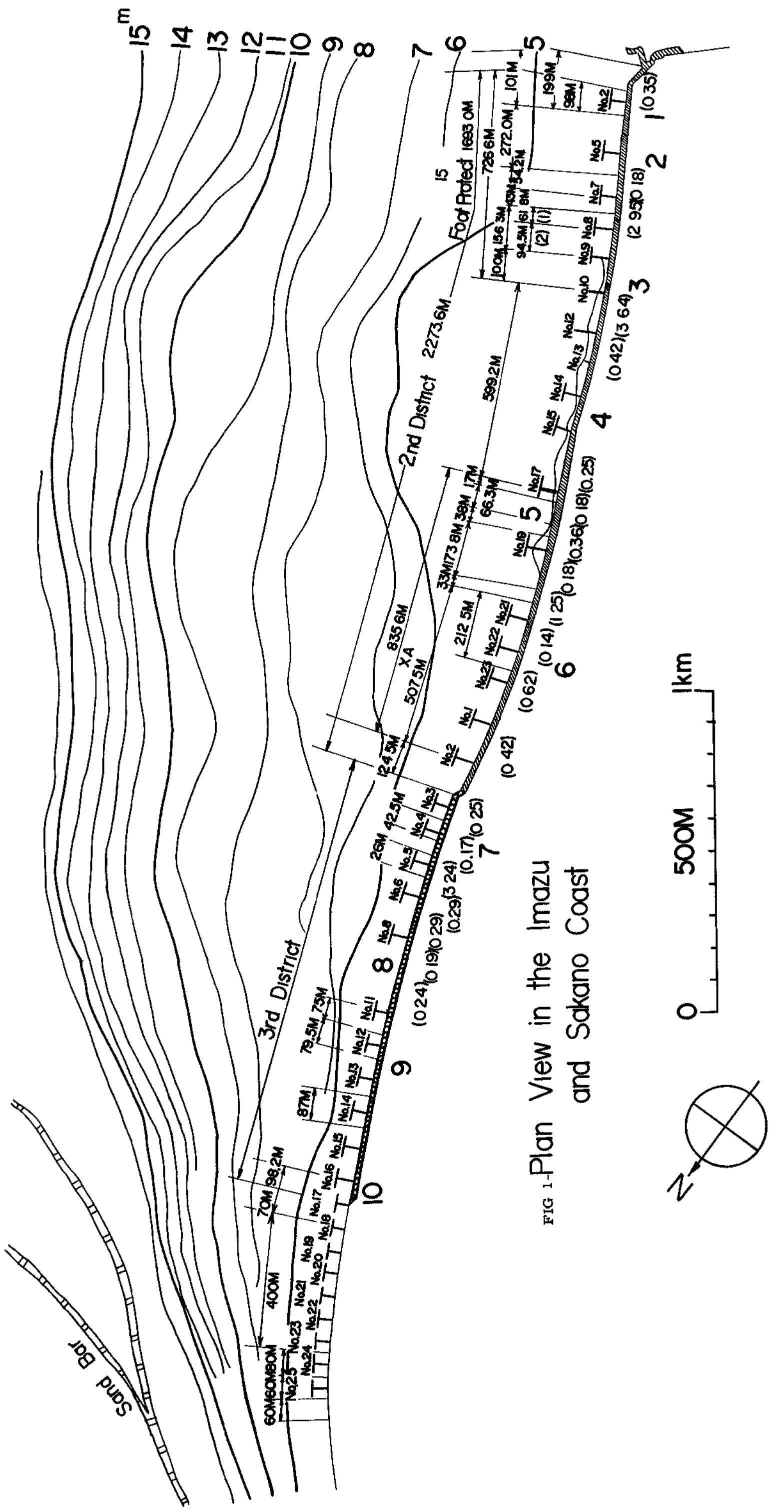

FIG 1-Plan View in the Imazu and Sakano Coast

The T-type groin made of hexaleg blocks is of permeable type, whereas the peninsular groin of cubic concrete blocks is impermeable. Both types of the groins consist of various scale in length and interval. The hexaleg block has six rectangular prisms adhering to the surface of its core cube as shown in Fig. 2, and the interlocking method of blocks and the porosities of accumulated blocks can be changed with the rate of littoral sand drift.

