

# **PART VI**

## **Coastal Estuarine and Environmental Problems**



## CHAPTER 207

### Beach Erosion Due to Large Coastal Structure and Its Control

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#### 1. Introduction

Beach erosion has recently been recongnized as accelerating due to the influence of coastal structures. This tendency is especially severe in Japan where coastal structures are over abundant. Blockage of the longshore sediment transport and changes in the wave field are the most common causes of structure induced beach erosion. In this paper, these are indentified as the first and second causes of erosion. Examples of such beach erosion in Japan are provided.

In order to explain the two common erosion causes and beach erosion control, results of numerical simulations of shoreline change by a coastal structure and nearshore currents due to wave fields changed are also shown. In the numerical simulation, a countermeasure for beach erosion which is caused by changing of nearshore currents by the coastal sturcture is proposed.

The scenario for the beach erosion can be easily described by Figure 1. In this figure beach erosion due to the first erosion cause, the blockage of longshore sediment transport, is shown in (a) which explains the continuous erosion extending downstream in longshore sediment transport. Beach erosion due to the second erosion cause, the change of nearshore currents by the coastal structure, is shown in (b) which describes ersoion taking place within a limited area. Due to both the first and second erosion causes, beach erosion generally takes place. Beach erosion control should be considered by taking into account these erosion processes, and more strictly speaking for the beach erosion the sandy beach being eroded must be stabilized. For this purpose a dynamical background for the formation of stable

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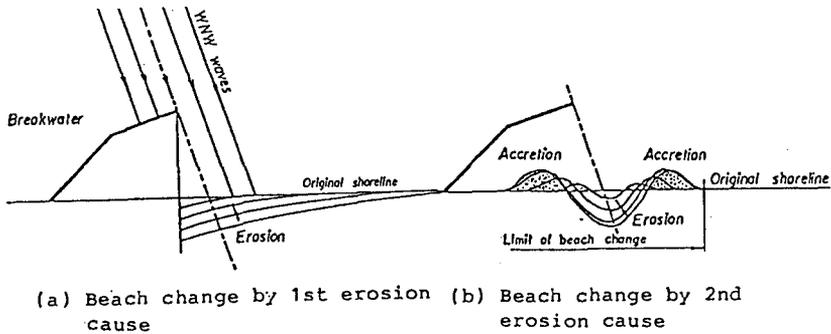


Figure 1 Shoreline changes by two common beach erosion causes.

sandy beaches has to be established. Applying our recent theory of nonuniform longshore sediment transport along the sandy beach, a theory of the formation of stable sandy beaches was recently established by Tsuchiya and Refaat(1990). The theoretical result is very briefly introduced, and then a methodology for the structure induced beach erosion is proposed with a special reference to the Ogata coast facing the Japan Sea.

## 2. Beach Change by Large Coastal Structure

In order to describe beach changes such as changes in shoreline and bottom topography, an example of the Ogata coast beach erosion is shown in Figure 2. The Naoetsu Harbour shown in this figure has recently been enlarged. NW or WNW and N or NNE waves are predominant to the coast, the former waves are 8 to 10 sec in wave period with a very high wave height, and the later ones are 12 to 14 sec with a small wave height. The predominant direction of longshore sediment is therefore mostly easterly and sometimes changed. In the area just upstream the Naoetsu Harbour, the Seki river is flowing into the area to supply sediment which is the main sediment sources for the coast. The harbour breakwaters were constructed on the right side of the river mouth. Since no longshore sediment can be transported downstream, severe beach erosion has then taken place, and it has recently been accelerated by extending the breakwaters.

Changes in shoreline due to the construction of the breakwaters are shown in Figure 3 where the origin of the distance is taken at Gotsu and the harbour is located

