Volume 23/1991/EMECS '90

Beach Nourishment and Field Observation of Beach Changes on the Toban Coast Facing Seto Inland Sea

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The topographic changes after the beach nourishment conducted at the Toban Coast are investigated on the basis of the bottom sounding data. The stability of the nourished beach on the coast where wave direction seasonally changes is studied in detail. The effectiveness of groins to contain nourished sand is discussed.

I. INTRODUCTION

In recent years beach nourishment has been frequently conducted at many locations in order to recover the once disappeared sandy beach. In the beach nourishment some structures such as groins are usually built to prevent sand loss from the artificial beach. On the coast where predominant wave direction is almost constant, the shoreline separated by groins will approach to the stable form soon after the nourishment. On many coasts, however, wave direction has a seasonal change, and therefore nourished sand between groins may be lost due to the offshore sand movement accompanied with the seasonal variation of the shoreline position. Accordingly, deep consideration is needed for the possibility of sand loss from a region divided by groins in making a beach nourishment plan on the coast where wave direction varies seasonally. For this purpose the change in bottom contour lines responding to the change in wave direction should be studied. On the other hand, as long as the nourished sand does not discharge from the region divided by groins, sand movement is considered to be useful to keep the sandy beach clean and to improve water quality. From this point of view the extent of the beach changes should be studied in detail, too. On the Toban Coast facing the Seto Inland Sea beach nourishment has been widely conducted in place of constructing wave dissipating works in order to create better coastal environment. On this coast wave direction changes seasonally to a large extent and therefore the study on littoral transport on this coast is useful for the general understanding on the stability of the nourished beach on the coast where wave direction seasonally changes. From this, the present study aims to investigate the topographic changes after the nourishment on the basis of the bottom sounding data.

II. BEACH NOURISHMENT ON THE TOBAN COAST

The Toban Coast is located west of Kobe Port and faces Osaka Bay and Harimanada at the eastern and western parts of coast, respectively, as shown in Fig. 1. This coast has been famous for the cliff erosion and shoreline has retreated. Photo. 1 shows the situation of Eigashima area on this coast in 1953. It is evident that the sea cliff was eroded due to the wave abrasion. Then coastal revetment was continuously built on foot of the sea cliff in order to prevent further retreat of the sea cliff as shown in Photo. 2. Although the construction of the coastal revetment was effective to prevent further erosion of the sea cliff, the concrete revetment is not satisfactory for the utilization of the coastal zone or for the protection of the shoreline environment. Thus, a necessity of the recovery of sandy beach was of great importance. By the above mentioned

Marine Pollution Bulletin, Vol. 23, pp. 155–159, 1991.
Printed in Great Britain
0025-326X/91 $3.00+0.00

reason, beach nourishment had been planned until 1982 and the plan was initiated in the same year. The artificial beach formed by the nourishment has the backshore of 25m wide, and the top height of the beach is 2.5m above the M.S.L. The initial foreshore slope was planned to be 1/10. In order to contain the nourished sand, impermeable groins were built as shown in Fig. 2. The distance from the coastal revetment to the tip of the groin is 100m, the point depth is 2.5m below the M.S.L. and their interval is 180m. The arrangement of the groins is shown in Fig. 2. The median diameter of the nourished sand is 0.88-1.1mm. The nourishment between No. 1 and No. 2 groins was carried out in 1982-1984, and about 30000 m^3 of sand was nourished. After the nourishment beach surveys have been carried out in order to investigate the beach changes along the survey lines as shown in Fig. 2.

