CHAPTER 77

Beach fill at two coasts of different configurations

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ABSTRACT

Movements of borrow sand replenished at two coasts of different configurations are investigated by analyzing the topographic data which were surveyed periodically after the beach fill placements. One is a long straight beach and borrow sand was placed behind a submerged breakwater. Another is a pocket beach which has an arc-shoreline with a groyne at one end and a headland at another.

It is found that the amount of borrow sand moved in the long-shore direction surpasses the amount of borrow sand transported in the cross-shore direction regardless of the shape of the coast. A clear correlation is also found between displacements of shoreline and changes of sectional areas. These results imply that the deformation of the artificially nourished beach and the dissipation rate of borrow sand can be predicted by the so-called one-line theory.

1. Introduction

Artificial beach nourishment is a commonly utilized approach for treatment of shore protection problems such as beach erosion, wave over-topping and so on. It is also the direct method to maintain and improve recreational benefits in the coastal zone.

In Japan, there are many coasts where beach fill have been already replenished. At these coasts, structures such as an off-shore submerged breakwater, a detached breakwater and a groyne have been constructed simultaneously in order to prevent beach fill from flowing out from the replenished field.

However because the effective beach fill design involves so many physical factors, the precise degree of beach fill utilization to stabilize a shoreline is not always predictable.

The objective of this study is to investigate behaviors of beach fill replenished at two coasts of different configulations by analyzing successively measured beach profiles to offer informations as to what is the governing factor in the determination of the effctiveness of beach fill.

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2. Configulations of Two Coasts and Location of Beach Fill

Locations of two coasts are shown in Fig.1.

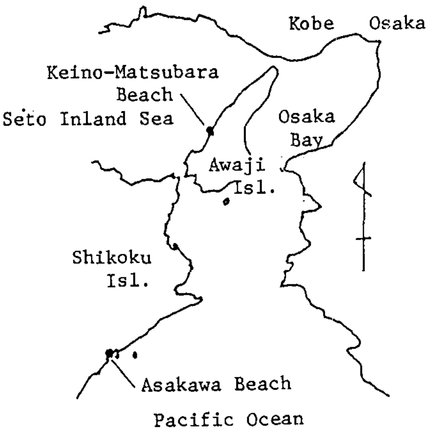


Fig.1 Locations of investigated two beaches

One is Keino-Matsubara-Beach which is on the east side of the Awaji Island facing the Seto Inland Sea and has a long straight beach of about 5km long as shown in Fig.2(a). In this coast, a test offshore submerged breakwater of 80m long and 20m wide was first constructed in 19B3 and borrow sand of about 5000m³ was replenished behind it about one year after the construction of the breakwater.

The upper surface of the submerged breakwater is about 1.5m below D.L.. H.W.L., M.W.L. and L.W.L. correspond to D.L.+1.8m, D.L.+1.2m and D.L.+0.5m. The water depth was measured upward from D.L.. The average beach slpoe is about 1/7 to 1/10 in the shallow water region(shallower than -2m) and about 1/30 in the deeper resion. Mean grain size d_{50} ranges from 0.2mm to 3mm and there is no correlation between d_{50} and water depth. Mean graion size of borrow sand is 1.5mm. These data are summerized in Table 1.

Figure 2(b) indicates a location of the submerged breakwater and the region where beach fill would be placed based on the measured beach profile just after the construction of the submerged breakwater.

Another is Asakawa-Beach which is a so-called pocket beach and has an arc-shoreline of about 400m long and the radius of which is 260m as shown in Fig.3. There is a rockey head land at the south end of the beach and a groyne of 150m long was constructed in 1974 at the other end. A beach slope in a shallow region (shallower than -3m) is about 1/7 to 1/10 and about 1/30 in the deeper region.

