NUMERICAL STUDY ON DYNAMIC RESPONSE OF SUBMERGED FLOATING BREAKWATER WITH IMPERMEABLE MOORING PLATE

Department of Civil Engineering, Nagoya University, Japan. ○ Peng, Wei
Department of Civil Engineering, Nagoya University, Japan. Lee, Kwang-Ho
Department of Civil Engineering, Nagoya University, Japan. Norimi, Mizutani

Objectives: Floating breakwaters have gained more and more attention for numbers of merits such as eco-friendliness, lower cost and convenience of installation. However, with the wide application of floating structures, the safety and sustainability of themselves become another challenging issue. In a general way, researchers employ chains as the main component of mooring system and idealize the effect of them as force term. Nevertheless, the interaction between mooring part and waves can not be ignored in the numerical simulation, especially for the floating breakwater with complex mooring arrangement. In this paper, a numerical model is proposed to study the dynamic response of submerged floating breakwater with thin impermeable mooring plate employing the immersed boundary (IB) method and volume of fluid (VOF) method.

Experimental and Numerical Models: To investigate the performance of the new type floating breakwater, experiments were carried out in a two-dimensional wave tank (Fig. 1) at Nagoya University. An impermeable plate and a permeable plate were adopted on the offshore side and onshore side, respectively. At the same time, a two-dimensional numerical model was developed to analyze the problem numerically and expected to extend the modeling to various wave conditions and configurations. The numerical model used in this paper based on the IB-VOF method [Lee and Mizutani, 2009], which was composed of the IB method for treating the floating breakwater and the VOF method for tracking the free surface, to calculate the interactions between the floating structure and wave. The IB method can handle interface problems with complex geometry on a standard regular Cartesian grid instead of body-fitted grid, which may decrease the computation cost sharply (Fig. 2). In the IB method, Physical Virtual Model (PVM) [Lima E Silva et al., 2003] was applied to calculate the force field over a sequence of Lagrangian points, which represent the interface. Two-step projection method is applied to solve the governing equations including the continuity equation, the Navier-Stokes equation for viscous and incompressible fluid and the advection equation that represents the behavior of the free surface.

Additionally, the dynamic properties of the submerged floating breakwater due to its interaction with wave are formulated (Fig. 3). Three degrees of freedom for the motion of floating breakwater including displacement in horizontal direction (sway), vertical direction (heave) and rotational displacement with respect to surge axis (roll) are considered. For the floating body, considering the moments acting on the centre of gravity, resultant horizontal and vertical force acting on the body, the motions can be modeled employing Newton’s second law and the law of rotation. For the mooring plates, only the roll motion is involved.

Results: In this paper, experimental and numerical results are compared for the following case: wave period T_i=1.6 s; wave height H_i=0.1132 m; depth of wave tank h=0.63 m; distance from the static water level to the top surface of floating breakwater d=0.03 m; wave steepness H_i /L=0.04. Numerical model results for sway, heave and roll of motions of floating body are compared with the experimental data in the Fig. 4. It is observed that the numerical results are in good agreement with the experimental data. The free-surface evolutions at four stations are predicted and showed in Fig. 5 for five wave cycles. At the offshore side, Fig. 5(a) and Fig. 5(b), the proposed model performs well in simulating the wave height and phase although there is small disparity between the shape of curves of experimental and numerical results. At the onshore side, Fig. 5(c) and Fig. 5(d), the time variation of water surface profiles indicates a complex form in the reformed area after the wave breaking due to the interaction with the submerged floating breakwater. Figure 6 shows the transient velocity field and the corresponding free surface position during one wave period at the interval of 0.4 s. Utilizing the water surface profile, complex forms such as the wave breaking phenomenon can be monitored. Further, vortexes are observed under and behind the floating body when the incident wave is propagating over the submerged floating breakwater. Also, the corresponding positions of the breakwater are captured in this figure, which show an oscillation due to the interaction with waves.