III. CLIMATIC AND WAVE CONDITIONS

The incident wave direction to the Toban Coast is strongly affected by the seasonal change in wind direction. The wind velocities measured between 1982 and 1987 at Eigashima located at about 5km west of the study site show that the wind direction of W or WSW are predominant in winter because of the development of monsoon. On the other hand in summer SE wind strongly dominates. As a result, the wind direction on the Toban Coast can be characterized by W-WSW wind in winter and SE wind in summer. The fetch diagram of this coast is shown in Fig. 1. The fetch from this coast to the west is restricted by the presence of the Ieshima islands and it is 28km long. The fetch to WSW is 70km long. As for the other predominant wind direction, SE, the fetch extends up to 45km long through a narrow window in Akashi Strait toward Osaka Bay. Both seasonal wind characteristics and fetch distribution can cause the prevailing wave incidence from W-WSW and SE. Wave observations have been carried out off Eigashima on the Toban Coast by using a ultrasound wave gauge installed at a depth of 10.5m. Probability of occurrence of significant wave height and wave period in a year term and in winter can be obtained from the observed data in 1984-1988. By this calculation the probability of occurrence of the wave height larger than 0.5m is 0.07 in a year term, and its dominant wave period is 3-4s. On the other hand, during the winter period its probability increases up to 0.15 and longer period as 4-5s can be observed.

IV. TOPOGRAPHIC CHANGES OF NOURISHED BEACH

4.1 Shoreline change

The change in shoreline positions on the nourished beach between October, 1984 and February, 1986 is shown in Fig. 3. In a period between October, 1984 and January, 1985 the shoreline retreated in an area next to No. 2 groin, whereas the shoreline advanced on the west side of No. 1 groin. Maximum shoreline advance and retreat can be seen at Sts. 6 and 9, respectively. These shoreline changes can be attribute to the obstruction of eastward longshore transport by the groins in winter time. In a period between January and June in 1985 the opposite type of the shoreline changes was observed; shoreline retreat between Sts. 6 and 8, and the advance between Sts. 8 and 10. These changes are totally opposite to those measured in a period between 1984 and 1985. The cause of these shoreline changes is due to westward littoral drift generated by the wind waves from SE dominating in summer. Then, in a period between June, 1985 and February, 1986 the same pattern of the shoreline changes as the one in 1984-1985 was observed. Finally it should be noted that the cyclic mode of shoreline variation reponding to the change in wave direction dominates on this beach and longshore sand transport changes its direction from west to east. This kind of seasonal changes in shoreline position were also observed at the Kashimanada Coast facing the Pacific Ocean (Uda et al., 1988). From these points, this phnomenon observed on this coast is considered to have a high generality.

4.2 Comparison of sounding maps

Three dimensional beach changes are studied through the commparison of contour maps. Contour maps observed in October, 1984 right after the nourishment and in February, 1988 were selected for the typical cases, and they are shown in Figs. 4 and 5. Figure 4 expresses the beach topography after the incident wave action driven by southeast wind in summer, and Fig. 5 the same except wave incidence from W or WSW in winter. The comparison of both figures shows that there is no change at the contour line deeper than -2.5m off the groin. In the vicinity of Sts. 6 and 7 the contour lines between 1.5m and -1.0m advance, and they retreat near St. 9 during this period. In these changes contour lines apparently move parallel each other, and this fact elucidates that the beach changes were caused by the eastward longshore sand transport.

4.3 Beach profile changes

Temporal beach profile changes along typical survey lines are investigated based on the survey data (Fig. 6). For the typical survey lines, Sts. 6 and 9 are selected from the accreted and eroded zones, respectively. At St. 6 large amount of sand accumulated relative to the initial profile in October, 1984. The landward limit of the accretion on the foreshore is at $z=1.5$m, and a berm develops seaward from this point. The berm crest gradually increased its height from 1.2m in 1985, 1.5m in 1986 and 1.8m in 1987. In 1987 the berm approaches to the stable form. The increase rate of berm crest height between 1984 and 1987 becomes 0.3m/yr. Below the sea surface apparently beach profile changes are dominant in a depth less than about -2m, and in deeper zone than this critical depth, bottom changes tend to diminish. Consequently it is concluded that at this location beach changes are confined between 1.5m and -2.0m. At St. 9 beach has been eroded since 1984. On the foreshore the height of the landward limit in the eroded zone increases with time, and in 1988 the landward limit reaches up to the top of the beach. The reason is due to the fact that the beach cliff formed on the foreshore with a constant slope retreated in accordance with the shoreline recession. At St. 6, where sand gradually accumulated with seasonal variations, the height of the landward limit of the profile changes is kept almost constant as 1.5m above the M.S.L., whereas its height gradually increases up to the top of the backshore with time at St. 9. It is pointed out that these are the characteristic differences in the erosive and accretive profile changes. Regarding the sea bottom changes, the region shallower than -0.8m was eroded with the foreshore erosion. Moreover, the critical depth for sand movement, where dominant beach changes diminish is about -2.0m. In conclusion it is realized that the active zone of littoral transport accompanied with wind wave action is restricted in a zone shallower than -2m, and the beach changes in a deeper zone than this depth may be neglected, judging from the beach changes measured in 5 years after the beach nourishment.