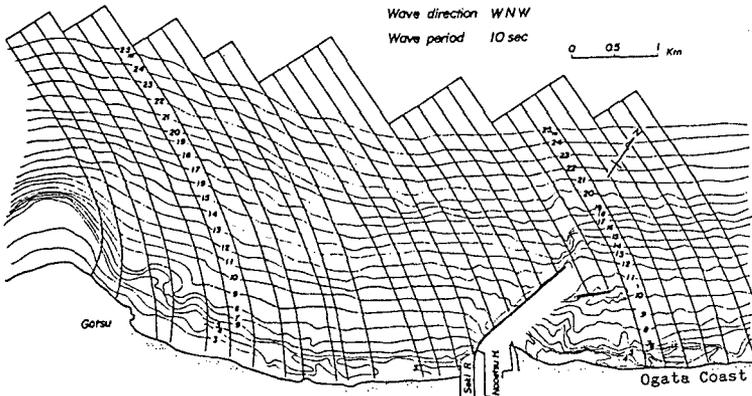
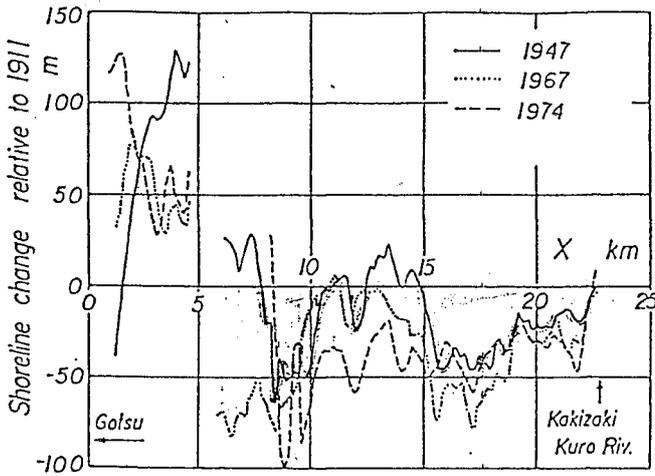


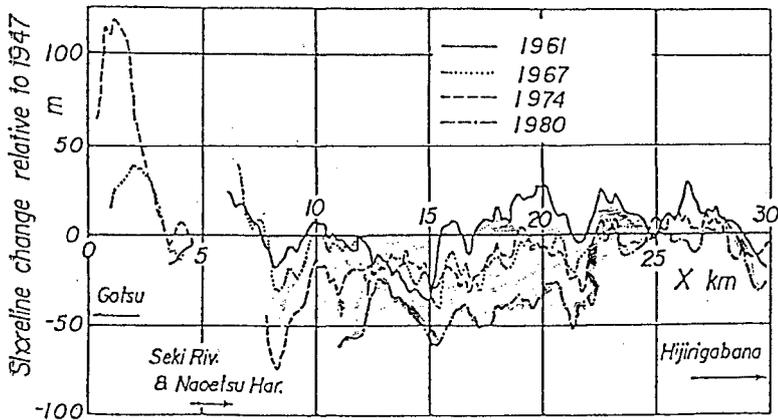
Figure 2 Locations of Ogata coast and Naoetsu Harbour, and refraction diagram of WNW waves with a period of 10sec.

around 4 to 7km. In reference to the shoreline positions in 1911 and 1947 the shoreline changes are shown in (a) and (b) of the figure, respectively. It should be understood that the beach erosion has advanced greatly and the erosion waves have been propagated in the easterly direction, showing some undulations in the waves. To the contrary on the west side, sediment deposition has recently taken place due to the effect of waves reflected by the breakwaters.

To prevent beach erosion, sea dikes were first constructed, but beach erosion had advanced and sandy beaches no longer existed. Secondly, offshore breakwaters were constructed and a great number of concrete units were used. However, the beach erosion have been still in progress and accelerated by structure reflected waves. The water depths have deepened in front of sea dikes and offshore breakwaters. As seen in Figure 4, concrete unit weight to be used increased with an increase in water depth in front of the structures. In advance of beach change beach profiles become generally steep. An example of beach profile change is shown in Figure 5 where the beach profiles measured in 1968, 1972 and 1976 are compared. At that time in 1968 the coast was so-called wave energy dissipative beach, but gradually changing beach profiles more steep they have already become so-called wave energy reflective beach. Catastrophic beach change has therefore sometimes taken place in the coast. This may mean that nature intends to recover the beach profiles to her native ones. It can therefore be concluded from these cases that more natural sandy beaches must be



(a) Shoreline change from 1911 to 1974



(b) Shoreline change from 1947 to 1980

Figure 3 Changes in shoreline due to construction of breakwaters of Naoetsu Harbour.

