CHAPTER 81

VARIATION OF TOPOGRAPHY OF SEA-BED CAUSED BY THE CONSTRUCTION OF BREAKWATERS

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INTRODUCTION

In Japan, many breakwaters or jetties have been constructed in the sandy beach from the past decade for new ports to cope with the development of industry It is needless to say that the construction and prolongation of breakwaters or jetties cause the change of bottom-topography in their vicinity, but many points remain indistinct on this change of bottom-topography

In this paper, some general properties on the change of the topography of sea-bed caused by the construction of breakwaters are discussed on the basis of the hydraulic sounding maps of several ports and the results of model tests The terminology used in this paper is given in Figure 1

VARIATION OF SEA-BED TOPOGRAPHY AT KASHIMA PORT

Port Kashima is located on the coast of Kashimanada facing the Pacific Ocean, as shown in Figure 2 Waves of the coast of Port Kashima approach from the direction almost perpendicular to the shore line, though the southerly waves exceed a little than the northerly waves The maximum significant wave observed in the period from 1961 to 1968 is 5 m in height and 10 3 sec in period The mean diameter of bottom material is about 0 15 mm in the offshore and 0 6-0 2 mm in the inshore The alongshore littoral transport per year is estimated to be the order of 600,000 cubic meters both in the southerly and northerly directions on the basis of the hydraulic sounding data and the calculation of wave energy, though the littoral transport from the south exceeds a little that from the north in the sum of several years

Figure 3 and 4 shows the position of equi-depth lines for each summer from 1963 to 1968

In July 1963, the down-side breakwater and the jetty of the working basin were constructed as far as the alongshore bar The shore line advanced upside of the jetty and severe scouring was seen in the vicinity of the tip of the jetty

In July 1964, the working basin was completed and the up-side breakwater was constructed for nearly 200 m These parts of the breakwater was constructed with rouble stones The equi-depth lines of 0 to 3 m advanced near the jetty of the working basin on the up-side,

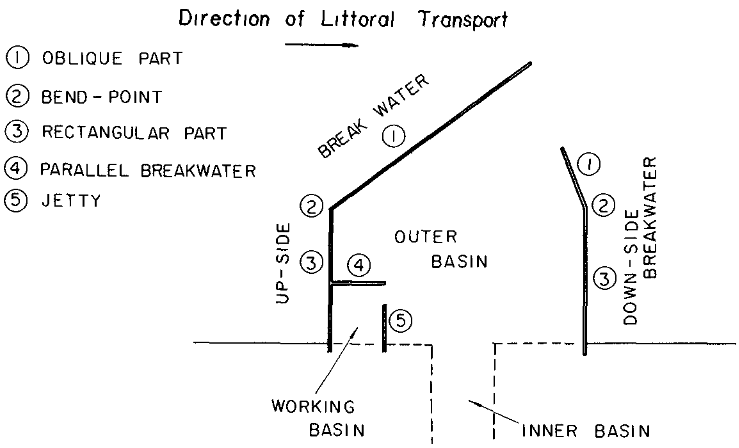

Figure 1 Terminology of each part.

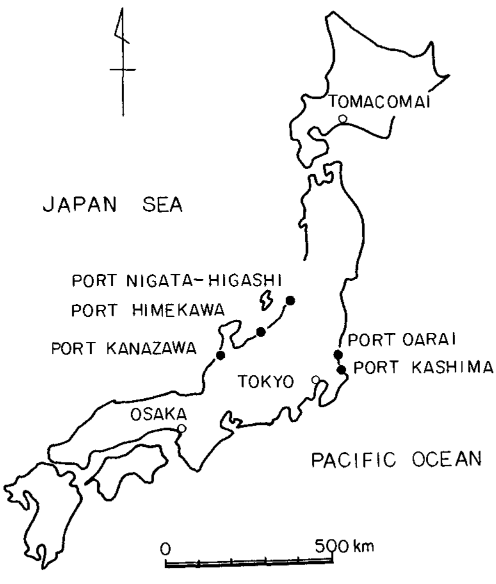

Figure 2 Position of ports

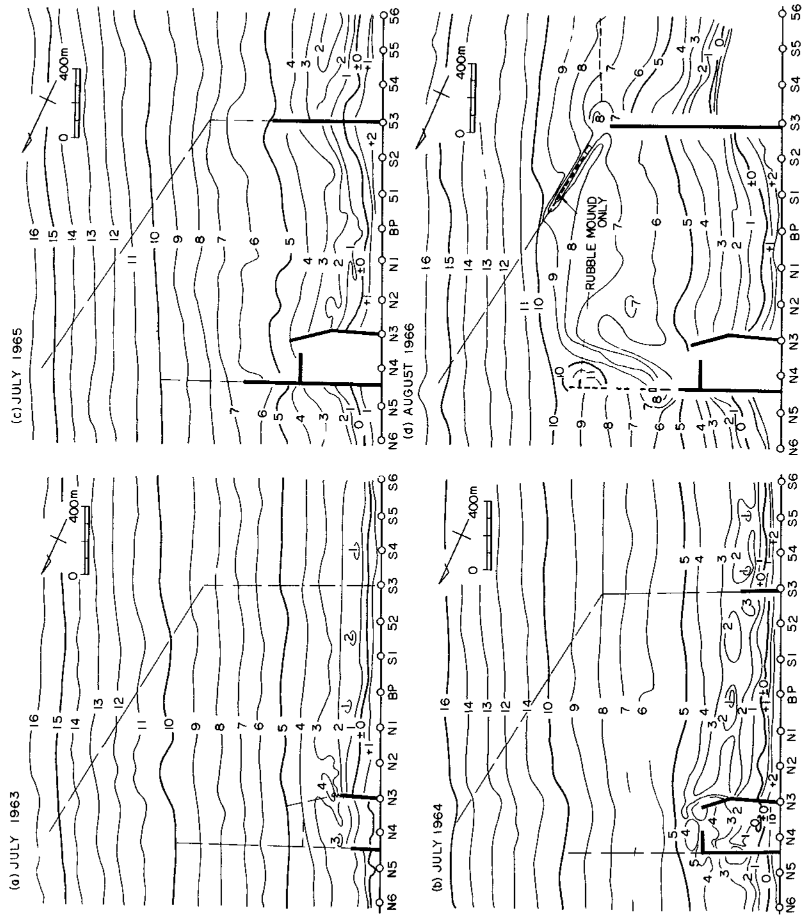

Figure 3 Variation of bed-topography at Port Kashima, (a).

