LABORATORY STUDY ON THE EFFECT OF WALLS FOR PREVENTING OFFSHORE SEDIMENT MOVEMENT AROUND A SUBMARINE CANYON

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Fuji coast has several submarine canyons with steep slope. According to the previous surveys one of them located in front of Yoshiwara may cause the material of beach nourishment to move offshore. In this study the effect of the submarine wall proposed as the countermeasure was investigated using the 2-D hydraulic model test with sandy bed. As the results, it is found that the eddy yielded nearby the wall caused by waves has a significant effect on the sediment movement, and that effect depends on the location and the height of the wall.

Key Words: Sand movement, Beach nourishment, Submarine canyon, Large-scale experiments

1. INTRODUCTION

Offshore sand loss to submarine canyon is significant on the Fuji Coast in Shizuoka prefecture located in the Suruga Bay because of extraordinary steep beach slope in the offshore area. The bottom slope is observed as steep as 1/2.3 (Tanaka 1998, Nishikawa 2006). Although we have been providing 100 x 10³ m³ of gravels to the coast every year, the beach width has not recovered to the target level, indicating the need for additional countermeasures. We propose a continuous shore-parallel wall using sheet-piles as a countermeasure against offshore sediment loss. The structure aims at promoting shoreline advancement by trapping nourished sand nearshore and reducing the volume of beach nourishment by decreasing the volume of offshore loss of sediment near a submarine canyon.
However, because the presence of the wall under waves actually causes sediment to be suspended and carried offshore through the action of eddies that are formed around the wall, it is necessary to optimize the depth and height of the wall (Ikeda 1985).

In this study, two-dimensional sandy bed hydraulic model experiments were conducted on preventing offshore sediment movement and also conducted by changing the installation depth and the height of the wall.

2. EXPERIMENTAL METHOD

(1) Profile of experimental model

On the Fuji coast, the amount of sediment loss into the submarine canyon depends on the distance from the shoreline to the edge of the canyon. Two profiles were selected as standard profile and canyon profile as shown in Fig.1(a), (b). In the standard profile, the distance from the shoreline to the edge of the canyon is far. On the other hand, in the submarine canyon is near.

(2) Experimental method and conditions

The experiments were carried out by installing a 1/30 scale model in a large wave flume 140m long, 2m wide and 5m deep. Unless the scale is specifically noted, the following description will be by spatial scale converted to prototype scale.
the field. Therefore beach nourishment material in the model was arranged so that the grain diameter was geometrically scaled in the range \(d=0.33-5.00\text{mm}\).

The incident waves were regular waves. The incident wave heights were \(H=5\text{m}\) for Wave A, corresponding to wave heights with a return period of 1-3 years and \(H=10\text{m}\) for Wave B, corresponding to that of return period of 30 years. The wave period was based on long-term ocean wave observation data and decided at \(T=11\text{s}\) as the typical wave period of storm waves. Wave duration for Wave A was 120 minutes (11 hours local conversion), which was confirmed long enough to develop an equilibrium profile. Wave duration for Wave B was 60 minutes (2.7 hours local conversion), which was decided at double of typical storm duration, 30 minutes.

(2) Experimental case

Experimental conditions in each case are summarized in Table 1. The volume of beach nourishment material that lost to the submarine canyon in CASE1-2, the effect of the wall in CASE2-10 were discussed.

3. EXPERIMENTAL RESULTS AND DISCUSSION

(1) Properties of beach nourishment movement on standard profile and canyon profile

Beach nourishment transformation of the standard and the canyon profiles is shown in Fig.4. On the standard profile, an offshore bar is formed near the breaking point (B.P.). The location of the bar moves offshoreward but does not reach the outer edge of the submarine canyon. It was confirmed that the beach nourishment material fell

<table>
<thead>
<tr>
<th>CASE</th>
<th>Experimental profile</th>
<th>Beach nourishment condition</th>
<th>Sediment outflow prevention wall</th>
<th>Offshore wave height</th>
<th>Experimental time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
<tr>
<td>1</td>
<td>Standard profile</td>
<td>Profile A 14m</td>
<td>No installation performed</td>
<td>50(1.17)</td>
<td>(3)</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Profile A 14m</td>
<td>No installation performed</td>
<td>50(1.17)</td>
<td>(3)</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Profile A 14m</td>
<td>14m 3m</td>
<td>100(0.33)</td>
<td>(3)</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Profile A 14m</td>
<td>14m 5m</td>
<td>50(1.17)</td>
<td>(2)</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Profile B 17m</td>
<td>No installation performed</td>
<td>50(1.17)</td>
<td>(2)</td>
</tr>
<tr>
<td>6</td>
<td>Submarine canyon profile</td>
<td>Profile B 17m</td>
<td>17m 3m</td>
<td>100(0.33)</td>
<td>(2)</td>
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<tr>
<td>7</td>
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<td>Profile B 17m</td>
<td>17m 5m</td>
<td>50(1.17)</td>
<td>(2)</td>
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<tr>
<td>8</td>
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<td>Profile C 20m</td>
<td>No installation performed</td>
<td>100(0.33)</td>
<td>(2)</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>Profile C 20m</td>
<td>20m 3m</td>
<td>50(1.17)</td>
<td>(2)</td>
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<tr>
<td>10</td>
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<td>Profile C 20m</td>
<td>20m 5m</td>
<td>100(0.33)</td>
<td>(2)</td>
</tr>
</tbody>
</table>

Table 1 List of experimental cases

Fig.4 Profile change of the standard profile and the canyon profile
into the submarine canyon by the horizontal wave orbital motion. The nourishment material could not return to the direction of the shore from the submarine canyon once they moved across the canyon edge, and continued falling along the 1/2.3 steep slope.

