VARIATION OF FORESHORE DUE TO DETACHED BREAKWATERS

by

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1. INTRODUCTION

As coastal areas are very valuable for mountainious Japan, many countermeasures against beach erosion have been taken. The length of seawalls for beach erosion amounts to 5,600 kilometers, which is much longer than the length of seadikes for flood tide, which is 2,900 kilometers. In addition, 10,000 groins and 2,300 detached breakwaters have already been constructed for beach erosion. Especially, we used many detached breakwaters for the last ten years.

Fig.1 showes the increase of total length of seawalls and seadikes for the last twenty years.

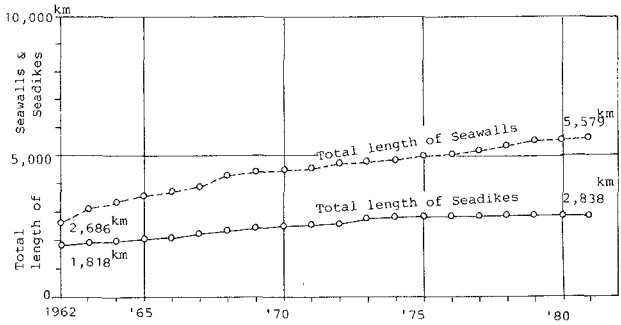

Fig.1 Increase of seawalls and seadikes in Japan.

The rate of the increase of seawalls and seadikes are as follows respectively.

seawalls : 5,579 km / 2,686 km = 2.08

seadikes : 2,838 km / 1,818 km = 1.56

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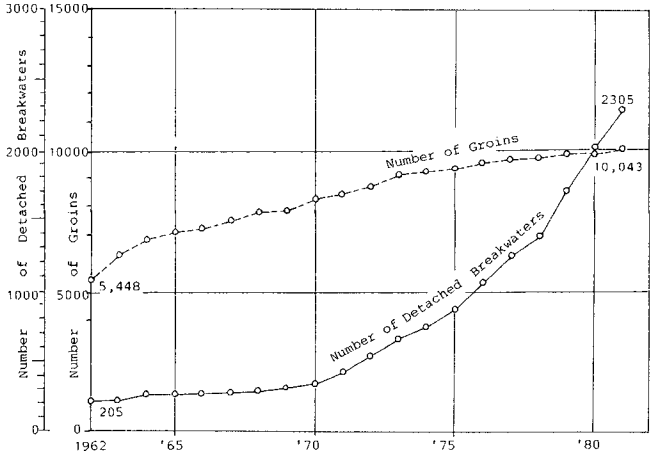

Fig. 2 Increase of groins and detached breakwaters.

Fig.2 showes the increase of number of groins and detached breakwaters for the last twenty years. The rate of the increase of groins and detached breakwaters are as followes respectively.

groins : 10,043 / 5,448 = 1.84

detached breakwaters : 2,305 / 205 =11.24

It was in the year 1966, that the author proposed a new detached breakwater system as a new countermeasure against beach erosion. After the year 1970, number of detached breakwaters showes sharp increase in contrast with that of groins in Fig.2.

Here, I take the Kaike coast as an example of the detached breakwater system, and show the variation of the tombolo and sea bed in the foreshore due to the detached breakwaters.

2.OUTLINE OF THE KAIKE COAST

Kaike coast locates on the root of the Yumiga-hama Peninsula which is believed to be a sand spit formed by sand deposition discharged from the Hino River that fed sand to this coast.

Huge waves from the east-northeast are refracted in Miho Bay as shown in Fig.3. These refracted waves give rise to the longshore current in the western direction along the Yumiga-hama Peninsula.

In the 1910's, the shoreline of the Kaike coast was advancing offshoreward year by year, and at that time, Kaike coast had sandy beach of width of more than 200 meters.

About 1920, iron sand collecting for Japanese traditional steel making was abondaned in the upper reaches of the Hino River. In addition to this, a number of Sabo dams and agricultural weirs were constructed

along the Hino River. These facts brought a remarkable reduction in sediment supply from the Hino River, and the advancing tendency of the Kaike coast turned into the receding one. The shoreline at Kaike has receded more than 200 meters during the last half century.