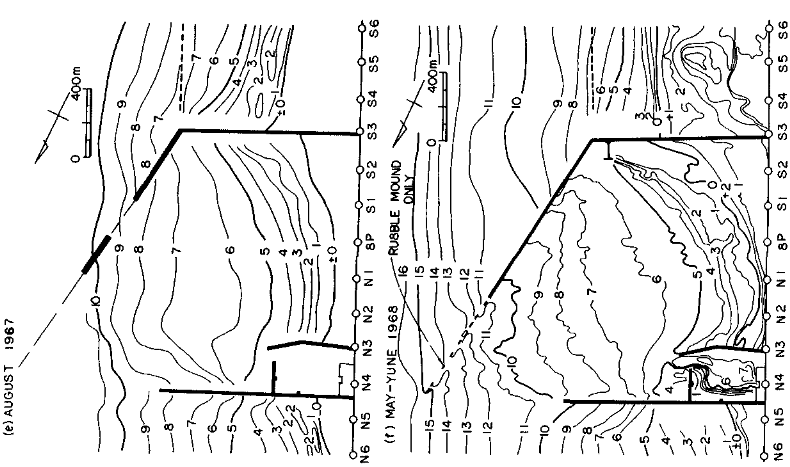

Figure 4 Variation of bed-topography at Port Kashima, (b).

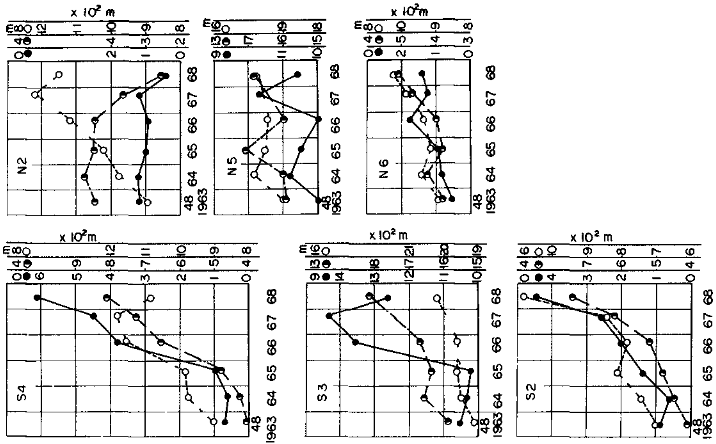

Figure 5 Time change of distances of depth-lines from the datum line at Port Kashima

and alongshore bars advanced up-side of both jetty and breakwater and became indistinct down-side of them

In July 1965, the equi-depth lines shallower than 5 m in the outer basin move landward, especially at the center, near to the datum point BP The longshore bar remained distinct on the out-side of the up-side breakwater, but is indistinct in the outer basin and on the down-side of the down-side breakwater The advancement of shoreline out-side of the down-side breakwater is due to the discharge of materials dredged in the working basin

In August 1966, the portion between the tip in July 1965 and the bend point of the up-side breakwater was constructed with concrete blocks Thick dotted lines indicate the portion where only the rubble mound base of caissons is constructed Scour along this rubble mound was more severe on the inside than on the out-side of it Especially, the inside portion along that of the down-side breakwater is scoured remarkably and remarkable shoaling is seen within this scoured portion The central portion of the outer-basin was shoaled and the equi-depth lines shallower than 5 m moved further landward than in 1965 The remarkable shoaling out-side of the up-side breakwater is due to the discharge of the materials dredged from the inner basin The dredging of inner basin started in June 1965 by dredgers which entered in the part of the inner basin dredging from the working basin through the broken line shown in Figure 6 Therefore, the shoreline between the jetty and downside breakwater (between datum points S3 and N3) was not disturbed by the dredging

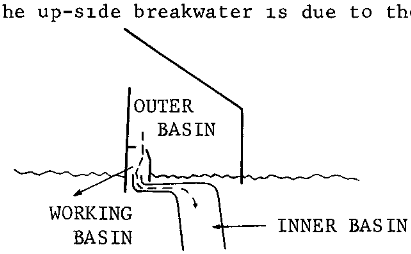

FIG 6

In August 1967 and May - June 1968, the equi-depth lines of 6 meters and less became still more landward-convex in shape and that of 7 m and more became seaward-convex in shape with the prolongation of the breakwaters Morever, he most receded point of shoreline was shifting towards the working basin The equi-depth lines deeper than 7 meters outside of the up-side breakwater bulged offshoreward, on the offshore of the oblique part of the breakwater The remarkable shoaling outside of the rectangular part of the up-side breakwater was mainly due to the discharged materials mentioned above, but some part of them passed through the breakwater into the basin and deposited in the vicinity of datum points S1 to S3

Figure 5 shows time change of the distances of 0 m, 4 m, 8 m and other depth-lines from the datum line S6 to N6 at the points S4, S3, S2, N2, N5 and N6 The time change graph serves to make more clear the characteristics of the bottom changes described above For example, at S2, the line of 0 m receded in July 1964 when the up-side breakwater was about 200 m in length and then advanced steadily and remarkably until 1968, the depth-lines of 4 and 6 m

