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A Nonlinear Static Procedure for the Design and Assessment of Buildings to Tsunami

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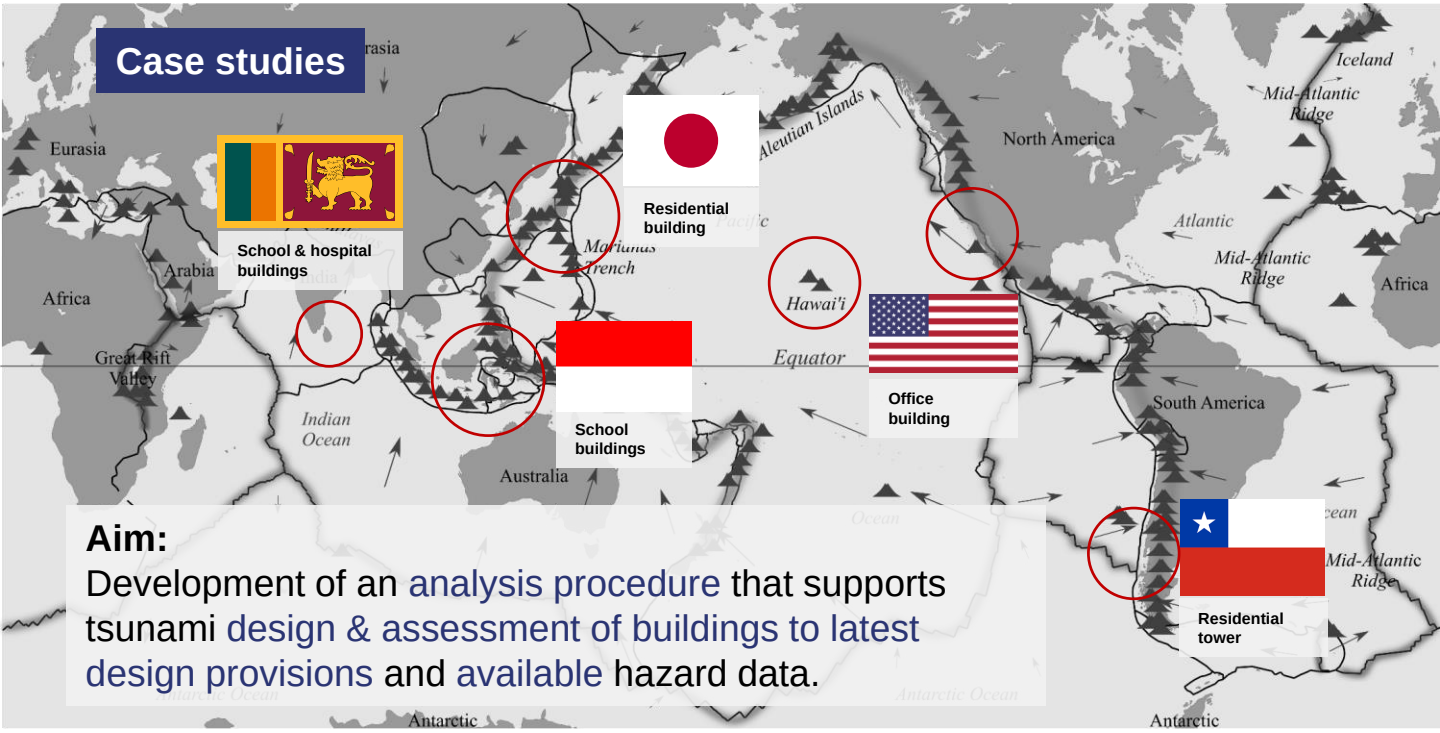
1. Research Question & Aim

How to design and assess buildings to tsunami?



Aim:
Development of an analysis procedure that supports tsunami design & assessment of buildings to latest design provisions and available hazard data.

Map downloaded from: https://commons.wikimedia.org/wiki/File:Tectonic_plates_and_ring_of_fire.png

2. Analysis tools

Current nonlinear static analysis for tsunami loading

CDPO **Constant Depth Pushover** – [1,2,3,4,5]

- **Feature:** constant inundation depth & increasing flow velocity.
- **Type:** response-control pushover analysis (e.g. seismic PO).
- **Tsunami loading:** max overall tsunami hydrodynamic force

VDPO **Variable Depth Pushover** – [3,5]

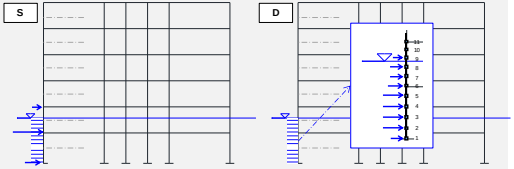
- **Feature:** increasing h & u (assuming constant Froude number).
- **Type:** load-control pushover analysis.
- **Tsunami loading:** time-history of tsunami hydrodynamic force

Common features

- **Load discretisation for systemic response:**

S = Applied at each level of the building. [1,2,3]

D = Distributed along seaward columns. [3,4]



- **FEM modelling:** for loading discretisation D, *distributed plasticity* is used to simulate flexural response under tsunami loading (instead of lumped plasticity). [3,4]

References

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3. Petrone C, Rossetto T, Goda K (2017). Fragility Assessment of a RC Structure under Tsunami Actions Via Nonlinear Static and Dynamic Analyses. *Engineering Structures*, 136:36–53.
4. Alam MS, Barbosa AR, Scott MH, Cox DT, van de Lindt JW (2018). Development of Physics-Based Tsunami Fragility Functions Considering Structural Member Failures. ASCE *J Struct Eng*, 144(3):04017221.
5. Rossetto T, de la Barra C, Petrone C, De la Llera JC., Vasquez J, Baiguera M (2019). Comparative assessment of nonlinear static and dynamic methods for analysing building response under sequential earthquake and tsunami, *Earthquake Engineering & Structural Dynamics*, 48(8):867–887