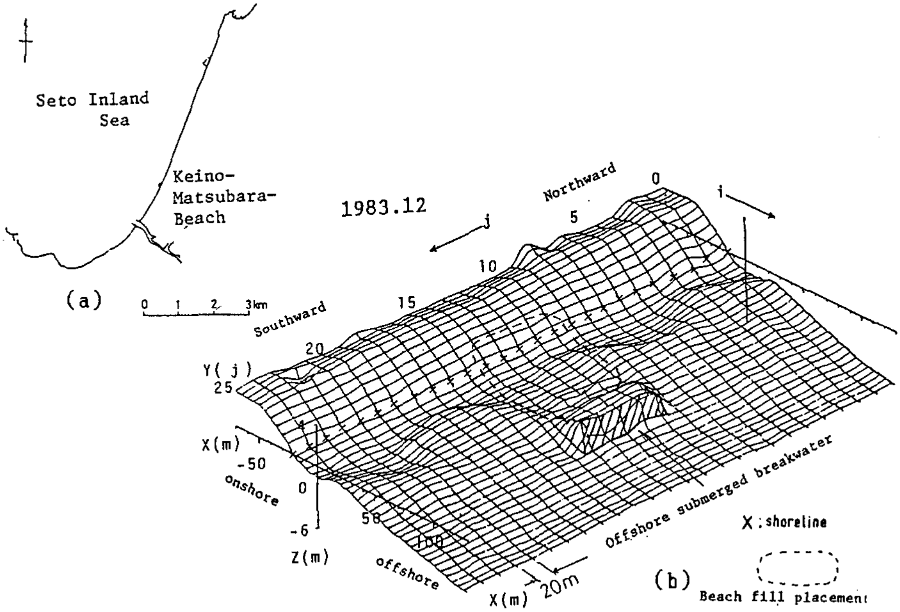
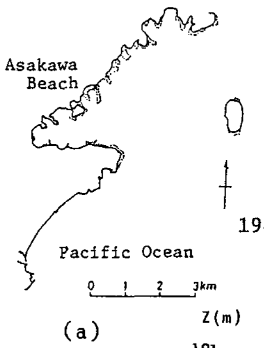


Fig.2 Beach profile of Keino-Matsubara-Beach just after the construction of submerged breakwater



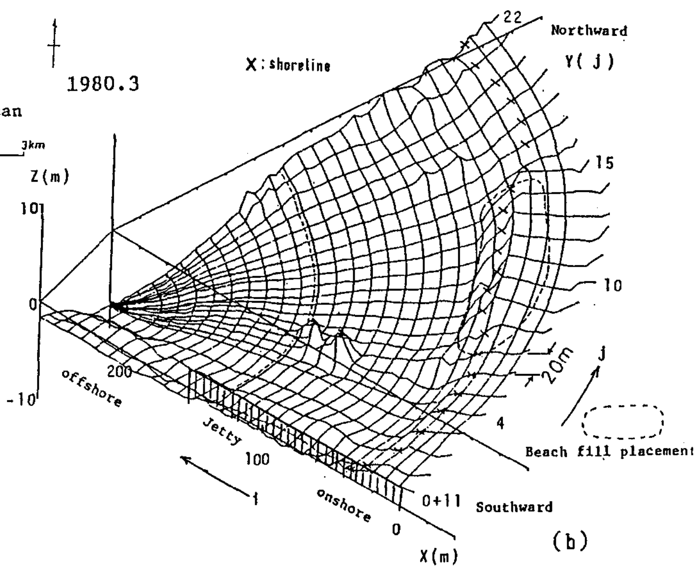
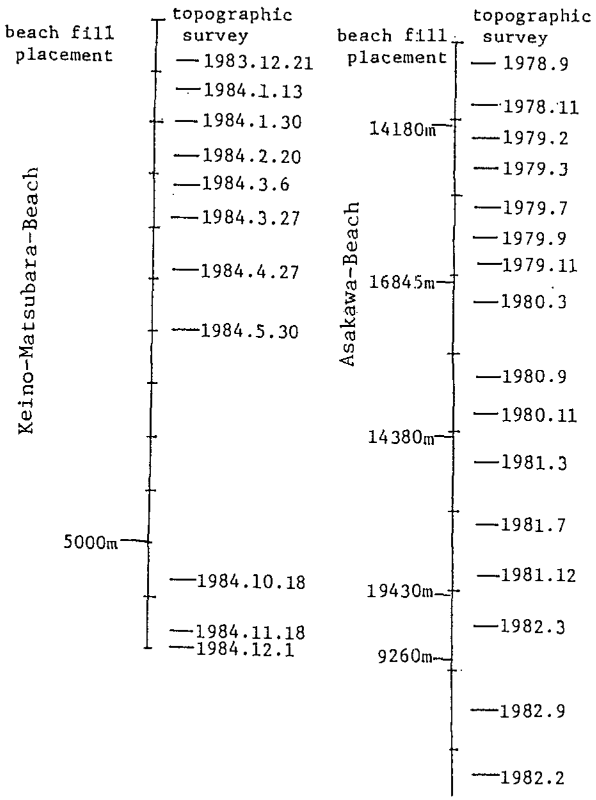


Fig.3 Beach profile of Asakawa-Beach just after the beach fill placement

Table 1 Characteristics of two beaches

	Keino-Matsubara-Beach	Asakawa- Beach
[d_{50}]		
native sand	0.2mm-3mm	0.5mm-3mm
borrow sand	1.5mm	0.4mm and 0.8mm
[Beach slope]		
shallow region	1/7-1/10	1/7-1/10
deep region	1/30	1/30
[waves]		
winter-spring	probability of appearance of waves higher than 1m is 35%.(from W-NW)	large part of waves are less than 40cm
summer-autumn	large part of waves are less than 40cm	waves higher than 1m incidents several times a year in a typhoon seasons.(from SE-E)

Table 2 Progress of beach fill and topographic survey



Water depth was measured upward from D.L.. H.W.L. and L.W.L. correspond D.L.+2m and D.L.+0.8m. Mean grain size of native sand d_{50} ranges from 0.5mm to 3mm. These data are also summarized in Table 1.