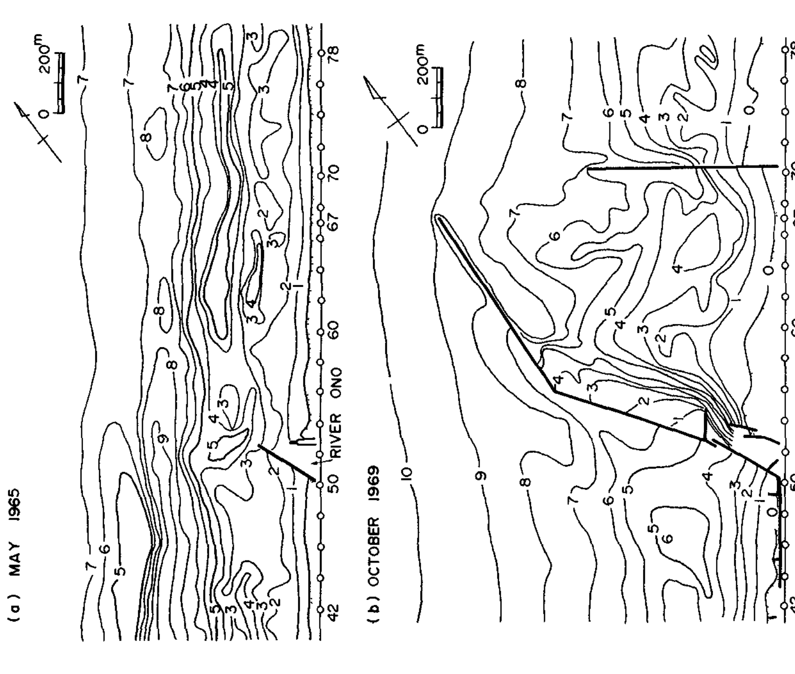

Figure 7. Variation of bed-topography at Port Kanazawa

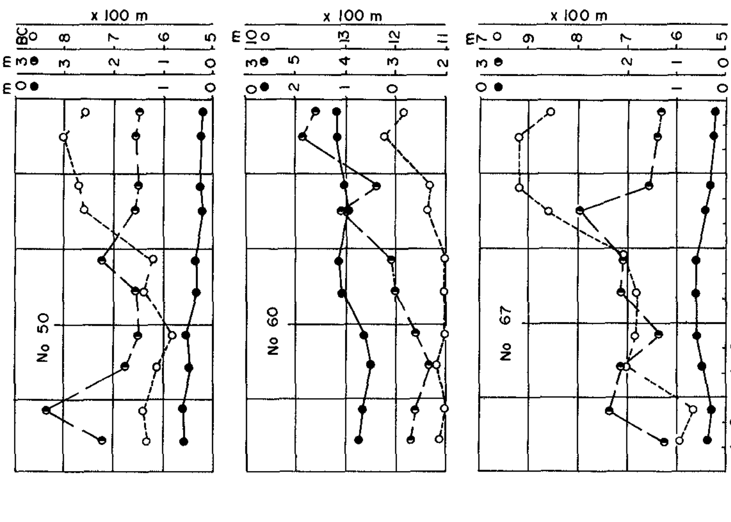

Figure 8 Time change of distances of depth-lines from the datum line at Port Kanazawa

continuing to advance through this period except for 6 m line in August 1966 These advances are remarkable in 1967 and 1968 when the oblique part of the up-side breakwater was being extended Also, at N2, the depth lines of 0 and 4 m advanced in 1964 and then continued to recede, especially remarkably in 1967 and 1968 On the other hand, the line of 8 m at the same datum point advanced steadily except in 1968

VARIATION OF SEA-BED TOPOGRAPHY AT KANAZAWA PORT

Port Kanazawa is located on the coast of Japan Sea as shown in Figure 2 The wave approach in a direction almost perpendicular to the shoreline, though the southerly waves exceed the northerly waves a littile similar to Port Kashima Waves of 3 to 5 m in significant wave height and 7 - 10 sec in period very often attack during winter But the sea is very calm in summer The mean diameter of bottom materials is 0 15 - 0 3 mm in offshore zone The littoral transport from the south is slightly more than that from the north

Figure 7 shows the position of equi-depth lines in May 1965 and October 1969, and Figure 8 shows the time change of the distances of some equi-depth lines at the datum points Nos 50, 60 and 67 from the datum line The construction of the up-side breakwater began with prolonging the jetty which had existed at the mouth of River Ono, as shown in the sounding map of May 1965 of Figure 7

From these figures, the pattern of change of bottom topography is found to be similar to that of Port Kashima except the severe recession of the shoreline outside of the up-side breakwater This recession appeared in 1967 and 1968, as can be seen from the time change of 0 m at No 50 in Figure 8, and hence a sea wall was constructed along the shore-line between the datum points 50 and 44 in the summer of 1968 The recession seems to be caused by the extension of the up-side breakwater in the direction oblique to the shoreline

The line of BC of No 50 in figure 8 shows the time change of the longshore bar which existed about 630 m seaward of the datum line in May 1965 This longshore bar advanced with the prolongation of the breakwater though it became indistinct since 1968 The down-side breakwater began to be constructed in the spring of 1968, which caused the recession of shoreline near and inside of that breakwater as seen from the time change of 0 m line on the datum point No 67 in Figure 8 The bottom material dredged in the channel extending from the mouth of River Ono were discharged on the outside of the down-side breakwater, which advanced the equi-depth lines there as seen in Figure 7

VARIATION OF SEA-BED TOPOGRAPHY AT NIIGATA-HIGASHI

Port Niigata-higashi is located on the coast of Japan Sea, as shown in Figure 2 The predominant wave direction is NNW, almost perpendicular to the shoreline, but the westerly waves are slightly predominant than the easterly waves, and hence the direction of the net alongshore transport is from west to east along the shore The other wave condition and the mean diameter of bottom materials are

