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Laboratory Study on the Effect of Walls for preventing Offshore Sediment Movement around a Submarine Canyon

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

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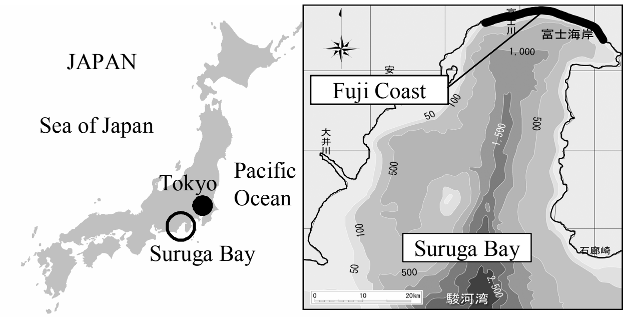
Fuji coast has several submarine canyons with steep slope. According to the previous surveys one of them located in front of Yoshiwara may cause the material of beach nourishment to move offshore. In this study the effect of the submarine wall proposed as the countermeasure was investigated using the 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.

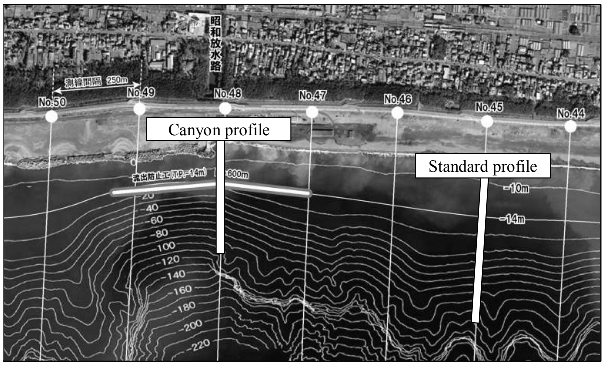
Key Words : *Sand movement, Beach nourishment, Submarine canyon, Large-scale experiments*

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 $10^3 m^3$ 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.



(a) Suruga Bay (Japan)



(b) Sedemt outflow prevention wall installation area

Fig.1 Location map of the Fuji Coast

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.

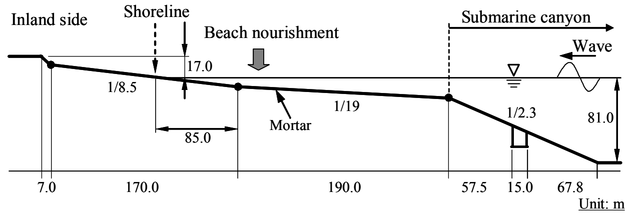
2. EXPERIMENTAL METHOD

(1) Profile of experimental model

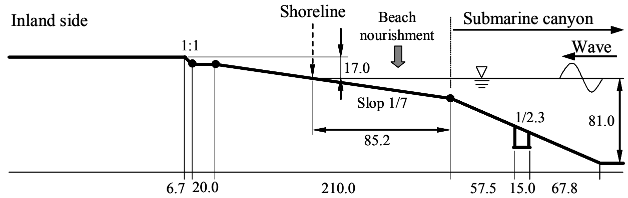
On the Fuji coast, the amount of sediment loss into the submarine canyon depends on the distance from the shoreline to the edge of the canyon. Two profiles were selected as standard profile and canyon profile as shown in **Fig.1**(a), (b). In the standard profile, the distance from the shoreline to the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



(a) Standerd profile



(b) Submarine canyon profile

Fig.2 Profile of the experiment model

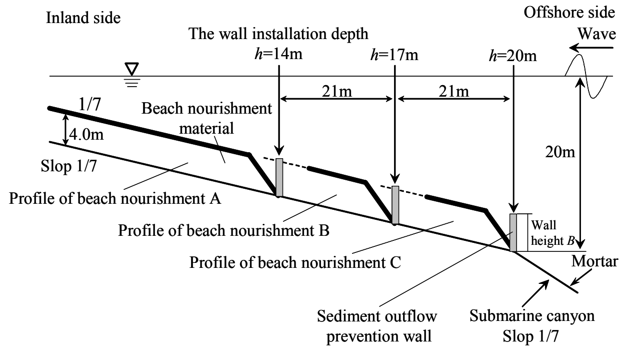


Fig.3 Profile of beach nourishment and wall installation depth

Profile of experimental models are shown **Fig.2**. Figure (a) is standard profile, figure (b) is submarine canyon profile. Submarine canyon is shown at the right side in figure. A fixed bed was fabricated with mortar for the experiment cross-section as shown figure. The standard profile is slope of 1/8.5 for h<10m, slope of 1/19 for 10m<h<20m and slope of 1/2.3 for h>20m. The submarine canyon profile is slope of 1/7 for h<20m and slope of 1/2.3 for h>20m.