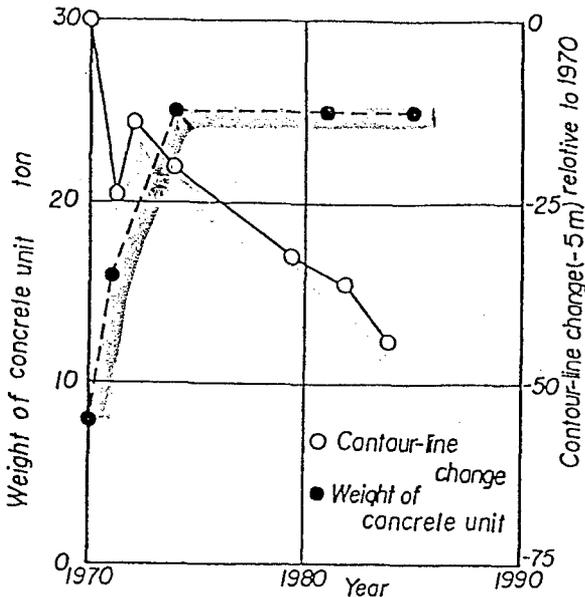


Figure 4 Changes in concrete unit weight used and contour-line of water depth of 5m.

recovered for erosion control (Tsuchiya, 1987).

### 3. Numerical Simulations of Changes in Shoreline and Nearshore Currents and Their Control

By use of one line models for shoreline change, calculation was made to predict changes in shoreline in a model condition. One of the numerical results of shoreline change by the breakwaters is shown in Figure 6 where the incident wave conditions being 4 m in wave height, 7 sec in wave period and 10 degrees in wave direction from the north are given. It can be easily understood by the time sequence in shoreline change that the shoreline change occurs continuously to extend in the downstream direction, and that as shown in Figure 2 beach change severely takes place in the area where the two common causes for beach erosion exist.

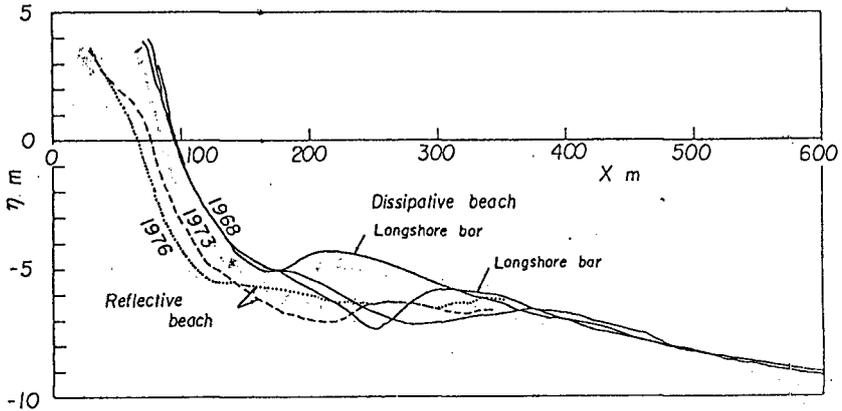


Figure 5 Changes in beach profiles at Ogata coast.

As discussed in Figure 2, the breakwaters generally induce change in the nearshore currents. By use of a nearshore current model numerical calculations were made to find changes in wave field in the area where breakwaters exist and in the

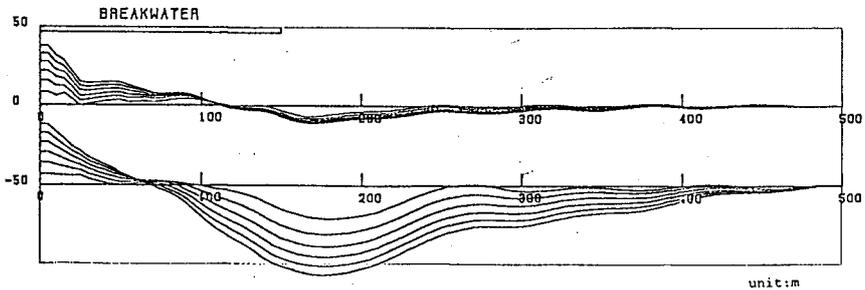


Figure 6 Numerical result of shoreline change due to blockage of longshore sediment transport.

structure induced nearshore currents. Figure 7 shows an example of the numerical calculations where the incident wave conditions being 4 m in wave height, 7 sec in wave period and normal wave incidence were given. In the numerical simulations the