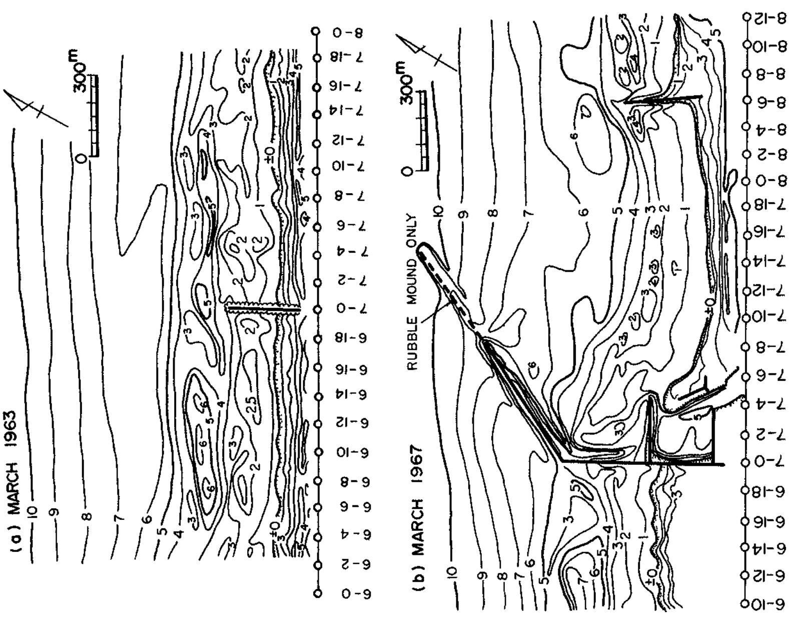

Figure 9 Variation of bed-topography at Port Niigata-higashi

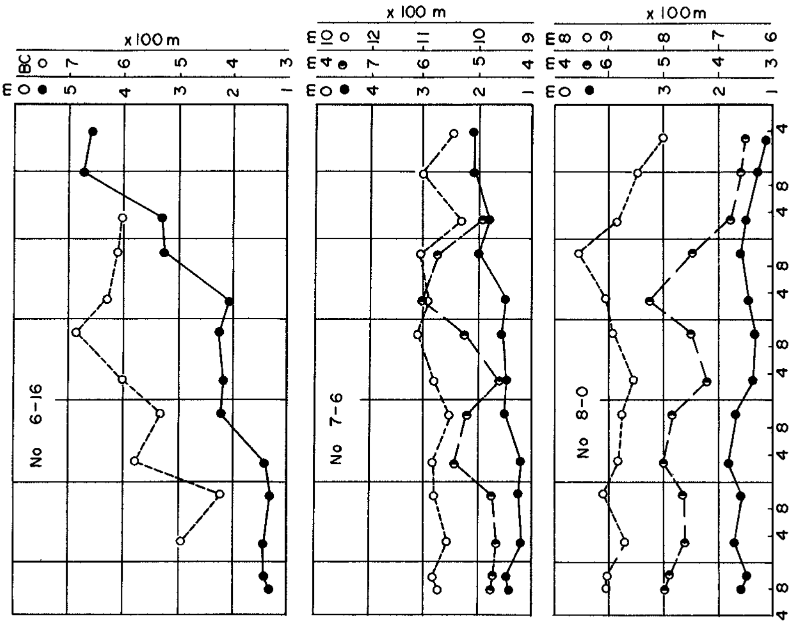

Figure 10. Time change of distances of depth-lines from the datum line at Port Niigata-higashi

nearly the same as those at Port Kanazawa The construction works of breakwaters is stopped in winter due to severe waves similar to Port Kanazawa Figure 9 shows the sounding maps of March 1963 and March 1967 and Figure 10 the time change of the distance from the datum line of a few equi-depth lines at the datum point Nos 8-0, 6-16 and 7-6

The above figures show the same tendency as Port Kashima on the bottom-change due to the construction of breakwater, though the deeper equi-depth lines did not become seaward-convex in shape in the map of March 1967 This is due to the down-side breakwater being still short The down-side breakwater began to be constructed in 1966

The inner basin was dredged by dredgers which entered from the working basin similarly to Port Kashima, and the dredged material was discharged on the outside of the up and down-side breakwaters It caused the abrupt advancement of shoreline out-side of the breakwaters since 1964, as seen in the time change of 0 m line on No 6-16 in Figure 10 As seen also in Figure 10, the alongshore bar advanced until October 1965, receded till March 1967, and then disappeared due to the above-mentioned discharged materials 0, 4 and 8 m lines on No 8-0 receded abruptly from 1966 when the down-side breakwater began to be constructed

TOPOGRAPHY OF PORT OARAI AND HIMEKAWA

Port Oarai is located near to Port Kashima, and Port Himekawa between Port Kanazawa and Niigata-higashi as shown in Figure 2

Figure 11 shows the sounding maps of Port Oarai in 1967 In this case, the bulge of equi-depth lines is not seen offshore of the oblique part of the up-side breakwater, but the shoaling is remarkable inside of the tip of breakwater This seems to be due to the extension of the oblique part of the up-side breakwater at a small angle to the shoreline

Figure 12 is for Port Himekawa in 1969 In this case, the rectangular part of the up-side breakwater is very short, and so the shoreline has advanced remarkably on the down-side to form a tombolo and has receded on the up-side of the breakwater

MODEL TEST ON CHANGE OF SEA-BED TOPOGRAPHY CAUSED BY A JETTY

Some model tests were conducted on the change of sea-bed topography caused by a jetty in a basin, 30 m wide, 50 m long and 0 8 m deep At first, a model beach of 18 m long in the direction of shoreline and of 1 15 bed slope was made with fine sand of about 0 2 mm in mean diameter The model beach was attacked by waves which were 8 cm in height, 1 2 sec in period and 15 degree against the shoreline in wave direction Morever, sand was fed in the shoreline of up-side end so that the shore line there did not change during the wave action

