

Paper:

Estimation of Tsunami Force Acting on Rectangular Structures

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Hydraulic experiments were conducted to estimate tsunami wave force acting on rectangular onshore structures. Used building models placed at several distances from a shoreline. Wave pressure was measured at points on exposed structures. Impact and standing-wave pressure at different points peaked at different moments in time, so tsunami force tended to be overestimated by integrating maximum wave-pressure distribution envelope. Measured total force was thus used to formulate tsunami force estimation equations. Hydrostatic formula was successful for structures near a shoreline, despite large scattering for structures far from a shoreline. Hydrodynamic formula was successful in all cases, although inertia was considerable for structures near a shoreline.

Keywords: tsunami force, design formula, wave pressure, drag coefficient

1. Introduction

The 2004 Sumatra Earthquake and Indian Ocean Tsunami vividly demonstrated the menace of major tsunamis. As the tsunami destroyed most coastal buildings, this wreckage destroyed remaining buildings. Minimizing tsunami damage thus requires that shoreline buildings withstand tsunamis. Besides, solid shoreline structures can be used for evacuations.

Of the considerable research done on tsunami forces acting on structures and the many tsunami force estimation equations proposed, most (e.g., Asakura et al. [1], Yeh [2], Simamora et al. [3]) introduced inundation depth where no structure exists for evaluating external force. Yeh [2] and Simamora et al. [3] considered both inundation depth and velocity under such conditions and Simamora et al. [3] examined inundation depth at the front of buildings assuming hydrostatic pressure. We have classified these into two groups – hydrostatic equations in which inundation depth alone is the considered variable because such equations are expressed similarly to that assuming hydrostatic pressure, and hydrodynamic equations in which both inundation depth and velocity are considered.

Because the applicability and nature of these formulas are as yet poorly understood, we conducted basic experiments to better grasp wave pressure time history and total force. The applicability of tsunami force formulas was checked using our own data together with that of Yeom et al. [4, 5].

2. Experimental Setup

Hydraulic experiments were conducted in a two-dimensional (2D) wave basin 11 m long, 7 m wide, and 1.5 m deep, and having a piston for generating waves. The basin seabed modeled sea-floor deformation from offshore through shallow water to onshore. The experimental setup is shown in Fig. 1.

Several experiments were conducted varying the building's scale, the distance from the shoreline, and the incident wave stroke. We used two models in experiments – model $B = W = H = 10$ cm where B = width along-shore, W = width cross-shore, H = height, and model $B = 20$ cm, $W = H = 10$ cm. Distance from the shoreline to the structure D was set at 20, 50, 80, and 150 cm. A wave paddle was programmed to move back once slowly and forward, with the paddle stroke set at 10, 15 and 20 cm. The incident wave broke in shallow water in all cases, and hit the vertical wall (seawall). Part of the wave then inundated the onshore area, hitting the vertical wall (structure model) again. Wave gauges measured the wave profile offshore and in shallow water and inundation depth onshore with and without a structure. Propeller current meter determined velocity. Load cell measured wave force on the model. Pressure gauges measured wave pressure. Inundation depth and velocity onshore were measured under the same conditions of runup distance and wave stroke without a structure.

We studied wave pressure on structures 20 cm onshore from the shoreline, and wave stroke of 15 cm alone was applied to avoid having waves overtop the model. Pressure gauges were set for several lines as shown in Fig. 2 to observe wave pressure for individual elements on the exposed model area. Visual observation using a high-speed camera (250 fps) determined the relationship of pressure and waveform in front of the model.