Figure 3(b) is a bottom topography drawn based on the measured water depth in Sept.1978 just before the continuous sand replenishments began. Since then, beach fill of about 15000m^3/year has been continuously placed in the center of the beach. From 1982, a submerged breakwater of 14m width has been constructing along a broken line shown in the figure from the north end of the beach and the construction of total 170m length are finshed in 1984. In this coast, two kinds of barrow sands of which mean grain sizes were 0.4mm and 0.8mm were used.

3. Method of Analysis and Data used

At Keino-Matsubara-Beach, a series of topographic survey have been conducting just after the construction of submerged breakwater. Water depth was measured on 26 surveying lines at the interval of 2.5m. The surveying lines were set at the distance of 20m along the shoreline. Beach profile measured just after the construction of the submerged breakwater in Dec.1983 which is shown in Fig.2(b) is selected as a initial profile in the following analyses.

At Asakawa-Beach, topographic survey has also been conducted periodically from Nov.1977. Water depth was measured on 24 surveying lines at the interval of 5m. Surveying lines were spaced as shown in Fig.3(b) which was drawn based on the water depth measured in March 1980. Beach profile measured in Sept. 1978 is used as a initial profile in the following analyses.

Progresses of the constructions of structutes, beach fill placements and topographic surveys at these beaches are shown in Table 2.

Based on the measured beach profiles, the following are investigated :

a) characteristics of the beach deformation around artificially nourished beach and behaviors of beach fill, and
b) remaining or dissipation rate of beach fill $\alpha(t_n)$ or $1-\alpha(t_n)$.

To investigate these, changes of water depth $\Delta h(i,j,t_n)$ and $\delta h(i,j,t_n)$ were first calculated from the measured water depth $h(i,j,t_n)$ where i indicates the i-th measureing point on the j-th surveying line and n shows the water depth measured at n-th topographic survey. That is,

$$\delta h(i,j,t_n) = h(i,j,t_n) - h(i,j,t_0) \tag{1}$$

$$\Delta h(i,j,t_n) = h(i,j,t_n) - h(i,j,t_{n-1}) \tag{2}$$

where t_o means the initial beach profile.

These topographic changes were also investigated by the empirical eigenfunction method by expanding Δh and δh as linear combinations of products of functions of the distance normal to the shoreline $e_k(i,t_n)$ and those of the distance parallel to the shoreline $c_k(j,t_n)$ as follows;

$$\Delta h(i,j,t_n) \text{ or } \delta h(i,j,t_n) = \sum e_k(i,t_n)\ c_k(j,t_n) \qquad (3)$$

Remaining rate of replenished barrow sand $\alpha(t_n)$ is defined in this paper as follows;

$$\alpha(t_n) = \delta V(t_n)/\sum Vb \qquad (4)$$

where $\sum Vb$ is the total volume of replenished borrow sand and $\delta V(t_n)$ is a volumetric change within the analyzing area, that is,

$$\delta V(t_n) = V(t_n) - V(t_o), \quad V(t_n) = \iint h(i,j,t_n)\ dx\ dy. \qquad (5)$$

4. Characteristics of beach deformations around artificially nourished beach and behaviors of beach fill

i) Keino-Matsubara-Beach

Figure 4 shows the topographic change took place during 2-month after the beach fill placement.

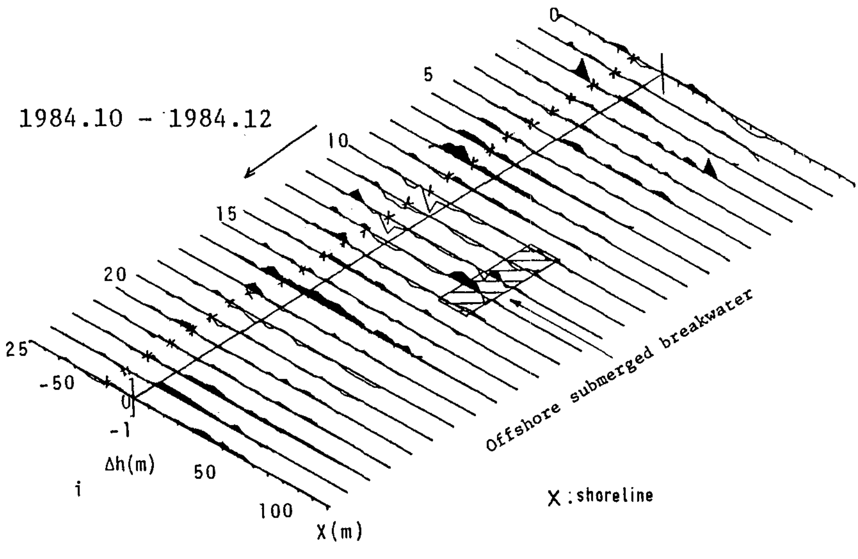


Fig.4 Change of water depth took place during 1-month after beach fill placement at Keino-Matsubara-Beach