Change of bed-topography caused by a long jetty

Figure 13(a) shows the bed topography after two hours of wave

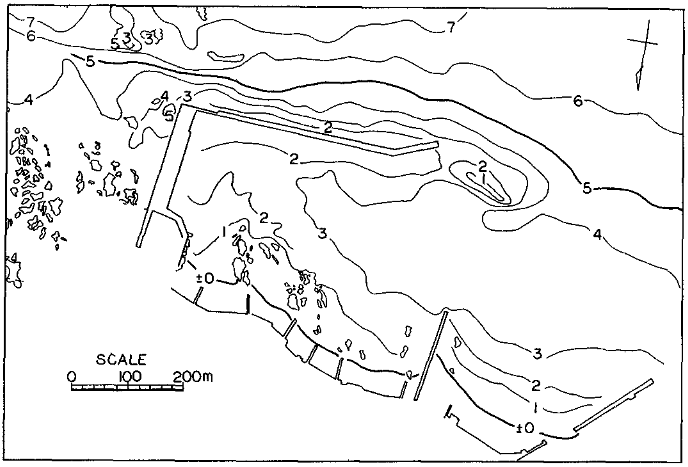

Figure 11 Port Oarai in 1967

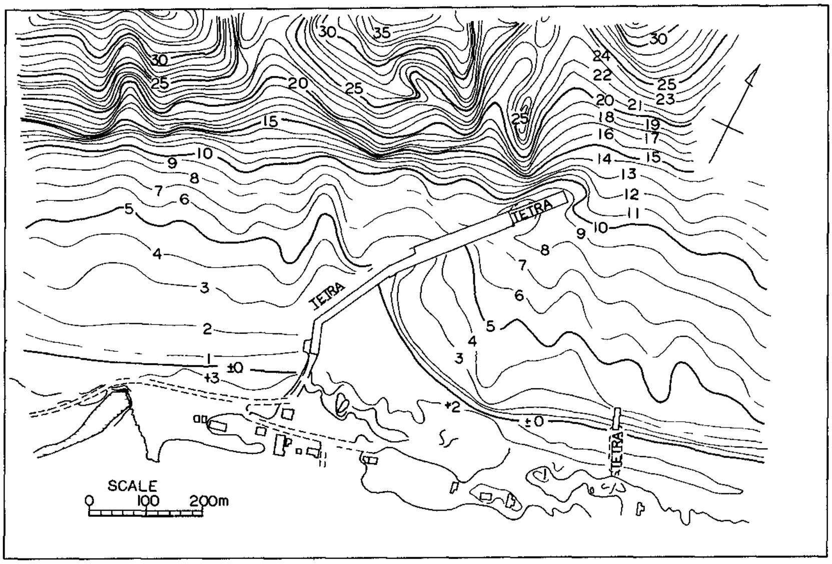

Figure 12 Port Himekawa in 1969

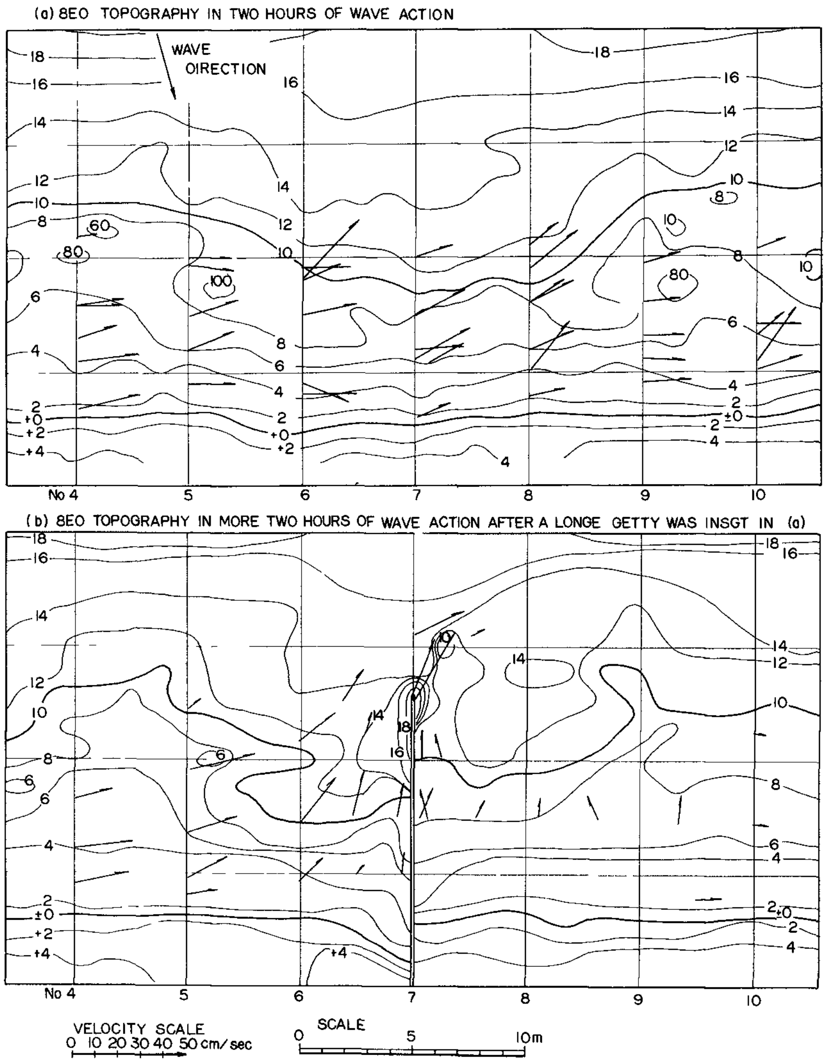

Figure 13 Changes of equi-depth lines and bottom currents by a long jetty (model test)

action on the above-mentioned initial model beach and Figure 13(b) shows the bed after an additional two hours of wave action, after a jetty was inset in the bed of (a) The arrow marks show bottom currents measured using a plastic ball of 1 5 cm in diameter filled with water, which moves along the bottom The jetty was made with a plastic plate having smooth surfaces

The longshore bar is seen between the equi-depth lines of 6 to 10 cm in (a), and it advances offshoreward in front of the datum point No 3 to 6 and 8 to 11 The bottom currents are flowing nearly parallel with the shoreline mostly, except that they go obliquely offshoreward on the up-side of the advancing part of the longshore bar

In (b) with a jetty, there are seen severe scouring at the tip of jetty, scour along the jetty and erosion of the shoreline on the up-side of the jetty The alongshore currents on the up-side of the jetty change their direction towards the tip of the jetty as they approach the jetty Morever, seaward currents exist along the up-side of the jetty from the foreshore These alongshore currents and seaward currents join to become a strong current in the vicinity of the tip of the jetty, which cause the above-mentioned severe scouring there, together with the breaking wave along the jetty The wave height is higher along the jetty than in the area away from the jetty, because the wave comes obliquely to the jetty, which results in the increase of disturbance of bottom materials and the rise of the water level at the foreshore near to the jetty The rise of the water level causes the above-mentioned seaward bottom currents The other hand, on the down-side of jetty, the area near to the jetty is by some degree sheltered by the jetty from waves, which results in the advancement of shoreline and the disappearance of alongshore bars

<u>Relation between length of a jetty and erosion of up-side foreshore</u>

Figure 14 shows the change of bed topography for jetties of 2 0, 1 5 and 1 25 m long from the datum line with the same surface as the above-mentioned jetty of figure 13 and also for a jetty of 2 5 m long with the surface of rouble stones In the figure, equi-depth lines are drawn by dotted lines for after two hours of wave action on the initial model beach of 1 15 in bed slope and by full lines for after an additional two hours of wave action after a jetty was inset

