Three Dimensional Hydraulic Characters around Breakwater under Tsunami Overflow

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1. Introduction

Tsunami flow over the breakwater during the Tohoku tsunami of 2011 was reported as the cause of local scouring at the foundation mound of the breakwater. Arikawa *et al*. (2012) reported that the failure of the Kamaishi Bay Mouth Breakwaters in the Kamaishi Port was caused by sliding mode. That sliding was caused by dynamic water pressure as wave force, the decline of bearing capacity caused by increasing of pore water pressure, and scouring of the foundation mound caused by overflowing and joint flow velocity. Based on the study conducted by Sulianto and Murakami (2015), tsunami overflow on the breakwater forms complex phenomena including vortexes that mainly contributes to the local scouring of rubble mound. Therefore, it is important to extend the investigation of flow characteristic in the prototype model.

This paper is intended to reveal flow characteristics of tsunami overflow on the breakwater based on the prototype model. Hososhima Kitaoki breakwater is one of three breakwaters located in Hyuga Port, Miyazaki was adopted as a prototype model. This paper discusses the effect of the gap between caissons, and the flow characteristic around breakwater including seepage flow in the rubble mound and the flow pattern in around of the breakwater. CADMAS-SURF 3D used to simulate flow characteristic of tsunami flow over on the breakwater. The result of flow characteristic and hydrodynamic processes around breakwater are discussed.

2. Methodology

CADMAS-SURF, a model that solves the Navier-Stokes equation and continuity one, and also employs volume of fluid (VOF) method to solve the temporal elevation of free surface, was used to investigate the flow characteristic around breakwater. The numerical flume size was 219.5m in X-axis, 36m in Y-axis, and 56m in Z-axis. The total number of grids was 5.265.792, with grid size varied from 0.5-0.25m in X-axis, 0.25m in Y-axis and 0.5m in Z-axis. The configuration of numerical wave tank can be seen in Figure 1.

Simulation of bore wave propagation in CADMAS-SURF requires time history of wave surface elevation and wave velocity on the input boundary. In this study, following analytical formula purposed by Fukui *et al.* (1962), (Eq. (1) was employed to estimate the fluid velocity from water surface elevation on input boundary, because the water surface elevation is commonly measured in experiments and fields in comparison with the fluid velocity and we used tsunami bore height 10m along 60 seconds to set steady state overflow condition.

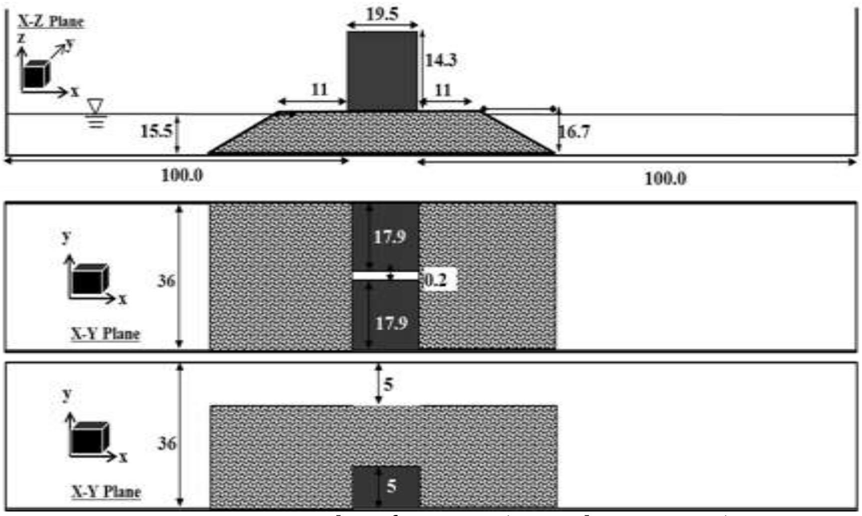

Figure 1. Numerical configuration (not scale; units in m)

Where U is the mean velocity, g the acceleration of gravity, $H=h+\zeta$ the total depth from the datum, ζ the temporal bore height. η is the velocity coefficient which equal to 1.03, and was taken from the ratio of water level and wave height.

