STUDY ON EARTH PRESSURE INFLUENCE OF INNER CORE RUBBLE IN FRONT OF CAISSON OF BREAKWATER UNDER TSUNAMIS

Shiro Yamagata, PARI, yamagata-s-p@p.mpat.go.jp
Kojiro Suzuki, PARI, suzuki_k@p.mpat.go.jp
Naoki Tsuruta, PARI, tsuruta-n@p.mpat.go.jp
Yuhi Nakazawa, PARI, nakazawa-y88s3@p.mpat.go.jp
Norihito Nishinosono, Kyushu Regional Development Bureau, MLIT, nishinosono-n89yk@mlit.go.jp
Tetsuya Yamaguchi, Kyushu Regional Development Bureau, MLIT, yamaguchi-t89ya@mlit.go.jp

INTRODUCTION

There are two kinds of breakwaters covering with wave-dissipating blocks in Japan shown in Figure 1. If breakwater is covered with pure wave-dissipating blocks (Figure 1(a)), it is known that the wave-dissipating blocks in front of caisson are self-supporting so that their horizontal loads are not expected to act on the caisson under basic conditions such as calm water[1)]. If rubble, as an inner core, is substituted for some, particularly inside the block group (Figure 1(b)), the rubble may exert a horizontal force on the caisson as the earth pressure. In addition, installing of wave-dissipating blocks on the rubble part may result in stronger horizontal force. These situations have not been sufficiently investigated. In this study, hydraulic model experiments are conducted to investigate the earth pressure of inner core rubble. Further, the impact of the breakwater under tsunami is also investigated.

HYDRAULIC MODEL EXPRIMENTS

Measuring the earth pressure

In order to clarify the earth pressure of rubble and wave-dissipating blocks act on the caisson, static and active earth pressure was measured by the test as shown in Figure 2. Earth pressure was measured when the blocks were submerged, assuming that tsunami overflowing the caisson. The rubble shape of this model reproduces the rubble and wave-dissipating blocks in front of caisson shown in Figure 3.

Experiment on caisson stability during tsunami

Figure 3 shows the model used in this experiment. The model was made at a scale of 1/24 of B-port breakwater with inner core. The experiment was conducted in the large channel (L: 105m, B: 3.0m, D: 2.5m) shown in Figure2. This channel is divided into a main channel and secondary channel in the middle and merges again at the end. The water levels inside and outside the breakwater during tsunami were reproduced by lowering the inside water level using the current generator (difference is 14cm). Wave pressure at the front, top, back and bottom of the breakwater model were measured as shown in Figure 3. The deformation of breakwater model was filmed by video camera, and its movement was measured by image analysis.

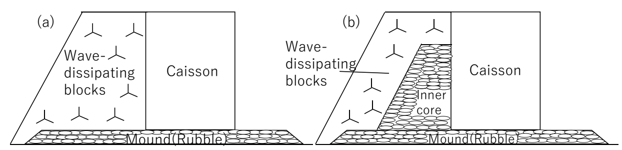

Figure1: Breakwaters covered with wave-dissipating blocks
(a): pure covered with blocks (b): with inner core

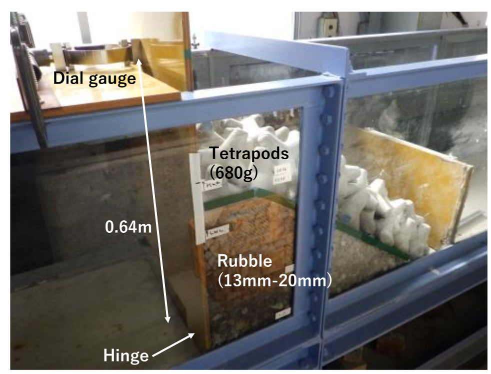

Figure 2: Method of measuring the earth pressure

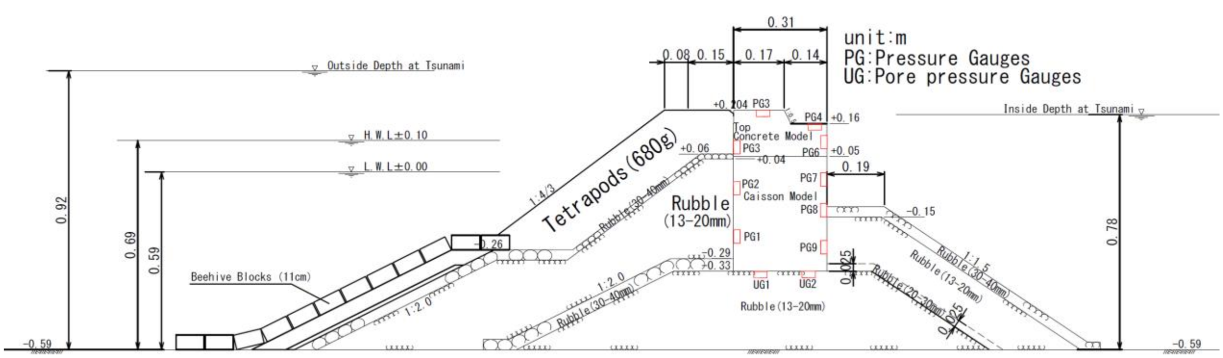

Figure 3: Breakwater model

EXPERIMENTAL RESULTS

Result of the earth pressure

Figure 4 shows the moment per unit width due to static and active earth pressure of rubble and wave-dissipating blocks. When only the rubble is installed (Case A), the static earth pressure was half of Jaky's static earth pressure. In addition, the active earth pressure is also lower than Rankine's active earth pressure. This difference was caused by the trapezoidal shape of experimental cross section. When wave-dissipating blocks were installed in Case A (Case B), both the static and active earth pressure increase, especially the static earth pressure increased 62.8N*m/m, more than twice that of Case A. Thus, it is clear that static and active earth pressure increases more when wave-dissipating blocks are installed. In the case of wave-dissipating blocks only (Case C), it was confirmed that static earth pressure acts but not active earth pressure.