In this figure, accreting resions are painted black. At the end of Sept.1984, borrow sand of about 5000m³ was replenished behind the submerged breakwater between the surveying lines No.10 to No.14. Figure 4 indicates that replenished sand mainly moved in the longshore direction and deposited in both north and south sides of the submerged breakwater. A few portion of borrow sand moved both in onshore and offshore directions and deposited in the landwards of the shoreline and behind the submerged breakwater. However, the amount of those sand is not so large.

Figures 5 and 6 show cross-shore and longshore eigenfunctions $e_1(i,t_n)$ and $c_1(j,t_n)$ calculated from $\Delta h(i,j,t_n)$ which correspond to the largest eigen value.

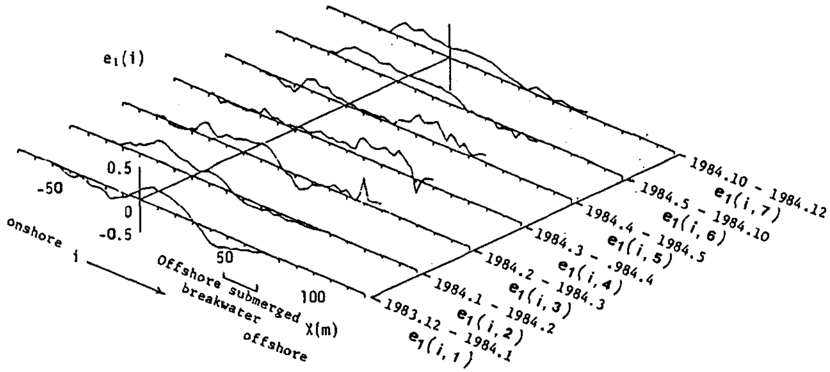


Fig.5 Cross-shore empirical eigenfunction corresponding to the largest eigenvelue

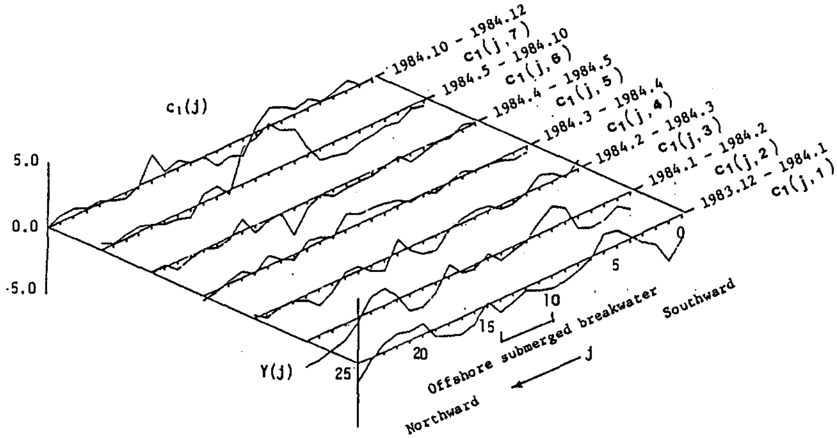


Fig.6 Longshore empirical eigenfunction corresponding to the largest eigenvalue

$e_1(i,1)$ calculated from the topographic changes took place during 1-month after the construction of the submerged breakwater changes its sign negative - positive - negative with the increase of the distance from the shoreline. $c_1(i,1)$ at this duration also alters its sign in the longshore direction. These results imply that both on-offshore and longshore sediment transports took place just after the construction of the submerged breakwater.

As can be seen from $e_1(i,2)$ and $c_1(j,2)$, on-offshore sediment transport became less significasnt and only longshore sediment transport remained when one month passed after the construction of the submerged breakwater. Because $e_1(i,2)$ does not change its sign with increasing the distance from the shoreline.

$e_1(i,6)$ and $c_1(j,6)$ calculated from the topographic change took place before and after the replenishment of beach fill clearly show the effect of beach fill placement.

