DEVELOPMENT OF PREDICTING MOTION OF FLOATING CAISSON UNDER REGULAR AND IRREGULAR WAVES

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INTRODUCTION

Breakwaters for outer harbor facilities are considerably affected by wave conditions, rendering the control of caisson motion difficult. Its motion during breakwater installation is important to improve its operational efficiency and safety.

In recent years, caisson motion has been studied using 3D solid-gas-liquid three-phase simulations. Nakamura et al. (2021) investigated the dynamic characteristics of floating caissons under regular and irregular waves. Takagi et al. (2021) studied its sway and contact with mounds when the bottom clearance was changed and demonstrated the validity of their numerical method. However, due to inevitable scale effects of the small-scale experiments and simulations, these studies require examination at a large scale.

In this study, the numerical simulation developed by Arikawa et al. (2009) was used to investigate the motion characteristics of life-sized floating caissons under regular and irregular waves for case studies conducted at the Port of Kochi (Ishimi et al. 1996).

METHOD

This study was conducted numerically using the coupled fluid-structure analysis model (CADMAS-STR) developed by Arikawa et al. (2009). CASMAS-STR is a coupled model combining a three-dimensional fluid calculation model based on the Navier-Stokes equations with a structural analysis model based on the finite element method. Coupled analysis is performed by passing pressure from the fluid to the structure side for each element and communicating the volume occupancy of the structure step-by-step. This occupancy varies as the structure moves from the structure to fluid side.

Figure 1 shows the positive and negative directions of the six components of levitated body motion and computational domains. In the wave source model, the source for wave generation was set as the center of the specified cell. All the boundary surfaces of the computational domain were assumed to be transparent boundary conditions.

The schematic and specification of the caisson installed at the Port of Kochi, Japan, in 1993 are presented in Figure 2 and Table 1.

Table 1 - Specification of the caisson without the hootings.

Mass	2685 tf
Width	18.00 m
Length	13.30 m
Height	17.50 m
Draft	10.76 m

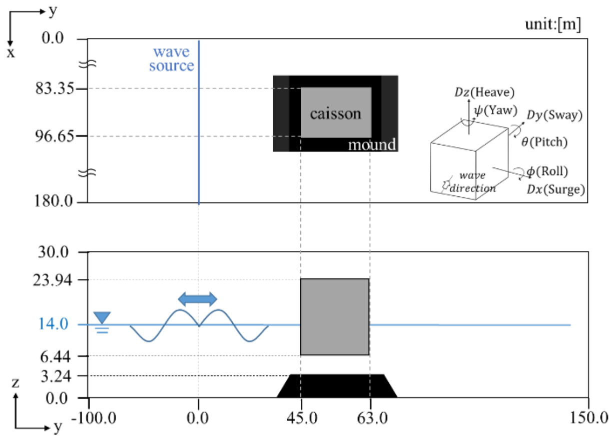

Figure 1 - Computational domain and definition of the six degree-of-freedom motion.

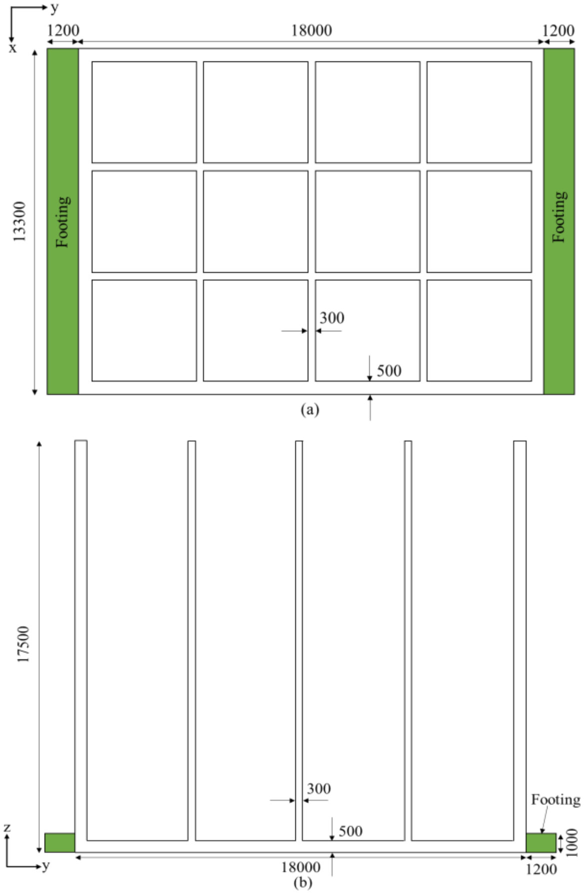

Figure 2 - Schematic of the caisson : (a)top and (b)cross-sectional view (mm).