This coast faces the Pacific Ocean in the direction of SE,SSE and S, and the north-east side faces the Osaka Bay and Kii Channel. The fetches in each direction are shown in Table 1. Therefore, the characteristics of incident waves generated from northward are generally steeper than the one of coming wave from southward. Wave heights from southward, however, are remarkably larger than the ones from northward since the coming waves from southward are mainly generated by typhoons.

Then, the predominant direction of littoral sand drift along this coast may be specified from south to north.

INVESTIGATION

The field investigation was conducted twice, in August 1962 and in march 1963, because the directions of waves to this coast indicate the seasonal change.

In the above mentioned periods of investigation, the characteristics of shallow water wave and the hydrographic survey around the groin system were observed at fixed time. Bed materials were also collected at 20 points along the shorline and were sieved by J.I.S.* sieves. The distribution of medium grain size at the shoreline along this coast is indicated numerically in the parentheses in Fig. 1.

The characteristics of wave at deep water during the period of investigation were hindcasted the meteorological data of Tokushima Weather Bureau.

The coming waves from southward during August, 1962 were mainly attributed to typhoons which send large swells from outer ocean or bring extraordinary storm waves. For hindcasting the waves generated by typhoons, the scale as well as the location of typhoon are considered in this study. Fig. 3 indicates the courses of typhoons during this investigation.

When the estimated wave heights are compared with observed wave heights under the consideration of wave refraction, the former comes from SE pretty coincides with the latter, but the coming waves from ESE, SSE and S are diffracted by Shiono Cape and Gamoda Cape and fall into decay about half of an ordinary wave height.

The characteristics of waves generated within several decade km in fetch as shown in Table 1 from northward in March are determined by

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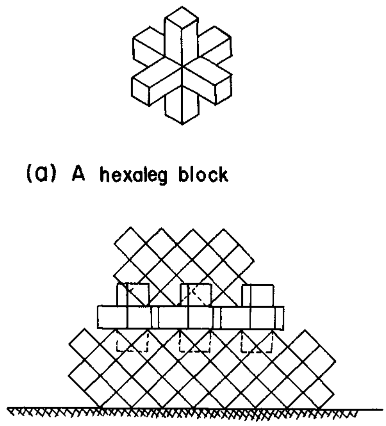
* J.I.S. abbreviates Japanese Industrial Standards.



