CHAPTER 34

MODEL STUDY ON THE FILLING-UP OF A FISHERY HARBOR BY DRIFTING SAND

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This paper is concerned with certain field investigations and model experiments whose purpose was both to discover the mechanism of the movement of coastal material and its deposition in harbor basins and to consider some protective measures which might be taken against the filling-up of basins by drifting sand. From view point of similarity for the falling velocity of bottom materials, vinyl pellets were used as the model sediment. In experiments the height of the deposition of sediment was measured, together with the direction and velocity of currents, while in various cases the wave height inside and outside the harbor was measured as a means of elucidating the behavior of drifting sand as it fills up a harbor basin.

It is concluded from these experiments that the filling-up of a harbor basin can be reproduced quantitatively in a model and that currents induced in basins by waves and harbor oscillations may have an important bearing on the problem of filling-up.

INTRODUCTION

It has frequently been observed in many harbors constructed on sandy coasts that the navigation of boats is prevented by the invasion of drifting sand into the harbor and its deposition in the basin. Gumizaki Fishery Harbor to be treated here has quickly filled up during certain periods every winter. Dredging has been used to keep the harbor open for navigation; however, it is strongly requested that measures are taken which will protect the basin from filling-up by drifting sand.

The filling-up of the basin by drifting sand is mainly caused by waves and currents, but is also influenced by beach topography, beach materials and the shape of the harbor. It is difficult, therefore, to solve this problem simply by prototype investigations. But it will not be possible to find an effective measure against the filling-up of the basin by drifting sand until the effects of many factors influencing it are individually disclosed by model experiments.

In order to grasp the actual conditions of the filling-up of the basin of Gumizaki Harbor, field investigations were made in the period 1959 to 1960.

Furthermore, in order to solve this problem, and in addition, to discover the mechanism of the invasion of drifting sand into the harbor and its deposition in the basin, model experiments were made at Ujigawa Hydraulic

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DESCRIPTION OF THE PROTOTYPE

GUMIZAKI FISHERY HARBOR. Gumizaki Fishery Harbor is located on the Echizen Coast facing the Japan Sea. The sketch view of beach areas adjacent to this harbor is shown in Fig. 1. The topographical features of these beach areas may be described as follows: the shoreline is complicated by many shore reefs found along various parts of the coast and the beach areas can be divided into two parts according to the nature of the bottom topography: that is the area to the south of this harbor, where the sea bottom is composed of sand and the beach slope is relatively gentle (the station at a depth of 10 m is about 400~500 m seaward from the shore.), and the area to the north side of it, where the sea bottom is almost entirely composed of rock and the beach slope is steep as well as irregular (the station at a depth of 10 m is about 100~200 m seaward from the shore.).

As shown in Photo. 1, this harbor is only about 250 m long and 25 m wide and has a rectangular basin. It has two openings, one at the south and one at the north end, but only the southern one is serviceable as the harbor entrance, its width being 40 m. The narrow north opening with a width of 4 m is connected to the open sea, so that flow can occur through the opening.

Although the basin depth must be maintained at 1.8~2.0 m for navigation, it has been annually filled up by drifting sand during the winter period. The results of soundings which were made on 10th August 1959 and 19th December 1959 after dredging operations had been carried out are shown in Fig. 2 and 3 respectively. Especially in the latter case, it appeared that the sand deposit had reached a state of equilibrium and it can be seen from a comparison of these figures how the water depth quickly decreases with the action of waves and currents.

PROTOTYPE INVESTIGATION. The purpose of the prototype investigations was to collect the data necessary for understanding the phenomenon of the invasion of drifting sand into a harbor and its deposition in the basin. Investigations with regard to the following items were made to determine the hydraulic characteristics of waves and currents, together with the characteristics of bottom sediment and drifting sand, and to ascertain the extent of sand movement: 1) the sounding of beach areas adjacent to Gumizaki and the inside of the harbor, 2) the sampling of bottom sediment and drifting sand, and 3) the observation of waves and currents.

The observation of waves at Gumizaki was made in December, 1959 by using a transit type wave meter. According to observations, incident waves presumed to influence the filling-up of the basin are about 4 m in height, 6 seconds in period and NW~NNW in direction, and are generated by winter storms of which the duration time per storm is 10 to 20 hours.

It is well known that most of the sediment transport is caused by waves and currents shorewards from the breaker zone and at Gumizaki Harbor, when incident waves were as high as 4 m, it was observed that the sea water near the harbor entrance became muddy. This indicates that a large quantity of bottom sediment is suspended by wave action and then, transported into the harbor by currents.

In order to understand this phenomenon, currents were observed with the use of buoys consisting of a rubber ball connected by rope to a stone and the position of each buoy was measured by two transits set on land every 30 seconds. Fig. 4 shows a number of buoy positions traced by two transits, in which the current direction is denoted by an arrow-head. From this figure, it can be seen that the current directions are almost exactly anti-clockwise, and the mean velocity of the currents is about 40 ~ 50 cm/sec, so that much suspended sediment is transported into the harbor by these currents.

The sampling of bottom sediment was made in the summer of 1959. Fig.5 shows the relationship between the median diameter of sand on the sea bottom inside and outside the harbor and the water depth where sand samples were collected. Since the grain sizes of sand inside the harbor, which are 0.14 to 0.32 mm in median diameter, are smaller than those outside the harbor and also, a definite source of littoral drift can not be found, it is presumed that the suspended sediment spread around the harbor is transported into the harbor and deposited in the basin through the action of waves and currents. In addition, the characteristics of drifting sand sampled at the north opening in the winter of 1959 were almost the same as those of the bottom sediment.