$$U = \frac{C\zeta}{H} = \zeta\sqrt{\frac{gH(H+h)}{2H(H+\eta\zeta)}} \quad (1)$$

3. Result and Discussion

Firstly, validation of the numerical model was conducted to verify numerical simulation. The experiments were conducted with model scale 1:120. The verification was based on wave velocity on various impoundment heights of initial water surface elevation. Figure 2 shows the horizontal velocity profile with initial water level a half of the breakwater's height. The velocity was measured at 13 points in the gap between caisson breakwaters from the front until behind the breakwater. As shown in this figure, the trend of velocity value obtained from the 3D simulation shows very good agreement with the experimental data. Secondly, observation of water surface elevation in the front and behind the breakwater to identify steady overflow time history during tsunami flow over the breakwater. Figure 3 shows water surface elevation profile in the front and behind the breakwater. The figure shows that tsunami hit the breakwater at 5.5 second then flow over the breakwater, and the elevation increase irregularly due to wave reflection.

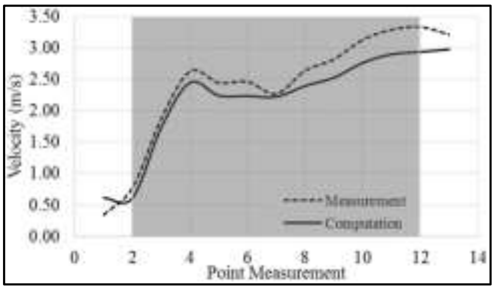

Figure 2. Horizontal velocity profile

The steady overflow occurs during time history from 7 sec until 11.5 sec with the average elevation 23.5m from initial water level or 8m above breakwater. Flow characteristic and hydrodynamics process will be discussed based on the steady overflow time history. The horizontal velocity distribution in the gap between caisson breakwaters can be seen in Figure 4. The figure shows that the velocity profile in the gap of caisson breakwaters increase sharply more than two times larger after the flow came inside through the gap and gradually decrease when the flow reach outside of the breakwater. The increasing velocity occurs due to the principle of continuity and conservation mass. Figure 5 shows velocity profile of seepage flow in the rubble mound. It can be seen that velocity in the upper part of rubble mound fluctuates due to the seepage flow from the top of rubble mound as shown in Figure 6.

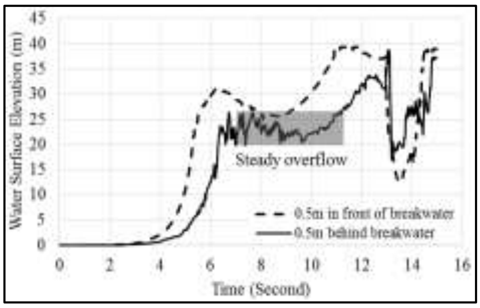

Figure 3. Water surface elevation profile

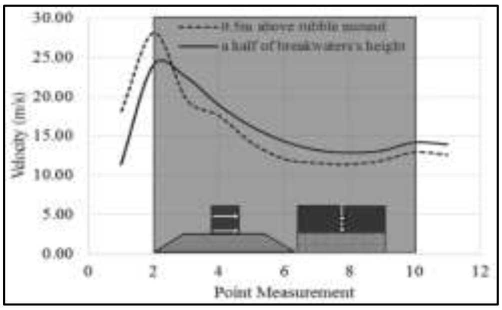

Figure 4. Velocity profile in the gap of caisson

Figure 7 presents the flow pattern besides a breakwater from the top view. As shown in the figure that tsunami flows from the front side of the breakwater, and forms a vortex beside of the obstacle. The flow came around in the beside and behind the breakwater, Vortex flow also can be seen in the back side of the obstacle. This flow characteristic may affect the bearing capacity of the breakwater and cause scouring on the rubble mound.