References: (1) Lima e Silva, A. L. F., A. Silveria-Neto and J. J. R. Damasceno (2003): J. Comp. Phys., Vol. 189, pp. 351-370; (2) Lee, K. H. and N. Mizutani (2009): Coastal Eng. Journal, Vol. 51, pp. 27-48.

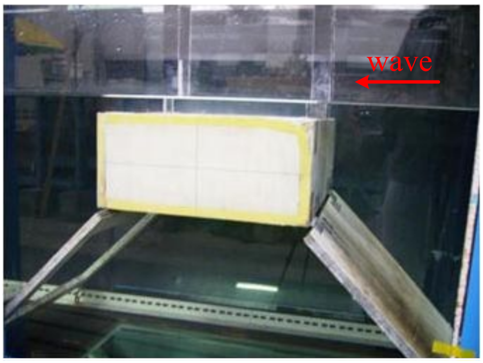

Fig. 1 Side view of the floating breakwater set up

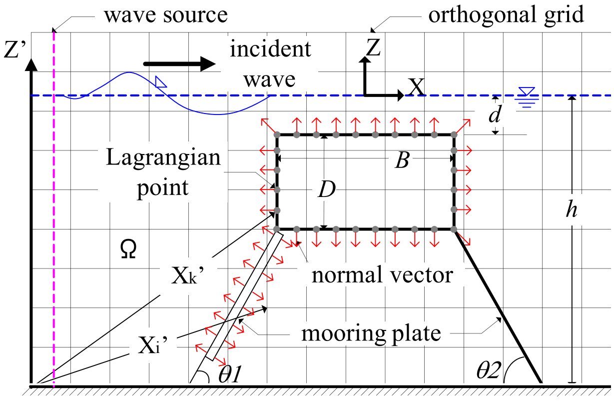

Fig. 2 Schematic illustration of computation domain

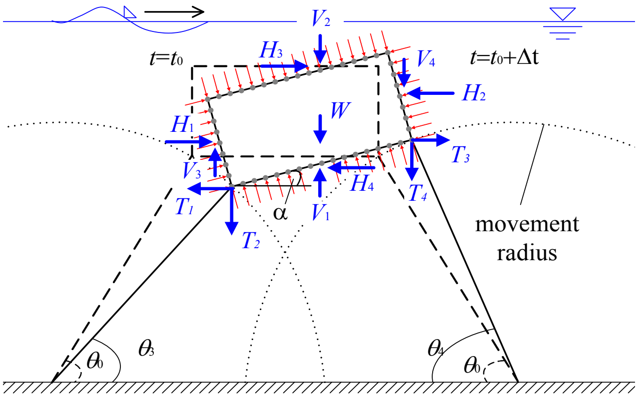

Fig. 3 Instantaneous position of the floating body during its interaction with wave

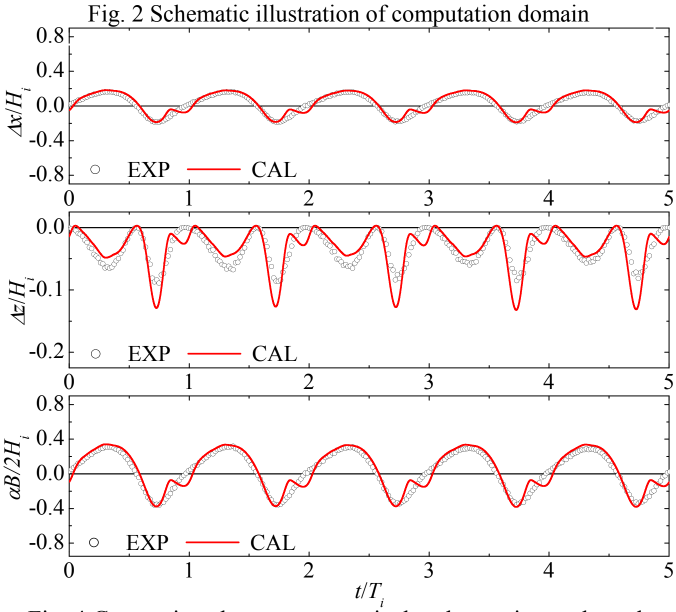

Fig. 4 Comparison between numerical and experimental results of the time series values of displacement of floating body

