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國家實驗研究院

Study of Tsunami Loadings for Low-rise Reinforced Concrete Buildings

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2014/11/20

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For SCSTW-7

2004 Indian Ocean earthquake and tsunami

(http://upload.wikimedia.org/wikipedia/zh/f/f0/BandaAcehBeforeandAfter2004Tsunami.jpg)

2011 Tohoku earthquake and tsunami

before

After

(http://www.abc.net.au/news/specials/japan-quake-2011/)

Destruction of residential timber-framed construction (2004 Indian tsunami)

Saatcioglu, M., Ghobarah, A., et al. (2006a). "*Performance of Structures in Indonesia during the December 2004 Great Sumatra Earthquake and Indian Ocean Tsunami*." Earthquake Spectra 22(S3): S295

Engineered RC-framed buildings that survived the tsunami in downtown **(2004 Indian tsunami)**


Saatcioglu, M., Ghobarah, A., et al. (2006a). "*Performance of Structures in Indonesia during the December 2004 Great Sumatra Earthquake and Indian Ocean Tsunami*." Earthquake Spectra 22(S3): S295

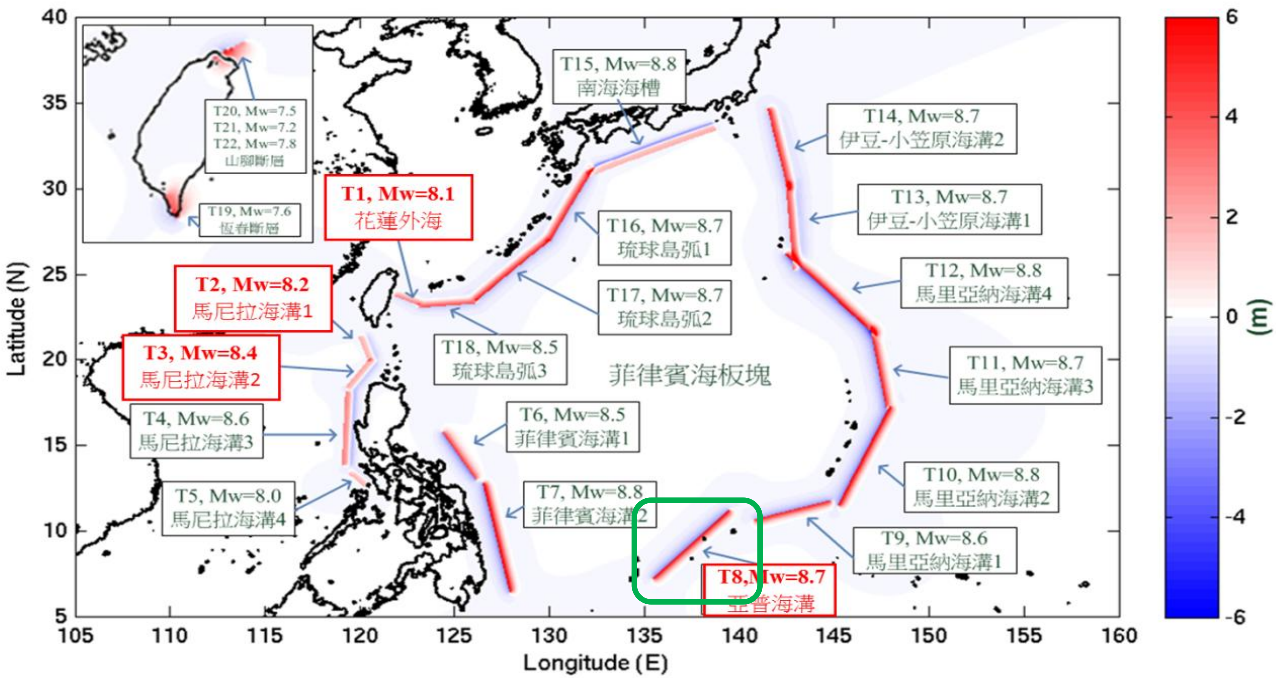
Effects on Structures

Debris loads

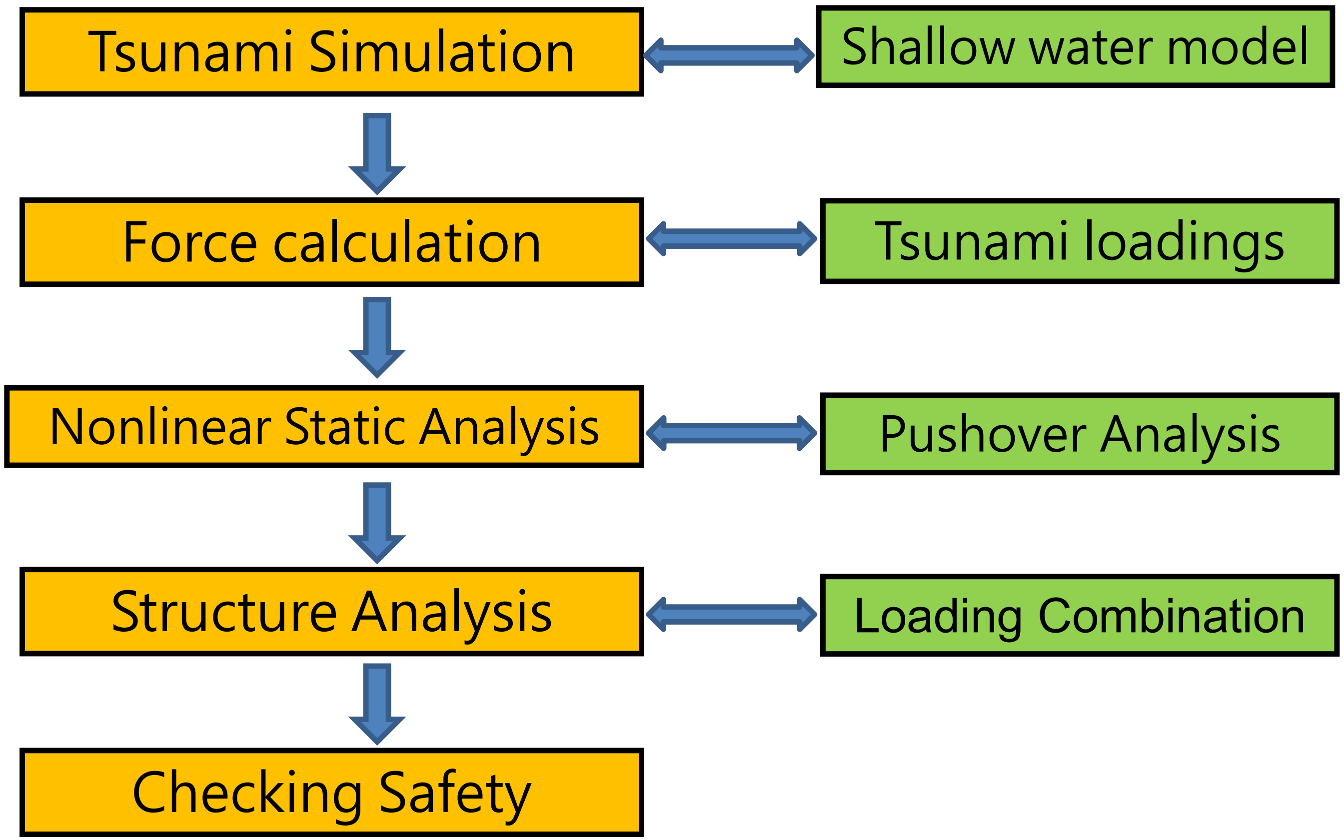
Earthquake Engineering Research Institute (EERI), (2011a), "*The Tohoku, Japan, Tsunami of March 11, 2011: Effects on Structures.*" Special Earthquake Report, Earthquake Engineering Research Institute, California.

