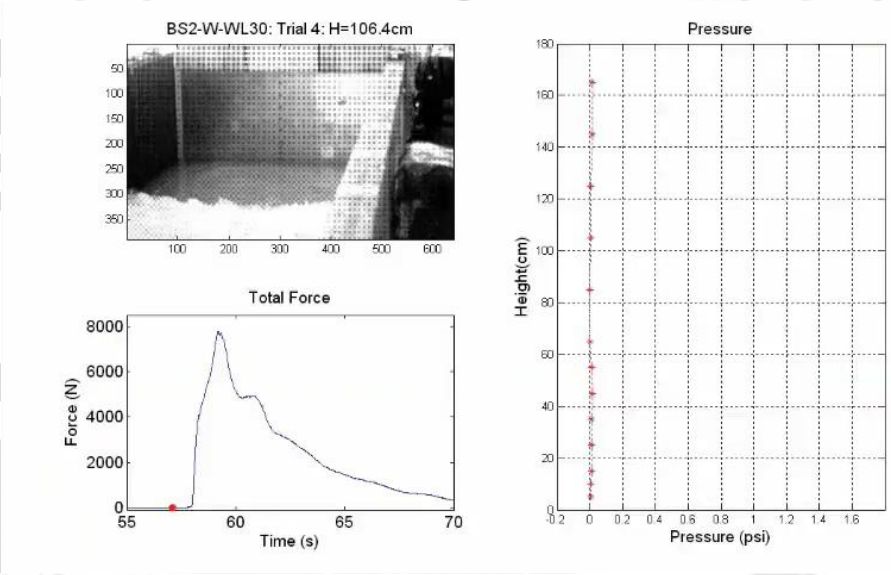
- ASCE 7-2016 Minimum Design Loads for Buildings and Other Structures - Chapter 6 Tsunami Loads and Effects will include a prescriptive method and requirements for site-specific hazard analysis for determining the inundation and flow at a site.
- Design equations for hydrostatic, hydrodynamic, and debris impact forces and the physical conditions for application will be included.
- Prescriptive foundation design to resist scour
- Economic impact in high seismic regions is anticipated to be nominal since most buildings subject to these requirements will be designed to Seismic Design Category D or greater (design for inelastic ductility).

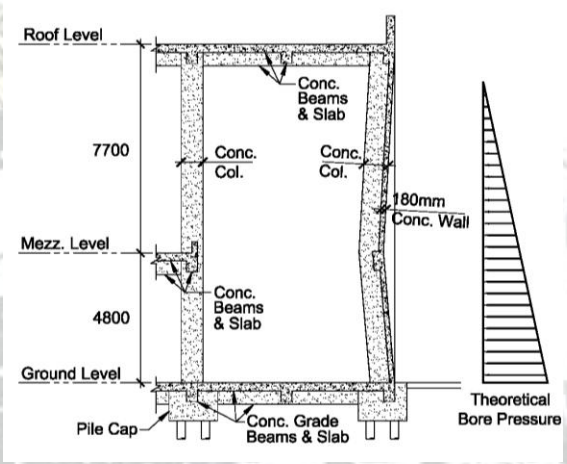
Tsunami Loads and Effects

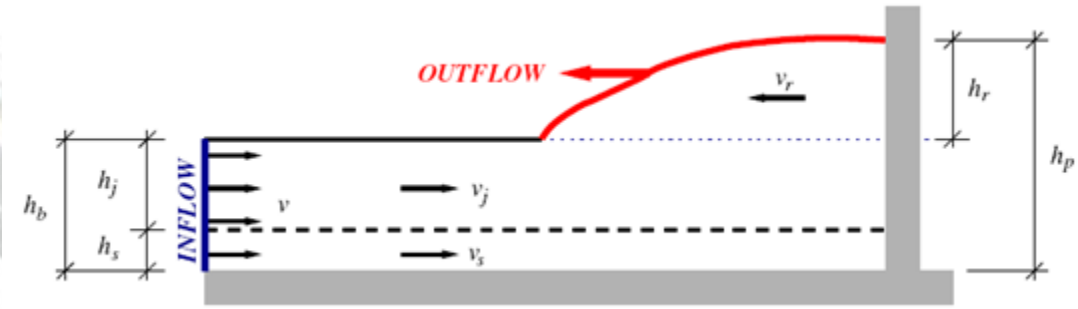
- **Hydrostatic Forces:**
  - **Unbalanced Lateral Forces**
  - **Buoyant Uplift**
  - **Residual Water Surcharge Loads on Elevated Floors**
- **Hydrodynamic Forces:**
  - **Lateral Impulsive Forces of Tsunami Bores**
  - **Hydrodynamic Pressurization**
  - **Surge Forces**
  - **Damming by Waterborne Debris**
- **Waterborne Debris Impact Forces**
- **Scour Effects:**
  - **Shear of cyclic inflow and outflow**
  - **Transient liquefaction during rapid drawdown**

