13 FUNCTIONS OF GROINS
FUNDAMENTAL STUDY ON BEACH SEDIMENT AFFECTED BY GROINS (I)

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1. Introduction

1-1. Review of previous studies

Groins are extensively used to protect and stabilize the beach. The determination of the most reasonable disposition of groin, however, still remains one of the vital problems in coastal engineering. Numerous studies have been made with respect to this problem, both in Japan and abroad.

In Japan, researches on the groin have a long history; but a theoretical or experimental approach was made by S. Sato, S. Nagai, and the authors [1,2 & 3]. A brief review of the studies is presented in "Design Manual for Shore Protection" (海岸保全施設設計便覧), 1957, [4]; a chapter on the coastal groin was prepared by one of the authors, K. Horikawa. Our knowledge today, however, lacks in many important aspects, and a more extensive study is essential.

The studies abroad have also been very active. To the knowledge of the authors, they principally consist of: a series of reports by Per Brunn [5], a field survey at Lake Michigan by C.E. Lee [6], and a study by Brater [7]. It has also been reported that a research on the groin was performed at the University of California [8]. It was discovered while the authors were already embarked on a study on coastal groins that the two were very similar, but no further information was available.

Our past studies were performed in a fixed-bed basin. This paper presents, however, a preliminary result of the experiment now in progress in a movable-bed basin. More comprehensive data will be available for presentation at the time of the conference.

1-2. Purposes of study

The purpose of this study is to examine the fundamental mechanism of beach deformation and provide reasonable criteria for the design of a groin. Functions of a groin are wide-reaching. They are immediately related to various fundamental factors such as the characteristics of shallow-water waves in the surf zone, sediment motion by waves and littoran currents, and eventual deformation of a beach and nearshore topographies.

1-3. Beach Deformation

An experimental study on beach deformation under wave action may date back to a research made by G.H. Keulegan [9] on the formation of submarine sand bars and sand movement in the vicinity. In a re-analysis of experimental results obtained by Meyer and others, J.W. Johnson [10] indicated the distinction between the storm and ordinary beaches, and also suggested the existence of equilibrium profiles.

The relationship between the beach profile deformation and breaker characteristics was shown to exist by T.Hamada [11]. Later an experimental measurement was performed by Y. Iwagaki and T.Sawaragi [12] in a two-dimensional wave flume on the distribution of sand movement perpendicular to the shoreline. A different approach to the nature of the equilibrium was made by S.Hayami [13]. He showed, with reference to the results of H.W.Iversen [14], that a critical wave steepness between the plunging and spilling breakers depends on the bottom slope, and further that the deformation of beach tends to result in a definite slope corresponding to the prevalent wave steepness. Taking into consideration the factor of grain size, R.L.Rector [15] presented a formula obtained through experiments with varying bed materials:

$$M_{do} / L_o = 0.0146 \ (H_o / L_o)^{1.25}$$

where M_{do} is the mean diameter, and L_o and H_o the wave length and wave height in deep water, respectively. In reality, however, the deep-water wave steepness, δ, the beach slope, and the grain size may exert a combined effect on the progress of erosion and accretion.

According to a study by Kurihara, Shinohara, Tsubaki and Yoshioka [16], however, the effects of the specific gravity of beach materials are also reported to play a significant role in the quantity of suspended and bed-load material disturbed by wave action.

1-4. <u>Alongshore beach drift</u>

The net quantity of the alongshore drift of bed-load materials and its ratio to the total quantity of alongshore drift were examined by Th. Saville, Jr., [17], and shown that they are subject to wave steepness and the rate of energy transmitted by waves. According to J.W. Johnson [18] the quantity of the alongshore drift also depends upon the direction of wave orthogonal and attains its maximum for the angle of 30° between the wave orthogonal and the shoreline.

It has been observed in our experiment that the alongshore drift of beach materials consist principally of the two different categories, i.e., (1) <u>beach drift</u> transported in a zigzagging path by the alternating action of uprush and backwash along the forebeach either rotating or saltating; (2) <u>littoral drift</u> transported primarily as suspended material by the littoral current. Both of the two categories should be taken into consideration in order to estimate the entire quantity of sediment transported alongshore.

