Impact assessment of sediment transport on breakwater during tsunami attack compared with hydraulic experiments

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1. Research background and purpose:

It is predicted that there is a possibility for great earthquakes and tsunamis to happen in The Nankai Trough in the near future. There is a dune in front of the breakwater which protects the nuclear power station. When the tsunami strikes, the impact of the tsunami may damage the breakwater, and cause damage to the nuclear power station. Radiation can even cause explosions, causing large-scale casualties and damage to the soil and water environment. However, relevant research has not been well conducted. Therefore, the purpose of this research is to ascertain the influence of the existence of dune and sediment transport on tsunami waves by conducting simulation analysis and comparing the results to hydraulic experiments.

2. Overview of the analysis model

In this study, a hybrid of the 2DH-3D (two-dimensional horizontal and three-dimensional) numerical analysis model is adopted based on the nonlinear long-wave theory of Yoneyama et al. [1]. The behavior of sediment transport is analyzed considering bedload, suspended load, and wash load.

3. Analysis area and analysis conditions

The analysis area is shown in Fig. 1. The target topography was set up with the breakwater and the dune on the seafloor topography and onshore. The height of the breakwater is 25 cm, and the installation positions are 80 cm and 137.5 cm from the revetment shoreline on the land side. The diameter of the sand is 0.3 mm. Since this calculation uses a 2D (two-dimensional) cross-section, the shore side of the boundary is a 2D model, and the offshore side of the boundary is a 1D model. The calculation time is 35s or more for long-period waves, and the calculation end time differs depending on the case. The analysis output interval is finer than the 0.25s interval. However, in the spatial distribution of the flow velocity, long-period waves are output at intervals of 0.5s. For long-period waves, the test wave height data is applied. The analysis cases are shown in Table 1.

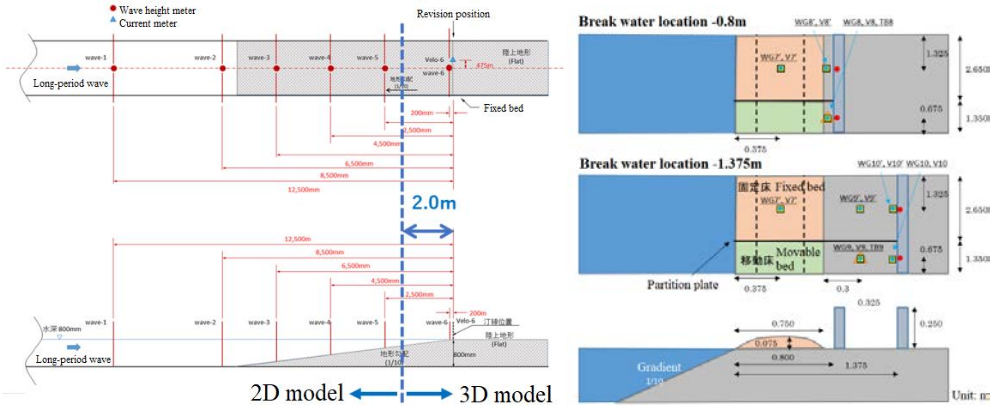

Fig. 1 Experimental setup of the analysis area

Table 1 Analysis cases

CASES	TYPE OF SEABED	POSITION OF THE BREAKWATER
CASE 1	Movable bed	-137.5cm
CASE 2	Movable bed	-80.0cm
CASE 3	Fixed bed	-137.5cm

Keywords: sediment transport, numerical analysis, suspended load, bedload
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4. Analysis result

Fig. 2, 4, 6 show the velocity of V7 (the top of the sand dune), and Fig. 3, 5, 7 show the wave force acted on the breakwater. Fig. 2-7 show that the velocity and force are in good agreement with the hydraulic experiments.