Finally, $e_1(i,7)$ which corresponds to the topographic change took place during 2-month after the replenishment of beach fill shows positive through the whole cross-shore region and $c_1(j,7)$ is negative behind the submerged breakwater and positive in the out side of the submerged breakwater. This implies again that the replenished borrow sand moved off in the longshore direction from the replenished place and no significant offshore sediment transport beyond the submerged breakwater did not take place.

However, because the ratios of eigenvalues of these eigenfunctions to the trace become 0.4 to 0.5, only 40% to 50% of the whole topographic change can be interpreted by these eigenfunctions.

The authors further conducted numerical simulation concerning wave deformation and wave-induced current around the artificially nourished beach at Keino-Matsubara-Beach. In the simulations, wave direction and height are first calculated using equations of wave kinamatics and wave dynamics based on a linear wave theory at grid points. Then, depth averaged velocities of wave-induced current and displacements of the water level are calculated from the equations for concervations of depth and time averaged momentum and mass fluxes (Sawaragi et al.(1984)).

Some results are illustrated in Fig.7. Wave height H_0 and period T used in the similation are 2m and 5sec and wave direction together with the calculated wave breaking points are shown in the figures.

From these figures, it is found that forced wave breaking takes place on the submerged breakwater and strong wave-induced current in the longshore direction is generated behined the submerged breakwater. It seems that replenished borrow sand were easily transported by these current in the longshore direction.

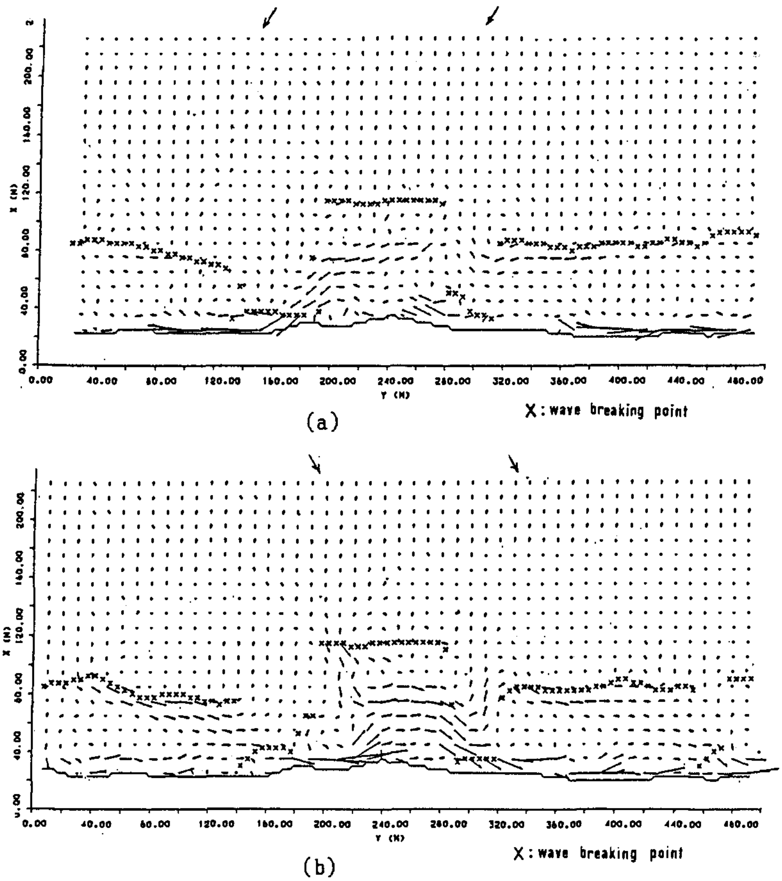


Fig.7 Simulated wave-induced current at Keino-Matsubara-Beach

At this coast, a close correlation between the displacement of shoreline and the change of sectional area at each surveying line is found through out the investigated beach.

ii) Asakawa Beach

As indicated in Table 2, borrow sand of about 15000m³ was placed once a year in winter between the surveying lines No.8 and No.14 above L.W.L.. Figure 8 shows the topographic change took place during Sept.1979 and March 1980 when borrow sand of 16845m³ was placed around the shoreline between surveying lines No.7 and No.15. Figure 9 indicates the topographic change tookplace during 6-month after the beach fill placement.

