CONTRIBUTION OF MOMENTUM IN TSUNAMI LOADING ON A VERTICAL SEAWALL.

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BACKGROUND AND MOTIVATION

Tsunami are often very long wavelength, long period gravity waves generated in deep water. Some of the largest and most damaging tsunami are associated with subduction zone ocean trenches and their related convergent plate boundaries such as the Aleutian Islands (1946), Chile (1960), Indian Ocean (2004) and Tohoku (2011) events. When tsunami approach the continental shelf, the wavelength decreases and wave height increases meaning man-made and natural coastal structures can be impacted by large amplitude waves imparting increased forces caused by a combination of hydrostatic and hydrodynamic components.

McGovern (2023) has conducted recent research into the induced loadings of non-breaking tsunami wave impacts on vertical seawalls. Their work, undertaken in large scale physical modelling facilities at HR Wallingford, concluded that for prototype tsunami wave periods T≥ 280s at 1:50 scale, the observed loading is no more than 1.2 times the hydrostatic force. This would imply that current guidance for tsunami design maybe overly conservative.

This current paper attempts to explain this hypothesis by relating the excess force generation above the hydrostatic force to the excess momentum generated by the hydrodynamic component of tsunami wave energy.

METHODOLOGY

A series of experiments were undertaken at HR Wallingford UK in their “fast flow facility” (Whitehouse, 2014). The experimental setup at Froude scaling of 1:50 consisted of a third-generation pneumatic long wave generator, 4m high, 4m wide and 4m long placed at the end of a 70m long, 4m wide and 2m deep racetrack flume. Full details of the setup are detailed in McGovern (2019) and a sketch is shown as Figure 1.

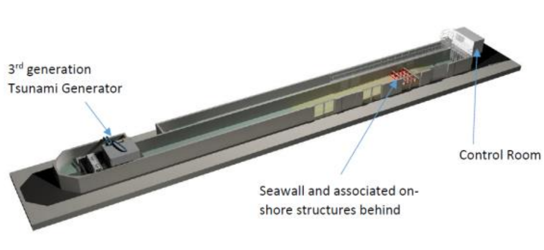

Figure 1 - An isometric sketch of the Fast Flow Facility at HR Wallingford Ltd where the experiments were conducted. The sloping bathymetry is shown in yellow shading. (HR Wallingford).

A 20m long 1:20 sloping bathymetry was constructed near the end of the channel which led onto a horizontal section 4m long, 1m above the flume floor datum. At the top of the bathymetry, a scaled model of a vertical seawall was installed across the full width of the flume and was instrumented with two sets of five horizontally mounted pressure transducers - one set close to the centre of the seawall and the other halfway between the wall centreline and the flume edge (Figure 2). In addition, downward looking pressure transducers to measure hydrostatic water pressure were placed directly in front of the wall and Vectrino velocimeters placed to measure wave velocity (Figure 3)

Figure 2 - Test wall section showing two arrays of horizontal mounted pressure transducers. In this picture a failure section is shown to the right of the picture.

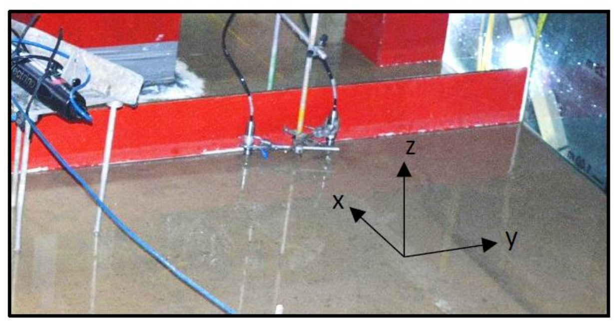

Figure 3 - Downward looking pressure transducers (centre) and Vectrino (left). Reference axes are shown for flume

RESULTS

Waves were run in the Fast Flow Facility to prove similitude with the recorded results of integrated force analysis as detailed in McGovern (2023). For this study, in a shorter but deeper flume, with different bathymetry slope, we concentrate on an elevated T=160s model wave with calculated characteristics at bathymetry toe of prototype tsunami height 6.45m and prototype period of 1074s (17.9 minutes).

An example of the resultant force per linear metre wall length time history is shown as Figure 4. This validates the earlier work of McGovern (2023) and suggests the forces for longer period waves are marginally greater than the measured hydrostatic force.

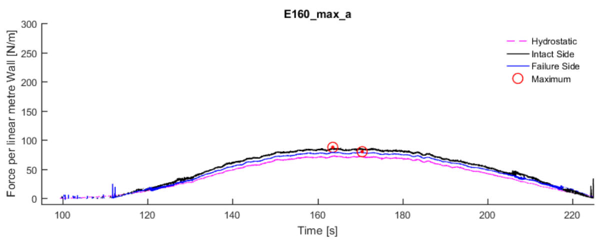

Figure 1 - Force time series for an elevated T=160s wave showing the measured hydrostatic force as a function of intact and failure side pressure transducer arrays.

In terms of the excess force generated by the wave impact on the vertical wall, it has been postulated that this is as a result of the hydrodynamic contribution of wave energy as represented by momentum. This momentum (per unit width of wall) is a product of water mass and velocity and can be linked to wave celerity and wave displacement (Equation 1):

$$(mu) = \rho . C^2 . \int_0^t \eta(t) dt \qquad (1)$$

where m is mass of water (kg), u is velocity (m/s), ρ is density (kg/m^3), C is wave celerity (m/s), $\eta(t)$ is the instantaneous wave displacement (m) at time, t (s).

CONCLUSION

The work evaluates the momentum contribution to the overall wall forces over a long period laboratory test tsunami wave and provides evidence for the correlation of this momentum to the hydrodynamic component of overall force generation.

We compare results from two separate experimental campaigns on a similar long period, non-breaking elevated wave. Flume dimensions and bathymetry varied but the same excess momentum phenomenon was observed in both sets of data. In this conference presentation we present the analysis of these two datasets and propose the link between excess momentum and the observed differences in integrated forces observed on a vertical coastal seawall.

The findings have implications for design engineers when estimating the forces associated with long period non-breaking tsunami waves onto onshore located vertical seawalls.

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