The factors affecting the rate of beach drift would be predominantly the rate of wave energy transported into the surf zone and finally onto the foreshore, i.e., the height and period at the final breaking line and the characteristics of the subsequent damping. This problem was studied by S.Sato and T.Ijima. S.Sato considers a critical maximum height of a shallow-water wave corresponding to the depth [19]. The approach of T.Ijima consists in the assumption of a constant, uniform eddy viscosity in a fluid [20].

The authors have also been studying the same problem in a two-dimensional wave flume, mainly engaging the nature of turbulence which may govern surf-zone damping.

The longshore drift is overwhelmingly dependent both on the longshore currents and concentration of suspended sediment caused by the turbulence of breaking waves. The theoretical formula presented by Putnam, Munk and Traylor [21], and later revised by Inman and Quinn [22], may only provide the mean value of longshore current velocities. The authors are strongly in the opinion, however, that in stead of the mean value the distribution of velocities across the surf zone should be considered as far as the rate of longshore drift is concerned. 3 According to the field study of G.Watts [23], the maximum concentration was found at the plunging point immediately inshore of the breaker line.

Summing up, the design of groins must fundamentally rest on the enlightenment of all the problems stated above, for the principal function of a coastal groin is to control the balance of supply and loss of beach materials where a considerable quantity of sand drift already exists.

2. Laboratory equipment and procedures

2-1. Experimental basin

The experiment was performed in a wave basin 15 meters wide, 15 meters long and 0.8 meters deep (Figure 1). At one end of the basin was installed a pneumatic wave generator driven by a 15-HP mortor. At the other end of the basin a sand, model beach was built sloping 1 on 15 and inclined 30° to the wave crest at the constant depth (35 cm). The sand for the model beach was derived from the reclaimed soil of Chiba, a port inside the Bay of Tokyo.

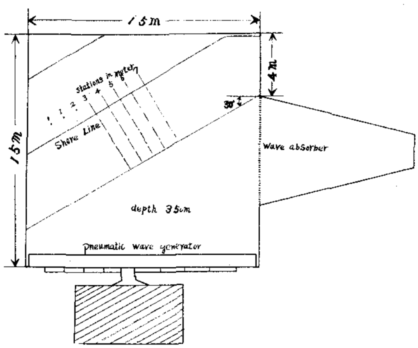


Figure 1 - View of experimental basin.

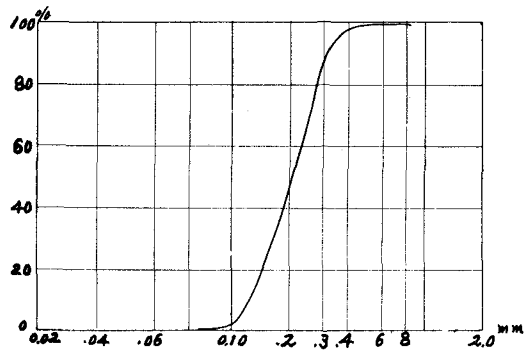


Figure 2 - Mechanical analysis of sand.

2-2. Beach material

The result of mechanical analysis of the beach material is shown in Figure 2. It contains a minor amount of impurities, but this was practically negligible for the purpose of our study. The mean diameter is 0.20 mm, specific gravity 2.68.

2-3. Wave characteristics

The experimental waves were so selected as to form three groups of varying power content, each consisting of as wide a variety of wave steepness as possible. Only two waves have been tried up to this moment. The general characteristics are shown in Table 1. H_{35}, H_o, E, and P are theoretical values obtained by considering the effects of energy dissipation due to refraction. E and P were taken to represent the values of energy and power per unit length parallel to the shoreline.