MODEL STUDY

SIMILARITY OF MODEL EXPERIMENTS INCLUDING SUSPENDED SEDIMENT TRANSPORT.

In order that the dynamic similarity between the model and the prototype be established in a hydraulic model which includes sediment transport to be treated here, the conditions of dynamic similarity for the sediment movement as well as the fluid motion must be satisfied in model experiments.

Although these similarity laws under wave action have been recently studied by Goddet and Jaffry (Ref. 1), Sawaragi (Ref. 2), Yalin and Russell (Ref. 3), and others, the general theory has not yet been established.

When the wave transformation due to viscous effect is negligible, it is expected that the dynamic similarity of the wave motion offshore from the breaker zone is satisfied by the Froudian similarity law.

Taking H wave height, L wave length, T wave period, C wave celerity, and h water depth, the existence of the dynamic similarity between the model and the prototype implies in the case of an undistorted model:

$$\left.\begin{aligned} H_m/H_p &= L_m/L_p = h_m/h_p = \lambda_p \\ T_m/T_p &= C_m/C_p = \lambda_t \\ \lambda_t &= \sqrt{\lambda_l} \end{aligned}\right\} \quad (1)$$

in which suffixes m and p denote the quantities for the model and the prototype, and λ_l and λ_t the length and the time scale, respectively.

On the other hand, since littoral drift is predominant in a surf zone, it is important to know the characteristics of waves and currents shorewards from the breaking zone. A laboratory study for scale effects involving the breaking of waves by Diephuis (Ref. 4) showed that the ratio of the depth of breaking to the deep-water wave height increases with a decreasing wave period, if the period is shorter than about 2 seconds. This experiment indicates that the condition of dynamic similarity in relation to the breaking of waves cannot be satisfied in the case of a small and undistorted model. Therefore, it is desirable to use a wave period which is as long as possible in the model experiment in relation to the breaking of waves.

Next, an important problem in the present experiment is to determine the similarity law in sediment transport due to the action of waves and currents. However, it is difficult to establish the general condition of its dynamic similarity, because the mechanism of sediment movement due to wave action is not yet sufficiently understood. Therefore, the actual method used is to examine the reproductivity of the model by a comparison with the prototype. This method is convenient for learning the qualitative nature of beach processes, the filling-up of a harbor and so on, but it is almost impossible to verify the quantitative characteristics in the model experiment.

As mentioned above, it must be remembered that there is a close connection between the phenomenon of sediment suspension outside the harbor and the filling-up of the basin. This indicates that the condition of similarity should be determined by paying attention to the suspended sediment. Hence, as an attempt to treat the model experiments, including the drifting sand, quantitatively, the model sediment has been chosen so as to satisfy the condition of similarity for sediment concentration outside the harbor between the model and prototype.

Taking the vertical coordinate, z, upward from the sea bottom, the equation of sediment concentration is given by the following expression:

$$w_0 \frac{\partial c}{\partial z} + \frac{\partial}{\partial z}\left(\varepsilon \frac{\partial c}{\partial z}\right) = 0 \qquad (2)$$

where w_0 is the fall velocity of a suspended sediment particle, c the concentration of suspended sediment and ε a coefficient of eddy viscosity. By using Eq.(2), the similarity in sediment transport is determined as follows:

$$\frac{w_{om}\, c_m / z_m}{w_{op}\, c_p / z_p} = \frac{\varepsilon_m\, c_m / z_m^2}{\varepsilon_p\, c_p / z_p^2} \qquad (3)$$

This equation is obtained by the fact that all corresponding ratios of each term in Eq.(2) must be the same in model and prototype. Since $z_m/z_p = \lambda_\ell$, in the case of an undistorted model, Eq.(3) is expressed as

$$w_{om}/w_{op} = (\varepsilon_m/\varepsilon_p)/\lambda_\ell \qquad (4)$$

Hence, a coefficient of eddy viscosity ε must be deduced in order to determine the condition of similarity for sediment. A study for suspended sediment by Hom-ma and Horikawa (Ref. 5) indicated that the following relationship for the eddy viscosity is applied:

$$\varepsilon = \kappa^2 \left|\frac{\partial u}{\partial z}\right|^3 \Big/ \left(\frac{\partial^2 u}{\partial z^2}\right)^2 \qquad (5)$$

where u is the horizontal velocity component of a water particle and κ the

Kármán Constant. On the other hand, Kishi (Ref. 6) denoted a coefficient of eddy viscosity on the basis of Kajiura's (Ref. 7) theory as follows:

$$\mathcal{E} = \kappa \,\widetilde{u}_B^* (z + z_0) \tag{6}$$

where $\widetilde{u}_B^*$ is a quantity proportional to the maximum shear velocity due to waves and z_0 roughness length. In the application of Eq.(6) to Eq.(4), the bottom friction factors must be estimated on a natural beach; however, it is difficult to deduce them accurately because the knowledge concerning them is as yet incomplete. Therefore, considering that Eq.(5) may be applied, Eq.(4) may be expressed as:

$$w_{om} / w_{op} = \sqrt{\lambda_\ell} \tag{7}$$

This indicates that the condition of similarity between the sediment of the model and the prototype is expressed by the ratio of each fall velocity and the scale of fall velocity is equal to the square root of the length scale.

The relationship between the size and specific gravity of the model sediment, corresponding to prototype sediment with a fall velocity of 2.02 cm/sec against various values of λ_ℓ, is shown in Fig. 6 as an example.

In a small model, it is almost impossible to use a natural sand as a model sediment, because the size of the model sediment is less than 0.1 mm. On the other hand, in a large model, it is possible to use natural sand, but a large quantity of sand is required in experiments, so that it is difficult to control the supply and movement of the model sediment. If a light sediment could be found, a large model would not be required and would also be of great convenience in conducting experiments.