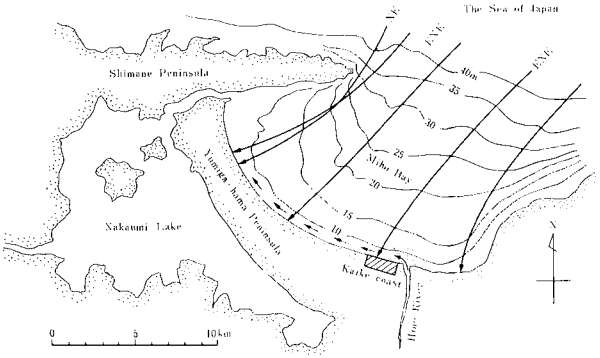

Fig. 3 Kaike coast and longshore current.

In 1947, after the War, the first experimental groin composed of rubble stones was constructed. Between 1949 and 1954, thirteen groins composed of large scale concrete blocks were constructed. As seen in Fig.4, the function of groin system gave satisfactory effect in 1954. In 1955, the Kaike coast was heavily eroded by giant waves caused by a typhoon and shoreline was in full retreat.

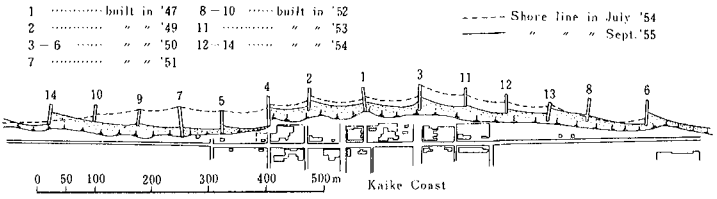

Fig. 4 After completion of groin system, Kaike was eroded.

After the heavy erosion due to a typhoon, seawalls along the shoreline were constructed. Based on the technical consideration in those days, concrete stepped face seawalls illustrated in Fig.5 have been adopted as suitable prevention structures against beach erosion in Japan. The construction of seawalls was made between 1955 and 1961. For several years after the completion of the seawalls, the Kaike coast looked like a stable beach, where very wide sandy beach extended in front of the seawalls.

Even when the Kaike coast seemed to be stable, a large amount of beach sediment was carried offshoreward with every attack of severe wind

waves in winter. After a lull in beach retrogression, Kaike coast began to retreat again in the early 1960's. Incident waves directly struck and overtopped seawalls. In order to reduce wave overtopping, wave defence works composed of artificial concrete blocks were constructed in front of the seawalls.

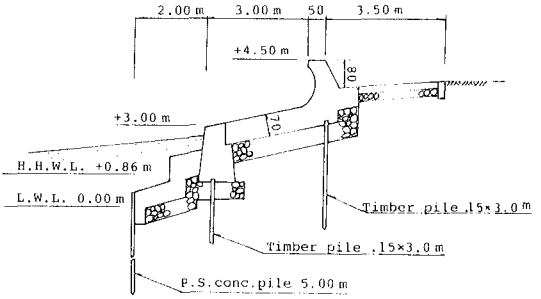

Fig. 5 Concrete stepped face seawalls was adopted.

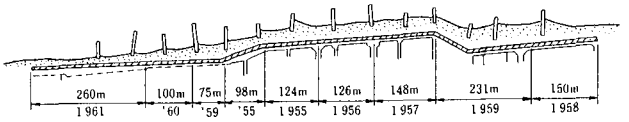

Fig. 6 Seawalls were constructed between 1955 and 1961.

As severe waves have repeatedly hit the Kaike coast, the combination system of groins and seawalls with wave defence works has shown its inadeqacy in the protection function against beach erosion. When incident waves approach normally to the shoreline, some portions of incident wave energy are reflected from the seawalls. This wave reflection results in considerable scour in front of seawalls and receding waves take away beach sediment offshoreward. Due to these unfavourable effects by the seawalls, groins and wave defence works settled and scattered. In the early 1970's, the Kaike coast was severely eroded again.

3. PROPOSAL OF A DETACHED BREAKWATER SYSTEM

Countermeasures against beach erosion in Japan was studied on a trial-and-error basis until the recent years. Many prevention works, such as seawalls and groins, have been constructed during the past thirty years. However, as the results of field investigations, it has become clear that, seawalls and groins have not been necessarily useful for beach erosion prevention, and adversely, in some cases they have promoted the beach erosion. Then, the author proposed a detached breakwater system as a new measure.