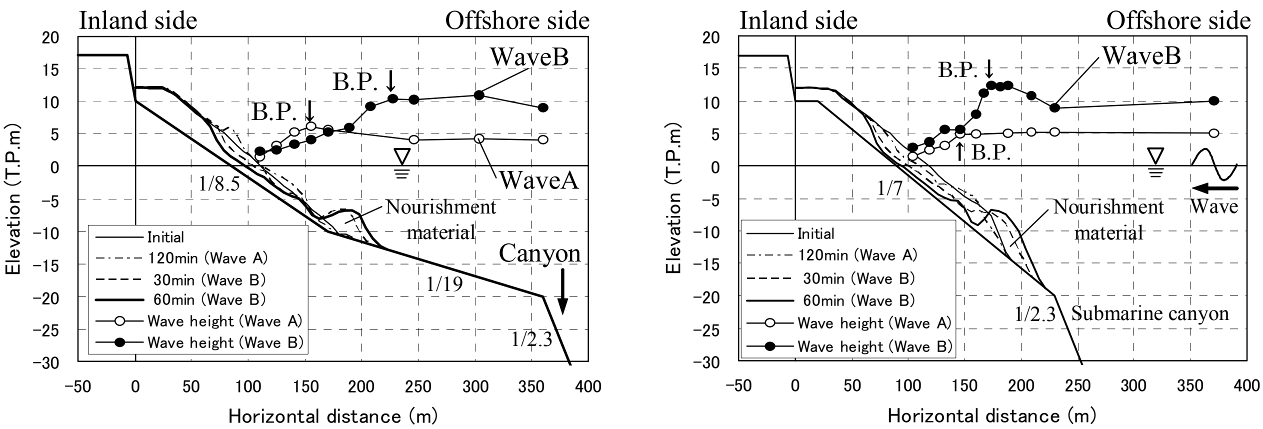
An L-shaped steel wall was attached to the fixed bed to simulate the wall. Nearshore zone shoreward of the steel wall was nourished to make an initially plane 1/7 sloping beach. Sediment outflow prevention wall was installed to depth h=14m, h=17m and h=20m as shown in **Fig.3**.

Beach nourishment material was located with a 4m thickness so that continuous wall installation depth and slope toe depth would agree and profile of beach nourishment A, B and C as shown **Fig.3**. A grain diamater of the beach nourishment material in the fieled was decided in the range of 10mm – 150mm considering influence on fishery and effect of beach nourishment. Reynolds number grows and its effect can be disregard, when a grain diameter of beach nourishment material is enough large size in

Table 1 List of experimental cases

CASE	Experimental profile	Beach nourishment condition	Sediment outflow prevention wall		Offshore wave height	Experimental time
		Slop toe depth (m)	Depth (m)	Heiht (m)	H(m)	(hr)
1	Standard profile	Profile A" 14m	No installation performed		5(0.17)	(3)
					10(0.33)	(3)
2	Submarine canyon profile	Profile A 14m	No installation performed		5(0.17)	(3)
					10(0.33)	(3)
3		Profile A 14m	14m	3m	5(0.17)	(2)
					10(0.33)	(2)
4		Profile A 14m	14m	5m	5(0.17)	(2)
					10(0.33)	(2)
5		Profile B 17m	No installation performed		5(0.17)	(2)
					10(0.33)	(2)
6		Profile B 17m	17m	3m	5(0.17)	(2)
					10(0.33)	(1)
					5(0.17)	(1)
					10(0.33)	(1)
7		Profile B 17m	17m	5m	5(0.17)	(2)
					10(0.33)	(2)
8		Profile C 20m	No installation performed		5(0.17)	(2)
					10(0.33)	(2)
9		Profile C 20m	20m	3m	5(0.17)	(2)
					10(0.33)	(2)
10		Profile C 20m	20m	5m	5(0.17)	(2)
					10(0.33)	(2)

( ) Model scale



(a) Standard profile

(b) Submarine canyon profile

Fig.4 Profile change of the standard profile and the canyon profile

the field. Therefore beach nourishment material in the model was arranged so that the grain diameter was geometrically scaled in the range d=0.33-5.00mm.