Table 1 - General Characteristics of Waves

	T sec	H_{35} cm	H_o cm	L_o cm	H_o/L_o	E joule/m	P watt/m
Wave II	0.96	5.6	6.0	144	0.042	3.43	3.58
Wave III	1.14	4.7	5.1	203	0.025	3.78	3.32

2-4. Model groins

A model groin used is a long, flat panel made of concrete, 2 cm in thickness and 40 cm in width. They were placed perpendicular to the shoreline, and extended toward offshore as far as the mid-point of the surf width (80 cm for Wave II and 55 cm for Wave III). The upper edge of the groin was made parallel to the beach slope and its offshore end flush with the still water level. The groin was located approximately at the center of the beach length where the growth of littoral currents is expected to be already in steady condition.

2-5. Current measurement

A propellar-type current meter was used. The effect of friction and consequent inefficiency of the meter was remedied by using quicksilver drop as a point of contact. The meter was connected to an ink recorder.

2-6. Sand trap

Sediment sampling was made using a simple rectangular bos walled with meshworks, 1 x 5 x 10 cm. It was placed at the bottom, the open side directed either parallel or perpendicular to the shoreline, fixed at position with the aid of the attached legs. The main problems with this device were scouring action around the body, intensification of turbulence inside the box and consequent loss of trapped sediment. However, the results obtained were satisfactory within the purpose of this experiment.

2-7. Experimental procedures

Each run of the experiment consisted of a study of beach deformation and littoral currents either with or without groins. When two were used, the distance was one or two times as large as the submerged groin length.

Each run was continued for about 4 hours for each combination of wave and groin disposition. This may seem a little too short to obtain a equilibrium beach. Keulegan succeeded, however, in obtaining an equilibrium profile in very short time, namely 2 hours for 1/30 slope and 4 hours for 1/70 slope. Our experiments may not provide, therefore, the data for a equilibrium slope. They are sufficient, however, to show the characteristics of beach deformation.

The deformation of profiles were measured at approximately one-hour interval. Measurement of current was started approximately two hours later the wave was generated.

One of the main difficulties encountered was a rapid recession of the upcoast end of tne beach. At first, a periodic nourishment of sand was done here, but it was soon evident that the rate of nourishment which had been determined to coincide with the rate of scouring through the quantity of trapped sediment, was inadequate. The trapped sediment refered to was the longitudinal drift. A strong perpendicular movement of sand also persisted. Later, the rate of recession at the upcoast end was directly measured and a proper rate of nourishment was determined. The nourishment was done in 15-minute interval. The results are not convincing.

3. Experimental results

3-1. Beach profile

Figure 3 shows the rate of beach-profile deformation for station 4 and Wave II. It should be noted that only a limited period of wave action was enough to cause a bar and obvious erosion at the foreshore. This rapid growth of longshore bar is not evident, however, for Wave III. (Figure 4) According to Figure 4 the appearance of a longshore bar is obscure

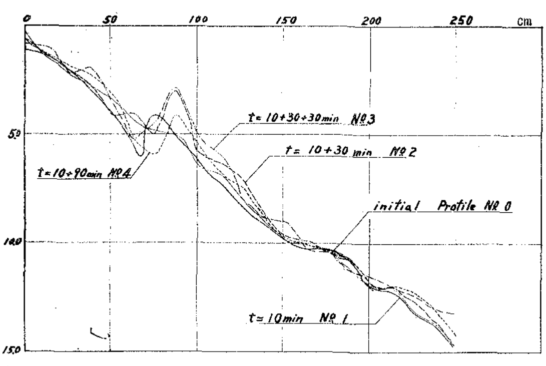


Figure 3 - Rate of profile deformation for station 4 and Wave II.

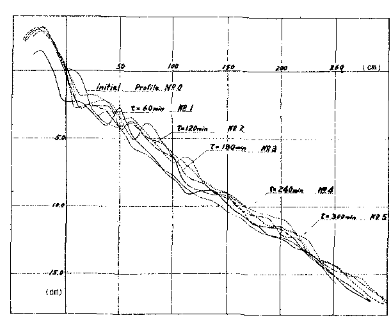


Figure 4 - Rate of profile deformation for station 4 and Wave III.

and, contrary to the case of Wave II, a considerable degree of accretion occurred at the foreshore, and the slope here was also steepened.