EXPERIMENTAL EQUIPMENT AND PROCEDURES. Model experiments for the filling-up of Gumizaki Fishery Harbor have been made by using a concrete wave tank 12.5 m long, 10.0 m wide and 0.4 m deep. The vertical and horizontal scales of the model are both 1/50. The bottom topography of the model was made so as to agree with that obtained from the sounding shown in Fig. 1, and the model sediment was placed on only the shaded areas shown in Fig. 7. In addition, the water depth of the model harbor was 4 cm deep and the bed of the basin was horizontal.

In the concrete wave tank, waves were produced by a flatter type wave generator with a 7.5 HP electric motor and incident wave heights were measured by two electric resistance type wave gages with an ink writing-oscillograph installed inside and outside the model harbor. The characteristics of incident waves in the prototype which should be used in experiments were determined to be 4 m in height, 6 seconds in period and NW in direction. Therefore, from the Froudian similarity law, when $\lambda_\ell = 1/50$, the characteristics of the incident waves used in the model were 8 cm in height and 0.85 sec. in period.

In the case of $\lambda_\ell = 1/50$, the characteristics of the model sediment, corresponding to the prototype one of median diameter 0.2 mm and specific gravity 2.65, are determined by B-curve in Fig. 8 which represents the relationship between the median diameter and specific gravity of the model sediment. It can be seen from this figure that the condition mentioned above is approximately satisfied by using well sorted vinyl pellets with a median diameter 0.13 mm and a specific gravity 1.15 (see the mark ● in Fig.8).

The profiles of deposited sediment in the model basin were measured by a point gage at 30 minutes, 1 hour, 2 hours,...... after the beginning of the experiment, and measurements were continued until it appeared that the state of equilibrium had been reached.

Moreover, in order to investigate the characteristics of currents inside the model harbor, the direction and velocity of currents near the water surface were measured by the method of filming a number of buoys with a 16 mm cinecamera and also the direction and velocity of currents near the bottom were measured by using a cubic particle with a diameter of 5 mm and a specific gravity of about 1.0.

Model experiments were made systematically to discover: 1) The reproductivity of the phenomenon of the filling-up of the basin by drifting sand (Test A), 2) The mechanism of the invasion of drifting sand into the harbor and its deposition in the basin (Test B), and 3) The basin maintenance layout as protection against the filling-up process (Test C).

The conditions of the experiments are shown in Table 1. Two trays with a depth of 10 cm were covered with the vinyl pellets as movable bed, though these could have been replaced by gravel to form a fixed bed.

RESULT AND DISCUSSION OF MODEL EXPERIMENTS

REPRODUCTIVITY OF MODEL EXPERIMENTS (Test A).

Although the condition of dynamic similarity for sediment concentration outside the harbor is given by Eq.(7), it is not clear whether the geometric similarity of the deposition height in the basin can be satisfied or not. Therefore, in this paragraph, the reproductivity of model experiments is examined by a comparison of the deposition heights in model and prototype.

An experiment for reproductivity was made by using the harbor condition shown in Fig. 9(a) and by forming both tray I and II as movable beds. The initial water depth of 4 cm in the basin was rapidly decreased for 30 min. after the beginning of the test until it finally reached a state of equilibrium after about 3 hours.

Fig. 10 shows a graphic comparison of the height of deposited sediment obtained from the experiment and the sounding made by the field investigations, in which the ordinate is the ratio of the deposition height in a state of equilibrium to the initial water depth h, and the horizontal coordinate x in the longitudinal direction of the basin taking $x/h = 0$ as Station 1 shown in Fig. 7.

From the fact that both deposition profiles in the model and the prototype reached a state of equilibrium and the deposition heights in the model agreed well with those in the prototype, it is verified that the above condition of similarity is almost satisfied.

MODEL EXPERIMENTS FOR DISCLOSING THE MECHANISM OF THE FILLING-UP OF THE BASIN. It is not until the mechanism of the filling-up of the basin is understood that the best methods of prevention can be established. At Gumizaki Harbor, it is surmised that the fine sediment spread over the sea bottom is suspended by waves during a period of storms, transported into the harbor and deposited in the basin by the action of waves and currents; however, it is difficult to verify the above assumptions analytically, because studies for this problem have not yet been satisfactorily developed.

Test B was conducted in order to investigate the mechanism of the filling-up of the basin experimentally, in conjunction with the results of field observations.

Fig. 11 shows the change of the relative wave height in the basin, in which the relative wave height is expressed by the ratio of wave height measured in the basin H to incident wave height H_0. It can be seen that the values of H/H_0 are about 0.15 to 0.20 except in the vicinity of the harbor entrance, namely $x/h = 80 \sim 120$, and it can be surmised that incoming sediment will be easily deposited in the basin.

On the other hand, Fig. 12 shows the direction and the mean velocity of currents measured in the vicinity of the water surface, in which the current direction is expressed by the arrow-head and the mean velocity by the length. It can be seen from this figure that the current flowing into the basin through the north opening is predominant and the anti-clockwise currents are to be found in the vicinity of the harbor entrance of the model as well as the prototype.

In order to estimate the quantities of the drifting sand transported into the harbor through each opening situated at the south and north ends of the harbor and also to establish the relationship between the quantity of drifting sand and external conditions such as waves and currents, Test B-I was conducted under various conditions necessary for the investigating of the mechanism of the filling-up of the basin.