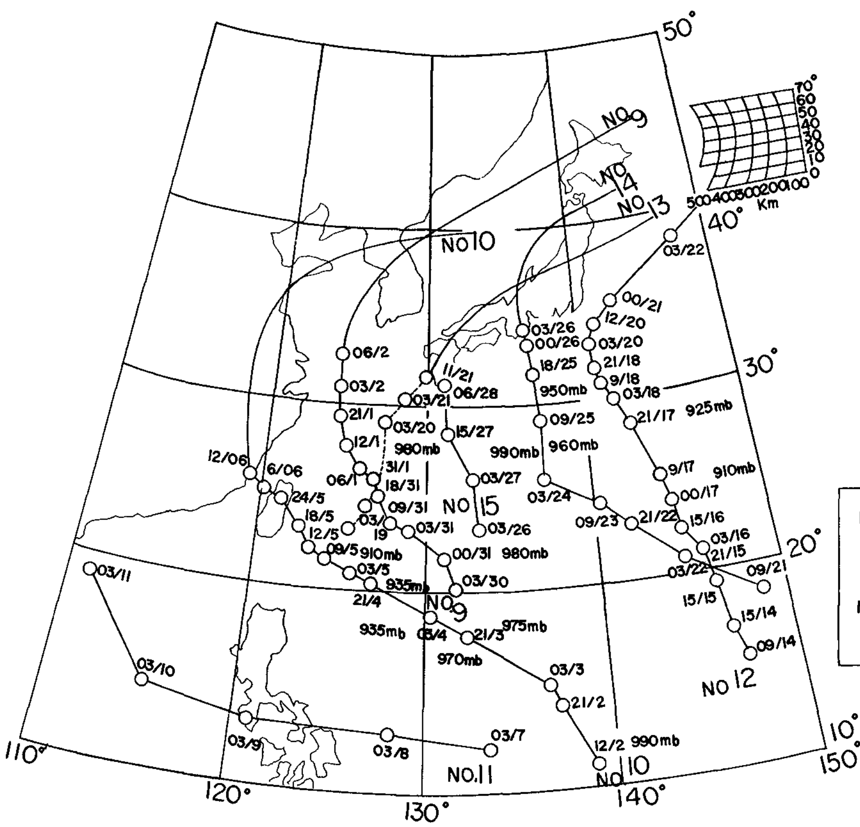
(a) A hexaleg block

(b) Interlocking hexaleg blocks

FIG 2

TABLE 1

direction	fetch Km
N	90
NE	105
NNE	55
E	40
ESE	85
SE	



COURSES OF TYPHOONS

Legend
09/14 = at 9 A M on the 14th of August
NO 10 = Tenth typhoon in the season

FIG 3

and wind velocity.[4] The characteristics of waves in the shallow water are obtained by drawing wave refraction diagram in each direction.

Consequently, the breaker height and incident angle at the breaking point are found.

BEACH PROCESS AFTER THE CONSTRUCTION OF GROINS

The parallel portion to shoreline of T-type groins at this coast is constructed under the mean water level so that it has the identical effect of submerged breakwater. The length of parallel portion of the groin is equal to the longitudinal length of groin, and the intervals between the groins are 1.5-2.0 times the longitudinal length of groins. The groins constructed at this coast have different longitudinal lengths such as 35, 50, 60 and 70 m, respectively.

As a general rule, when the groins of peninsular type are built perpendicular to or at an inclination with the shoreline, the deposition occurs on the updrift side of the groin and the erosion occurs on the downdrift side of the groin. The shoreline furiously fluctuates with the change of the direction of littoral drift as sketched in Fig. 4.

On the other hand, as shown in Fig. 4, the seasonal fluctuation of the shoreline between the T-type groins are almost independent with the seasonal changes of the direction of littoral drift. The beach configuration shows concave in plan and the maximum concave point deviates just a few from the center of interval of the groins with the change of the direction of littoral drift.

In Fig. 5, the observed configuration between the groins in August and March verifies the above description. Each number of the groins corresponds to the groin number as indicated in Fig. 1. The concave configuration due to the T-type groin is caused by the diffraction of waves at the both end of parallel portion of groins.
It is obvious that the longer groin is constructed, the flatter beach configuration results as shown in Fig. 5.

It is concluded from the above mentioned fact that the T-type groin gives the effective results for the stabilization of the beaches where the direction of littoral drift furiously changes.

But if the length of groin becomes shorter, the center of groins recedes. The wave concentrates in this part, and coastal construction there is easy to destructive. Therefore, in order to protect the concentration of the wave, the groin should be at least 60 m in length from the observed results.