The first experimental work of this system was carried out on Isizaki coast, Hokkaido Prefecture, under the direction of the author in 1966. Soon after the completion of the work, the tombolo was formed behind the breakwater, and the system was effective in the restoration of shoreline. Generally, of cause, construction work of the detached breakwaters is not easy and maintenance cost is also high, when they are constructed on steep and deep sea bed.

The detached breakwater system at Kaike coast was proposed by the author as a new countermeasure against the beach erosion. However, the planning position of the breakwaters had considerably deeper depth than those where the previous experimental breakwaters were constructed. Therefore, the adoption and positioning were determined after long series of field surveys and researches.

4. CONSTRUCTION OF THE DETACHED BREAKWATER SYSTEM IN KAIKE COAST

In June 1971, the construction of the first breakwater in Kaike was commenced, and was completed in September of the same year. The breakwater with the length of 150 meters was constructed 110 meters offshoreward from the seawall where the water depth was about 5 meters. The breakwater as seen in Fig.7 was composed of rubble stones and armoured by tetrapods.

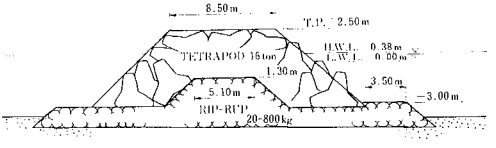

Fig. 7 Cross-section of the breakwater in Kaike

The breakwater has been quite effective in trapping sand transported from offshore zone and in forming a large scale tombolo behind it. The thickness of deposited sand was about 4 meters at the apex of the tombolo, and about 2 meters in front of the seawall.

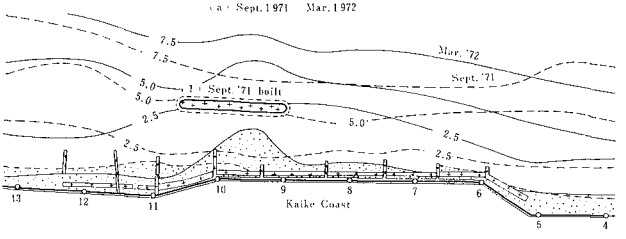

Fig. 8 The first breakwater was constructed in 1971.

Encouraged by the successful result of the first experimental detached breakwater, three more breakwaters were constructed as planned in the following three years.
The breakwaters, whose lengths were 150 meters, were positioned at equall space of 50 meters. The No.1 breakwater was constructed in downdrift zone of the longshore current along the Kaike coast, and the No.2 was constructed on the updrift side of the No.1 breakwater.
In progress of the No.2 breakwater construction, beach retrogression in the downdrift zone of the No.1 breakwater was observed.
To eliminate the undesirable effects by the Nos.1 and 2 breakwaters, the No.3 breakwater was sited on the downdrift side of the No.1 breakwater. The No.4 was in the updrift side of the No.2 in order to increase the covering area.

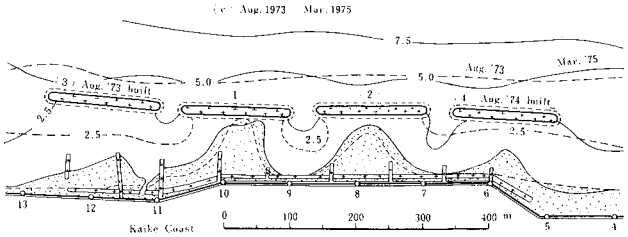

Fig.9 The No.4 breakwater was constructed in 1974.

During the later seven years, seven breakwaters were constructed annually, one breakwater every year respectively. In 1981, the detached breakwater system in the Kaike coast has completed with eleven breakwaters construction.

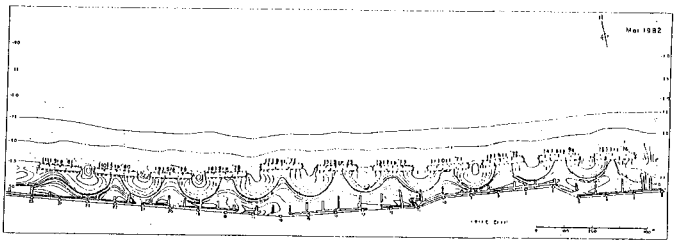

Fig. 10 The detached breakwater system has completed in 1981.