Firstly, the object of Test B-I was to ascertain the effect of the current as it passed through the narrow north opening in relation to the invasion and deposition of drifting sand. Test B-I was made by forming only tray II as a movable bed and by using the model shown in Fig. 9(a). Of course, when the test was carried out the attention was paid that the bottom topography of tray II should agree with that in the prototype during the time of the test. Changes of the deposition height in the basin were measured.

Fig. 13 shows the dimensionless plots of the deposition height η/h in the basin at 30 minutes, 4 hours and 5 hours after the beginning of the test. At 30 minutes, an approximate state of equilibrium is reached and the station of the basin at $x/h = 10$ is filled up to the water surface. Since tray I is a fixed bed, the sediment is only transported into the basin through the narrow north opening. Hence it is found that the filling up of the basin is greatly influenced by the action of this current.

Secondly, in order to investigate the sediment movement through the south opening, Test B-II was conducted by arranging tray I as a movable bed. Fig. 14 shows dimensionless plots of the deposition height η/h at 1, 3 and 5 hours after the beginning of the test. The invasion of sediment through the south opening occurs also in this case, but the quantity of incoming sediment is less than that in Test B-I. However, it must be noted that the sediment is deeply transported into the interior of the basin, whereas the direction in which incoming sediment is moved is contrary to that of the current. In addition, it can be seen that the deposited profile is characterized by a wavy pattern. This will be explained by the assumption that the sediment falling near the opening is moved in the form of bed load by harbor oscillation induced in the basin.

SOME TRIAL EXPERIMENTS ON THE BASIN MAINTENANCE PLAN FOR PREVENTING THE FILLING-UP OF THE BASIN. As it has been shown that the current flowing into the basin through the north opening is an impoftant cause of the basin filling-up, it is natural to consider that the filling-up of the basin can be effectively prevented by stopping the current. Hence some experiments were carried out after the north opening had been closed.

As shown in Fig. 9(b), Test C-I was made by arranging tray I as a movable bed and by using the model to close the north opening. Fig. 15 shows the dimensionless plot of the deposition height in this case at 0.5, 3 and 5 hours after the beginning of the test.

The quantity of the deposited sediment in this case is considerably less than that in the case of Test B, so that an effective measure for the purpose of harbor maintenance may be made by closing the north opening. But, at $x/h = 60 \sim 70$, the model basin is filled up so high that navigation becomes impossible. From this point of view, the result obtained from this test is scarcely different from that of Test A or B.

In order to prevent the invasion of the suspended sediment coming into the basin through the south opening, for Test C-II not only was the north opening closed but the breakwater on the north side of the entrance was extended by 40 m. (see Fig. 9(c))

Fig. 16 shows the dimensionless plot of the deposition height in such a case. It can be seen that the quantity of incoming sediment is greater than that in Test C-I. In particular, in the vicinity of $x/h = 70$, the basin is almost filled up to the water surface, hence compared with all the other cases mentioned above such measures are not good.

In order to give a reason why an increase in incoming sediment is caused by extending the breakwater, measurements of wave height in the basin were made under the same conditions as Test C-II, except that both trays were arranged as fixed beds. Fig. 17 is the result of the measurement expressed by the ratio of wave height in the basin H to incident wave height H_0. Then, comparing this with Fig. 11, it can be found that 1) the wave height in the vicinity of the entrance is reduced by extending the breakwater, 2) the interior of the basin becomes calm when the north opening is closed, and 3) the value of H/H_0 at $x/h = 60 \sim 80$ is about 0.3 and greater than that of 0.17 in Fig. 11.

From the above finding, it is surmised that harbor oscillation as a result of the resonance phenomenon is induced by extending the breakwater; however, it is felt that there is a wide gap between the harbor oscillation theory and the study of sediment movement due to harbor oscillation.

A study on the generation of sand bars due to stationary waves by Nomitsu (Ref. 8) indicated that the sand movement due to harbor oscillation occurs in the form of bed load. For the stationary wave of which the velocity u is expressed in the form of $u_0 \sin (n\pi/L)x \cos (2\pi/T)t$, the change of the deposition height η is expressed by using the formula of sediment transport rate $q = ku|u(u^2 - u_c^2)|$ and the equation of continuity for sediment transport is expressed as follows:

$$\eta = K_1 t\, u^4 (n\pi/L)^4 \cos (4\pi n/L)t$$

where k and k_1 are both constant values, n the number of node and L the wave length. Therefore, sand bars are formed in both node and antinode of stationary waves. This indicates that harbor oscillation has a close connection with the deposition of sediment.

Since the reason why sediment moves into the basin through harbor oscillation is not yet satisfactorily understood, measurements of the velocity and direction of currents in the vicinity of the bottom reveal the interesting fact that a particle near the bed is moved back and forth by the oscillatory motion of water over a long period but gradually comes into the interior of the basin (see Fig. 18).

In order to prevent the deposition of sediment through harbor oscillation, it is important to change the shape of the harbor lest the harbor oscillation should be induced in the basin. However, it is difficult to discover an ideal harbor shape experimentally or even to know how to improve Gumizaki Harbor whose shape is simple. An attempt to prevent harbor oscillation was made by using the model shown in Fig. 9(d). The initial water depth in the model basin was 6 cm.

Test C-IV was made under these conditions. Fig. 19 shows the dimensionless plot of the deposition height in this case, at 2 and 4 hours after the beginning of the test. In this case, the deposition profile reached state of equilibrium after 4 hours and it can be found that the quantity of incoming sediment is quite small and the sediment is not deposited in the interior of the basin. It is thought that the procedure used in this test could have a desirable practical application.

CONCLUSION

It is concluded from the results of these model experiments that:

1. Model experiments can be treated quantitatively by using the vinyl pellets as the model sediment.

2. An effective measure against filling-up is to stop the current flowing into the basin through the north opening.

3. Even if the north opening is closed, much invasion of suspended sediment may occur through the south opening. This is surmised because of

long period waves such as harbor oscillation.