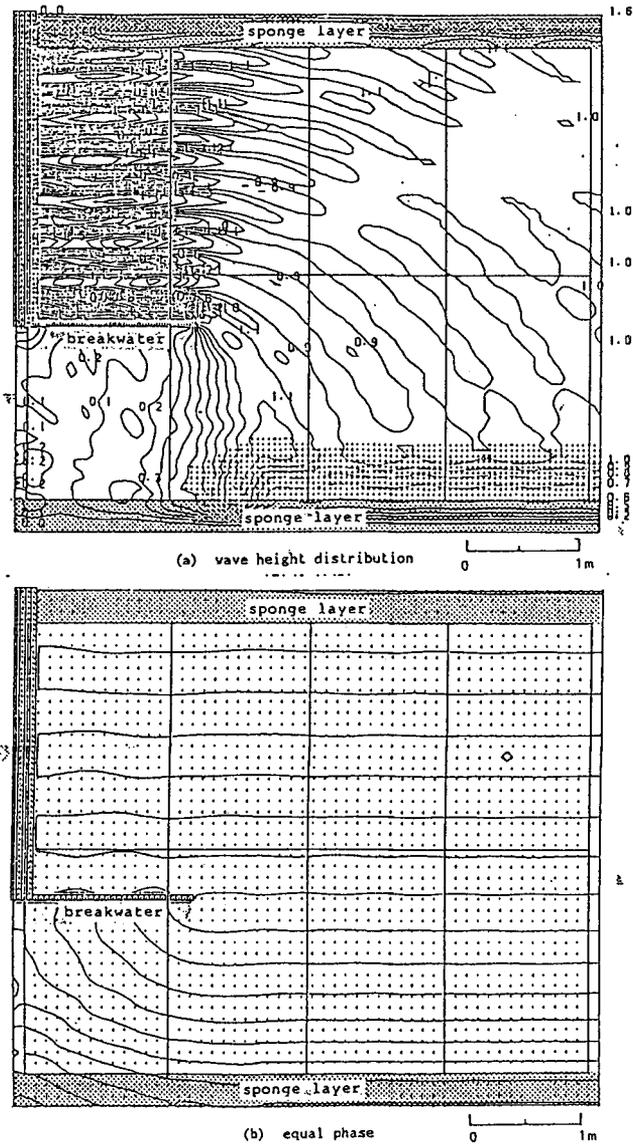


Figure 7 Numerical result of wave field in the area where a breakwater exists.

so-called sponge layer was employed both in the offshore and shoreline areas. The upper figure shows the wave height distribution and the lower figure does the equi-phase lines. Using this wave field nearshore currents were calculated as shown in Figure 8. It is clearly shown that there clearly exist a couple of nearshore

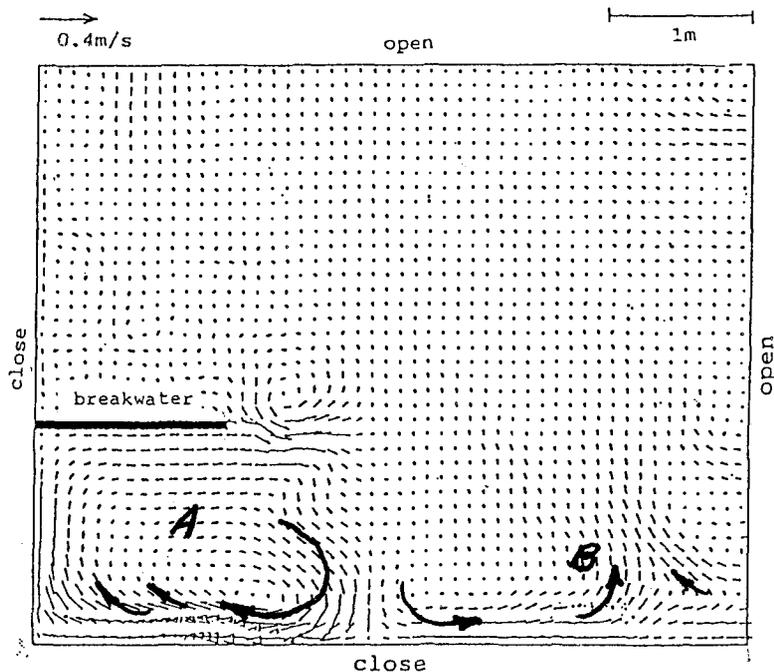


Figure 8 Numerical result of nearshore currents in the area where a breakwater exists.