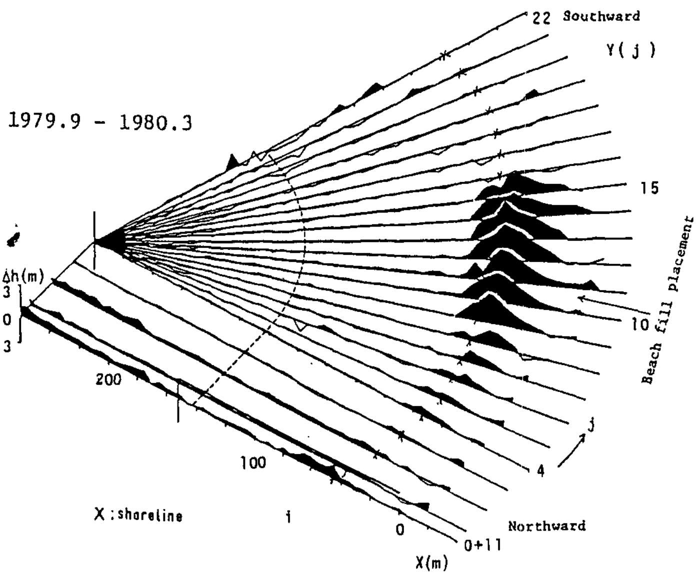


Fig.8 Change of water depth took place during Sept.,1979 and March, 1980 when borrow sand of 16845m^3 was placed around shoreline between surveying lines No.7 and No.15 at Asakawa-Beach

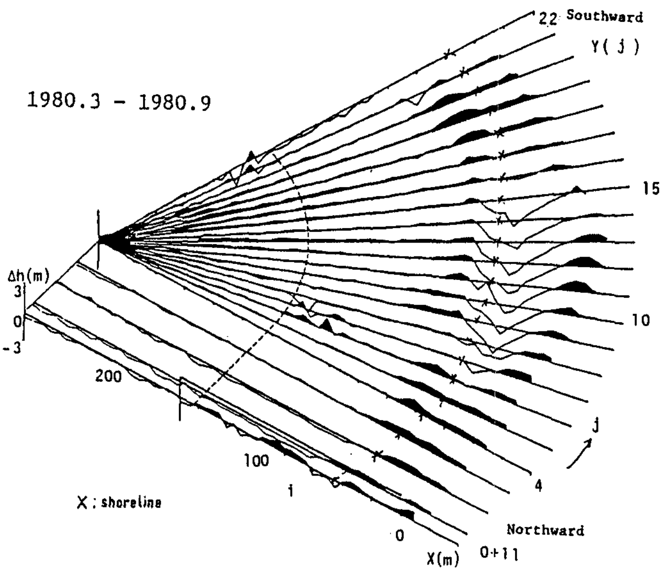


Fig.9 Channge of water depth took place during 6-month after beach fill placement at Asakawa-Beach

From these two figures, it is easily found that the replenished borrow sand moved from the replenished region mainly toward both southward and northward along the shoreline. As is the case of Keino-Matsubara-Beach, a few portion of borrow sand seemed to be transported in onshore and offshore directions.

Figures 10 and 11 show cross-shore and longshore eigenfunctions $e_1(i,t_n)$ and $c_1(j,t_n)$ which correspond to the largest eigenvalues.

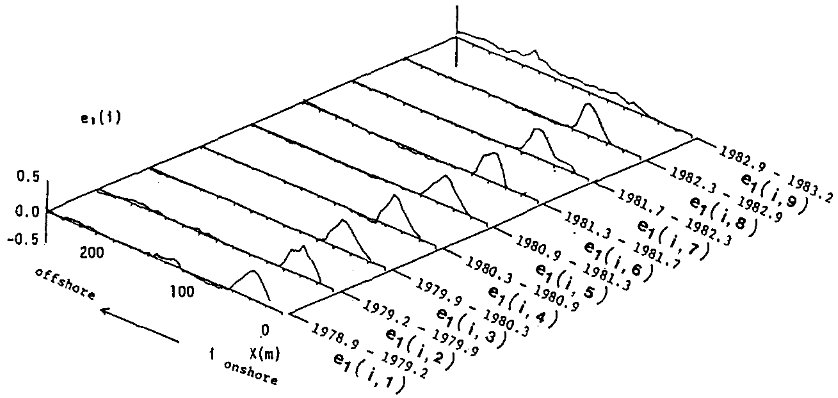


Fig.10 Cross-shore empirical eigenfunction corresponding to the largest eigenvalue.