4. In order to prevent the filling-up of the basin, first, it is important to prevent harbor oscillation and second, it is surmised that the closing of the north opening may be effective.

5. The method for preventing harbor oscillation shown in Fig. 9(d) is thought to be effective.

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Photo. 1. Gumizaki Fishery Harbor.

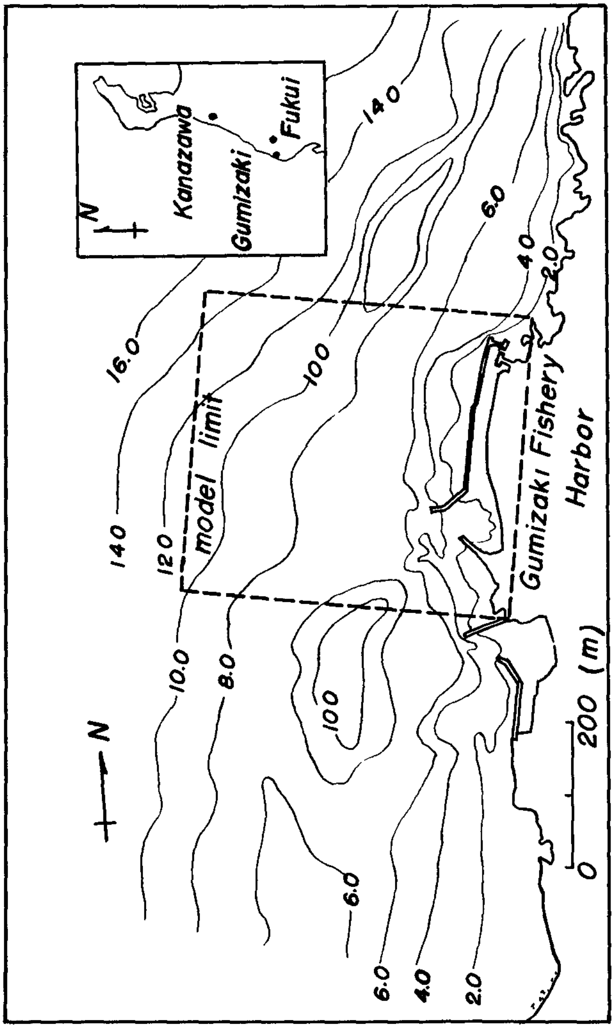

Fig. 1. Topographical map adjacent to the Gumizaki Fishery Harbor.

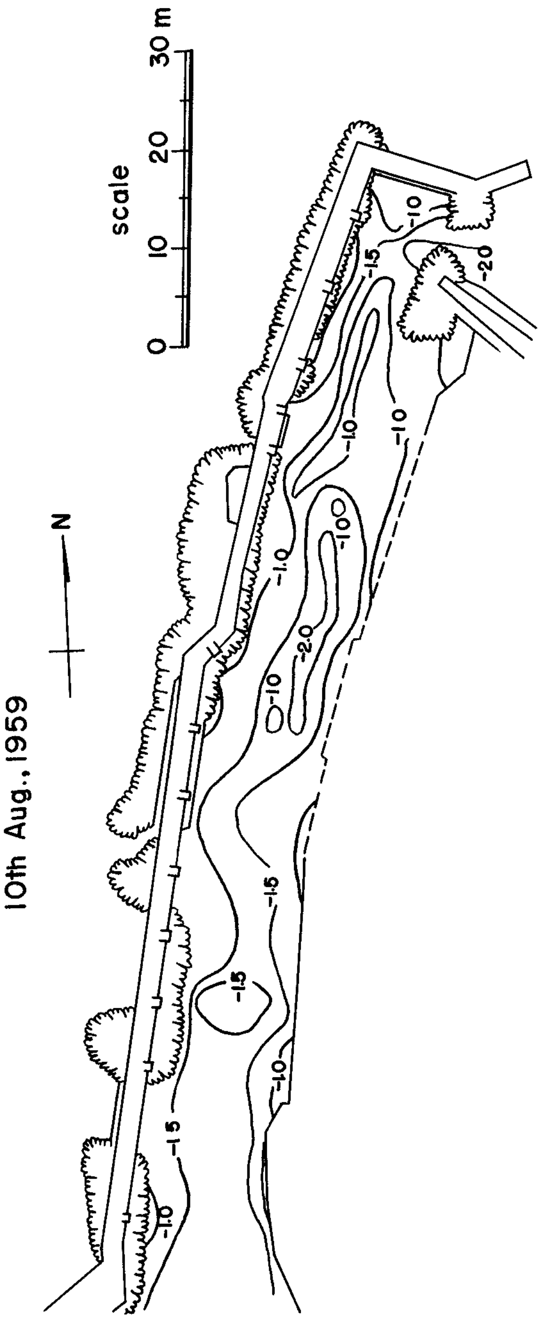

Fig. 2. Topography of harbor surveyed on 10th of August, 1959.