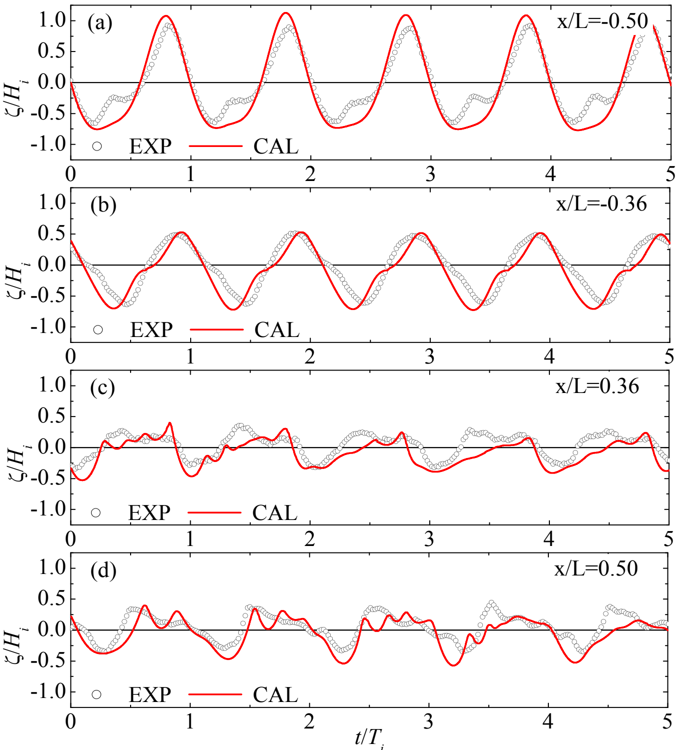

Fig. 5 Comparison between numerical and experimental results of the dimensionless water surface profiles

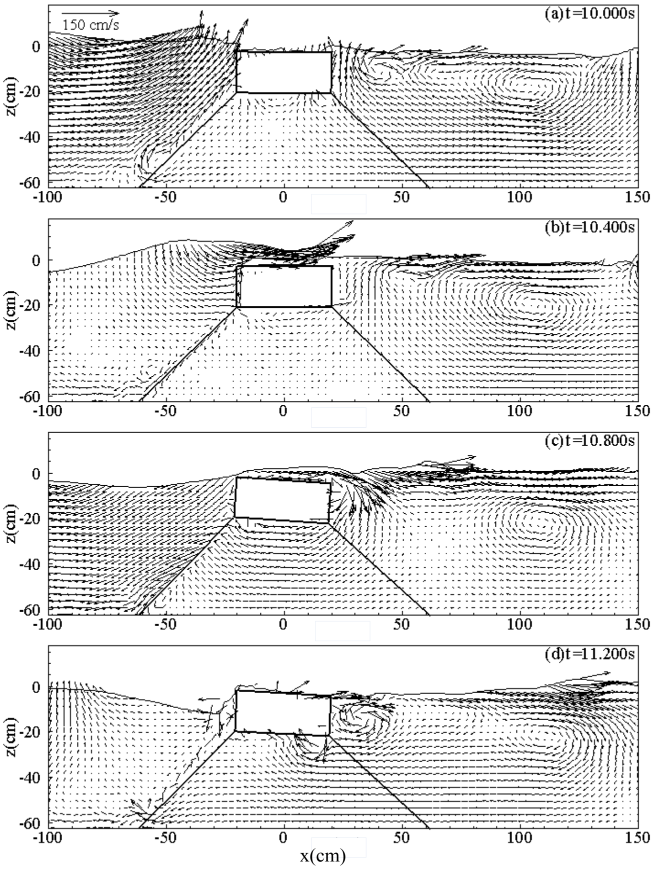

Fig. 6 Numerical model results of water particle velocity (cm/s) field abound the inclinedly moored floating breakwater