circulations, which are shown by A and B exist in the area behind the breakwaters. In order to control beach erosion caused by the changing wave field, these circulation must be reduced. Numerical consideration was made of changing nearshore currents by a small groin. Figure 9 shows the wave field in the case where a small groin is constructed in the nearshore circulation A. Using this wave field nearshore circulation was calculated as shown in Figure 10. It is concluded that the groin is

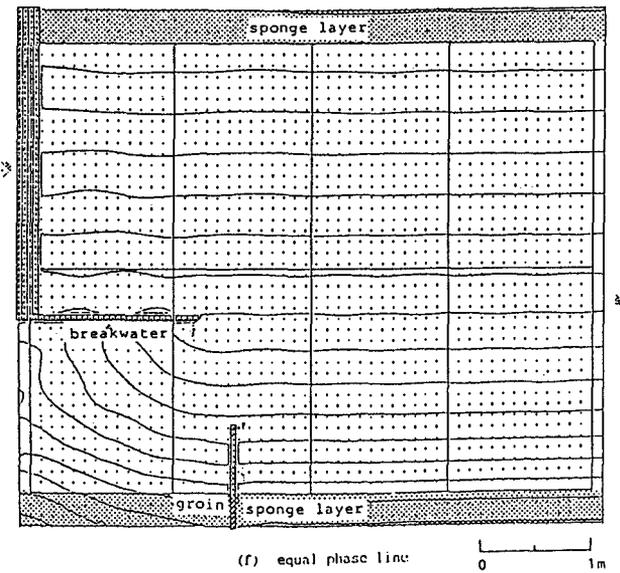
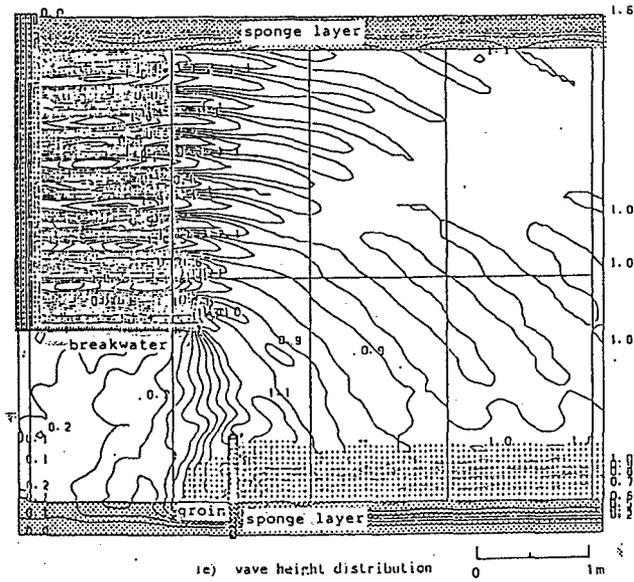


Figure 9 Numerical result of wave field in the area where a breakwater and groin exist.

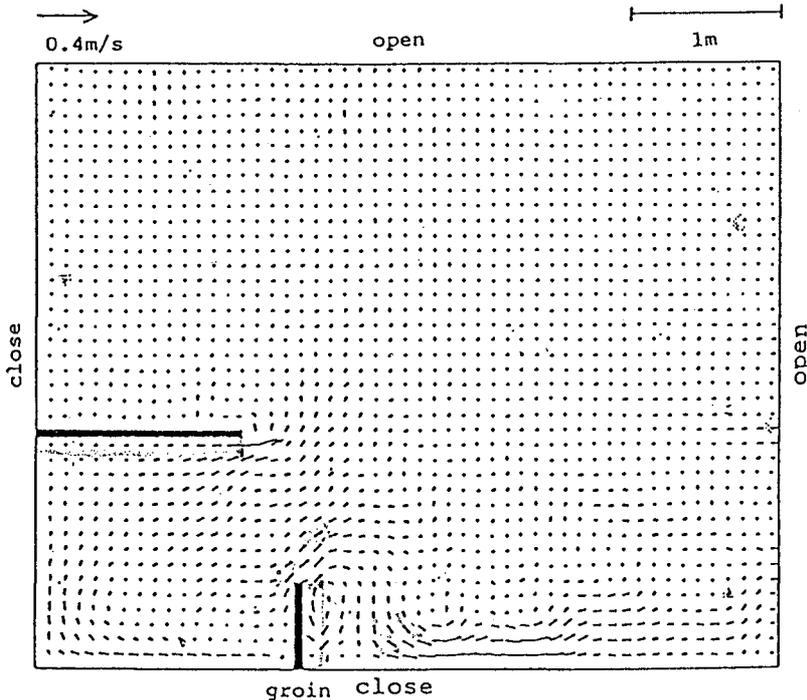


Figure 10 Numerical result of nearshore currents in the area where a breakwater and groin exist.

very effective to reduce the nearshore circulations. In the construction of offshore structures such as breakwaters, the beach erosion due to the change in wave field may be controlled by constructing a small groin in the area behind the breakwater.