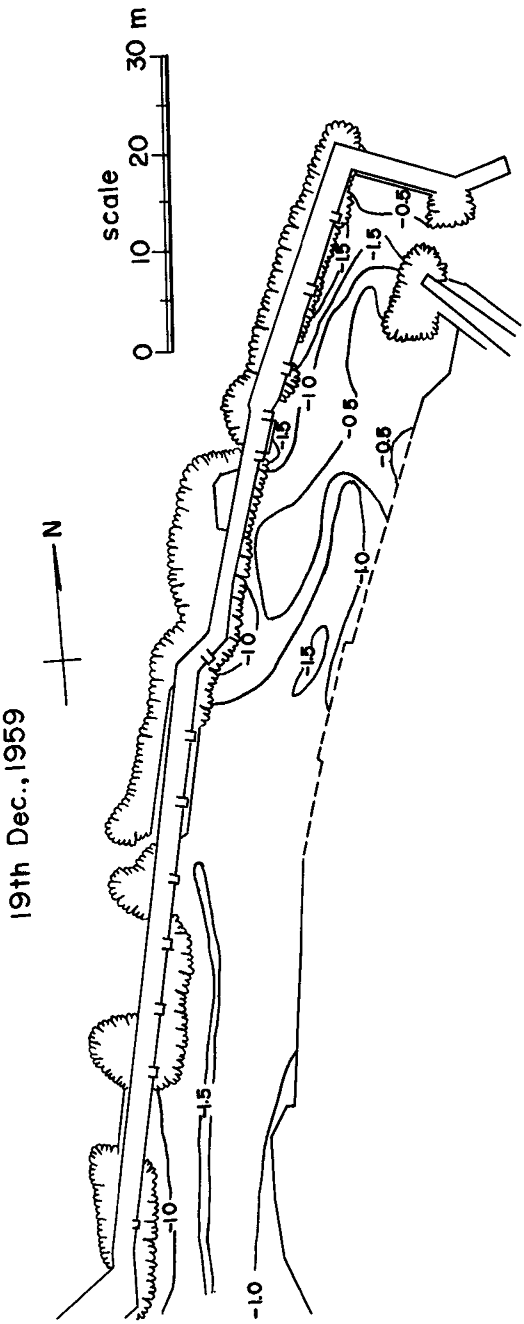

Fig. 3. Topography of harbor surveyed on 19th of December, 1959.

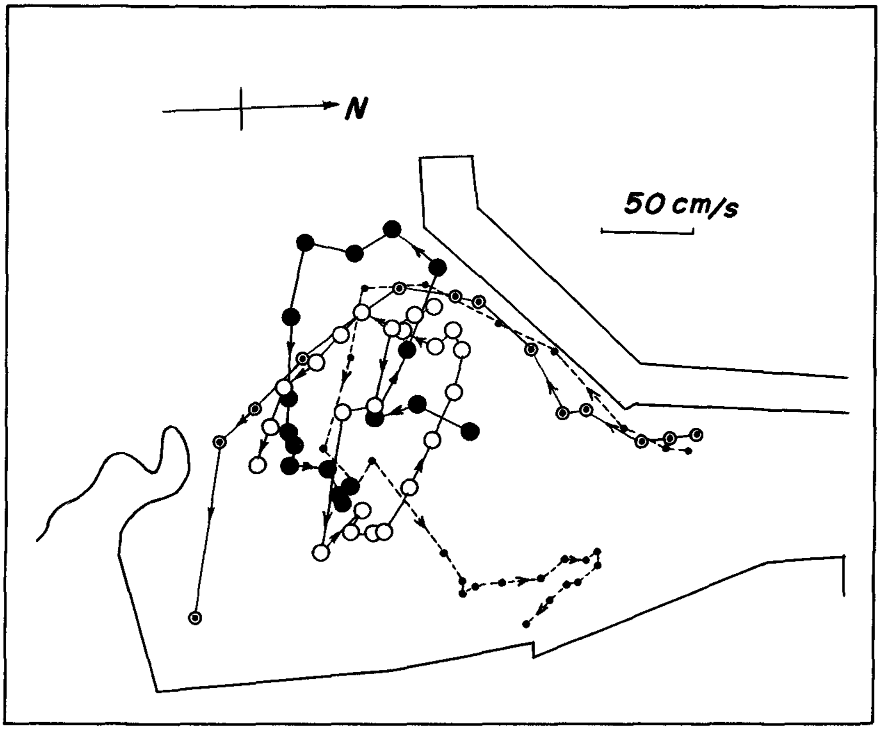

Fig. 4. Locus of buoy near the harbor entrance.

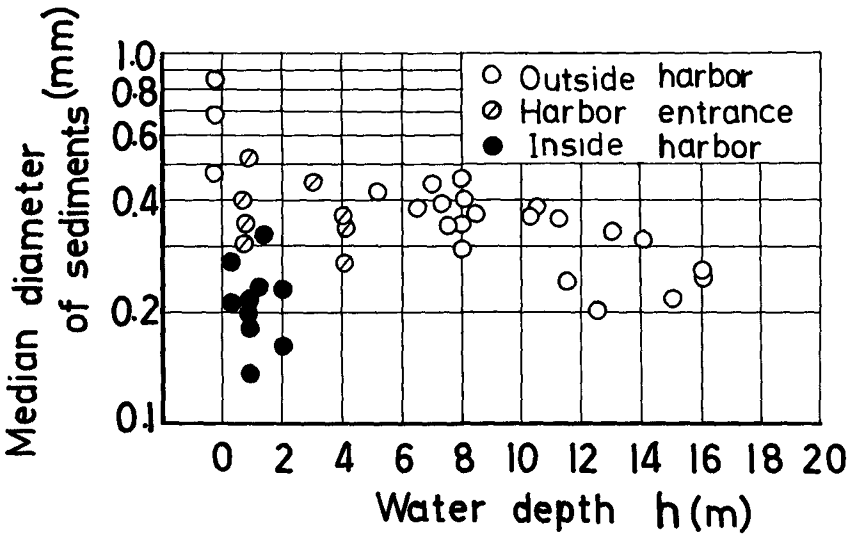

Fig. 5. Relationship between median diameter of sand and water depth.