Figures 5 and 6 show the net amount of beach deformation with time for each wave. The implications are that the most intensive deformation occurrs in the vicinity of bar or plunging point; this progresses toward offshore, but, after a certain time of wave action, alternating erosion and accretion prevail everywhere, and the magnitude of deformation decreases with time.

The pattern of sediment movement varies along a profile. In the depths seaward of the breaker line the sand oscillation is perpendicular to the shoreline. In the surf zone, however, the movement is entirely changed. There exists no oscillation of sand such as observed on ripple marks outside the surf zone. Immediately inside the bar, or in the vicinity of the trough, sand moves parallel to the shoreline, but a zigzagging motion prevails further inshore. The phenomenon seems to imply that the nearshore sediment motion is not the result of a simple superposition of two independent components longitudinal and perpendicular to the shoreline. These two components are more likely to inter-relate each other, to a greater extent than widely acknowledged to. This gives rise to a thought that the results obtained in a two-dimensional wave flume as to the movement of bottom sediment may be merely of a limited value. An invention was introduced to overcome this difficulty [12] , and application of non-dimensional factors expressed in ratio to the breaker characteristics, namely wave length L_b, was proposed. However, a further investigation is necessary.

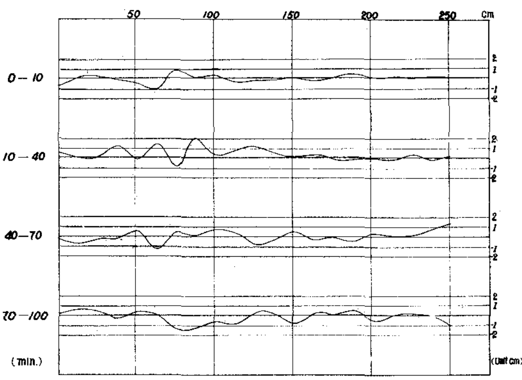


Figure 5 - Net amount of beach deformation with time, for Wave II.

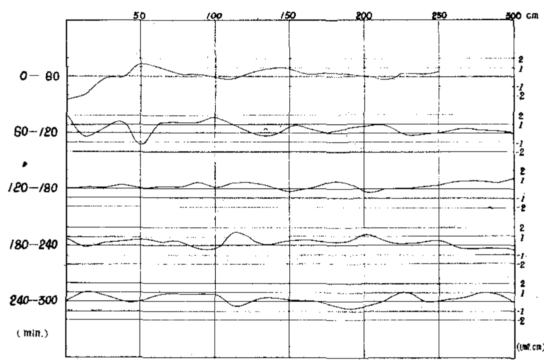


Figure 6 - Net amount of beach deformation with time, for Wave III.

3-2. Longshore current

Our previous study called attention to the pattern of longshore current distribution [4]. The distribution was also measured in our present investigation, and the results show that the two independent measurements are approximately the same.

Figure 7 shows the distribution of the measured velocities of longshore currents, u, expressed in ratios to the values computed from the widely approved formula by Putnam, Munk, and Traylor. The result shows; (1) the theoretical values appear roughly to represent the average of the actual observation, (2) the maximum velocity exists away from the shore approximately 30 to 40 per cent of the surf zone width, (3) the position of maximum velocity approximately coincides with the trough, (4) the pattern of velocity distribution seems independent of wave characteristics.

An examination of ripple marks inside the surf zone shows different trends near the shoreface and the trough, the former representing the direction of backwash deviated downcoast and the latter indicating the direction of breaking swash. These two flows and their combined effects seem to account for the creation of maximum velocity slightly inshore of the mid-point of the surf zone. It is estimated that the distribution of velocities across the surf zone and their magnitude may supply an important basis for the estimation of the rate of suspended and bed-load sediment.