The up-side foreshore near the jetty was eroded in (a) of 2 m long jetty as well as in Figure 13, changing little in (b) of 1 5 m long jetty and being accreted in (c) of 1 25 m long jetty In (d) of 2 5 m long and rough surface jetty, the up-side foreshore was accreted The rough surface, as well as the decrease of length, of the jetty serves in the decrease of wave height and the decrease of the off-shoreward current velocity along the jetty, which results in the decrease of erosion and scour along the up-side of the jetty

MODEL TEST ON CHANGE OF SEA-BED TOPOGRAPHY CAUSED BY TWO BREAKWATERS

Prior to the prolongation of the oblique part of the up-side break-water at Port Kashima, model tests were conducted for different stages

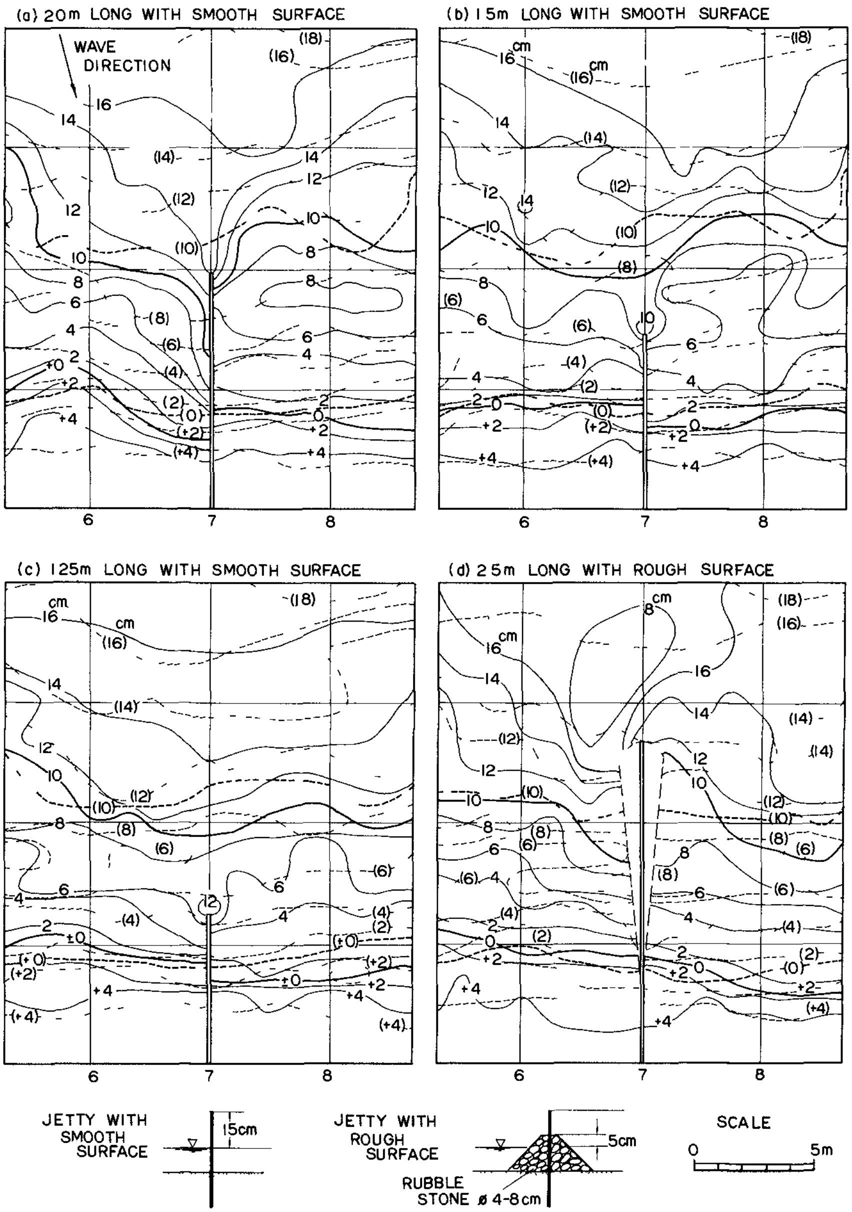

Figure 14 Relation between length of a jetty and erosion of up-side foreshore (model test)

of the construction of breakwaters in the same basin as the above-mentioned test Figure 15 shows a part of the model tests The up and down-side breakwaters were prolonged from the state in upper figure (a) to the state in the lower figure (b) and then waves were acted for four hours The result by the wave action is shown in the lower figure In this case, model waves in the offshore were 14 cm in height, 1 4 sec in period and INE in direction Model bed materials were sand of 0 22 mm in mean diameter and model scale was 1 200 in horizontal and 1 40 in vertical Also, the model of breakwater was made by concrete blocks which was impermeable against water Figure 16 shows the conditions of bottom currents and wave-heights for the bed condition in Figure 15(b)

Comparison of change of bottom topography between model and prototype

The length of breakwaters is not so much different between Figure 15(a) and Figure 3(d) though the latter has a little more extended breakwater than the former, and so also between Figure 15(b) and Figure 4(f) Therefore, the change of bottom topography from the above (a) to (b) of the model is compared with that from the above (d) to (f) of the prototype

The offshoreward bulge of equi-depth lines near the oblique part of the up-side breakwater on the out-side, the advancement of all equi-depth lines near the up-side breakwater on the in-side, the shift of the most receded point of the shoreline towards the jetty of working basin and the shoaling of the center part in the outer basin are seen both in the model and the prototype It is seen also in the model the tendency for equi-depth lines to become of landward-convex shape in the shallower area and of offshoreward-convex shape in the deeper area in the outer basin The tendency of change of bed-topography coincides between the model and the prototype, though there is some difference on the intensity or rate of the change

Distribution of waves and bottom currents

It is seen from (a) of Figure 16 that the wave height in the outer basin is larger in the portion extending from the mouth to the datum points N1 to N2 and smaller in the portion near the up-side breakwater It is also seen from (b) of Figure 16 that there is currents circulating in the anti-clockwise direction in the outer basin The velocity of the circulating current is smaller in the center of the outer basin and in the portion near the up-side breakwater This indicates that the pre-described most eroded point of the shoreline have the higher wave and more rapid bottom current, and the pre-discribed shoaling portion in the center of the basin has the slower current Also, the accumulation seen in the area near the up-side breakwater seems to be caused by the condition of current velocity and wave height which are smaller in the area near the up-side breakwater than in the area near the down-side breakwater