Remarks

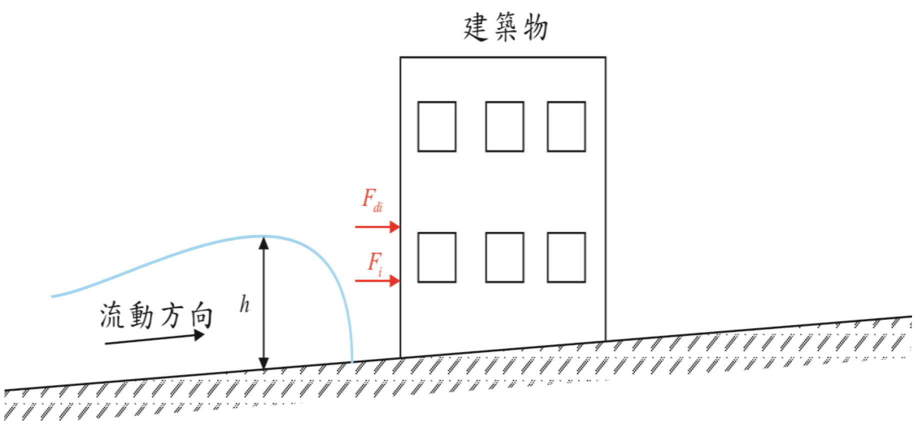
1. Large side loading of tsunami.
2. Debris impacts by tsunami.
3. Well fixed base is necessary.
4. Well designed RC structures can resist the loadings.