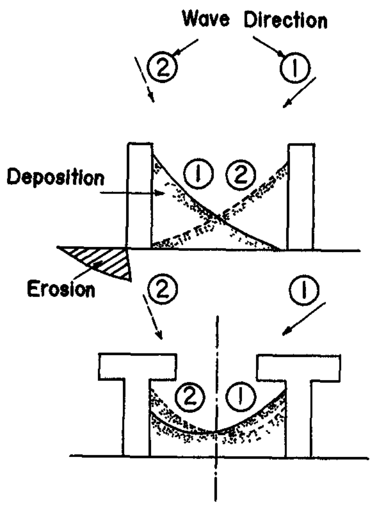


FIG. 4--SKETCH OF BEACH PROCESS AROUND GROINS

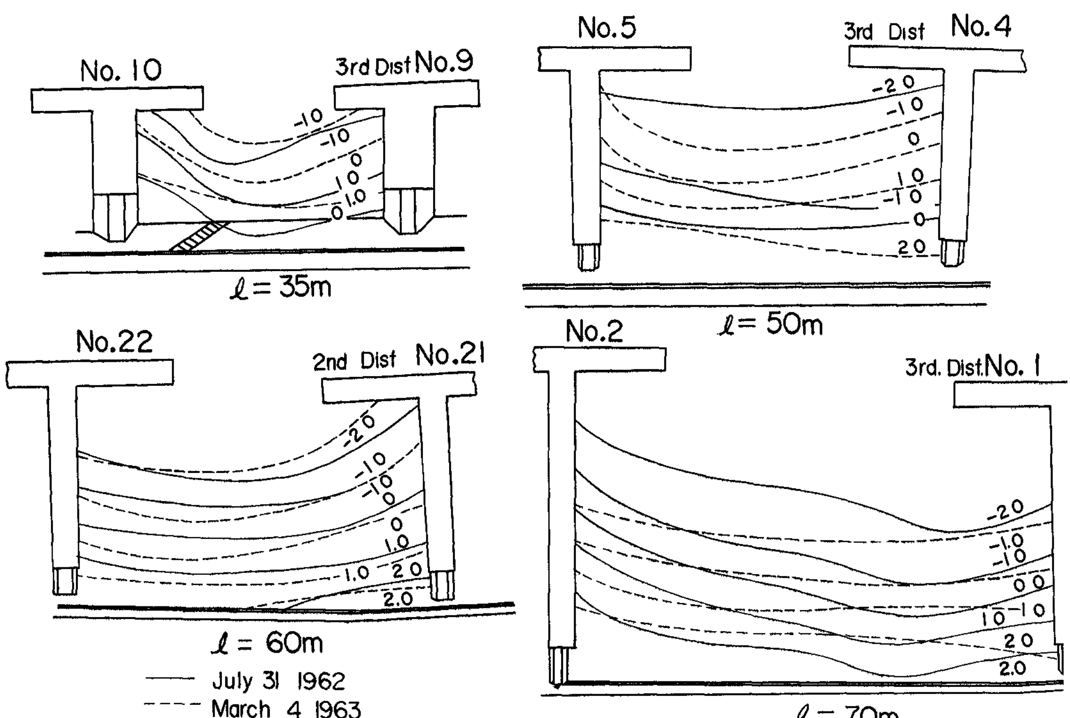


FIG 5 --SEASONABLE FLUCTUATION OF BEACH CONFIGURATION

ESTIMATION ON THE STORAGE CAPACITY OF SAND DRIFT BETWEEN GROINS

The installation of groins has not been designed effectively because the storage capacity of groin to littoral sand drift was not estimated properly.

The amount of sediment eroded or deposited between two groins can be estimated by the hydrographic survey of coastal configuration. Using these field data the authors have estimated the storage capacity to littoral drifts between the groins by the following procedure.

Now, let consider the case in which three adjacent groins are installed as shown in Fig. 6. In this figure, X_1, Y_1 and Z_1 denote the amount of littoral drift per unit time at each location before the installation of groins along the coast, X_i', Y_1' and Z_1' the amount of transport past a groin per unit time after the installation of groins and the amount of sediment between two groins are indicated by V_1' (between No. 1 and No. 2 groins) and V_2' (between No. 2 and No. 3 groins), respectively.

The following relationships are then obtained:

$$\sum_{i=1}^{n} X_1't_1 - \sum_{i=1}^{n} Y_1't_1 = V_1' \qquad \text{..............(1)}$$

$$\sum_{i=1}^{n} Y_i't_1 - \sum_{i=1}^{n} Z_1't_1 = V_2' \qquad \text{..............(2)}$$

where t_1 is the duration time of the wave under the identical conditions. When the ratios of amount of littoral transport past a groin to the amount of littoral transport in the case of no structure are defined by $a=X_i'/X_1$, $b=Y_1'/Y_i$ and $c=Z_1'/Z_1$, the storage capacities of the groin to littoral drift are expressed by (1-a), (1-b) and (1-c), respectively.

In the case when two groins, No. 1 and No. 2, are same in type, length and interval, a and c are obtained by the following equations, if a is assumed equal to b.

$$a=b= V_1'/(\sum_{i=1}^{n} X_1t_i - \sum_{i=1}^{n} Y_1t_i) \qquad \text{..............(3)}$$

$$c= (a\sum_{i=1}^{n} Y_1t_i - V_2')/\sum_{i=1}^{n} Z_it_1 \qquad \text{..............(4)}$$

Also assuming that No. 3 in Fig. 6 is very longer in length compared with No. 1 and No. 2 and it can perfectly catch the littoral transport, then a and b can be determined by Eqs. (5) and (6).

$$b= V_2'/\sum_{i=1}^{n} Y_1t_1 \qquad \text{..............(5)}$$

$$a= (V_1'+V_2')/\sum_{i=1}^{n} X_1t_1 \qquad \text{..............(6)}$$

In Eqs. (3) to (6), V_1' and V_2' may be estimated from the field observation.