The incident waves were regular waves. The incident wave heights were H=5m for Wave A, corresponding to wave heights with a return period of 1-3 years and H=10m 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=11s 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

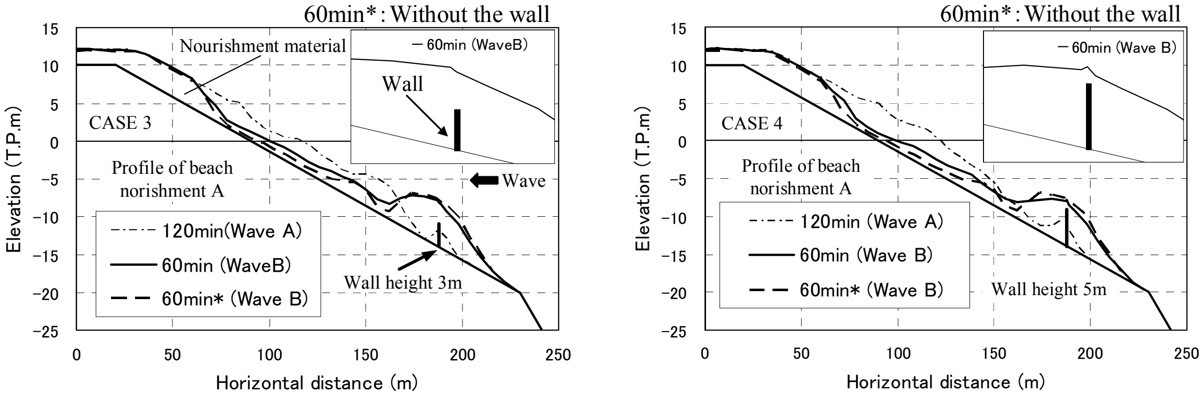
Experimental conditions in each case are summarized in **Table 1**. The volume of beach nourishment material that lost to the submarine canyon in CASE1-2, the effect of the wall in CASE2-10 were discussed.

3. EXPERIMENTAL RESULTS AND DISCUSSION

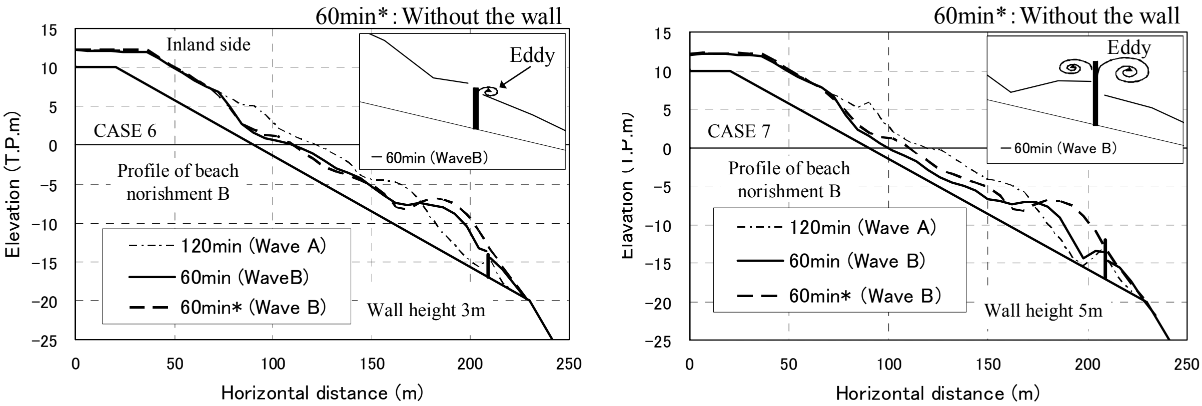
(1) Properties of beach nourishment movement on standard profile and canyon profile

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.

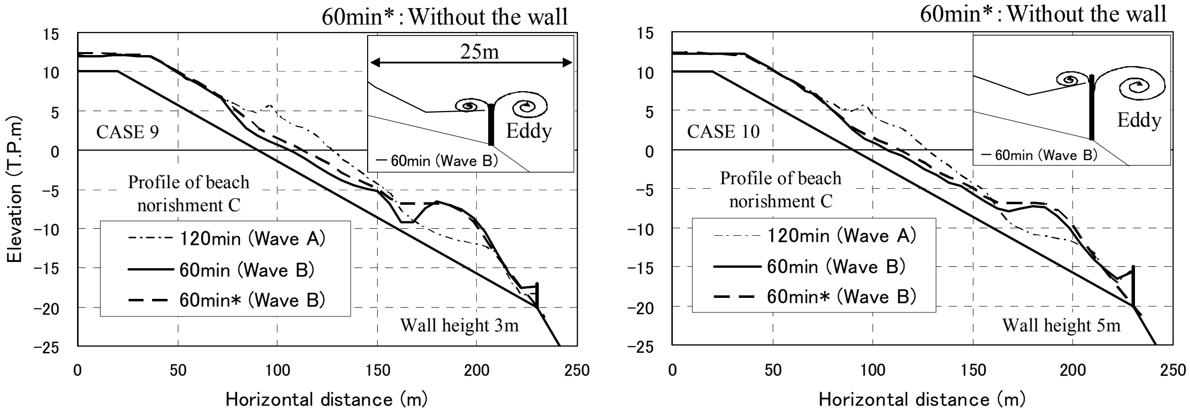
On the other hand, on the canyon profile, after the bar develops near the breaking point the bar gradually migrates offshoreward until it becomes stable near the edge of the submarine canyon. It was confirmed that the beach nourishment mterial fell