V. RELATIONSHIP BETWEEN CHANGE IN SHORELINE POSITION AND LONGSHORE COMPONENT OF WAVE ENERGY FLUX

Recently Uda Sakano (1989) experimentally studied the cyclic mode beach changes around coastal structures built on a coast where wave direction varies seasonally in a cyclic mode. Beach changes on the Toban Coast show the same pattern. Figure 7 shows the temporal change in shoreline position on each survey lines with reference to the shoreline configuration in August, 1984 right after the completion of the beach nourishment. It is found that at Sts. 6 and 7 the shoreline advances in winter, whereas it retreats in summer. On the contrary at Sts. 9 and 10 reverse mode of shoreline change can be seen. It should be noted that in the east and west half of the nourished beach divided by groins the shoreline movement is totally reversed, and those variations are seasonal. The cause is due to the fact that W or WSW wind prevails in winter, whereas in summer SE wind is dominant. To this reason, longshore component of wave energy flux was calculated from the wind velocity data at Eigashima and significant wave height and period measured off the same location, assuming that the wave direction is approximately equal to the wind direction. The result is shown in Fig. 8. Solid and broken lines correspond to the westward and eastward components of wave energy flux, respectively. As a whole, eastward component is larger than westward component, because winter waves dominate on this coast. In summer, however, eastward component considerablely increases. Comparing the change in energy flux with the shoreline change, it is evident that sand accumulates at Sts. 6 and 7 located in the eastern part of the nourished beach, and the shoreline retreats at Sts. 9 and 10, if eastward energy flux dominates. In conclusion, it is found that the beach topography has responded to the seasonal change of wave direction on this coast.

VI. CONCLUSIONS

The main results of this study are summarized as follows:

1) On the Toban Coast a cyclic mode of beach changes were observed. These changes were induced by the seasonal change in the direction of longshore sand transport, which in turn corresponded to the change of dominant wave direction from W-WSW in winter to SE in summer. The same kind of shoreline changes have been observed at the Kashimanada Coast. Thus, this phenomenon has a considerablely high generality.

2) It is found from the profile data that the critical depth for sand movement on this beach is about -2m and the maximum seasonal change of the shoreline is 10m. Taking account of both facts, the groins, of which length is 100m from the initial shoreline and whose point depth is about 2.5m are sufficiently long to stabilize the nourished sand.

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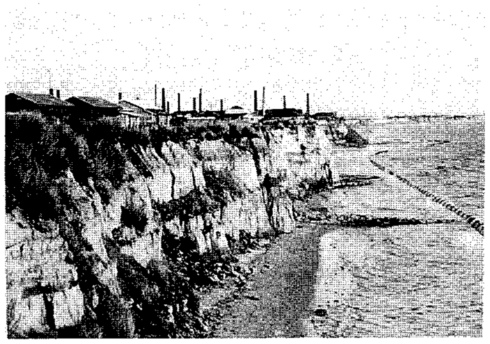

Photo. 1 Situation of Eigashima area on Toban Coast in 1953. Sea cliff was eroded due to wave abrasion.

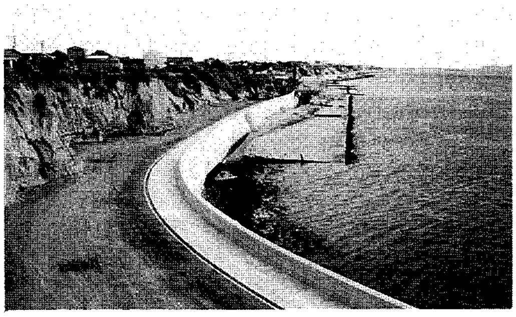

Photo. 2 Coastal revetment to prevent further retreat of the sea cliff.