CONCLUSION

The general characteristics of bottom topography change caused by the construction of breakwaters on a sandy beach are concluded from the foregoing chapters as follows Figure 17 is the illustration of the

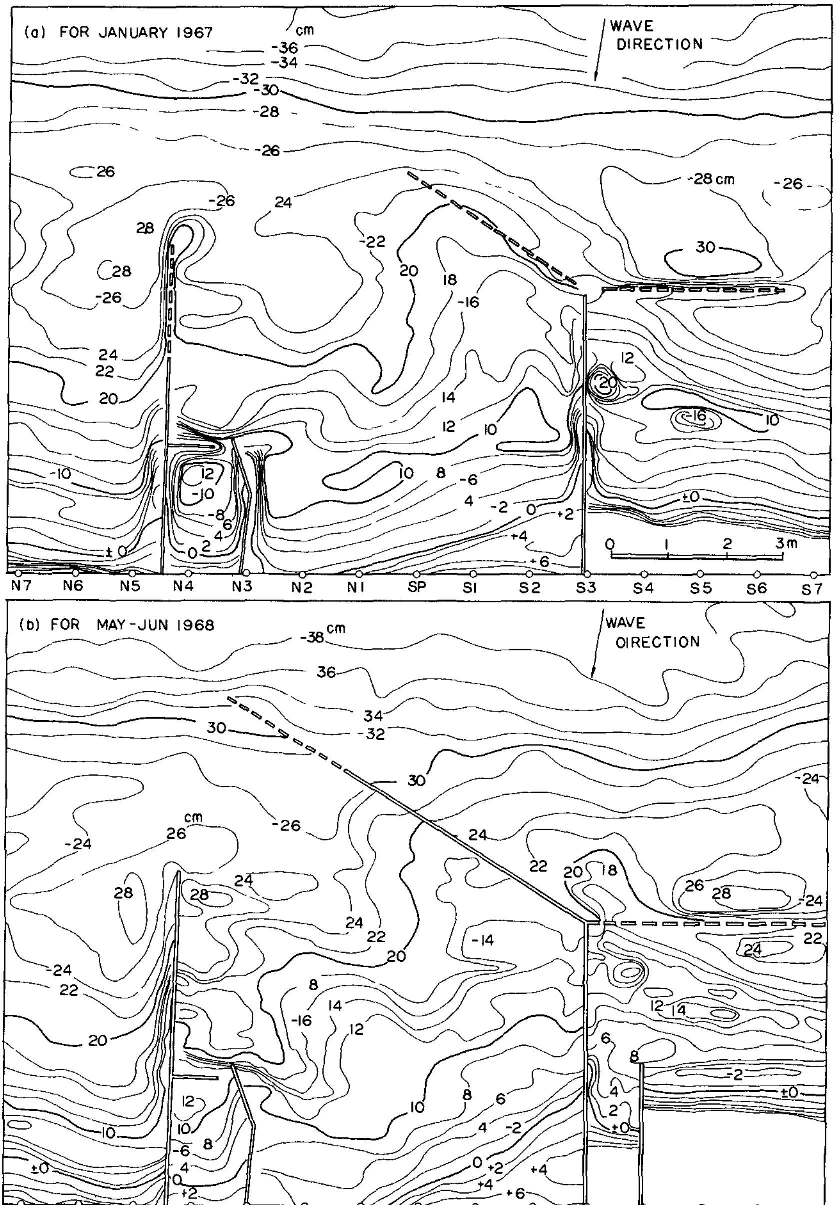

Figure 15 Change of bottom topography caused by the prolongation of breakwaters (model test of Port Kashima)

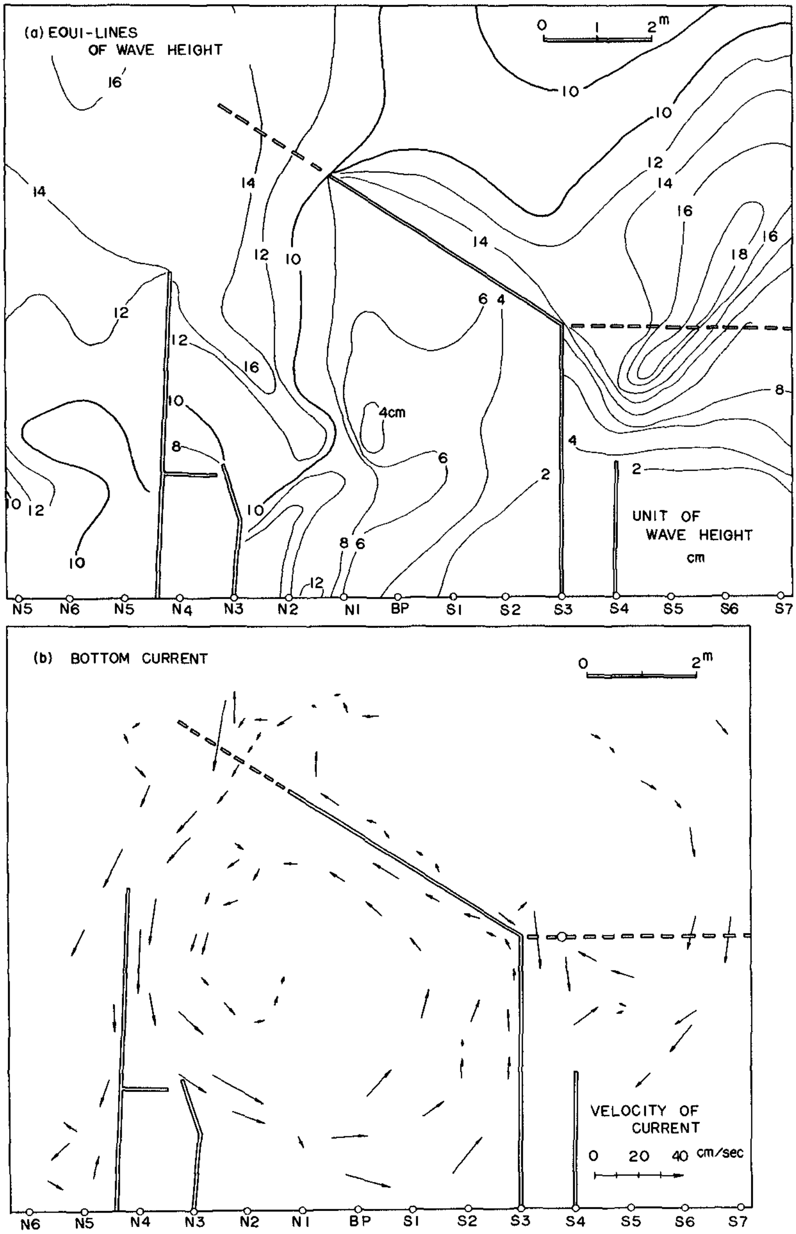

Figure 16 Distribution of waves and bottom currents for Figure 15(b) (model test).

