Reinforcement Mechanism of a Gravity-type Breakwater with Steel Walls

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Summary

"Persistence" is needed for the breakwaters, since the coastal areas of Tohoku have been extensive damaged by the tsunami caused by the Great East Japan Earthquake (M_w9.0). To achieve the persistence, the authors propose a new reinforcement method in which a steel pipe pile wall is placed behind a caisson and the space between the caisson and wall is filled with rubble. By the experiment and FEM, the proposed method shows the unique persistent feature that the resistance increases with increasing caisson displacement, because the steel pipe pile wall transfers tsunami force from a caisson to a seabed layer and utilize the soil resistance of the seabed layer.

Keywords: tsunami, breakwater, reinforcement structure, steel pipe pile.

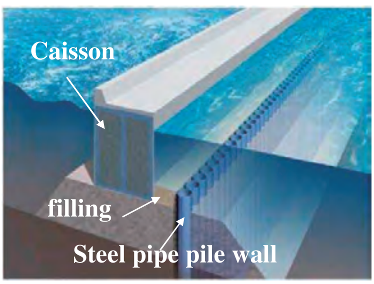

Fig. 1: The proposed method

1. Introduction

"Persistence" is the required performance for breakwaters, which requires them to rigorously withstand a tsunami, since the huge tsunami caused by the Great East Japan earthquake (M_w9.0) has damaged the coastal area extensively. On the other hand, a gravity-type breakwater, which is the main type of breakwaters in Japan, has a problem that it can be broken brittle due to sliding, overturning, and bearing failure.

To realize persistence, the authors propose a new reinforcement method using steel, as shown in Figure1. This method is constructed by steel pipe piles as a wall separated from the rear wall of the caisson and filled rubble between the caisson and steel pipe piles. In this paper, we show a basic experiment to investigate the features of the proposed method, and discuss a reinforcement mechanism by FEM.

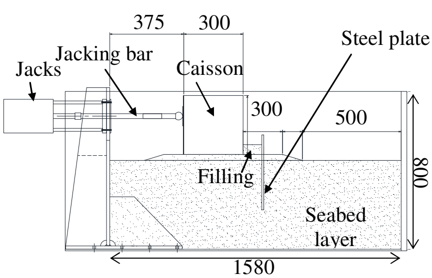

Fig. 2: dimension of the experiment

2. The Lateral Load Experiment and FEM

2.1 Basic reinforcement effect through the lateral load experiment

The experiment conducted without water or a fluid force to simplify the experiment, though Tsunami

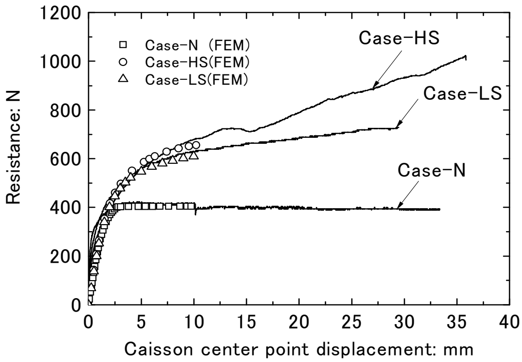

Fig. 3: Comparison of the resistance

causes complicated hydraulic phenomenon such as seepage flow or scouring by overflow. The experimental dimension is shown in Figure 2. The tsunami's horizontal wave force is represented by jacking force.

As a result, the proposed method indicates a profound reinforcement effect. Figure 3 shows the relationship between resistance and caisson displacement. Without reinforcement (Case-N), the caisson is broken in the sliding failure mode at 400N. On the other hand, with reinforcement (Case-HS, LS), the resistance starts increasing in the same way as Case-N, reaches the yield value, and then shows a small increase. This small increase in the resistance after the yield is characteristic "persistent" phenomenon. Also, the steel plate of Case-HS is used relative high bending stiffness (5.6×10^5Nmm^2/mm) and is embedded shallow depth (280mm), while the bending stiffness of Case-LS is 2.9×10^4Nmm^2/mm and embedded deep depth (500mm). The steel plate of both cases is positioned 50mm in width from the caisson edge face.

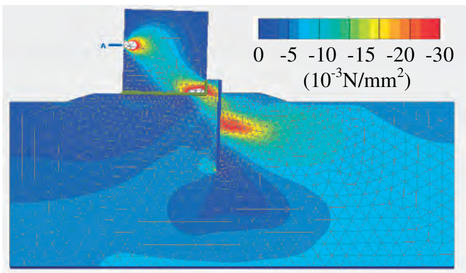

Fig. 4: The lateral stress distribution (Case-HS)

2.2 Discussion about resistance mechanism using FEM

The specifications of the steel plate, caisson and seabed layer of FEM model are same as those of the experiment. The Young's modulus of the soil, 3N/mm^2, is adjusted to close the relationship between resistance and displacement with that of the experiment. From the comparison of resistance shown in Figure 3, it is interpreted that the FEM can simulate the main range of experiment, 0–10 mm displacement, including the bending point.

Figure 4 shows the load transfer of proposed method, which the filling and the steel plate transfers the horizontal wave force from caisson to seabed layer, can utilize the soil resistance behind the steel plate. This load transfer is considered to make the "persistence" possible. In full paper, we analyze the interaction between caisson and steel plate more detail.

3. Conclusion

The following are the main conclusions.

1) By the laterally loading experiment without water, the proposed method indicates the "persistence", which increases resistance with an increasing caisson displacement after the yield load. This method changes the failure mode from sliding to overturning or bearing failure.

2) From FEM simulation about the experiment, it is shown that the unique load transfer of proposed method, which the filling and the steel plate transfers the horizontal wave force from caisson to seabed layer, can utilize the soil resistance behind the steel plate. This load transfer is considered to make the "persistence" possible.

3) In the proposed method, the high resistance will be gain when the steel plate has high stiffness and it behaves as a relatively short unrestrained pile. The reason is assumed that the rigid movement of the steel plate can utilize soil resistance in deep soil area.

For further work, it is necessary to clarify the interaction between the pile and soil. In addition, it is necessary to clarify the hydraulic characteristics such as seepage flow in the mound or scouring of the foundation due to overflow. Through these works, we will make the proposed method persistence and try to contribute to decrease the damage caused by a Tsunami.