Regarding the distance from the shoreline to the breaking point, the distance is short on the canyon profile compared with the standard profile. The wave impact is relatively weak on the standard profile and thus the shoreline is stable.

On the other hand, the nourishment material fell into the submarine canyon on the profile of canyon. As a result, the shoreline was gradually retreated.

(2) Properties of beach nourishment loss with a wall

Profile change when a wall is installed is shown in Fig.5. In the case of h=14m and Wave A is imposed, as shown Fig.5(a), the topography around the wall is developed in an inverted triangular shape which is stable. The dimensions of the triangular bed form is

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Fig.5 Profile change when a sediment outflow prevention wall is installed

(a) The wall installation depth h=14m (Profile of beach nourishment A)

(b) The wall installation depth h=17m (Profile of beach nourishment B)

(c) The wall installation depth h=20m (Profile of beach nourishment C)
larger for B=5m. In the case of Wave B, the wall becomes buried with the development of the bar on the wall height B=3m and 5m.

In the case of h=17m, when Wave A is imposed as in h=14m, triangular bed forms develops on both side of the wall as shown Fig.5(b). When Wave B is imposed after this, in the initial phase of B=3m the wall is buried on the slope of the bar. On the other hand, for B=5m, the wall is not buried and the dimension of triangular bed forms on both sides increases. This is thought that it is because, for B=5m the eddy is generated around the wall exposed the wall from the profile with no wall as shown in upper right figure of Fig.5(b). As for the beach nourishment materials movement mechanism, bed load transport was essentially dominant, but at the breaking point where broken water body produced strong turbulence, suspended load transport was significant for all grain sizes. It was visually confirmed that suspended beach nourishment materials were transported to the offshore side of the wall along with the eddy.

In the case of h=20m and Wave A is imposed, the beach nourishments are not change around the wall as shown Fig.5(c). In the case of Wave B is imposed, it is confirmed that the wall is not buried and the beach nourishment materials are transported offshore by the bed load on the surface. Stable profile is formed by eddies only on the shore side of the wall since the wall is situated at the outer edge of the submarine canyon.

(3) Time change of beach width

Fig.6 shows the temporal change of beach width for each case. According to this figure, the beach width will become smaller than 100m with beach nourishment alone for the case h=14m. However, the beach width of 100m can be maintained by installing a wall. For the cases h=17m, 20m, the beach width of 100m can be maintained with beach nourishment alone. This is considered to be because the beach nourishment material volume increased the wave dissipation performance compared with h=14m.

(4) Volume of the beach nourishment materials

loss to the submarine canyon

Fig.7 shows the volume of beach nourishment material loss to the submarine canyon. The nourishment material loss per unit width was measured by a container situated on the bottom of the wave tank. In addition, measurements of the profile were taken 30 and 60 minutes after the commencement of Wave B generation. The volume of the nourishment material loss was estimated by comparing the measurements with the initial profile.

It was found that the nourishment material loss for h=14m was decreased by installing a wall. In the case of h=17m, the volume of the nourishment material loss for B=3m was also decreased within 30 minutes. However, it was increased by installing a wall after 60 minutes. For h=17m (B=5m) and h=20m, the volume of nourishment material loss was also increased by the installation of the wall.

From the result of Fig.5 and Fig.7, it is clear that the closer the wall is installed to the outer edge of the submarine canyon and is exposed from profile with no wall, the volume of nourishment material transported offshore increases. However, it is thought
that the more the volume of the offshore transportation of nourishment material can be decreased when the wall is sufficiently-higher than the location of the bar top that can be naturally done.

4. CONCLUSION

The optimal installation depth and wall height for a sediment loss prevention wall was studied by two-dimensional sandy bed hydraulic model experiments.

As the results, it is found that the eddy yielded nearby the wall caused by waves has a significant effect on the beach nourishment material movement, and that effect depends on the location and the height of the wall. In the cases of experiment, the effect of the installing walls of h=14m-17m(3m) is effective for the reduction of the volume of beach nourishment material. Furthermore, a depth of h=14m would be the most economically efficient and advantageous from the perspective of beach nourishment material volume. Consequently, if the stability of the wall can be ensured, h=14m would be the most advantageous from the perspective of cost and benefit.

Hereafter, we plan to conduct experiments concerning scouring around the wall as well as stability of the wall and ascertain the effectiveness of the wall by conducting field experiments.

REFERENCES