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



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



(c) The wall installtion depth h=20m (Profile of beach nourishment C)

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

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

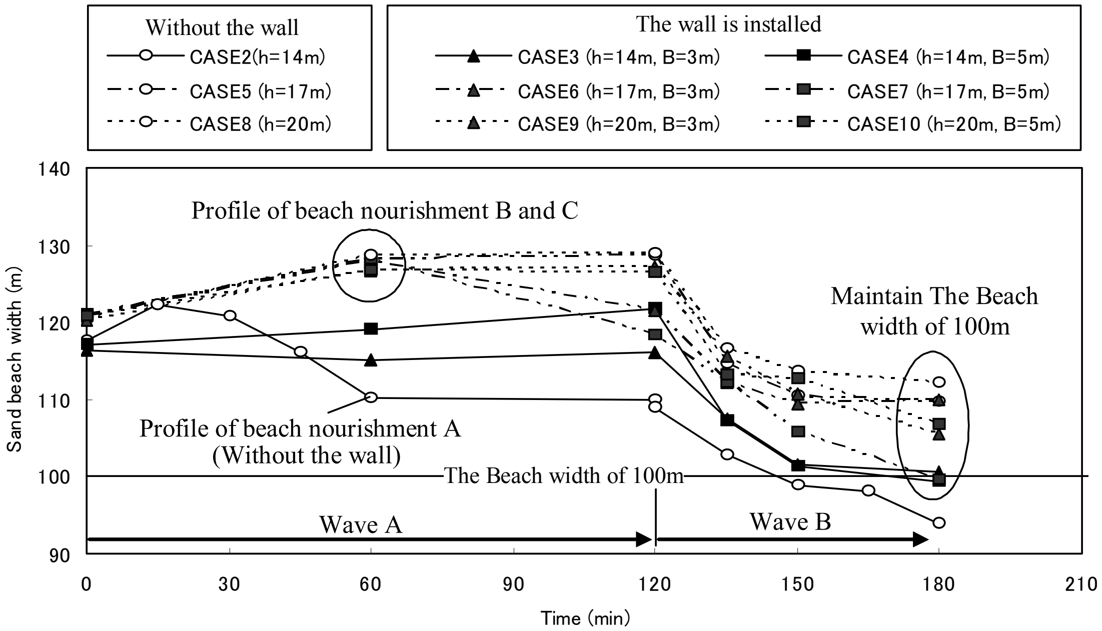


Fig.6 Time change of sand beach width

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

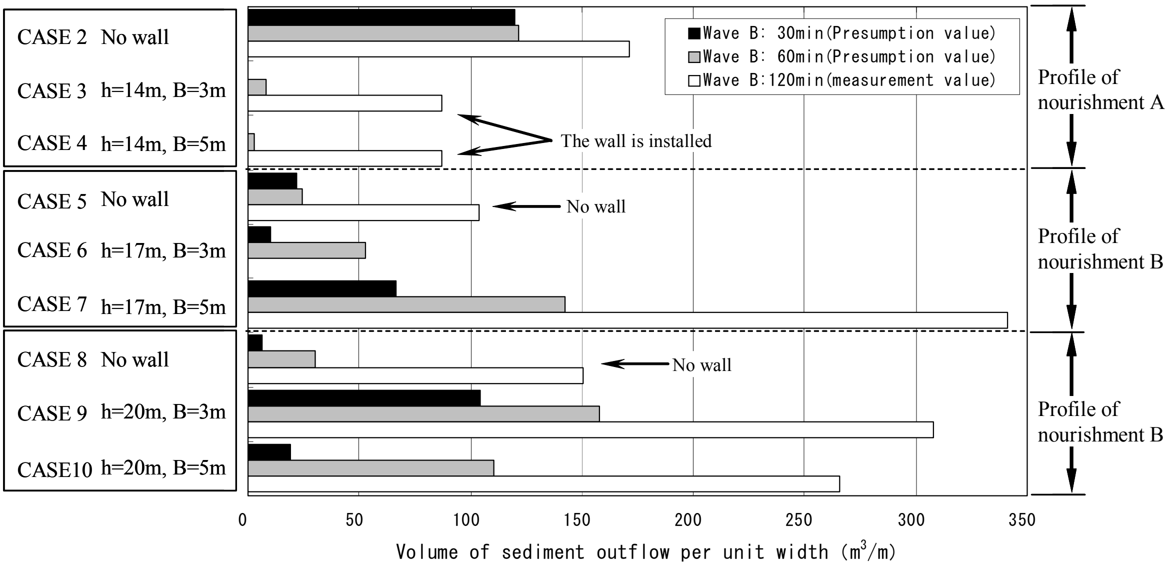


Fig.7 Volume of sediment outflow frow commencement of wave generation

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 beah 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.

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