5. TRANSFORMATION OF SEA BED

Before the construction of the breakwaters, there were considerable transformation in the sea bed configuration. However, after the construction, the transformation of the sea bed have become very little. Fig.11 and Fig.12 are typical example of survey results for profile line No.8 which is located at the center of the No.2 breakwater.

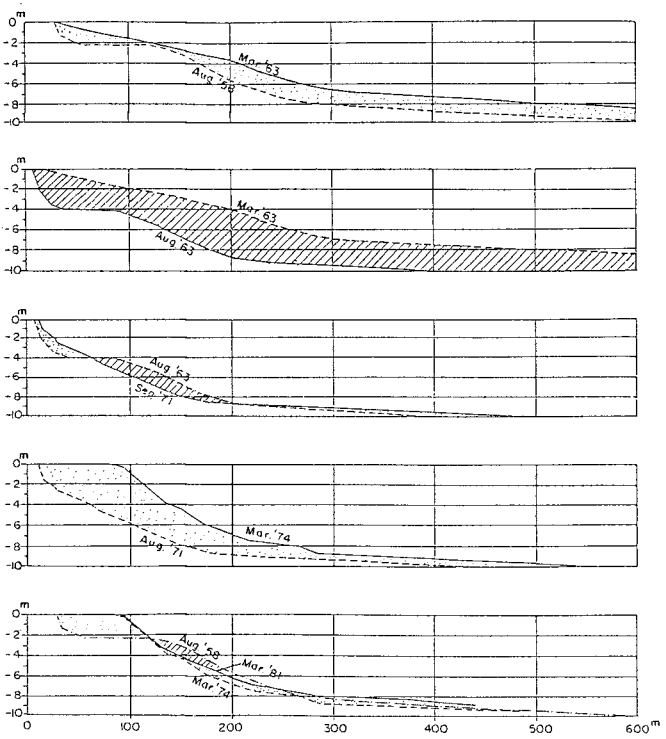

Fig. 11 Transformation of sea bed on the section No.8

The survey have been executed twice a year, spring and autumn. Fig.11 shows some striking transformations of the sea bed extracted from the annual survey results.

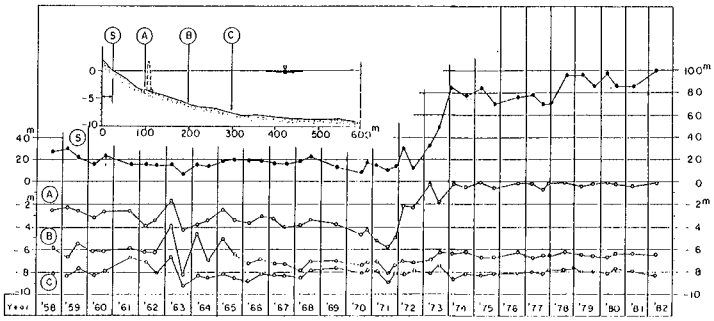

Fig. 12 Annual transformation of shoreline and sea bed on No.8

The greatest transformation of the sea bed configuration came about during March and Autumn in 1963. Maximum erosion of the sea bed amounts to about five meters in depth on the point 200 meters distant from the seawall.

In Fig.12, (S) represent the horizontal distance of shoreline from the seawall, and (A), (B) and (C) the water depth from the still sea water level at the points of 100, 200 and 300 meters distant from the seawall. The No.2 breakwater was constructed in front of the section No.8 in August 1972. Right after its construction, the sea bed at the point (A) indicated a remarkable shoaling, and the shoreline (S) greatly advanced. Since then the shoreline and sea bed have been very stable in contrast with that before the construction of the breakwater.

6. VARIATION OF SHORELINE AND EQUI-DEPTH LINE

Figs.13 to 20 show the variation of shoreline and equi-depth line before and after the construction of the detached breakwaters. Before the construction, there was considerable variation in the shore line and equi-depth line. However, since the construction, the variations of sea bed have become very little, and a lot of sand were transported from the offshore zone to the nearby areas of the breakwaters not only onshore side but also offshore side of the breakwaters.