same

Out-side of the up-side breakwater

(1) The shore-line near to the breakwater advances offshoreward first and then stops or recedes according to the prolongation of the breakwater In this case, the more oblique the direction of a breakwater is, the more severe the recession of shoreline is Such recession of shoreline is less in the breakwater with rough side-surface than that with smooth surface as shown in the model test

(2) The alongshore bar near to the breakwater advances offshoreward becoming distinct in shape with the prolongation of the rectangular part of the breakwater and stops or recedes becoming indistinct with the construction of the oblique part of the breakwater

(3) The equi-depth lines near to the oblique part of the breakwater bulge offshoreward, as most of littoral drift carried along the shore moved seaward along the rectangular part to deposit offshore of the bend-point without moving directly along the oblique part of the breakwater However, in the case where the rectangular part is short and the bending angle of the oblique part is large, such bulge of equi-depth lines does not occour but the shoaling tends to be remarkable inside the tip of the breakwater, **as in Port Oarai.**

Inside of breakwater (outer basin)

(1) According to the construction of an up-side breakwater, the shoreline advances in the part near to the breakwater and recedes in its down-side, namely, having a shape of landward-convex The most receded point in this case moves towards the down-side with the increase of length of the breakwater Such advancement of a shore line near to an up-side breakwater becomes larger when the direction of breakwater is oblique to the shoreline and is closely related to the diffraction of waves by the breakwater

(2) The alongshore bar in the outer basin becomes indistinct or disappears with the prolongation of breakwaters

(3) The scouring at the toe of the rouble mound is more severe inside of it than outside of it during the period before caisons are set on it This seems to be due to the swirl formed inside the rouble mound by waves passing over it

(4) When both up and down-side breakwaters are prolonged, equi-depth lines move landwards in the shallower zone and offshorewards in the deeper zone, namely, having a shape of landward-convex in the former and a shape of offshoreward-convex in the latter

(5) Waves entering from the mouth progress near the down-side breakwater so that they erode the foreshore near to the down-side breakwater and produce circulating currents flowing from the down-side breakwater to the up-side breakwater and then to the center of the outer basin

(6) In the shallower area, the bottom is eroded or scoured where

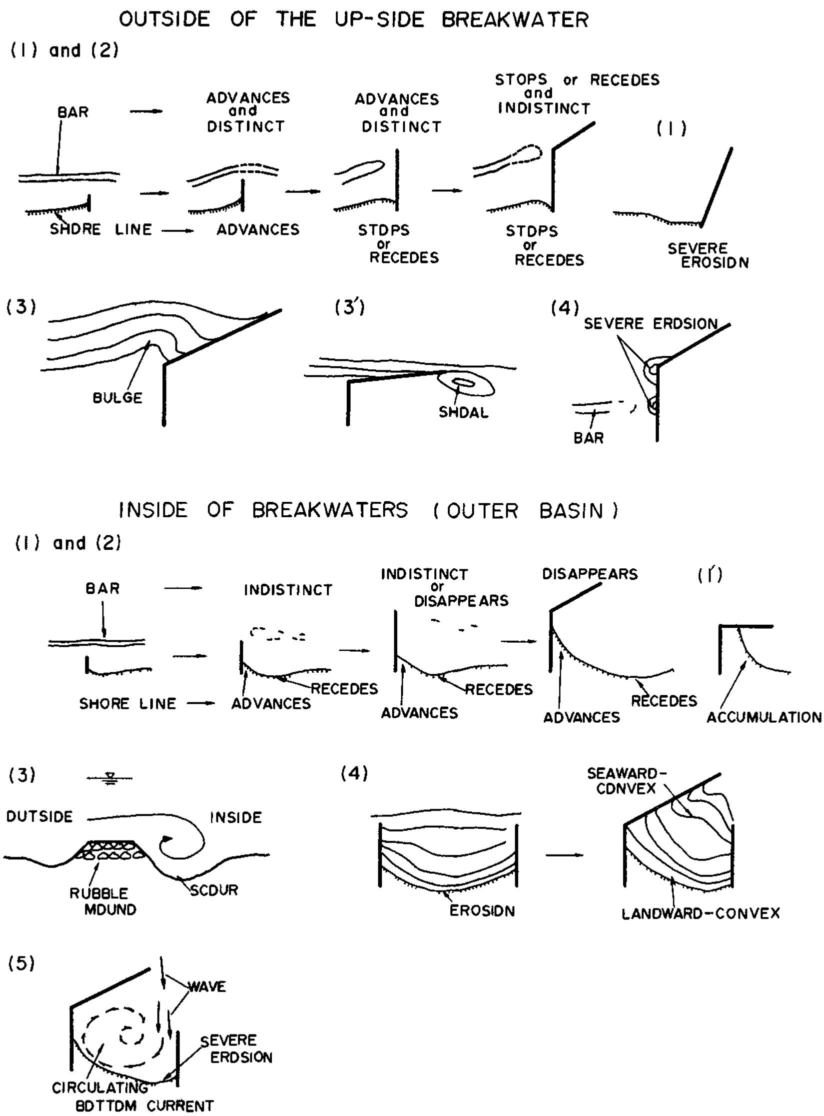

Figure 17 Typical pattern of bottom topography caused by the construction of breakwaters

waves and bottom currents are more severe than its surroundings and is shoaled where they become weak and slow down On the other hand, in the deeper area, the shoaling of bottom happens where bottom currents slow down rather than waves

Outside of the down-side breakwater

The change of a shoreline to landward-convex in shape, the disappearance of alongshore bars, and the scour of bottom along the breakwater are seen often in the area near to the breakwater