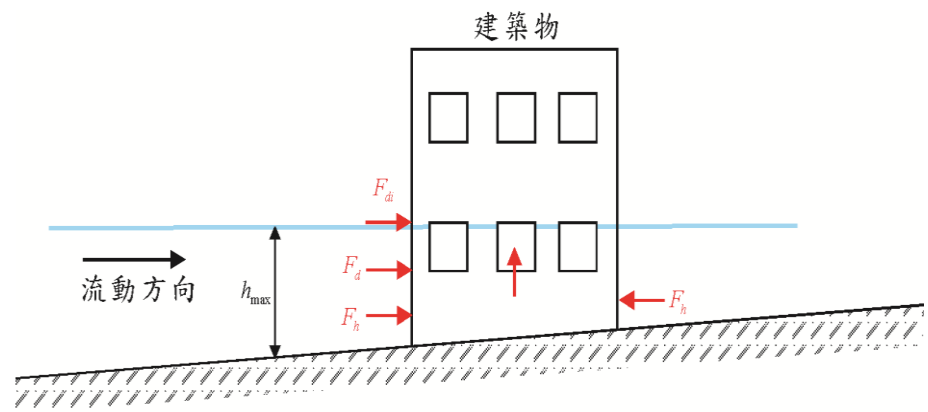


Procedures for Analysis



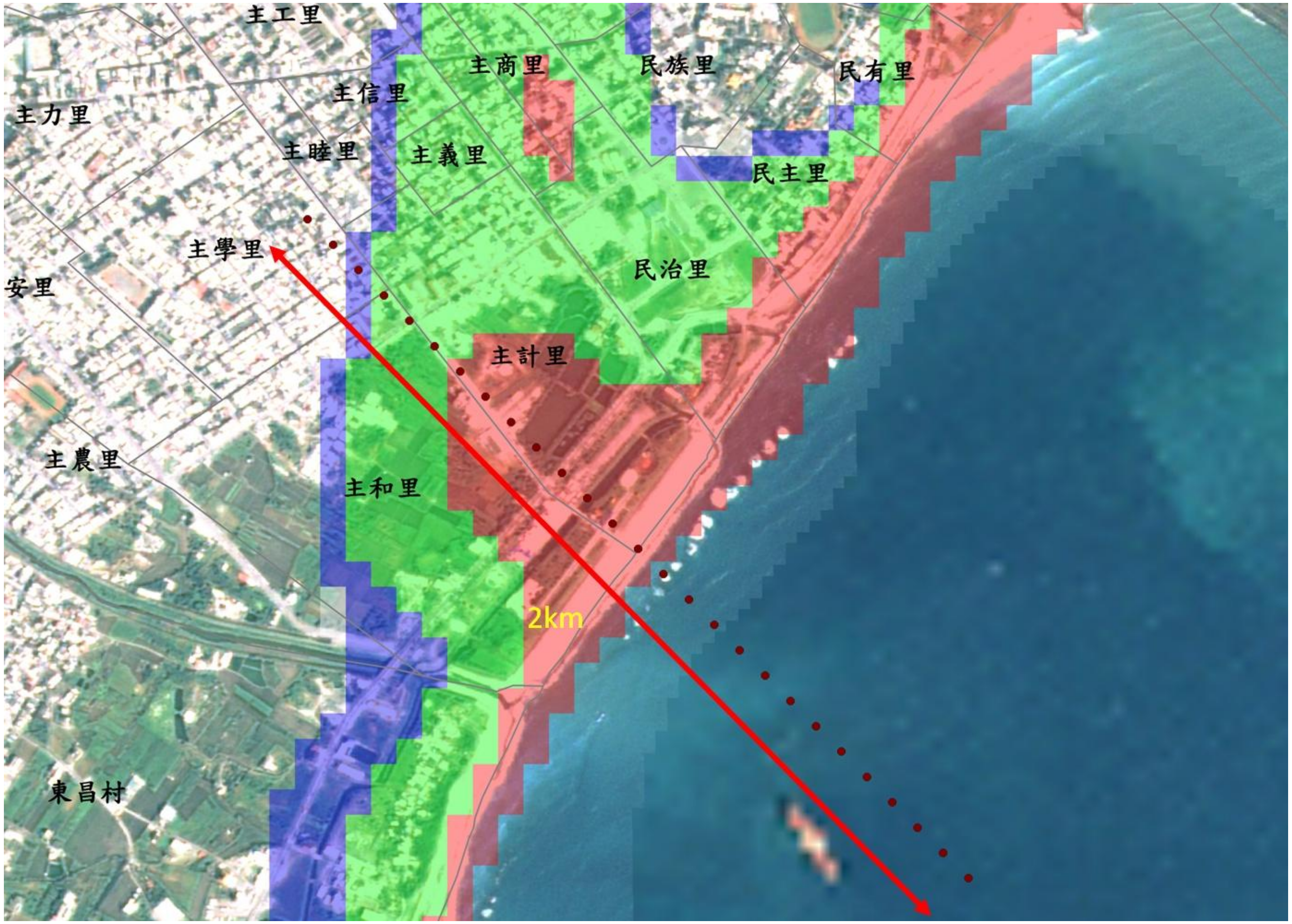
Tsunami loadings



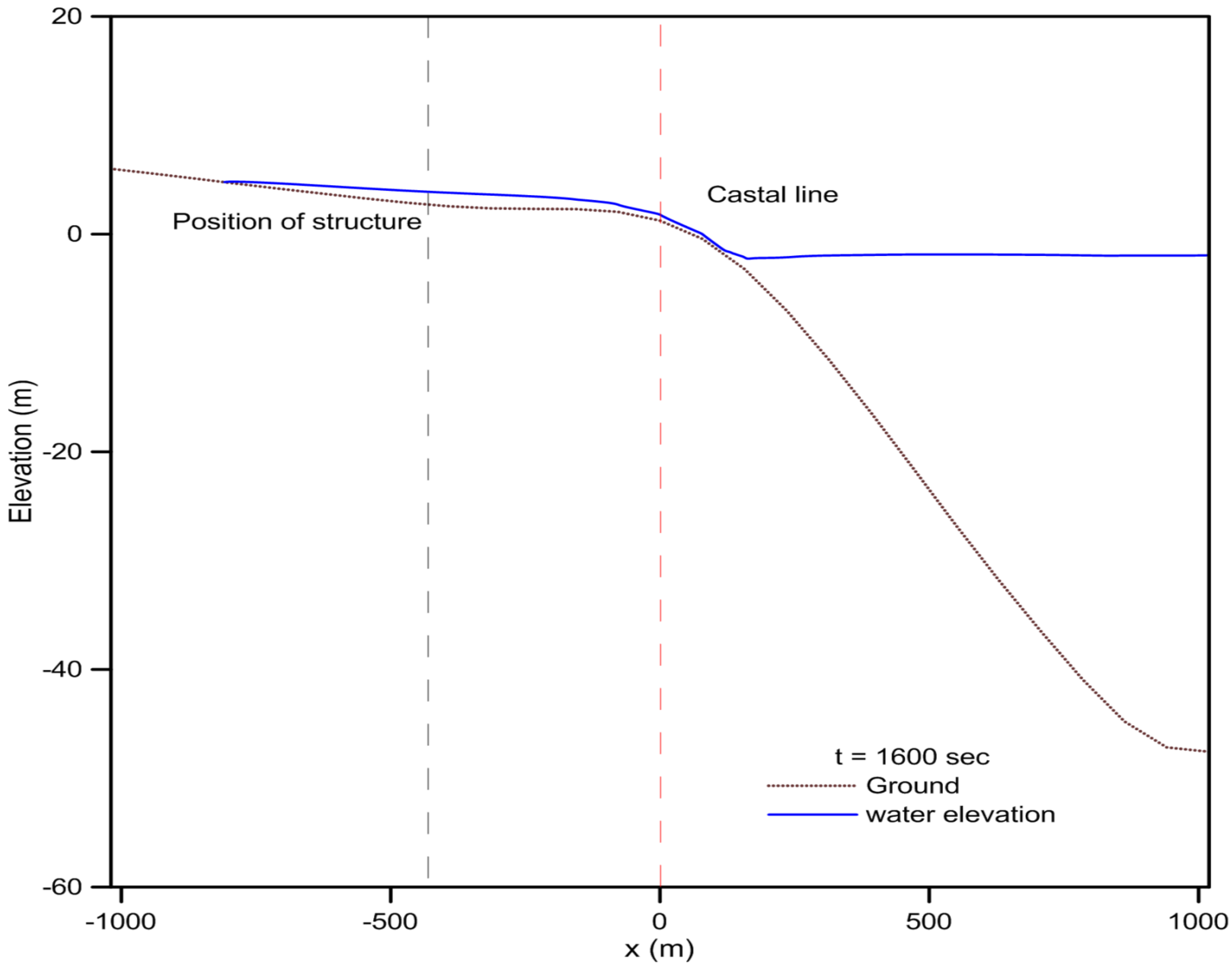


Tsunami Loadings	代號	Equations	Notes
Hydrostatic force	F_h	$F_h = \frac{1}{2}\rho g b h_{max}^2$	g :gravity ρ : density of fluid
Buoyancy	F_b	$F_b = \rho g V$	V : under water volume of structure
Drag force	F_d	$F_d = \frac{1}{2}\rho C_d B\left(h\overline{V}^2\right)_{max}$	C_d : drag coefficient $\overline{V}$: flow velocity $\left(h\overline{V}^2\right)_{max}$: maximum flux of fluid
Impulsive force	F_i	$F_i \approx 1.5F_d$	Refer to FEMA P646

Pseudo event (From NSC in Taiwan)

