SIMULATION OF TSUNAMI FORCE IN THE PRESENCE OF BEACHSIDE STRUCTURES

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INTRODUCTION

The 2011 Tohoku earthquake tsunami caused a catastrophic disaster along the northeast coast of the Honshu Island, Japan. To deal with such massive tsunamis (identified as "level 2" tsunamis in Japan), the concept of disaster mitigation using multifaceted countermeasures is essential in addition to the construction of shore protection facilities for tsunamis at relatively high frequencies ("level 1" tsunamis). This study focused on one of such countermeasures, which involved beachside rigid structures. Such structures are expected to be effective for disaster mitigation because of the complementation of shore protection facilities by reducing tsunami force on rear buildings. To quantitatively evaluate the influence of beachside rigid structures on tsunami force, a three-dimensional (3-D) numerical analysis was performed using a 3-D coupled fluid-structure-sediment-seabed interaction model (FS3M; Nakamura and Mizutani, 2014).

COMPUTATIONAL CONDITIONS

The FS3M was applied to a 3-D computational domain of Fig. 1, which was modelled from hydraulic model experiments (scale: 1/25) performed at Oregon State University, USA (Bridges, 2011). A specimen ($0.6 \times 0.6 \times 0.4$ m) was set on the land, and macro-roughness cubic elements $a = 0.6$ m on a side were set at a distance of d offshore from the specimen. A leading-elevation tsunami was generated so that water surface fluctuation at WG2 (see Fig. 1) matched with experimental data as possible. Under this wave condition, 58 patterns of numerical experiments including nine patterns in the hydraulic experiments (Bridges, 2011) were conducted changing the number and arrangement of the elements (Fig. 2).

RESULTS AND DISCUSSION

Figure 3 shows a comparison of inundation depth η in front of the specimen and tsunami force F on the specimen. From Fig. 3, it was observed that the numerical results were in good agreement with the experimental data except for seaward tsunami force (i.e., $F < 0$) induced by return flow because a wave absorbing beach behind the specimen was not modelled due to the lack of its detail. From this result, it was found that the FS3M can predict water surface fluctuation, inundation
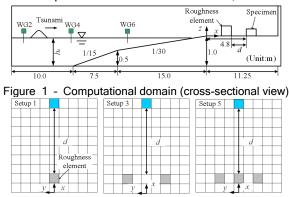
depth, and tsunami force with sufficient accuracy.

Figure 4 shows a ratio of the maximum tsunami force with the elements F_{max} to that for no elements F_{bmax}. From Fig. 4, it was found the numerical results had a similar trend with the hydraulic experiments. Moreover, it was suggested from $F_{max}/F_{bmax} > 1$ for $d/a = 1$ and 4 of Setup 3 that determining the arrangement of rigid structures is essential to reduce tsunami force on rear buildings.

The maximum tsunami force was estimated to be F_{0max} using the following drag force similar with the ASCE 7-16 standard from inundation depth η_0 and bottom flow velocity u_0 for no specimen:

$$F_{0max} = 0.5 \rho C_D a \left(\eta_0 u_0^2 \right)_{max} \tag{1}$$

where C_D is the drag coefficient (= 2.0; common value for a square cylinder) and ρ is the density of water. Figure 5 shows a comparison between F_{max} and F_{0max}. From Fig. 5, it was found that the maximum tsunami force can be predicted reasonably well using Eq. (1) regardless of the number and arrangement of beachside rigid structures.
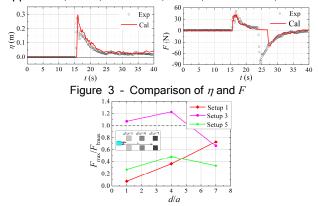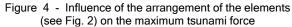
ACKNOWLEDGMENTS

REFERENCES

Bridges, K.-J. (2011): Influence of Macro-Roughness on Tsunami Runup and Forces, Master Thesis, Oregon State University, USA, 34 p.
Nakamura, T. and Mizutani, N. (2014): Development of fluid-sediment-seabed interaction model and its application, Proc., 34th ICCE, ASCE, sediment.85, E93.
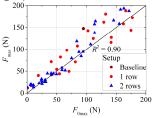
Figure 3 - Comparison of η and F

Figure 4 - Influence of the arrangement of the elements (see Fig. 2) on the maximum tsunami force

Figure 1 - Computational domain (cross-sectional view)

Figure 2 - Examples of the arrangement of the elements

Figure 5 - Comparison of F_{max} and F_{0max}