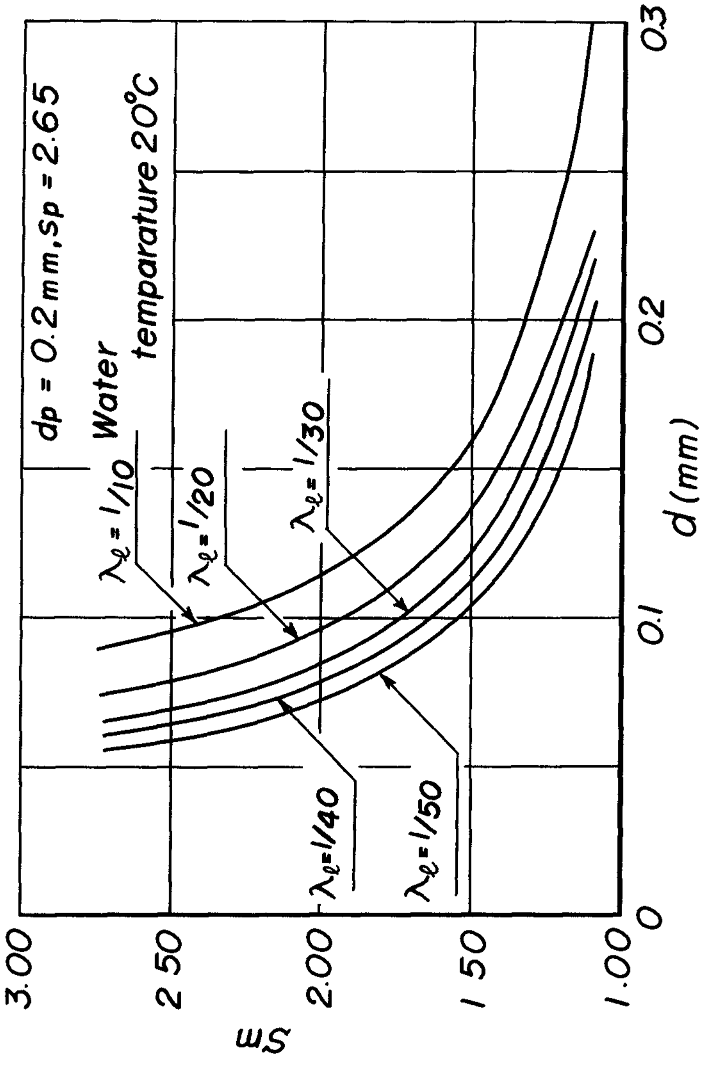

Fig. 6. Relationship between size and specific gravity of model sediment with a parameter of λ_e.

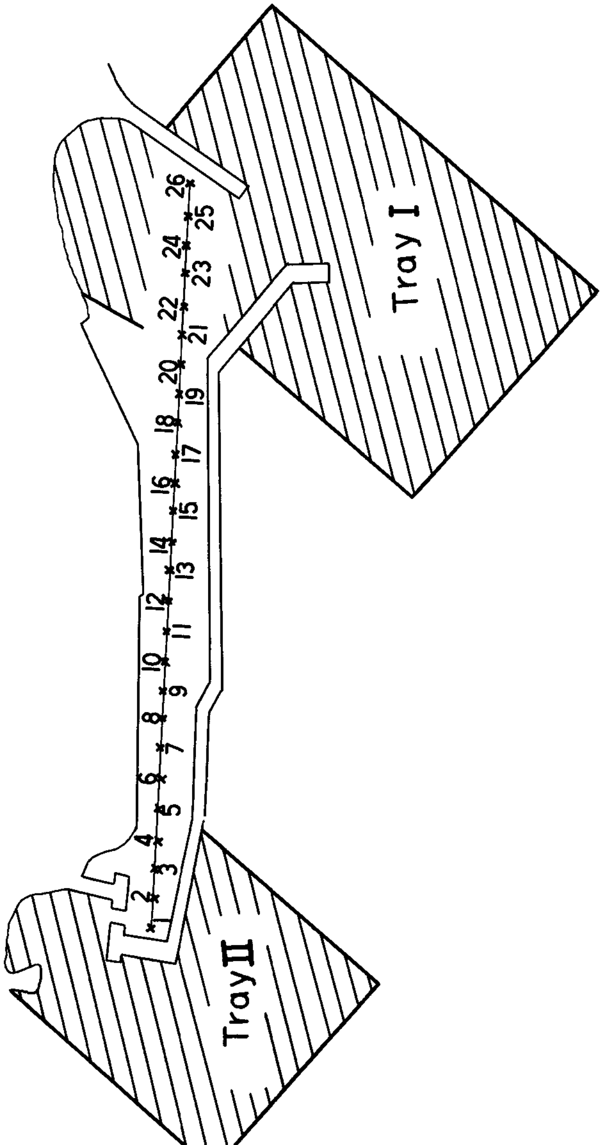

Fig. 7. Sketch of the model harbor.