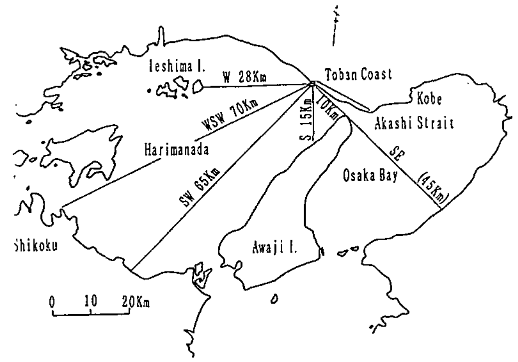

Fig. 1 Location of Toban Coast facing Harimanada and Osaka Bay in the Seto Inland Sea.

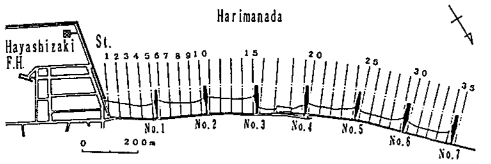

Fig. 2 Arrangement of groins and survey lines on Toban Coast.

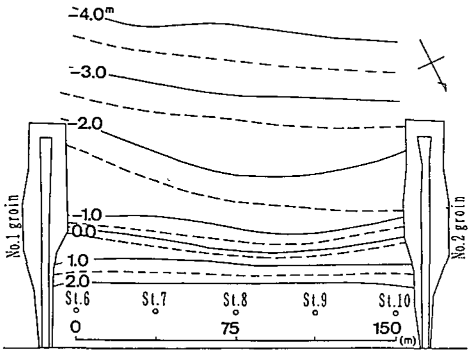

Fig. 4 Beach topography observed in October, 1984.

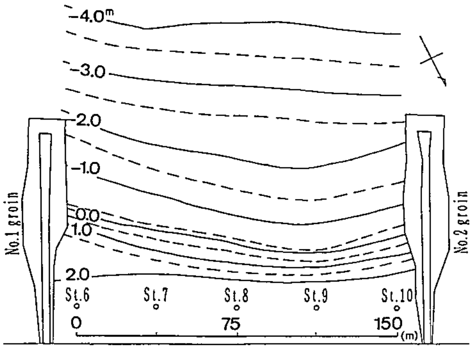

Fig. 5 Beach topography observed in February, 1988.

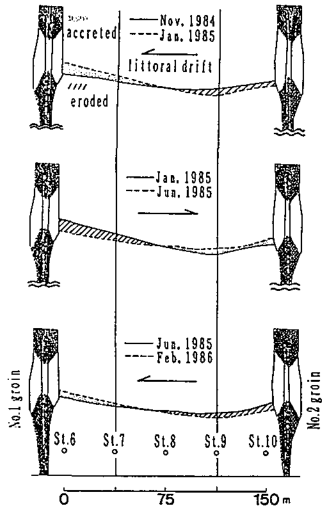

Fig. 3 Seasonal changes in shoreline position. It is evident that a cyclic mode of the shoreline change dominates.

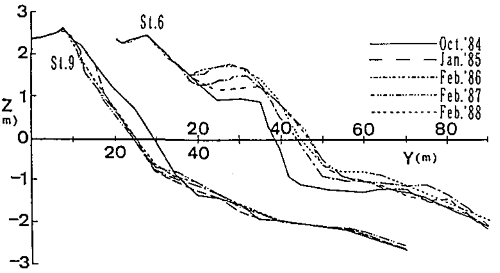

Fig. 6 Temporal change in beach profile at Sts. 6 and 9.

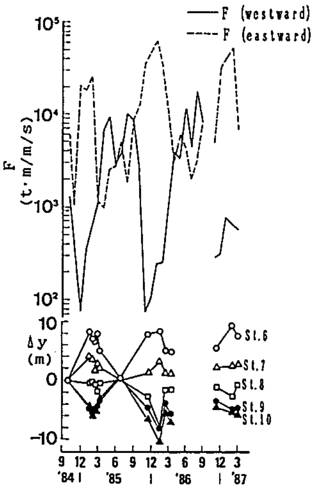

Fig. 7 Relation between shore-line change and longshore component of wave energy flux.