The several empirical formulae[5)6)7)] for the estimation of amount

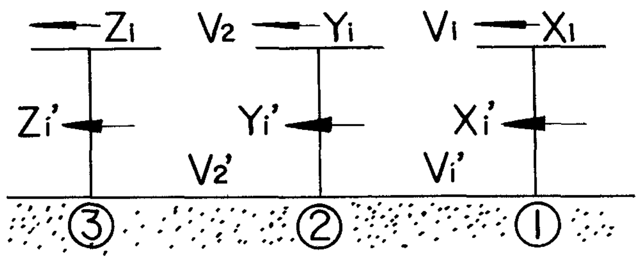


FIG. 6.--SKETCH OF GROIN SYSTEM

TABLE 2.--VALUES OF THE STORAGE CAPACITY OR THE PASSING RATIO OF GROIN

Date	a	1-a	c	1-c
Aug. 1-Aug. 7	0.48	0.52	0.38	0.62
Aug. 7-Aug.10	0.58	0.42	0.57	0.43
Aug.10-Aug.19	0.47	0.53	0.44	0.56
Aug.19-Aug.22	0.62	0.38	0.51	0.49
Aug.22-Aug.23	0.58	0.42	0.18	0.82
Aug.23-Aug.26	0.48	0.52	0.44	0.56
Mar. 7-Mar.14	0.45	0.55	0.43	0.57
Mar.14-Mar.21	0.51	0.49	0.40	0.60

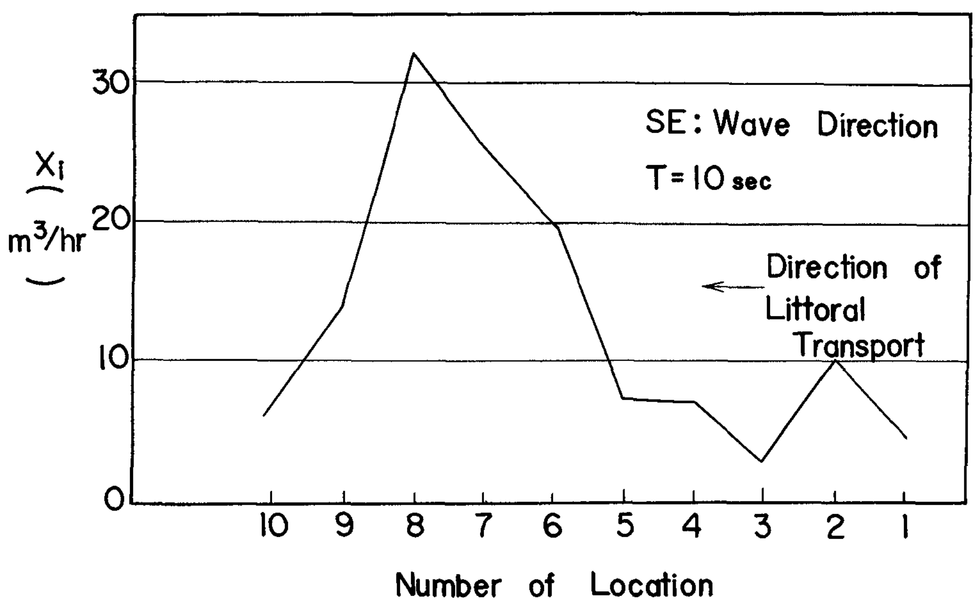


FIG. 7.--DISTRIBUTION OF AMOUNT OF LITTORAL DRIFT ALONG IMAZU COAST

of littoral drift are proposed by many investigators. In this investigation, the empirical formula proposed by Iwagaki and Sawaragi[7] is used. This formula has been derived by modifying the Kalinske-Brown formula for sediment transport in open cannels. The width of littoral sand drift zone may be obtained experimentally. Good agreement is obtained between this formula and the field investigation made at the North of the Akashi Strait between Honshu and Tokushima.