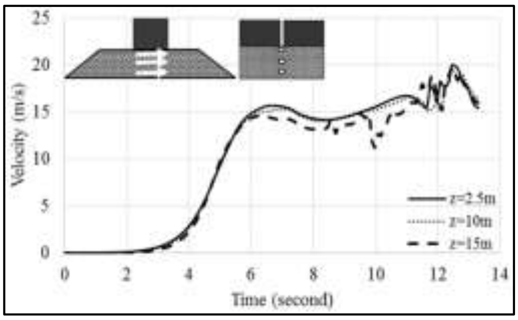

Figure 5. Velocity profile of seepage flow

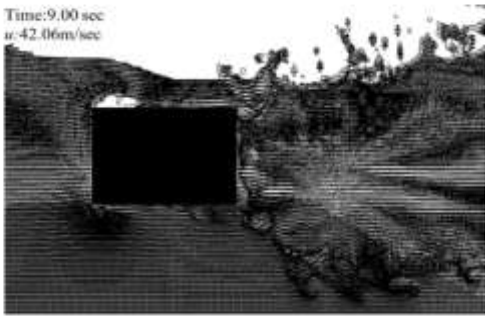

Figure 6. Flow pattern around breakwater

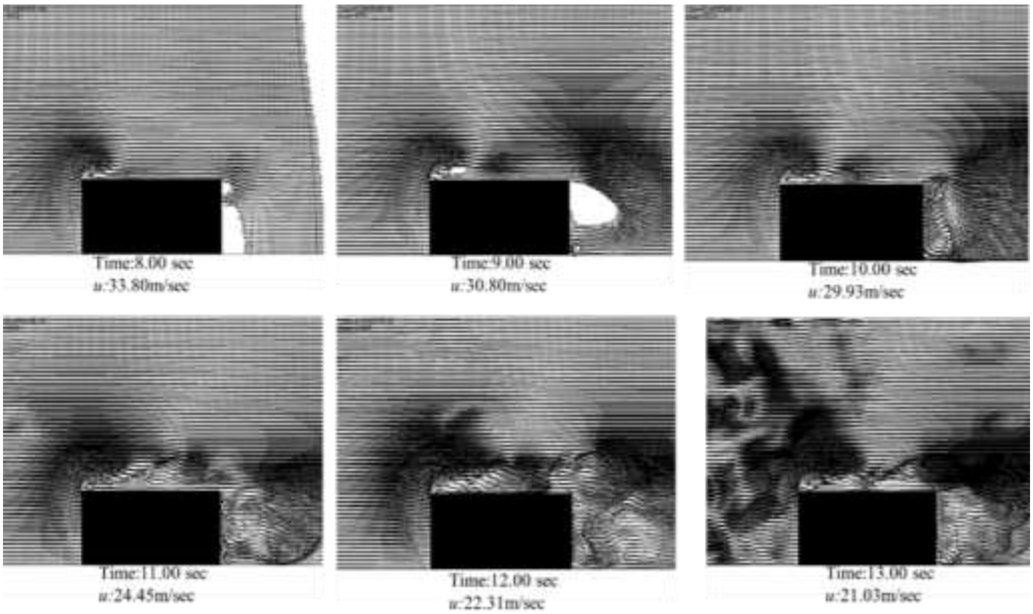

Figure 7. Flow pattern around breakwater from top view

4. Conclusions

Tsunami wave hit and flow over the breakwater forms complex phenomena including turbulence flow, supercritical flow, and also vortex in the behind of breakwater. The complex flow was also affected by seepage flow from rubble mound. The tsunami flows from the front of the breakwater and forms a vortex in the front side of the obstacle. Furthermore, the flow came around to the side and behind the breakwater, Vortex flow also can be seen on the back side of the obstacle, and came around to the side and behind the breakwater, Vortex flow also can be seen in the back side of the obstacle. The vortex indicated two trends of velocity profile that are the positive value and negative value of velocity. It means that there is reverse velocity, to the right direction and back to left direction. When the velocity shear is imposed on the free surface, and mixing layer seems to appear at the interface due to the sharp velocity gradient. It will affect the stability of the breakwater.

References

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