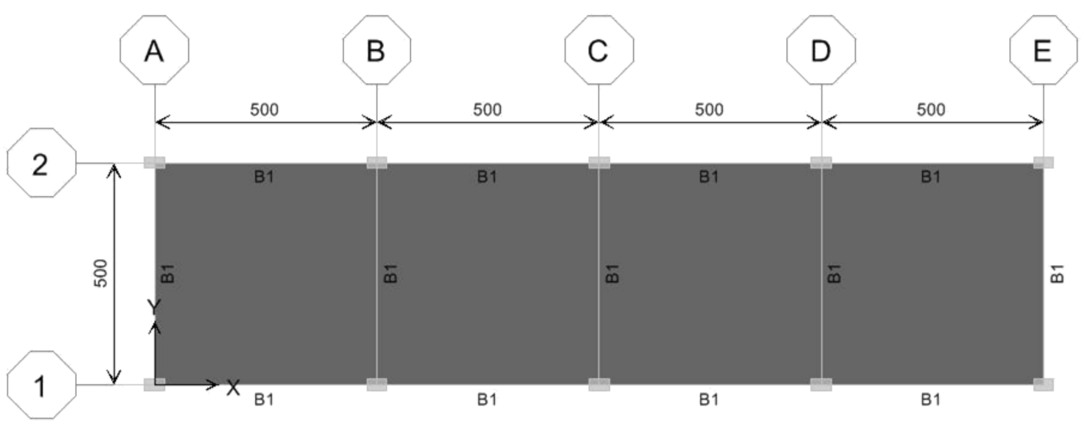


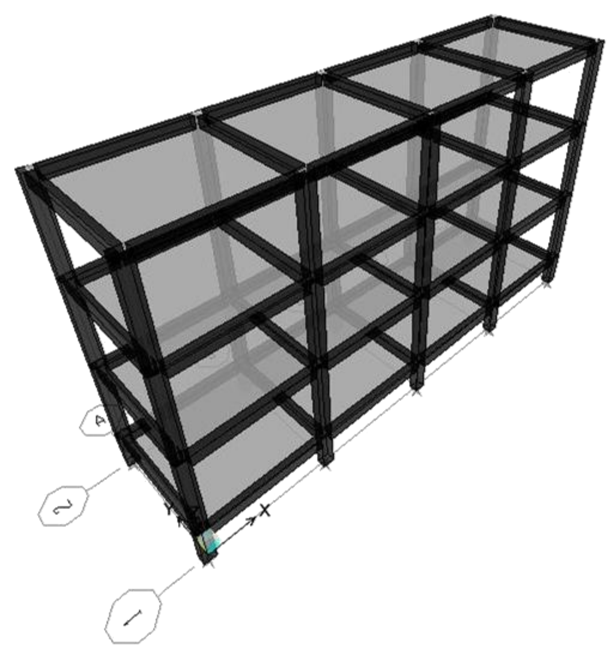
Maximum run-up calculation



Case study

- The example used in this study is a 3-story street front building. The length is 20m. The width is 5 m. The total height is 10.5m. The height of each story is 3.5m.
- The live load of the roof is $200 kgf/m^2$, and the live load of 2F and 3F is $50 kgf/m^2$. Concrete f'_c:$280 kgf/cm^2$. Steel f_y : $2,800 kgf/cm^2$.