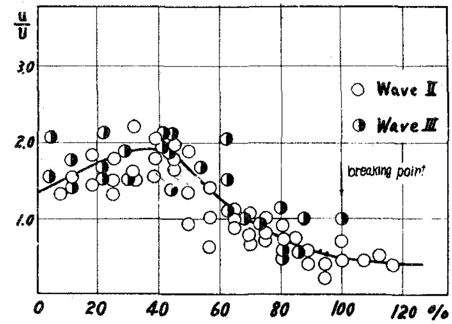


Figure 7 - Distribution of measured longshore current velocities,u,expressed in ratios to the theoretical values, U, by the Putnam-Munk-Traylor method.

3-3. Sand movement

Figures 8 and 9 show the longitudinal movement of beach sand obtained by our sampling traps, for Waves II and III, respectively. For Wave II, a steep wave, the sand movement is outstanding near the bar, while for Wave III, a flat wave, the beach drift constitutes the main portion of the alongshore drift. This is in agreement with the result obtained by Th. Saville, Jr. Our principal interest lies, however, in the effect of this phenomenon on the functions of a groin.

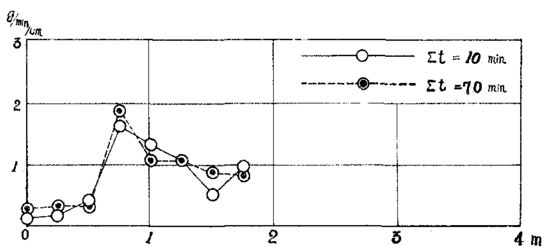


Figure 8 - Longitudinal movement of alongshore drift for Wave II.

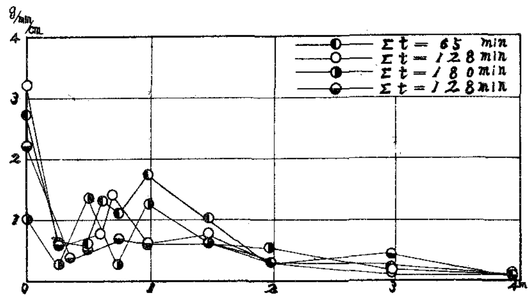


Figure 9 - Longitudinal movement of alongshore drift for Wave III.

The perpendicular movement of sand is similar to that observed in the two-dimensional wave flume. The perpendicular movement appears to excel the longitudinal movement. The former consists of minor oscillations, while the latter occurs only in one direction.

4. Phenomena due to groins in place

4-1. Variation in beach profile

When groins were not placed the bottom contours were almost parallel to the shoreline. A remarkable deformation resulted, however, from the existence of groins, particularly in their vicinity.

In order to compare bottom configurations under varying conditions of waves and groin dispositions, the variation in beach profiles was computed from contour maps. Figures 10,11, and 12 show, roughly, the contour maps in the vicinity of groins in the last stage of each run for Wave II.

The following observations were made:

(1) The scouring action at the tip of a groin is outstanding. This may be attributed partly to the formation of a violent vortex in site, fed by an accelerated seaward flow along the groin, and partly to the swash of waves at the groin tip and consequent generation of a strong turbulence and downward thrust by disturbed water mass.

The fact arouses a need for a greater consideration both in determining the height of the groin tip above the still water level and the structure sufficiently strong to stand wave action.

(2) Recession of the shoreline took place in the vicinity of the groin, but it was more remarkable at the upcoast side of the groin presumably due to the waves converging at

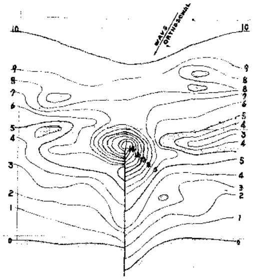


Figure 10

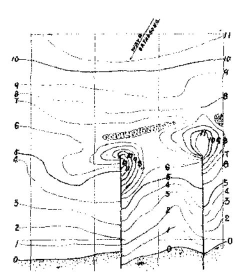


Figure 11

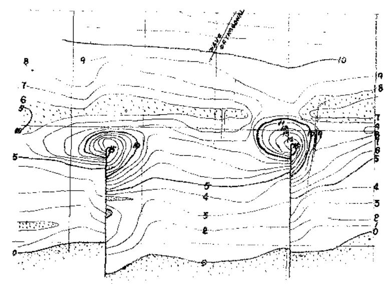


Figure 12

Contour maps in the vicinity of groins for Wave II.