3. Tsunami Design Provisions

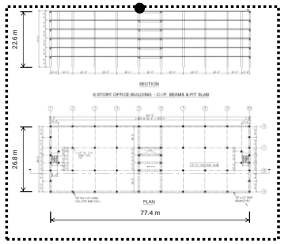
New ASCE 7-16 Standard

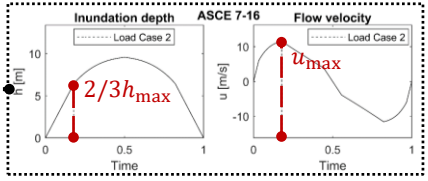
Building & Location

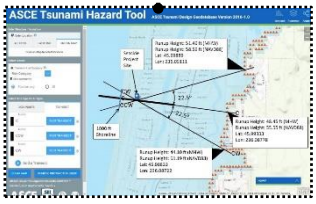
1 **MCT Inundation Depth and Flow Velocity**
Section 6.6

2 **Structural Performance Evaluation**
Section 6.8.3

3 **Load Cases**
Section 6.8.3.1







Case study

Seaside, Oregon

Structural Acceptance Criteria

Lateral-Force-Resisting **System** (LFRS)
Section 6.8.3.4

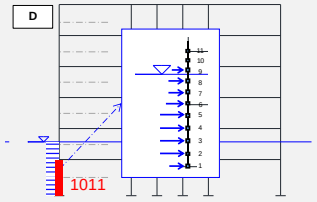
Structural **Component** (SC)

Component Design Strength
Section 6.8.3.5.1

Performance-Based
Section 6.8.3.5.2

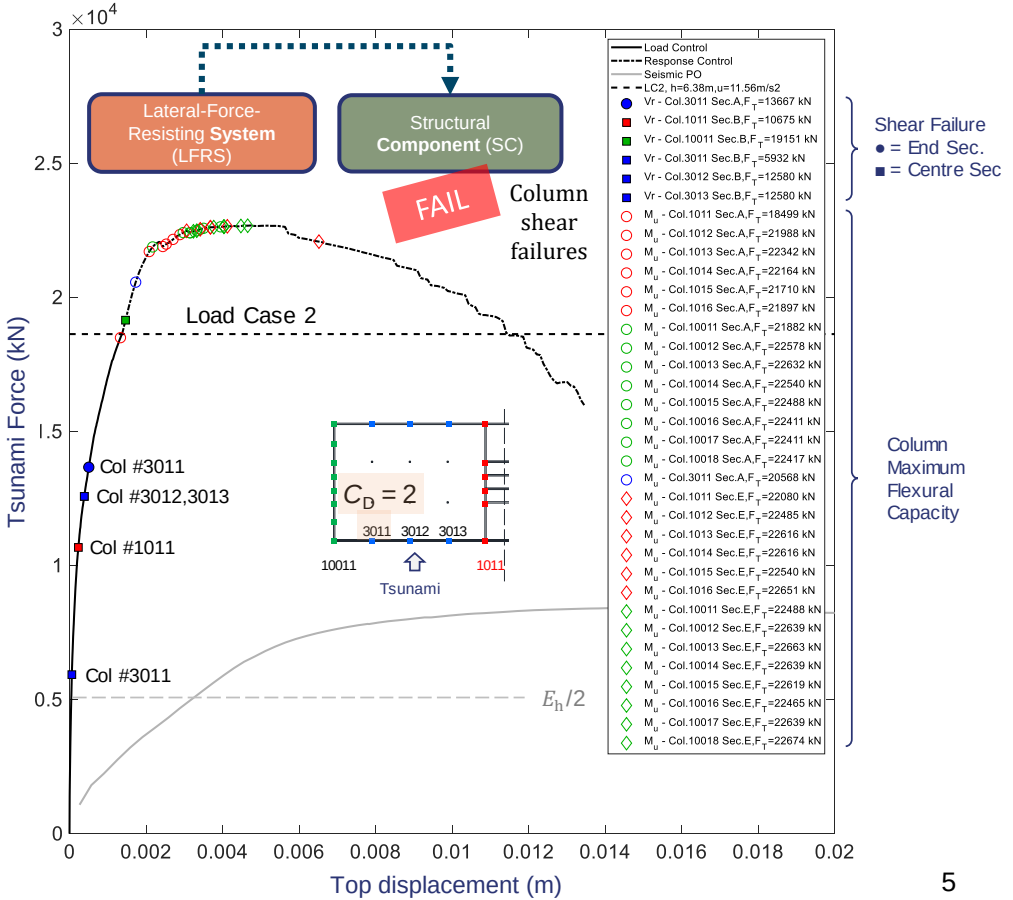
4. Structural Design via VDPO2

VDPO2



Tsunami loads **distributed along columns (D)**

The user can identify the structural elements that may need to be strengthened, to meet acceptance criteria (e.g. ground floor columns that need more shear resistance).



5. Concluding Remarks

- The proposed procedure provides a nonlinear analysis tool that is compatible with the current ASCE 7-16 guidelines. It can be implemented in commercial software (e.g. SeismoStruct).
- The user can estimate the effective lateral-resisting capacity of the building to ASCE 7-based tsunami loadings, and verify the systemic acceptance criteria & component loading.
- This approach is going to be further tested to check the cost savings that can be achieved through its implementation.
- The analysis procedure is currently being implemented for the assessment of school buildings located in coastal areas in Indonesia and Sri Lanka. This work will inform an assessment methodology that is applicable in developing countries where tsunami hazard data (e.g. hazard maps) are limited.