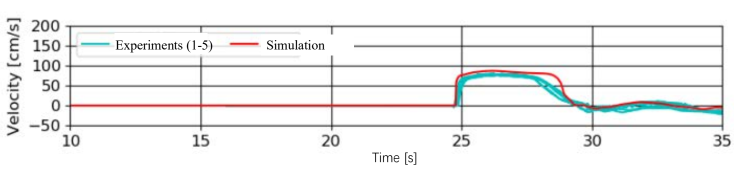

Fig. 2 Velocity of V7 of case 1

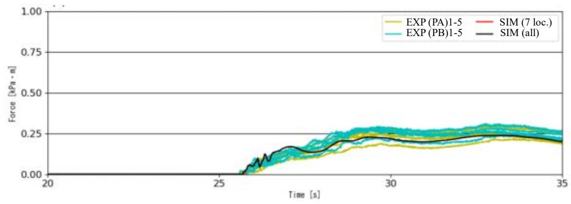

Fig. 3 Wave force of case 1

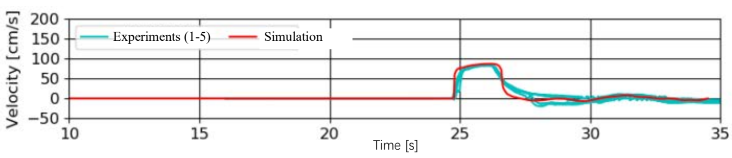

Fig. 4 Velocity of V7 of case 2

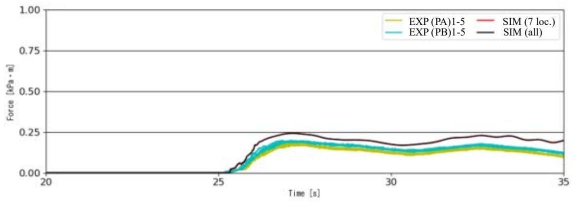

Fig. 5 Wave force of case 2

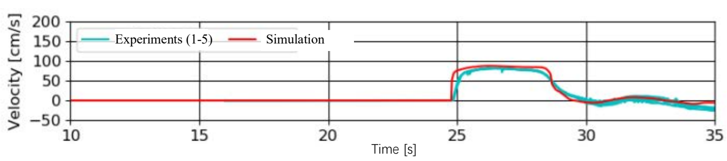

Fig. 6 Velocity of V7 of case 3

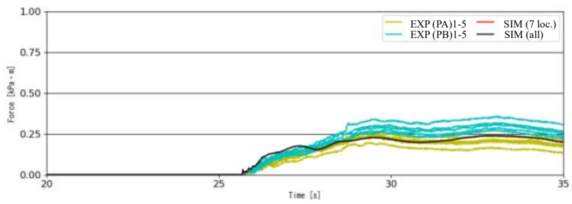

Fig. 7 Wave force of case 3

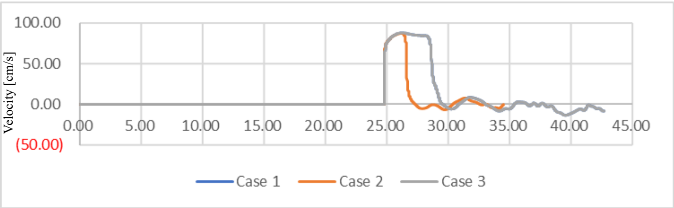

Fig. 8 Comparison by velocity of V7

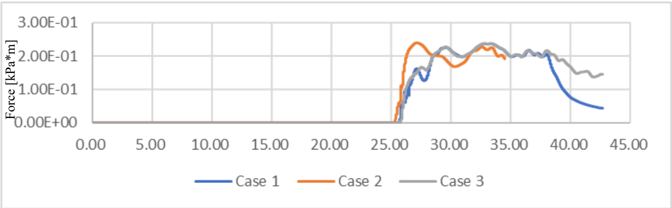

Fig. 9 Comparison by wave force

From Fig. 8, it can be observed that the velocities of cases 1and 3 have no significant difference. The reason for it could be that the velocity of the wave is too high to cause a deformation of the sand dune within a short period of time. Compared to case 2, the maximum velocity of case 1 is greater and the duration of which is also longer. This is because the location of the breakwater of case 2 is closer to the sand dune, causing the reflected wave to arrive sooner.

From Fig. 9, it is obvious that the wave force of case 3 is larger than it of case 1 and case 2. It is because the closer the breakwater is, the sooner the wave encounters the breakwater, the less the velocity losses. Compared with case 1 and 3, the wave forces are very similar, however, it of case 1 decays faster. The reason for it is that the movable bed creates more bed shear stress because of the bedload.

5. Conclusion:

(1) The model is able to perform the analysis on sediment transportation of long-period waves and quantitively evaluate the impact on the breakwater.

(2) The difference between the fixed floor and the movable floor is not significant during the propagation of tsunami waves.

(3) The location of breakwater influences the velocity and wave force acting on it. The further the breakwater is, the less the velocity but more wave force acting on it.

Reference:

[1] William J. Pringle, Nozomu Yoneyama, et al.: Two-way coupled long wave - RANS model: Solitary wave transformation and breaking on a plane beach, COASTAL ENGINEERING,114,99-118,2016.