the groin root. The downcoast side is sheltered from immediate wave action, where the wave height was reduced due to divergence and the flow was generally directed toward the groin. Further downcoast, however, this flow was seen to join the longshore current, and a remarkable shoreline recession was also observed here.

(3) The longshore bar was discontinued in front of the groin tip. This shows the existence of an intensified seaward current strong enough to carry the beach sediment into the deep water.

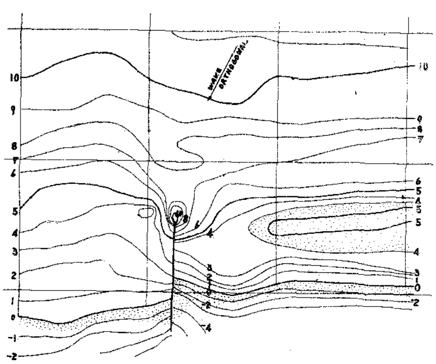


Figure 13

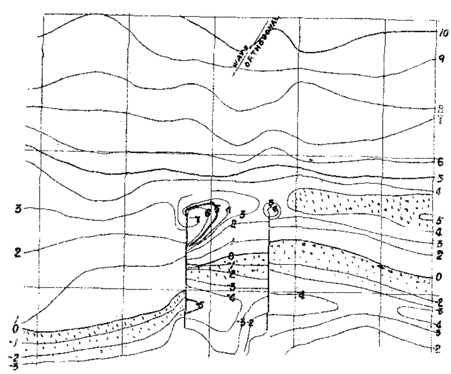


Figure 14

Contour maps in the vicinity of groins for Wave III.

Figures 13, 14 and 15 show the contour maps in the vicinity of groins for Wave III. The following observations were also made:

(1) A remarkable accretion was observed both at the upcoast side and at the inter-groin area, while recession was also remarkable at the downcoast side. Following the progress of deformation with time, it was noted that the accretion at the groin root was hindered by converging waves until a certain amount of deposit was attained there. The rate of accretion was accelerated with time and the resulting fill was gradually pushed toward the groin finally to form a continuous shoreline of accreted beach at the groin root.

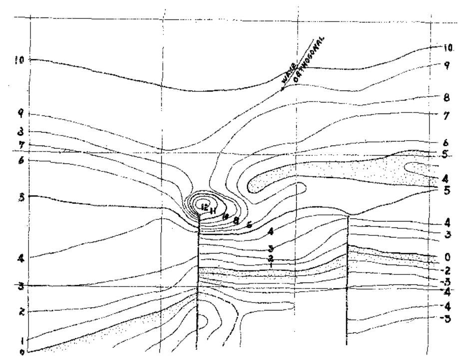


Figure 15 - Contour map in the vicinity of groins for Wave III.

(2) Some shoaling areas were found at the upcoast side of the groin, while at the downcoast side the bottom topographies tended flatter. This may be attributed to wide-reaching deposition of sand in the vicinity of groins.

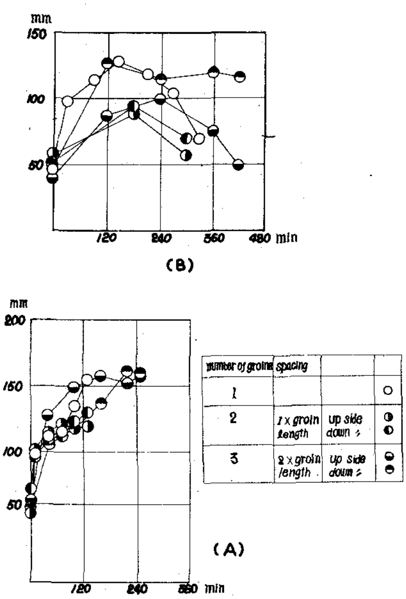
(3) Scouring at the tip of a groin was less distinguished.