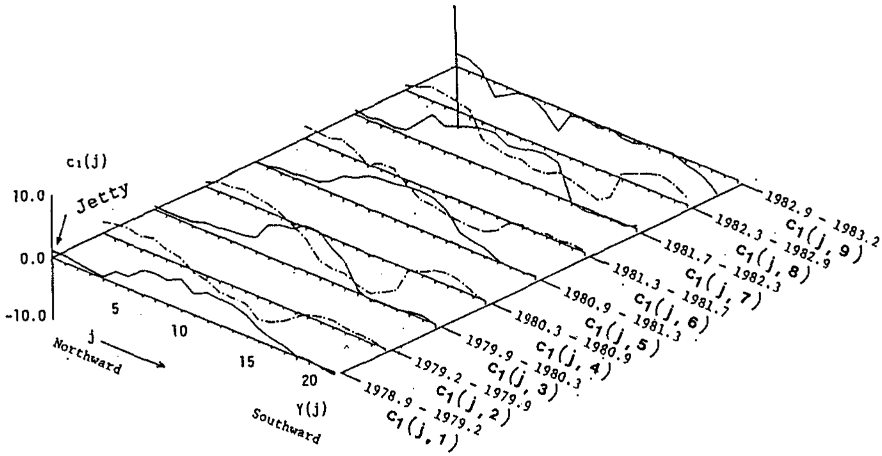


Fig.11 Longshore empirical eigenfunction corresponding to the largest eigenvalue

$e_1(i,t_n)$ has only positive values in narrow regions near the shoreline in all the investigated region and through the whole duration. On the other hand, $c_1(j,t_n)$ calculated from the topographic changes took place during autumn and winter and during spring and summer indicate clear contrast. That is, $c_1(j, t_n)$ in autumn and winter represents the topographic change corresponding to the beach fill placement and $c_1(j,t_n)$ in spring and summer shows the movements of borrow sand towards both ends of the pocket beach along the shoreline.

Further, the positive region of $c_1(j,t_n)$ in spring and summer is larger in the north end of the beach (near the groyne) than that in the south end. This implies that the magnitude of northward sediment transport is larger than that of the southward transport.

It is also found that any significant on-offshore sediment transport took place in the pocket beach.

About 65% to 80% of the total topographic change can be expressed by the product of these cross-shore and longshore eigenfunctions which correspond to the largest eigenfunction.

Fugure 12 illustrates some numerical results of wave-induced currents on a modeled pocket beach with a groyne at one end. Wave height and period used in the simulation are 2m and 5sec and wave diretion is shown in the figure together with the wave breaking points.

As can be seen from these figures, the direction of wave-induced flow near the groyne are always toward the groyne in the pocket beach regardless of the wave directions. This result will be of some help to explane why the magnitude of northward (toward the groyne) sediment transport is larger than that of southward sediment transport.

Again, at this beach, a clear correlation between displacements of shorelines and changes of sectional areas at eachsurveying line can be found.

5. Remaining (or Dissipation) rate of borrow sand

Finally, the remaining rate $\alpha(t_n)$ of replenished borrow sand is investigated in this section.

Figure 13 shows the volumetric change and remaining rate of borrow sand at Keino-Matsubara-Beach. Full and broken lines in the figure indicate the volumetric change δV behind the submerged breakwater between the surveying lines No.10 and No.14 and δV between the surveying lines No.8 and No.16 which appart 40m from region where beach fill was replenished.