Still more strange to say that, the equi-depth line at the offshore sea bed has become very smooth, uniform and paralleled to the line of the row of detached breakwaters.

We can not explain the reason of this flat and plane sea bed even now.

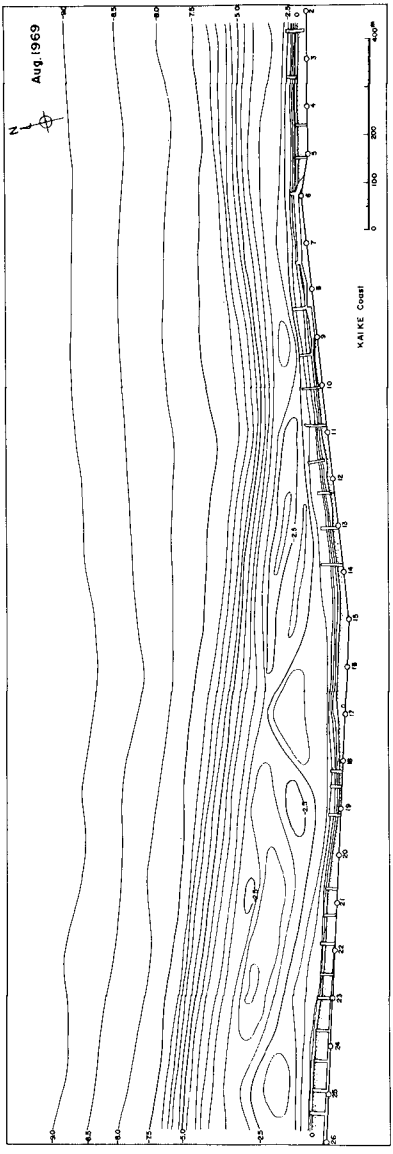

Fig. 13 Sea bed before the construction of the detached breakwater system in Kaike coast. There were many bars and troughs in the foreshore zone. These bars and troughs moved about every time the surveys had been executed.

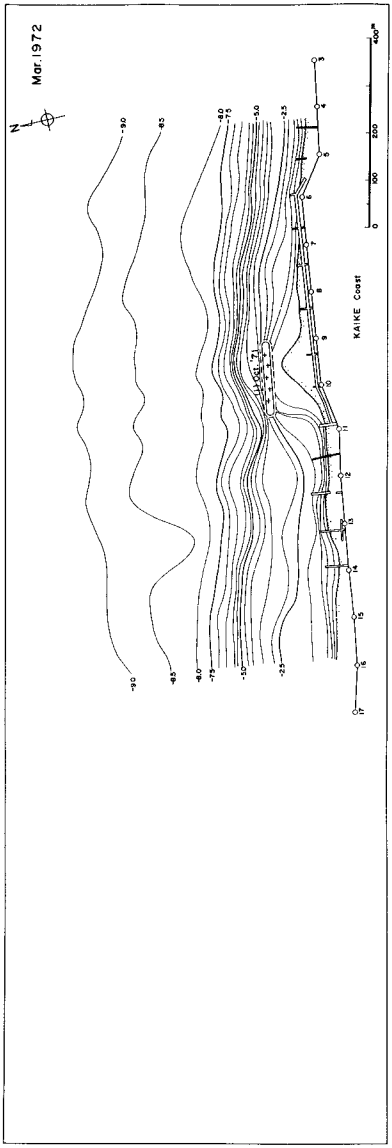

Fig. 14 The sea bed six months after the construction of the No.1 detached breakwater. A large tombolo developed behind the breakwater, and the shoreline in front of the station Nos.11 to 16 advanced offshoreward.