#### 4. The Formation of Stable Sandy Beaches

The authors have demonstrated that, as schematically shown in Figure 11 there exist static and dynamic equilibrium sandy beaches which are sometimes identified as static and dynamic stable ones (Tsuchiya, Silvester and Shibano, 1979 and Silvester, Tsuchiya and Shibano, 1982). The static stable beach and its application to beach erosion control was first proposed by Silvester(1956). He proposed the geometry of stable beaches as shown in Figure 12 where the solid curve

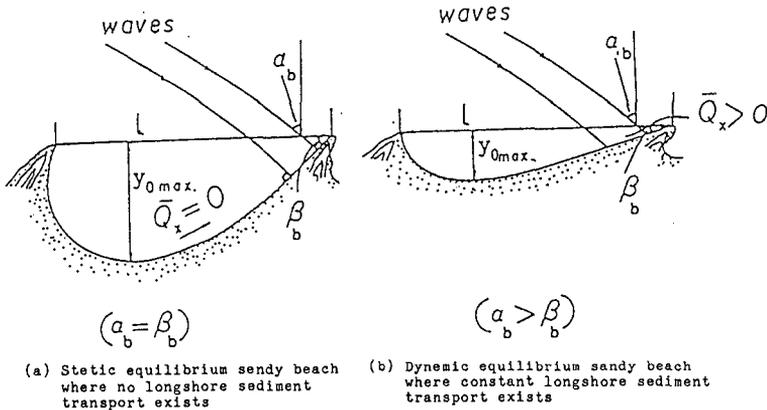


Figure 11 Schematic diagram of static and dynamic stable beaches.

indicates his empirical formula for static sandy beach and the values shown are field data of stable sandy beaches such as those in the Amanohashidate beach and others (Tsuchiya, Silvester and Shibano, 1979). Recently a theory of the formation of stable sandy beaches was proposed by Tsuchiya and Refaat (1990) by applying the non-equilibrium longshore sediment transport and equation of continuity of beach change. It was concluded by the theory that the stable sandy beaches can be formed by the upstream and downstream boundary conditions in the formation of sandy beaches. The existence of the stable sandy beaches was qualified and theoretical configuration of the stable sandy beaches were also obtained. Figure 12 shows an example of the theoretical configurations of dynamic stable beach which are compared with those of sandy beaches formed between two groins at the Amanohashidate Beach where a sediment amount of about 4,000 m<sup>3</sup> is bypassed annually. It is therefore noted that, based on this theoretical background stable sandy beaches can be formed by two headlands for beach erosion control.

##### 5. Application of the Headland Control Methodology to Ogata Coast

As already described in Section 2, the Ogata coast has being eroded severely

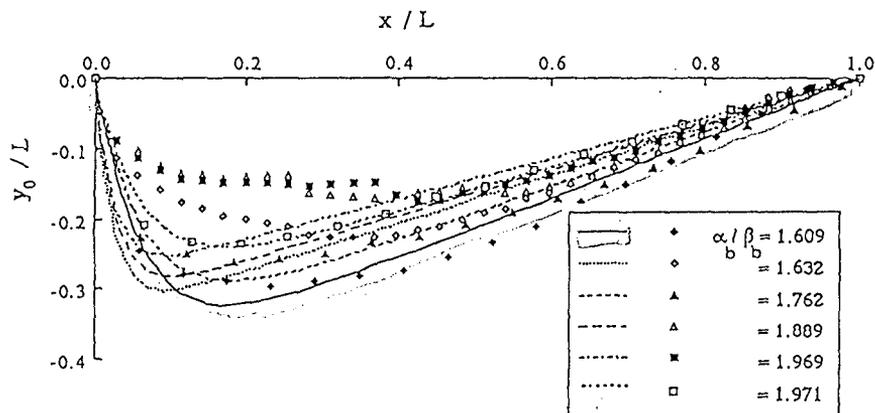


Figure 12 Comparison between theoretical and measured configurations of dynamic stable beaches.

following the construction of the breakwaters of Naoetsu Harbour. Numerous methods of beach erosion control by coastal structures have been implemented including sea dikes and offshore breakwaters. The reflection of incident waves due to such structures, as already shown in Figure 5, can transform a dissipative sandy beach with a longshore bar, into a reflective beach without a longshore bar, thus accelerating the erosion process (Tsuchiya, 1987). This particular situation may be labeled as a third main cause of structure induced shoreline erosion.