Result of experiment on caisson stability during tsunami

The caisson tilted slightly during the tsunami (Figure 5). This is because the change in earth pressure of the front rubble and rear rubble by the caisson tilting. At rest, the static earth pressure is greater than the active earth pressure, so the moment to topple the caisson (action moment) is large, and the caisson is unstable. On the other hand, when the caisson tilts and the earth pressure from the front rubble and that from the rear rubble respectively switches to the active and the passive one, the action moment becomes smaller and the moment to support the caisson (resistance moment) becomes larger, thus stabilizing the caisson.

Figure 6 shows the time series of elevation, wave force, moment and displacement of caisson during the tsunami. When the action moment exceeded the resistance moment when static earth pressure acts from the rear rubble about 20 seconds after start of experiment, the experiment video also showed that the caisson tilted about at the same time. Moreover, when the action moment reached the resistance moment when passive earth pressure acts from the rear rubble about 30 seconds after start of experiment, the experiment video also showed that the caisson stopped at about the same time.

CONCLUSIONS

From those experimental results, it is clear that the earth pressure from the front rubble affects whether the caisson moves or not in the case of a wave-dissipating block-covered breakwater with inner core. Therefore, it is necessary to consider the influence of earth pressure from the inner core and wave dissipating blocks, which have not been done on the stability of the caisson during a tsunami. Then, we propose the new design formula:

$$S.F. = \frac{M_m + M_{Rs}}{M_w + M_b + M_{Fs}} \quad \text{(1) At Static}$$

$$S.F. = \frac{M_m + M_{Rp}}{M_w + M_b + M_{Fa}} \quad \text{(2) After titled}$$

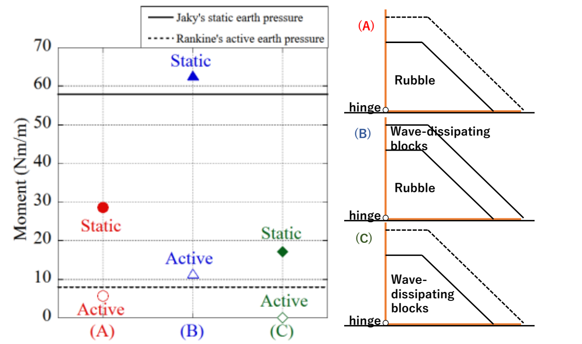

Figure 4: Moment due to static and active earth pressure
(A): Rubble only (B): Rubble & Blocks (C): Blocks only

Figure 5: Experiment on caisson stability during tsunami

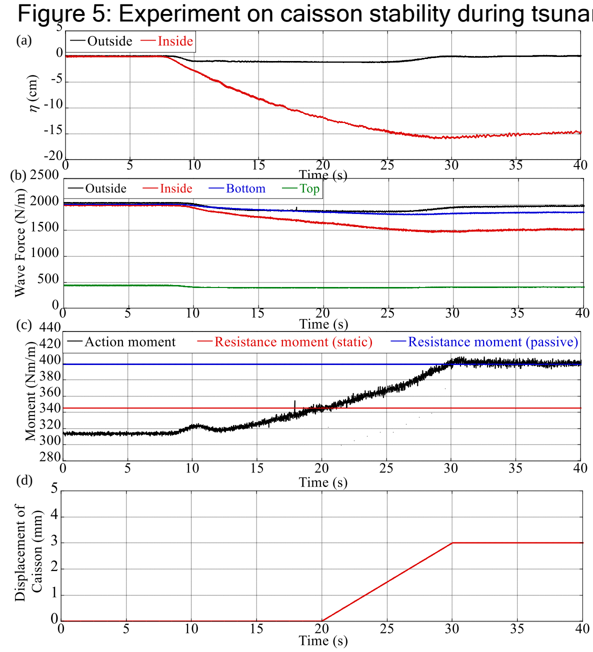

Figure 6: The time series of elevation (a), wave force (b), moment (c) and displacement of caisson (d) during the tsunami

Where, *S.F.*: Safety factor, M_m: Moment by caisson's weight, M_w: Moment by water level difference, M_b: Moment by buoyancy, M_{Rs}: Moment by static earth pressure from rear rubble, M_{Rp}: Moment by passive earth pressure from rear rubble, M_{Fs}: Moment by static earth pressure from front rubble, M_{Fa}: Moment by active earth pressure from front rubble.

REFERENCE

1) Takahashi, S. et al.: Wave and Block Forces on a Caisson Covered with Wave Dissipating Blocks, REPORT OF PHRI, Vol29, No.1, 1990 (in Japanese)