FORCE ON BREAKWATER DUE TO OVERTOPPING TSUNAMI BY 3D NUMERICAL SIMULATION

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1. INTRODUCTION

Tsunami overtopping breakwaters and seawalls are threats, not only obviously to the land and waters in behind, but to the structural stability of the coastal structures themselves. In this case, the breakwater or seawall's ability to dampen the effects of the tsunami is compromised at the very least. It is of interest therefore to at least have structures able to withstand the force from very large tsunami. Recently, breakwaters and seawalls were destroyed by the 2011 Tohoku tsunami in places such as Kamaishi, Ofunato, Hachinohe, Otsuchi. Due to the complex nature of breakwaters and the harbors they inhabit, it is our motivation to develop a 3D numerical simulation capable of observing the forces, turbulence and other complex wave phenomena present. Previous studies are limited in this area including both numerical and experimental work. The objectives of this study is to validate the numerical simulation by use of a previous experimental study, while investigating the forces involved with overtopping, the vorticity generation for scouring effects and the effect of the return flow on the structure (as experienced in Tohoku).

2. EXPERIMENTAL & NUMERICAL METHODS

2.1 Experiment

The experiment setup and results used for validation of the numerical simulation is taken from Hsiao and Lin (2010) and Lin et al. (2012). One purpose of their study was to bridge the gap in knowledge of overtopping and impingement on a coastal structure in experimentation, indeed for validation of numerical simulations (Hsiao and Lin, 2010).

The experiments were carried out in a 22 m long, 0.5 m wide and 0.75 m deep two-dimensional wave flume. The first 10 m length of flume consists of a flat bed, thereafter a 1/20 slope surface. At 13.6 m from the wave paddle there is a seawall with front slope 1/4 and back slope 4/9 (refer fig. 1). Pressure transducers along the seawall slopes measure the dynamic wave load. Three types of solitary wave cases were generated, as highlighted in table 1, by a piston-type wavemaker.

Table 1- Experimental and Numerical Wave Cases

	h_0 (m)	H_0 (m)	T (s)
Exp. A	0.2	0.07	-
Num. A1	0.2	0.07	3
Num. A2	0.2	0.07	15
Exp. B	0.256	0.0589	-
Num. B1	0.2557	0.0588	4.36
Num. B2	0.2557	0.0588	20

2.2 Numerical Simulation

Table 1 shows the different cases used in the numerical simulations. In the simulation, the period of the wave must be defined. The 99% characteristic period of a solitary wave is used in the case #1 experiments. Larger periods are used in the case #2 experiments.

2.2.1 Numerical Method

The 3D numerical model is based on the RANS equations with the k-ε turbulence closure solver. To model the free surface the VOF (volume of fluid) method is used. In this, a value F is defined as the proportion of fluid (liquid) in a cell. Thus, eq. (1) is derived for the advection of fluid between cells.

$$\frac{\partial F}{\partial t} + u_j \frac{\partial F}{\partial x_j} = 0 \qquad (1)$$

Keywords: Tsunami, VOF, Numerical Simulation, overtopping, breakwater, seawall

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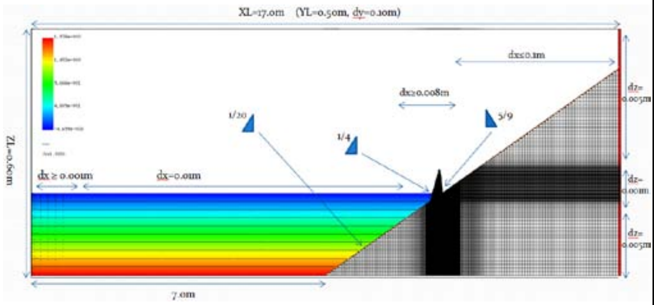

Fig. 1 – Domain and Mesh size of numerical simulation

2.2.2 Numerical Setup

The numerical setup is roughly analogous to the experimental except that it is only 17 m in length and 0.6 m deep for computational efficiency. Figure 1 shows the basic domain with mesh sizes indicated. The smallest mesh size is 0.001 m, while the largest is 0.1 m. A fine mesh size in the x direction was required near the wave generation point to avoid computational error.

3. RESULTS AND DISCUSSION

3.1 Free Surface

Figures 2 and 3 show the comparison of the free surface between the experiments and the numerical simulations for the larger period waves. The larger period appears to cause a small increase in the free surface height in the B experiments towards the wave generation end. In the Num. B2 simulation also, initially still water exists on the landward side (does not in experiments) to act as a breakwater, causing the increase in free surface profile.

3.2 Force and Turbulent Kinetic Energy

The maximum dynamic pressure force from the experiments generated for the various experiments reaches on the seaward side about half way up the slope. An estimated 0.7kPa is generated at the peak consistently throughout the different cases.

Figure 4 shows that once the wave overtops the breakwater, high turbulent kinetic energy is formed in behind the structure causing large dynamic forces. Indeed according to the experiments the maximum dynamic pressure force would reach almost 1kPa, larger than any force generated on the seaward side.

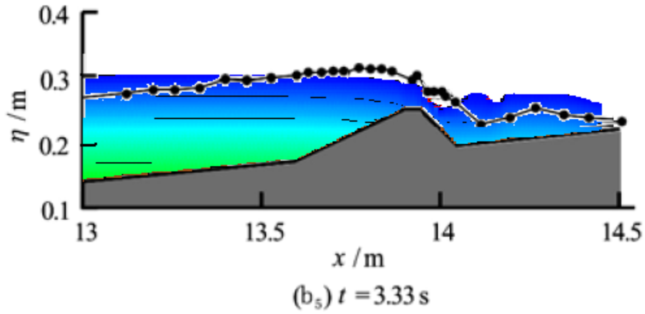

Fig. 2 – Free surface comparison, Exp. B and Num. B2

-•-=exp., colored region=num.

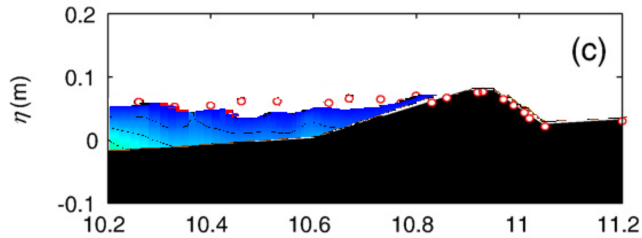

Fig. 3 - Free surface comparison, Exp. A and Num. A2

o=exp., colored region=num.

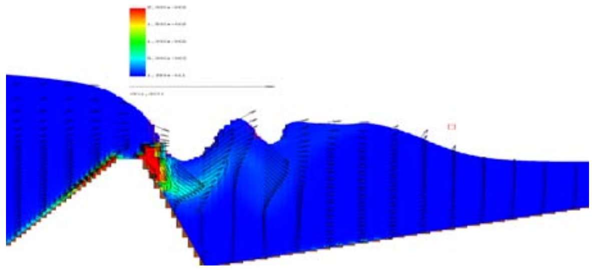

Figure 4 – TKE of Num. B2, highly turbulent region is colored red

4. CONCLUSION

A study was conducted on wave overtopping of a seawall/breakwater structure. Comparisons are made between an experimental study and the current VOF based numerical simulation study that is in progress. More simulations and improvements are required for an adequate comparison and evaluation.

REFERENCES

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