The formula is expressed by the following equation of

$$X_1,\ Y_1 \text{ and } Z_1 = m\cdot H_0'^{15/4}\cdot T^{-3/2}\cdot i^{4/3}\cdot d^{-1/2}\cdot (H_0'/L_0)^{-1/2}\cdot(\sin 2\alpha_b)^{4/3}\cdot\cos\alpha_b \quad \ldots(7)$$

where $m = (31.7)\cdot(1/16)^{3/2}\cdot(\sigma/\rho\ -1)^{-3/2}\circ g^{-1/4}$, $H_0' = K_b H_0$

X_1, Y_1 and Z_1 are the amount of littoral drift per unit time, H_0 wave height of deep water, d mean grain size, i beach slope, L_0 wave length of deep water, σ and ρ density of the bed material and water, respectively, α_b incident angle of breaker, K_b coefficient of refraction at the breaking point and g acceleration of gravity.

The passing ratio of groin, which is the ratio of the amount of littoral transport past a groin to the amount of littoral transport in the case of no structure, or the storage capacity of a groin may be obtained under the boundary condition mentioned in Eqs. (3) to (6). In the case where the boundary condition may not be satisfied, the storage capacity of groins in Eqs. (3) to (6) may be determined successively from the location where the conditions may be fulfilled.

Table 2 shows the result calculated for the passing ratios, a and c, by Eqs. (3) and (4). In Table 2 the groin having the storage capacity (1-a) is constructed by the hexaleg blocks. Its length is 60 m and the interval 100 m. On the other hand, in case of the storage capacity having (1-c) the half-length of the groin at the inshore side are made of the cubic concrete blocks and the other half the hexaleg blocks. From the table, it is cleared that the former's storage capacity indicates about 50 % and the latter one about 60 %.

The storage capacity of a groin may be influenced by the characteristics of wave and other factors. To clarify the effects of these factors for the storage capacity, however, is still very complicated in this stage.

DESIGN OF GROINS AND STABILITY OF BEACHES

To stabilize beaches by groins, the groins have to be designed to secure that the amount of transport past a groin along the coast should be held constant. In this respect, the distributions of the amount of transport along the coast without structure may be required in advance.

Now, the design of groin system is explained by the following example. Fig. 7 shows the distribution of the amount of littoral sand drift per unit time along the Imazu Coast without structure in the case when the direction of wave is SE and wave period 10 sec.. The amounts of littoral drift at the locations from No. 1 to No. 10 are expressed as X_1, X_2, ... X_9 and X_{10}, where X_{10} is the amount at the downdrift end. If a_i is the passing ratio of groins, the amounts of littoral drift past the groins at each location are expressed as a_1X_1, a_2X_2, ...a_9X_9, respectively.

To stabilize beaches, the amount of transport past a groin should be satisfied by the following equations,

$$X_{10}-a_9X_9 = 0, \quad a_9X_9-a_8X_8 = 0, \quad \ldots\ldots\ldots \quad a_2X_2-a_1X_1 = 0 \qquad \ldots.(8)$$

Using the amounts X_1 as shown in Fig. 7,

$$a_9=0.48, \quad a_8=0.20, \quad a_7=0.25, \quad a_6=0.33 \quad \ldots\ldots$$

are successively obtained by Eqs. (8).

The required passing ratios of the sand drift in groins are changed with length and interval of the groins. However, if the hexaleg block is used for groin, the required passing ratios of groins may be obtained by the change of interlocking method of blocks.

CONCLUSIONS

The following conclusions have been drawn from the results of this study.

(1) The T- type groins give the effective results for the stabilization of the beaches where the direction of littoral drift furiously changes.

(2) The longer T-type groins are constructed the flatter beach configuration results.

(3) Using the results of the field investigation, the method of estimation on the storage capacity of littoral sand drift for the permeable and impermeable groins are proposed.

(4) To stabilize beaches by groins, the storage capacity of the groins has to be changed with the locations such that the amount of transport past a groin is kept constant along the coast.

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