RESULTS AND DISCUSSION

Figure 3 shows the wave interaction and its contact with the mound caused by caisson motion. The interaction between the caisson and waves was confirmed via the wave height variations around the caisson; the contact force between the caisson and mound was also analyzed. For verification, we compared the observed and analytical results of motion amplitude at each stage of the sinking process (Figure 4); the horizontal axis is the draft depth ratio, while the vertical axis is the motion amplitude non-dimensionalized by the wave height. The results show that the motion amplitude decreases as the draft depth ratio increases. This is because the added mass force increases with an increase in the draft depth ratio. The repeatability of this calculation was approximately ±20 %, except in the case of the bottom clearance of 0.5 meters (Figure 5).

Figure 6 compares the motion amplitude for each bottom clearance by non-dimensionalizing the incident wave period T_i with the natural period of the heave T_{heave} obtained via free vibration analysis. Values of T_{heave} and T_i approximately equal to 1 indicate that the motion amplitude of heave ζ_{amp} is larger. It suggests that a design wherein the natural period does not coincide with the wave period during towing and sinking is necessary to control the motion.

CONCLUSION

Comparing the CADMAS-STR analysis data with the observed data, the validity of the proposed analysis method for predicting the motion of a large-scale caisson under regular and irregular waves was confirmed. This numerical model enables the prediction of caisson motion, considering the interaction of waves with caisson motion and mound collision. In the future, this model will be used to determine the installation conditions of large caissons.

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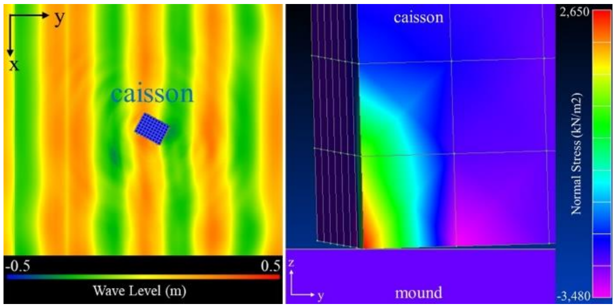

Figure 3 – Numerical calculation snapshots (left: waveform caused by caisson motion; right: normal stress distribution due to caisson and mound contact)

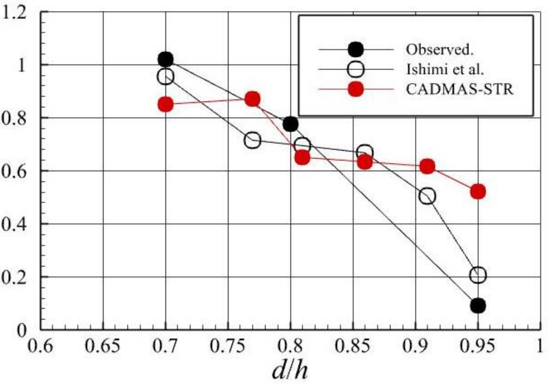

Figure 4 – Variation in heave with draft depth ratio.

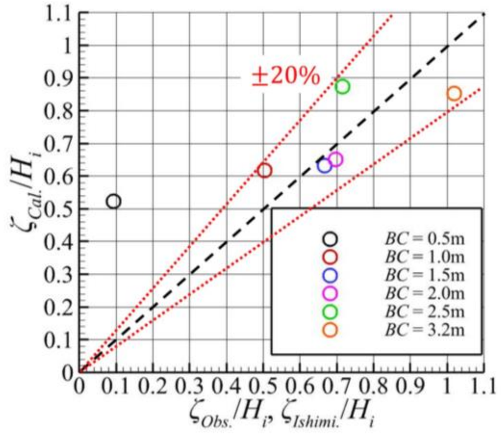

Figure 5 – Verification of accuracy between CADMAS-STR and observation and calculations reported by Ishimi et al..

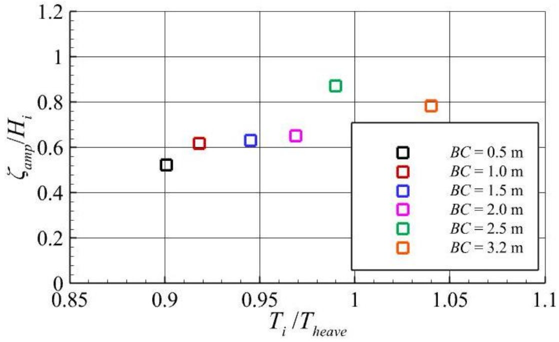

Figure 6 – Motion amplitude vs natural period for each bottom clearance.