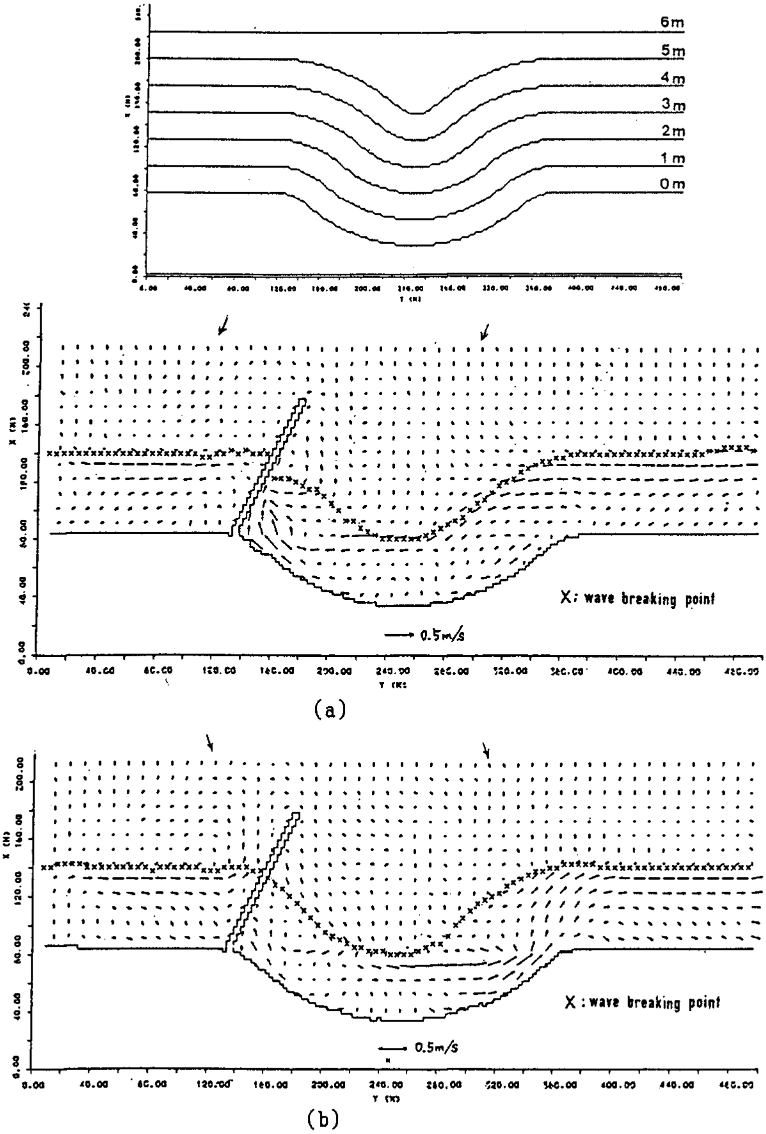


Fig.12 Simulated wave-induced current at Asakawa-Beach

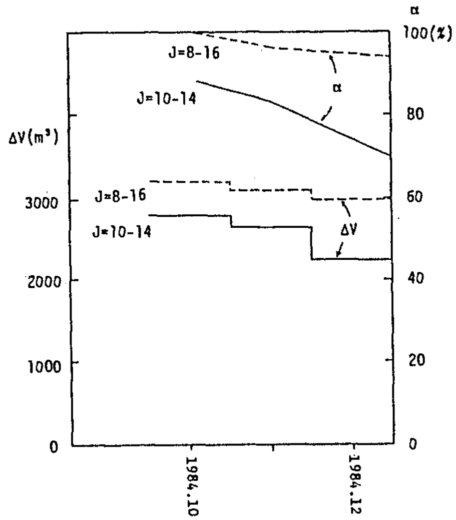


Fig.13 Remaining rate of borrow sand and volumetric change at Keino-Matsubara-Beach

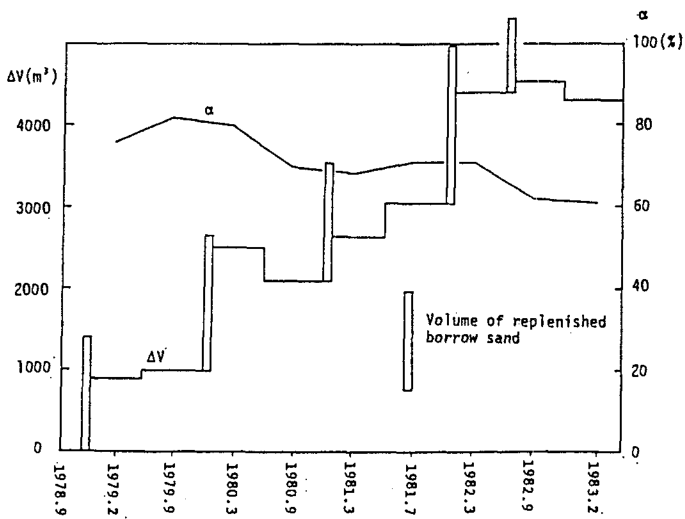


Fig.14 Remaining rate of borrow sand and volumetric change at Asakawa-Beach

Although borrow sand of $5000m^3$ was placed behind the submerged breakwater, the increase of the sand volume between the surveying lines No.8 and 16 was about $3300m^3$. Therefore, in the calculation of $\alpha(t_n)$ from eq.(4), we used $3300m^3$ for Vb.

It is found from this figure that the sand volume just behind the submerged breakwater decreased fast and only 70% remained two month after the beach fill placement. On the other hand, more than 90% of the borrow sand remained between the surveying lines No.8 and No.16. This means that the migration speed of borrow sand is not so fast and only 10% of borrow sand moved off more than 40m from the replenished region.

Figure 14 shows the volumetric changes and remaining rate of borrow sand at Asakawa-Beach. At this beach, the volume of sand in the whole beach increased at every beach fill placement. However, the remaining rate of the total borrow sand replenished in the beach from eq.(4) decreases gradually from 80% and finally reaches 60%. This implies that there is a certain limit to keep sand within a pocket beach which will be determined by the geometrical property of the beach, wave climate and so on.

6. Conclusions

Movements of borrow sand replenished at a long straight beach and a pocket beach which has an arc-shoreline are investigated by analyzing the periodically measured bottom topography after the beach fill placements.

It is found that the amount of borrow sand moved in the longshore direction surpasses the amount of borrow sand transported in the cross-shore direction regardless of the shapes of the shorelines. A clear correlation is also found between the shoreline displacements and the changes of sectional areas.

References

Sawaragi, T., I. Deguchi and J.S. Lee (1985), A new model for a prediction of beach deformation around a river mouth, Proc. Int. Sympo. Ocean Space Utilization '85, 2, pp.229-237.