Tsunami Loading - From Experiments to Field Load Test

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Summary

One-to-one hundred scale building models with 0%, 25% and 50% openings were tested in a wave flume under simulated solitary-like waves. A bi-linear pressure profile is proposed for determining the maximum tsunami force acting on solid square buildings. With openings, the tsunami forces are reduced from that exerted on the solid model. In addition, a building that has survived the 2004 Indian Ocean tsunami was field load tested in order to calibrate the FEMA-55 loading. The maximum velocity that occurred at the site in that event is assessed, and a velocity suitable for computation of tsunami load for southern Thailand is recommended.

Keywords: tsunami load; openings; calibration; FEMA-55; field load test; damage; flow velocity.

1. Introduction

The Indian Ocean tsunami on December 26, 2004 caused by an M_w 9.1 mega-earthquake in Indonesia (USGS 2008) left severe devastation in many countries in the region. Tsunamis of about 5-12 m heights struck the western coast of southern Thailand with heavy damage to buildings in the affected areas. However, a large number of engineered reinforced concrete (RC) buildings, especially those with openings in the masonry infill panels, have survived with minor structural damage even though they were not designed for tsunamis or earthquakes (Lukkunaprasit and Ruangrassamee 2008). Thus, there is an urgent need to investigate tsunami loading on buildings with openings. Furthermore, it is important to estimate the actual tsunami velocity that occured in the event since it is the major parameter that influences the tsunami force exerted on buildings. To this end, a building that has survived the 2004 Indian Ocean Tsunami was field load tested to calibrate the lateral tsunami loading stipulated by FEMA-55 specifications.

2. Experiments

2.1 Test setup

One-to-one hundred scale building models with square shape in plan were tested in a 40 m long hydraulic flume with 1 m x 1 m cross section. A mild slope of 0.5 degree representing the beach condition at Kamala,Phuket, Thailand was modeled in the laboratory. The model dimensions were 150 mm x 150 mm x 150 mm. Two opening configurations of the front and back walls were investigated, viz., 25% and 50% openings. Pressure sensors were placed on the faces of the model to measure the pressure distribution. A high frequency load cell was mounted at the base of the model to record the tsunami forces. The tsunami wave was generated by a sudden release of water through a controlled gate at the bottom of an elevated water tank located at the upstream end of the flume. Three nominal wave heights were investigated, viz. 40, 60 and 80 mm.

2.2 Results

2.2.1 Solid model

The pressure profile associated with the maximum wave force can be conservatively approximated by a bi-linear distribution shown in Figure 1 with a value of 2.75 times the hydrostatic pressure over one wave height above the base and decreasing to zero at 2 times the inundation height.

https://doi.org/10.2749/222137809796068145

2.2.2 Model with openings

The influence of the openings on the peak pressures on the front panel of the model is found to be practically insignificant. Table 1 shows the variation of tsunami force on the model with wave height for various opening configurations. The force decreases by about 30-40% in comparison with the solid model for the 50% opening ,and 15-25% for the case of 25 % opening.

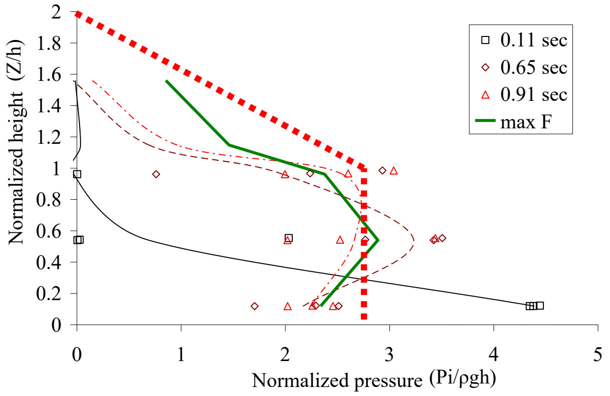

Figure 1 Normalized pressure profile at different instants of time

Table 1 Tsunami force (N) on square model with different opening configurations

Opening	Nominal Wave height		
	40 mm	60 mm	80 mm
00%	6.8 (100%)	18.1(100%)	37.9(100%)
25%	5.1 (75%)	15.5 (85%)	31.5 (83%)
50%	4.3 (63%)	11.2 (62%)	26.2 (69%)

Note: Values in parentheses are percentage of the model without openings.

3. Field Load Test of a Case Study Building

A weather monitoring building of the Meteorological station at Takua Pa, Phang Nga, which has survived the 4.4 m wave height (above the ground) with minor structural damage (Figure 2) is taken as the case study building. The single story RC structure has small columns (200 mm x 200 mm in cross section) which are lightly reinforced. Lateral ties consist of 6 mm diameter bars spaced at 200 mm. The building had essentially nonstructural panels all around the perimeter consisting of large window panes and 900-mm high masonry panels with 120 mm thickness. The primary members have suffered minor damage, with hairline flexural cracks observed in the columns. The girders are practically intact. In general, the masonry walls perpendicular to the water flow were completely destroyed, while those in the direction of flow survived. The building was field loaded by means of six hydraulic jacks bearing against a temporarily erected reaction frame until the damage from the testing was more severe than it was at the start of the test. The tested load was then used in back calculation in the hydrodynamic load formula to estimate the velocity of the tsunami that attacked the building.

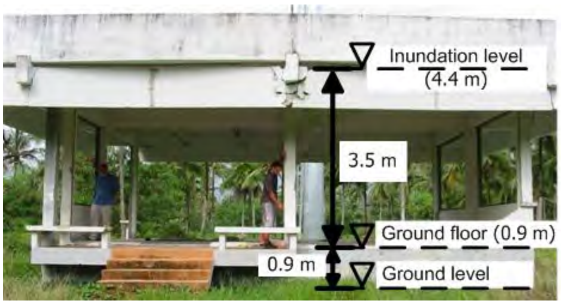

Fig.2 Photograph of case study building (front view normal to flow)

Conclusions

Openings in the walls have been found to be beneficial in reducing the tsunami loading. The tsunami force based on the hydrodynamic flow velocity of 2√(gh) as stipulated by FEMA-55 is over conversative. A flow velocity of about 1.36√(gh) has been recommended for Southern Thailand.

Acknowledgements

The funding from the Department of Public Works and Town and Country Planning, the Commission on Higher Education, the Royal Golden Jubilee Project of the Thailand Research Fund is gratefully acknowledged. The support of Chulalongkorn University and the Asian Institute of Technology is highly appreciated. The author greatly appreciate the valuable contributions of Prof. T. Takayama, Drs. P. Wanitchai, S. Weesakul, C. Chinnarasri, B. Stitmannaithum, A. Ruangrassamee, and C. Chintanapakdee. The contributions of Dr. Somboon Siangchin, Mr. Surakai Banchuen, Mr. N. Thanasisathit and many graduate students are also acknowledged.