(4) As accretion progressed, the sand fill gained height finally to exceed that of the groin. As a result, sand was supplied to the downcoast area beyond the top of the groin. However, a considerable length of time would be required until this supply becomes appreciable.

4-2. Scouring action at the groin tip

Practical interest should be taken as to the nature of the progress in scouring action near the groin tip. Figures 16 (A) and (B) show the variation of the maximum depth at the scouring position with time for Waves II and III, respectively.

For Wave II, the scoured depth appears to converge to a certain value, but it has not been confirmed. For Wave III, the progress of scouring is rapid in the early stage, but it is interesting to note that the scoured depth seems to decrease later, filled back by the accreting beach drift. The scoured depth by storm waves may gradually be restored at quiet weather conditions. No definite conclusion could be made as to the actual extent of scouring action by waves in the nature. The result of our experiment may no apply to the prototype unless an adequate law of similarity is established.



Figures 16 (A) and (B) - Variation of maximum depth of scour with time;(A) for Wave II,(B) Wave III.

4-3. Variation of foreshore slope

No measurement was made of the variation of the foreshore slope for Wave II, but at least the variation was not distinguished in the vicinity of the groins. For Wave III, however, the accretion at the foreshore was remarkable. (Figure 17) The foreshore slope was generally steeper at the upcoast side, but it tended to lessen at the downcoast side and at the inter-groin area as well.

In locations of steep foreshore slopes the stability of the beach seemed to be sustained by coarser materials sorted out by waves. Sorting action by waves is reported to be very active near the shoreline; therefore in these locations relatively coarser materials would be carried away by waves or currents, leaving even coarser materials near the groin.

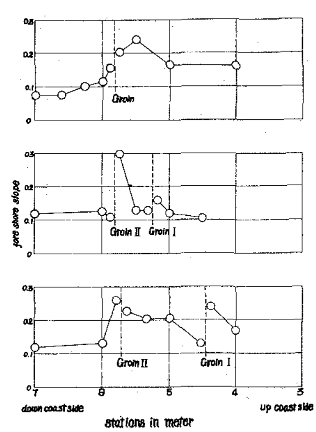


Figure 17 - Foreshore-slop variation

4-4. Longshore current

The effect of a groin practically disappeared at the distance, either upcoast or downcoast, two times the submerged length of the groin. This is indicative of the range affected by a groin. The longshore current was accelerated in the vicinity of the groin tip.

4-5. Sand movement

An active longitudinal movement of sand was observed at the inter-groin area.

For steeper waves, namely Wave II, in case the groin spacing two times their submerged length, the longitudinal movement in the inter-groin area became almost comparable with that of the upcoast and downcoast sides of the groins (Figure 18). For flatter waves, namely Wave III, which are related with creation of predominant beach drift, the existence of a groin may hinder the migration of beach drift and decrease the entire alongshore movement of sand. However, the sand movement ranges down to a considerably deep water. (Figure 19).

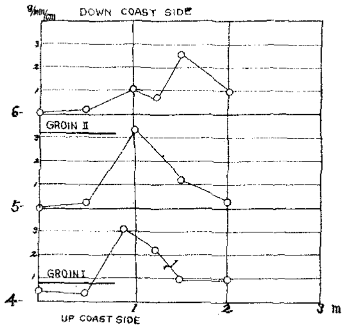


Figure 18 - Distribution of longitudinal sand transport across the surf zone for two groins in place. (Wave II)

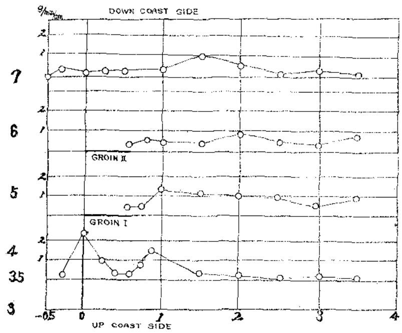


Figure 19 - Distribution of longitudinal sand transport across the surf zone for two groins in place. (Wave III)

5. Discussion of results

The data of our experiment so far obtained are insufficient to render any theoretical analysis in a complete form. Accordingly, the discussions to follow are only to summarize the substantial factors underlying the problem at large. A scope for further investigation will be also presented.