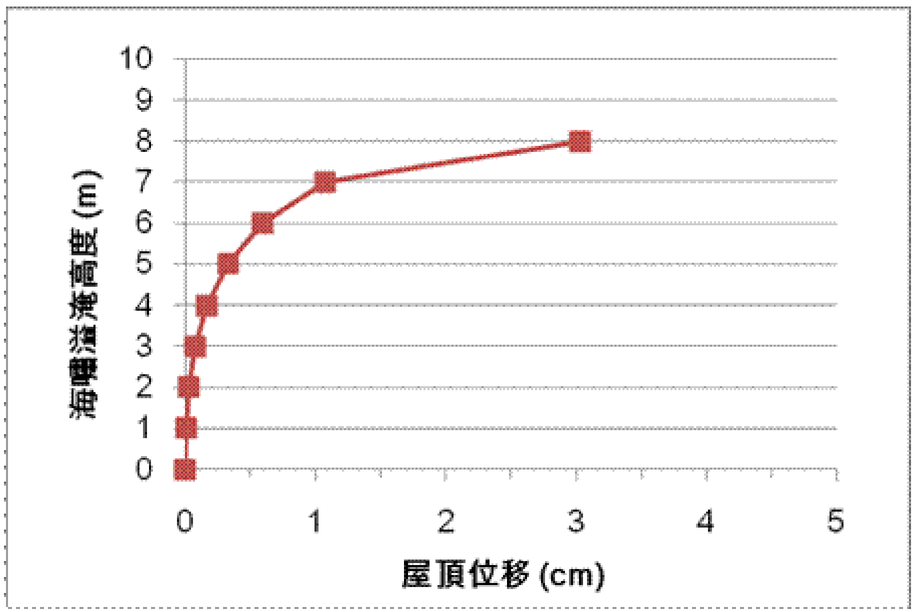


Assumption conditions

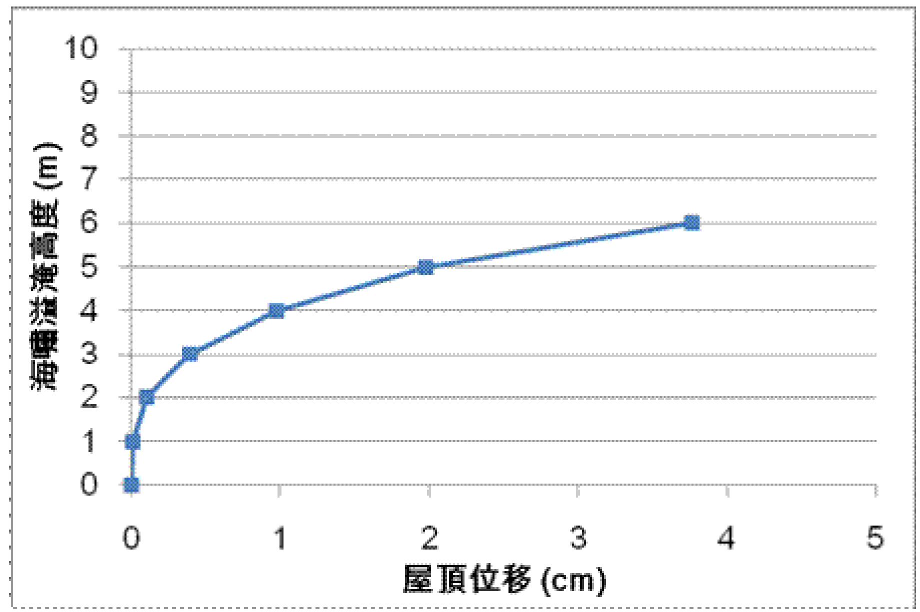
- It is neglected the effect of the non-structural walls in this study.
- In order to consider the larger tsunami force, it assumes the forcing on non-structural wall could transfer the tsunami force to the columns and beams.
- It is considered 0%, 10%, 25%, 50% and 100% airtight ratios in this study. The airtight ratio is the ratio of the airtight besides the structural body under water. 0% airtight ratio is the complete open space, and 100% airtight ratio is complete close space.

The result of the pushover analysis

- When narrow side faces tsunami, the building could resist 8m height tsunami attack, and the maximum of the roof displacement is 3.03cm.
- When wide side faces tsunami, the building could resist 6m height tsunami attack, and the maximum of the roof displacement is 3.76cm.