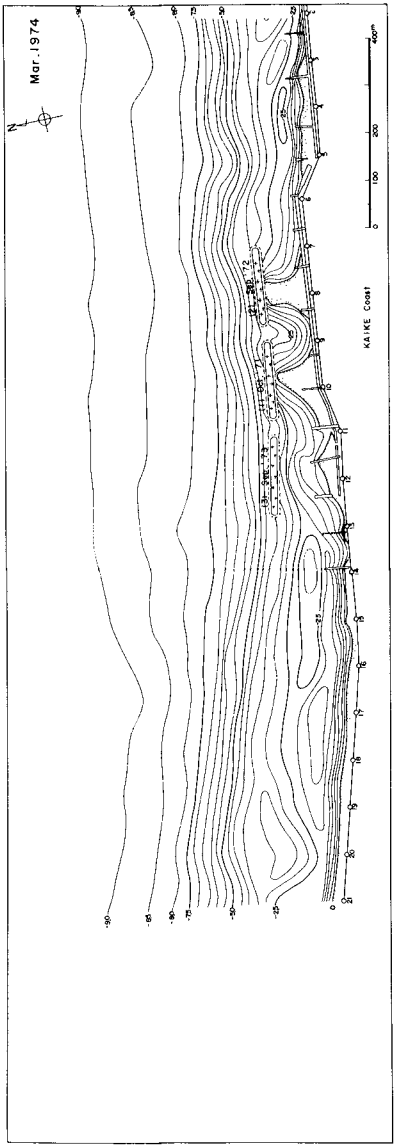

Fig. 15 Two years after the Fig.14. Three breakwaters are constructed, and there are three tombolos behind the each breakwaters. The left breakwater is the latest one, and the tombolo of it is still small in contrast with another two previous tombolos. The direction of the longshore current in Kaike coast is westward as previously stated, the rightmost tombolo is usually larger than the remaining left side tombolos.

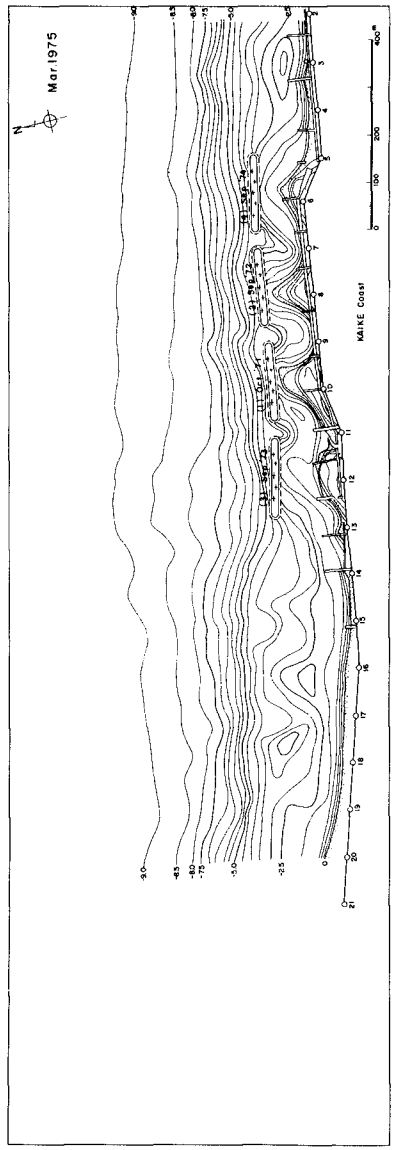

Fig. 16 One year after the former figure. No.4 breakwater was constructed six months before, and its tombolo is yet small though it is situated on the rightmost. The equi-depth line of -5 m advanced offshoreward a little in contrast with the Fig.13, before the construction of detached breakwaters.