Sandy beaches are thought to possess a stable configuration based on the properties of the predominant waves and beach sediments. This stable configuration is frequently altered by man's interaction, from its normal dissipative beach state to a reflective one, and erosion will proceed only until its normal dissipative state recovers. The three previously described main beach erosion causes are harnessed by the previously mentioned headland control, thus providing the necessary influence to restore and retain the dissipative beach form. Based on the theoretical background of the formation and existence of static and dynamic stable sandy beaches, the headland control methodology can be applied for beach erosion control at the Ogata coast. In order to examine the principal methodology of erosion control mentioned above, numerical and physical simulations of the beach change were carried out. By use of

the results of these investigations, the proposed erosion control method is shown in Figure 13 as a series of dissipative sandy beaches to be formed by man-made

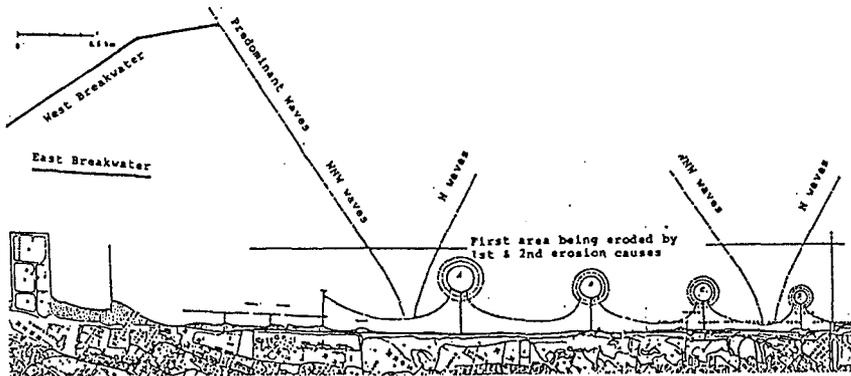


Figure 13 The proposed beach erosion control for Ogata coast by headland control methodology.

headlands. In this proposal, due to the economical sense in the construction, the man-made headlands are constructed slightly offshore the breaker depth and the water depth at which the headlands are constructed decreases in the downstream direction. The dimensions of the headlands and their spacings, as shown in the figure, are decided according to the first and second beach erosion causes. At the downstream end their dimensions become small, as shown in Figure 14, their influence must be vanished to reach the natural situation. Additionally a sediment amount of about  $5,000 \text{ m}^3$  per year may be bypassed. The headlands are of T-shaped groin type with a mild offshore face. A couple of these are now under construction.

## 6. Conclusion

In this paper, structure induced beach erosion causes were classified into the first and second, and their erosion processes were examined with a special reference to the Ogata coast facing the Japan Sea and by numerical simulations of shoreline and nearshore currents. In the headland control methodology, the theoretical background of the formation and existence of stable sandy beaches was very briefly described based on our current investigation.

Based on the theoretical background of the existence of stable sandy beaches, a series of stable, dissipative sandy beaches were proposed and they are to be formed by the headland control methodology.

### References

Silvester, R.: Headland defense of coasts, Proc. 15th ICCE, ASCE, 1972, pp. 1394-1406.

Silvester, R., Y. Tsuchiya and T. Shibano: Zeta bays, pocket beaches and headland control, Proc. 17th ICCE, ASCE, 1980, pp. 1306-1319.

Tsuchiya, Y., R. Silvester and T. Shibano: Beach erosion control by headland control methodology, Proc. 26th Japanese Conf. Coastal Engg., JSCE, 1979, pp. 191-194(in Japanese).

Tsuchiya, Y.: Beach erosion control, Proc. JSCE, No. 387/II-8, 1987, pp. 11-23(in Japanese).

Tsuchiya, Y. and H.E.A.A. Refaat: A theory of the formation of stable sandy beaches, Jour. Water Way., Port , Coastal & Ocean Engg., ASCE, 1990(in review).