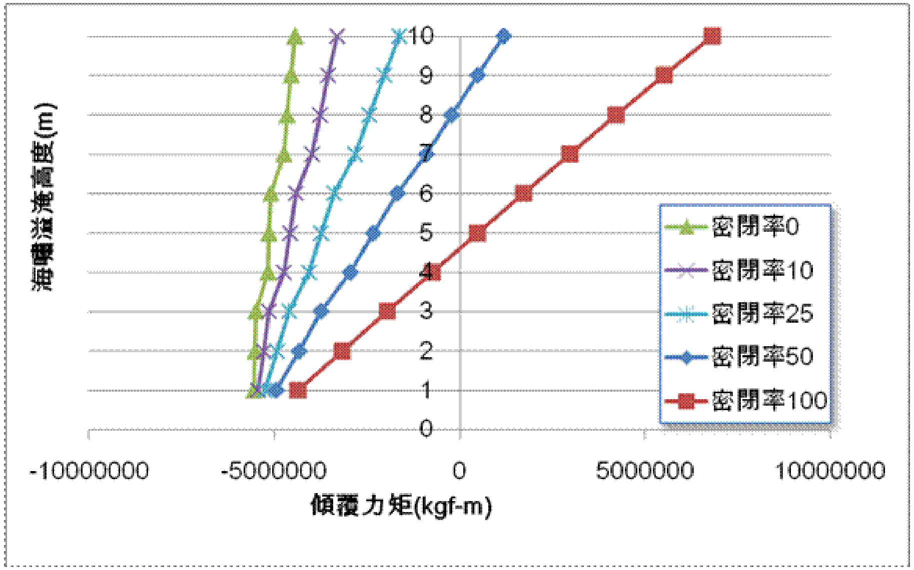
Narrow side

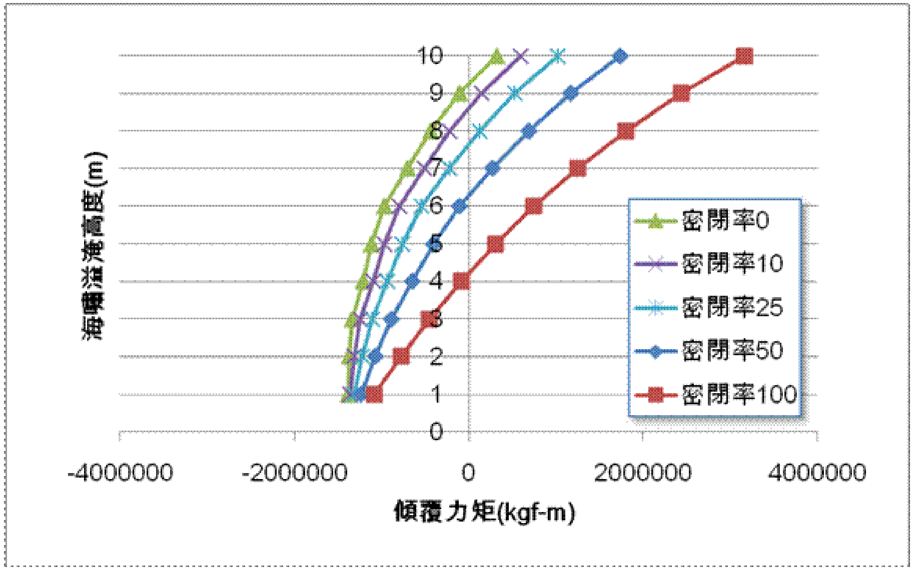


Wide side

Loading Combination 3：$1.0D + 1.0T_s + 1.0L_{REF} + 0.25L$

The result of the overturning analysis





Narrow side

0%	10%	25%	50%	100%
-	-	-	8.3m	4.6m

Wide side

0%	10%	25%	50%	100%
9.2m	8.6m	7.6m	6.3m	4.2m

Loading combination 4 : $1.0D + 1.0T_s$

The result of the tsunami assessment

- This study combined the results of pushover and overturning analysis. For narrow side faces tsunami:
  - 100% airtight ratio: the building can resist 4.6m height tsunami.
  - 50% airtight ratio: the building can resist 8m height tsunami.
  - 25% airtight ratio: the building can resist 8m height tsunami.
- For wide side faces tsunami:
  - 100% airtight ratio: the building can resist 4.2m height tsunami.
  - 50% airtight ratio: the building can resist 6m height tsunami.
  - 25% airtight ratio: the building can resist 6m height tsunami.

Conclusion

- A pseudo event was also applied to explain the details of proposed methodology for estimation the targeted buildings.
- The numerical techniques were used for tsunami simulation to obtain the essential parameters and the loadings of tsunami can be easily obtained to define the demands of targeted building for tsunami resistance.
- The nonlinear static analysis was applied to estimate the capacity of targeted building for tsunami resistances.
- The direction of tsunami wave propagation highly influences the analysis results.

Acknowledgement

- Architecture and Building Research Institute, Ministry of The Interior.
- Ministry of Science and Technology.

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Thanks a lot!