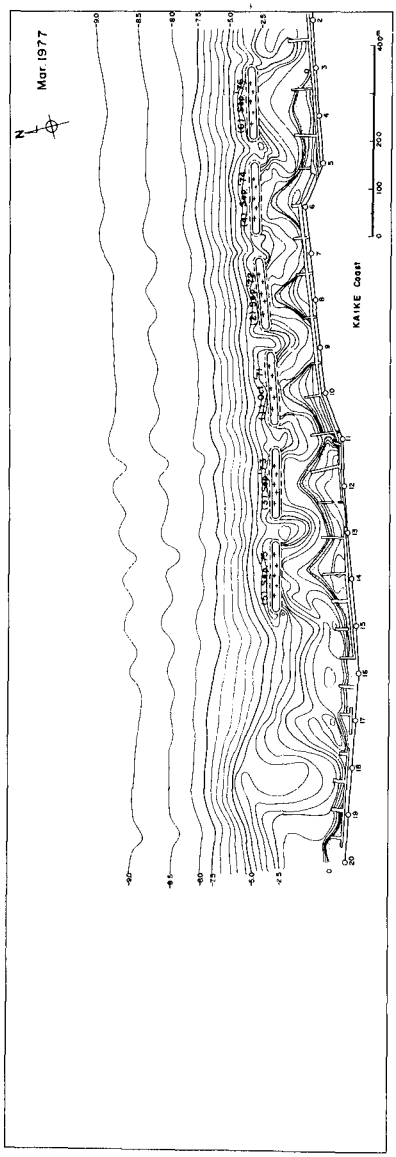

Fig. 17 Two years after the former figure, and the No.5 and No.6 breakwater were constructed during the two years. The tombolos developed respectively except the latest No.6's one. The equi-depth lines from -5m to -9m have become smooth and parallel gradually. However, the foreshore in front of station Nos.15 to 20 are left unstable.

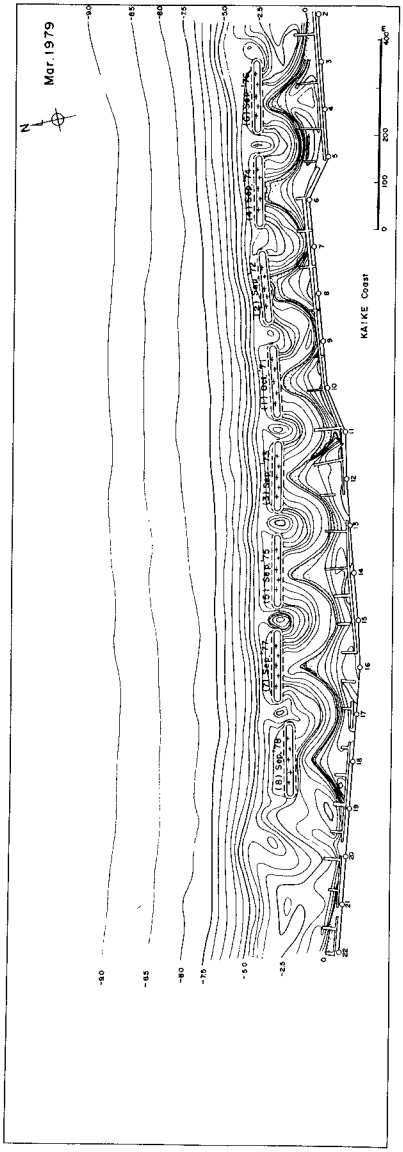

Fig. 18 Further two years after the former figure. Nos.7 and 8 breakwaters are constructed, and they have good-sized tombolos respectively. The equi-depth lines of the offshore zone have become smooth in succession.

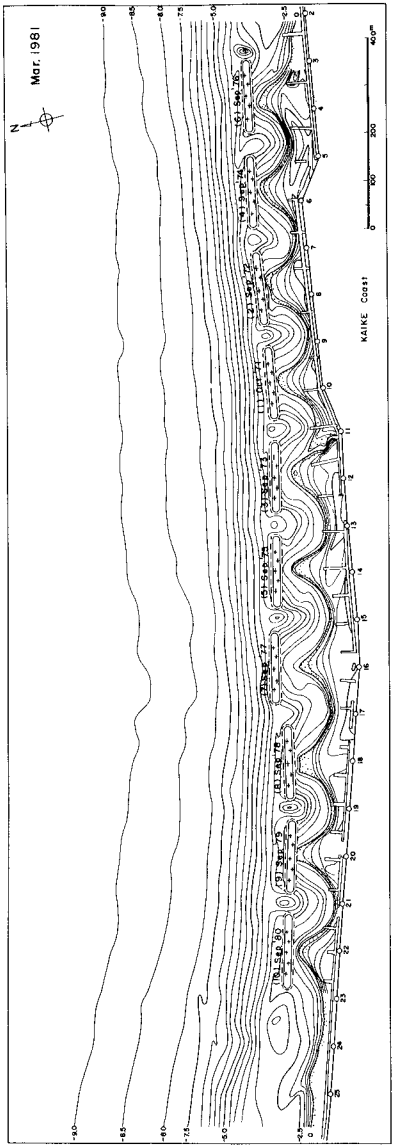

Fig.19 Ten breakwaters were constructed until 1980. Each breakwater has a good sized tombolo respectively, and the offshore sea bed has become stable and smooth.