Sendai 仙台市 Example of Bore Impact
Soliton Bore Strike on R/C Structure

Videos: Experimental and Full-Scale







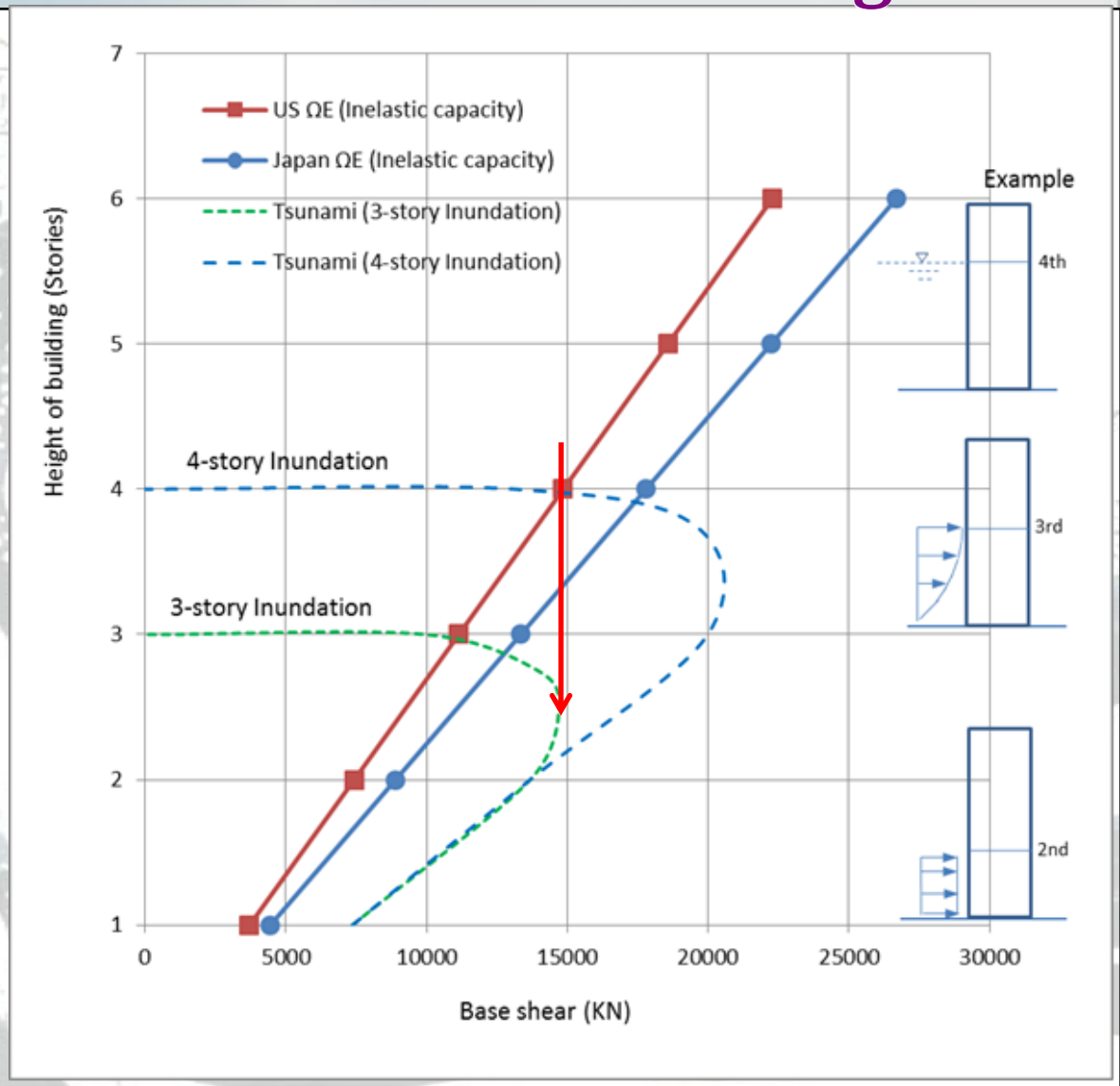
Sendai 仙台市 Example of Bore Impact
Soliton Bore Strike on R/C Structure

Proposed Scope of the ASCE Tsunami Design Provisions 2016 edition of the ASCE 7 Standard, Minimum Design Loads for Buildings and Other Structures

- 6.1 General Requirements
- 6.2 Definitions
- 6.3 Symbols and Notation
- 6.4 General Tsunami Design Criteria
- 6.5 Procedures for Tsunami Hazard Assessment
- 6.6 Procedures for Tsunami Inundation Analysis
- 6.7 Design Parameters for Tsunami Flow over Land
- 6.8 Design Procedure for Tsunami Inundation (Prescriptive)
- 6.9 Hydrostatic Loads
- 6.10 Hydrodynamic Loads
- 6.11 Impact Loads
- 6.12 Foundation Design
- 6.13 Structural countermeasures for reduced loading on buildings
- 6.14 Special Occupancy Structures
- 6.15 Designated Nonstructural Systems (Stairs, Life Safety MEP)
- 6.16 Non-building critical facility structures
- Commentary and References

Encouraging Indications of Comparing Low-Rise Seismic Inelastic Capacity vs. Various Hypothetical Max. Tsunami Loading

- Prototypical concretete shear wall building located in high seismic zones assumed substantially undamaged by earthquake.
- Connections and anchorage shall develop member inelastic capacities
- Tsunami flow velocity is 8m/s (inflow and/or outflow).
- The building is 25% open.
- Each tsunami inundation load curve represents the sequence of hydrodynamic loading effects as inundation increases to the maximum depth



Indications from Prototype Designs of Risk Category IV and III Buildings for Tsunami

- **Low-rise and lower-mass buildings could be governed by tsunami, especially port facilities.**
- **Tsunami collapse prevention:**
  - Mid to High-rise design for high seismic conditions may not require any systemic upgrading.
  - Structural Components may need local “enhanced resistance”
  - Ground level shear walls may also require localized detailing for out-of-plane hydrodynamic forces or pressurization effects
  - Vertical refuge appears to be a practical alternative use for mid to high-rise concrete buildings that have greater inherent resistance.
- The expected post-earthquake damage state needs to be considered in design to determine the usable inelastic capacity remaining during near-source tsunami inundation.

The ASCE Tsunami Loads and Effects Subcommittee

Questions to: Gary Chock, Chair gchock@martinchock.com