The median diameter of the sand was 0.20 mm. Applying this value to the result of R.L.Rector, the critical wave steepness are obtained (Table 2):

	M_{do} mm	T sec	L_o cm	M_{do}/L_o x10^4	(H_o/L_o) crit.	(H_o/L_o)
Wave II	0.2	0.94	144	1.39	0.025	0.042
Wave III	0.2	1.14	203	0.99	0.018	0.025

Table 2 - Critical wave steepness obtained through R.L.Rector's formula.

It is seen from Table 2 that Wave II and Wave III are both storm waves. According to our experiment, however, Wave II is definitely a storm wave, causing erosion of the beach, but Wave III, on the other hand, is considered to be an accretive, ordinary wave because it brought about a predominant beach drifting though a slight sign of bar formation was also noticed. This discrepancy between our observation and the values through Rector's formula may partly be attributed to the fundamental difference between the two-dimensional and three-dimensional treatment.

For Wave II , considering the great departure of wave steepness from the critical value, no question can be raised as to the erosive nature defined for this wave. The value of Wave III, however, shows a slight disparity from the critical value. It should be recalled that the formula of R.L. Rector was obtained as a result of a two-dimensional experiment. The sediment movement in the surf zone is primarily governed by the wave characteristics within the surf zone. The longshore current intensifies the damping effect in the surf zone waves and turn out a different wave pattern than the one in a 2-dimensional wave flume. Wave III may thus behave as an ordinary wave.

It will be misleading to consider only the ordinary waves as the basis for evaluation of the effects of groins. The sediment-holding ability of the inter-groin area as well as the effects of scouring in their vicinity should also be considered with respect to storm waves.

The storm waves may invade deep into the shore, scour the foundation of a groin, or bring about the settlement of the groin tip by scouring the adjacent bottom. To preserve the safety for a protected beach, the safety of the groin should also be preserved.

The seasonal variation of wave characteristics, and the amount of existing alongshore sediment must also be carefully surveyed and defined. We intend to proceed to examining the variation of bottom topographies in the vicinity of a groin under alternate action of storm and ordinary waves and for different quantity of entire alongshore drift.

Our experiment has also confirmed a remarkable erosion at the lee-side beach. It may take a considerable time until an inter-groin area arrest a sufficient amount of sand to provide the lee-side with an appreciable amount of sand supply.

The sand supply to the lee-side consists of: (1) littoral drift carried downcoast and then pushed ashore by waves, (2) beach drift piled on the foreshore and washed over the groin top into the lee-side beach. The former is affected principally by the length and spacing of the groins, and latter by the groin height. Consequently, the factors to be considered in constructing coastal groins are: (1) to be built toward upcoast, (2) to adjust the lengths of groins so that the tips may form a natural curve merging with the downcoast shoreline.

One of the structural problems of the groin is the evaluation of the effects of permeable and impermeable groins. Views conflict with respect to their structural reliability, and sediment-holding ability. Permeable groins have been constructed and tested in the Niigata coast. The results have not been reported.

The type of the cross section of a groin may also affect the scouring action around the body as well as the sediment-holding ability. The trapezoidal, rounded, and stepped types are thought to be more recommendable than the vertical-walled type, but this comparison is not based on a reliable basis. The authors have conducted some experimental research on this problem, which will be continued in the future.

The efficiency and reliability of sand sampling method may greatly influence the results derived from experiment. Our method should be given a great deal of improvement to render more reliable data.

Acknowledgment

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