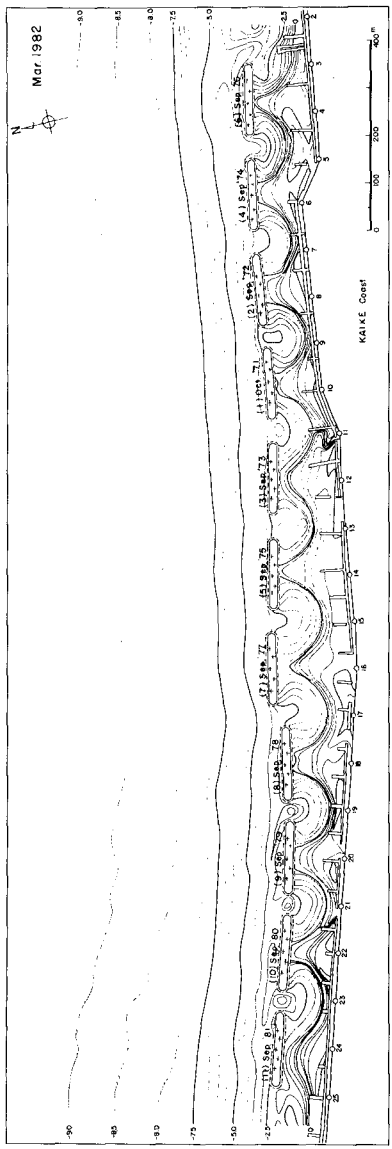

Fig.20 The Detached Breakwater System in Kaike Coast has completed in 1981. Eleven breakwaters are constructed, and all of them are successful. Each breakwater has a great tombolo behind it and all of these tombolos are very stable in spite of the every winter's huge waves. The equi-depth line in the offshore zone have become more smooth, uniform and paralleled to the line of row of detached breakwaters.

7. VOLUMETRIC CHANGES IN THE SEA BED

Table 1 shows volumetric changes in the beach profiles calculated from the survey results during the period from September 1971, before the construction, to March 1982, after the construction of the eleventh breakwater.

Table 1 Volumetric changes in the sea bed after the construction of the detached breakwaters.

Number of breakwater	Onshore side of breakwater	Offshore side of breakwater	Total volume
No. 1 breakwater zone	+ 35,800 m³	+ 86,100 m³	+121,900 m³
No. 2 breakwater zone	+ 48,800	+ 89,200	+138,000
No. 3 breakwater zone	+ 18,300	+ 49,200	+ 67,500
No. 4 breakwater zone	+ 45,000	+ 84,200	+129,200
No. 5 breakwater zone	+ 18,900	+ 21,800	+ 40,700
No. 6 breakwater zone	+ 28,900	+ 95,400	+124,300
No. 7 breakwater zone	+ 24,800	- 19,500	+ 5,300
No. 8 breakwater zone	+ 15,300	- 43,700	- 28,400
No. 9 breakwater zone	+ 13,400	- 31,600	- 18,200
No.10 breakwater zone	+ 28,300	- 41,100	- 12,800
No.11 breakwater zone	+ 7,400	- 68,700	- 61,300
Total	+284,900 m³	+221,300 m³	+506,200 m³

It is noticed from this table that a considerable volume of sand has been deposited on the sea bed in the onshore and offshore zones of the breakwaters since the construction schme of detached breakwaters commenced. However, there are some erosion in the offshore zone of station Nos.7 to 11. These areas correspond to down drift of the littoral transport in Kaike coast.

Now, Kaike coast has gained a stable sea bed and shoreline by virtue of this detached breakwater system.

Photo 1 The aerial view of the Kaike coast and four detached breakwaters on October 1974.

Photo 2 The detached breakwater system in Kaike Coast has completed in 1981. The photograph shows the Kaike coast just after the eleventh breakwater construction,on Octover 15th 1981.

8. OTHERS

Although the detached breakwaters are very effective in the shoreline protection, some problems involved in this system still remain to be solved. The most important problem is subsidence of the breakwaters. Up to now, the subsidence of the breakwaters in Kaike coast is fortunately considered to be moderate, but it is urgently needed to develop methods by which the speed of subsidence can be minimized.

Hereupon, our efforts must be continued without a break, so that the re-created beach may not be lost again.

(END)