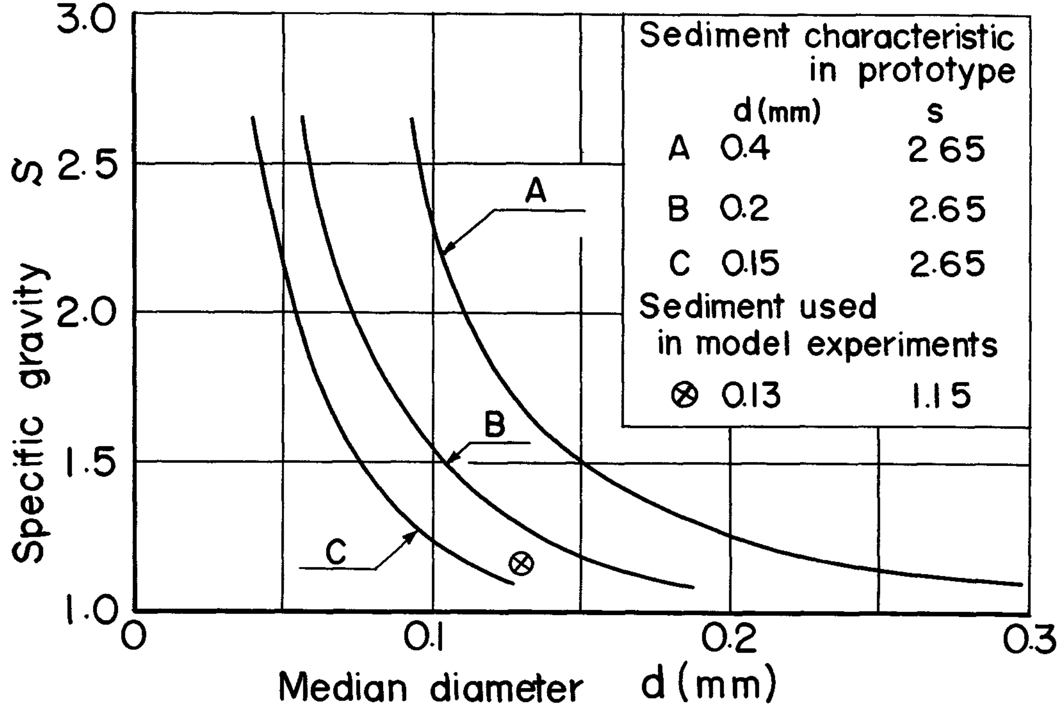

Fig. 8. Relationship between median diameter and specific gravity of model sediment, in the case of $\lambda_e = 1/50$.

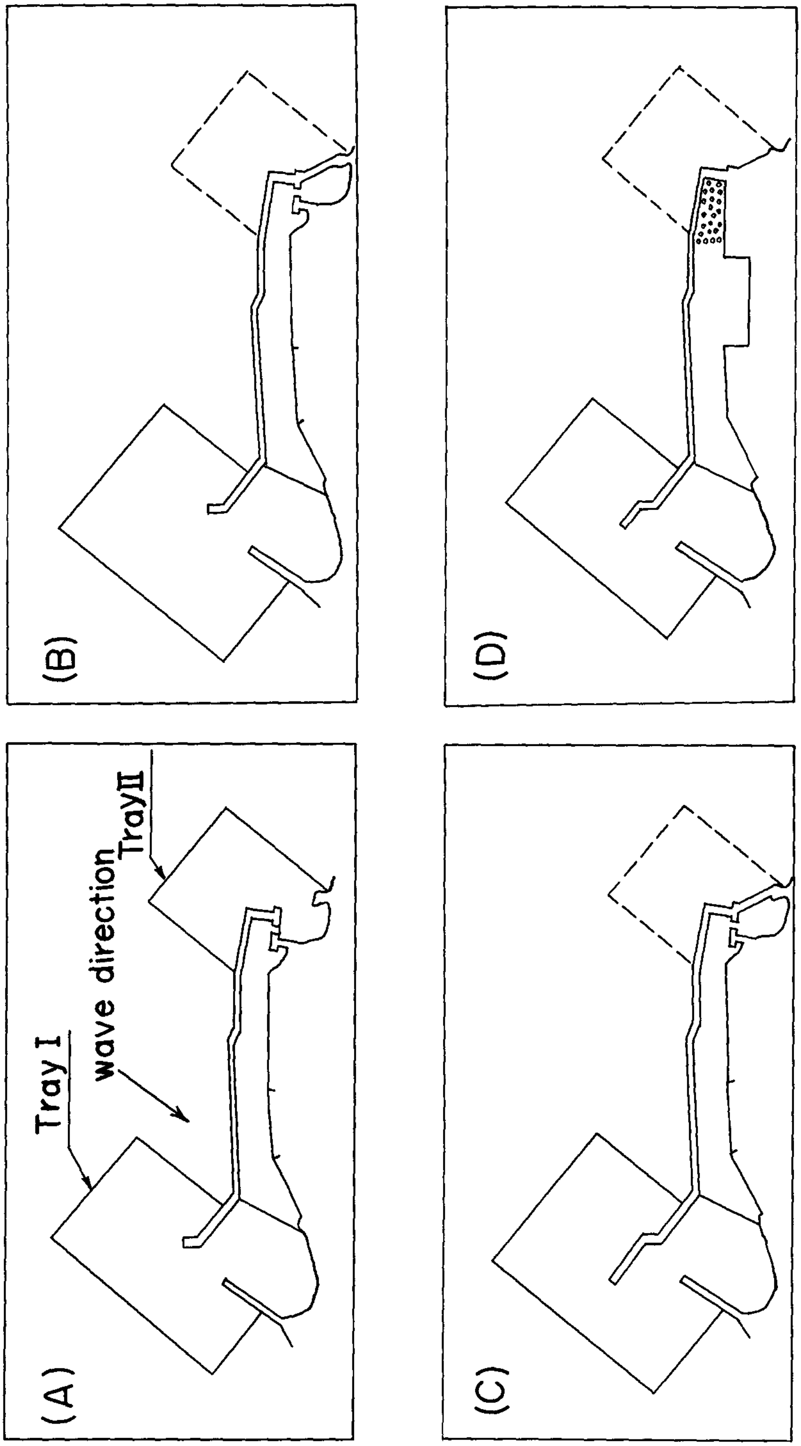

Fig. 9. Model test condition.

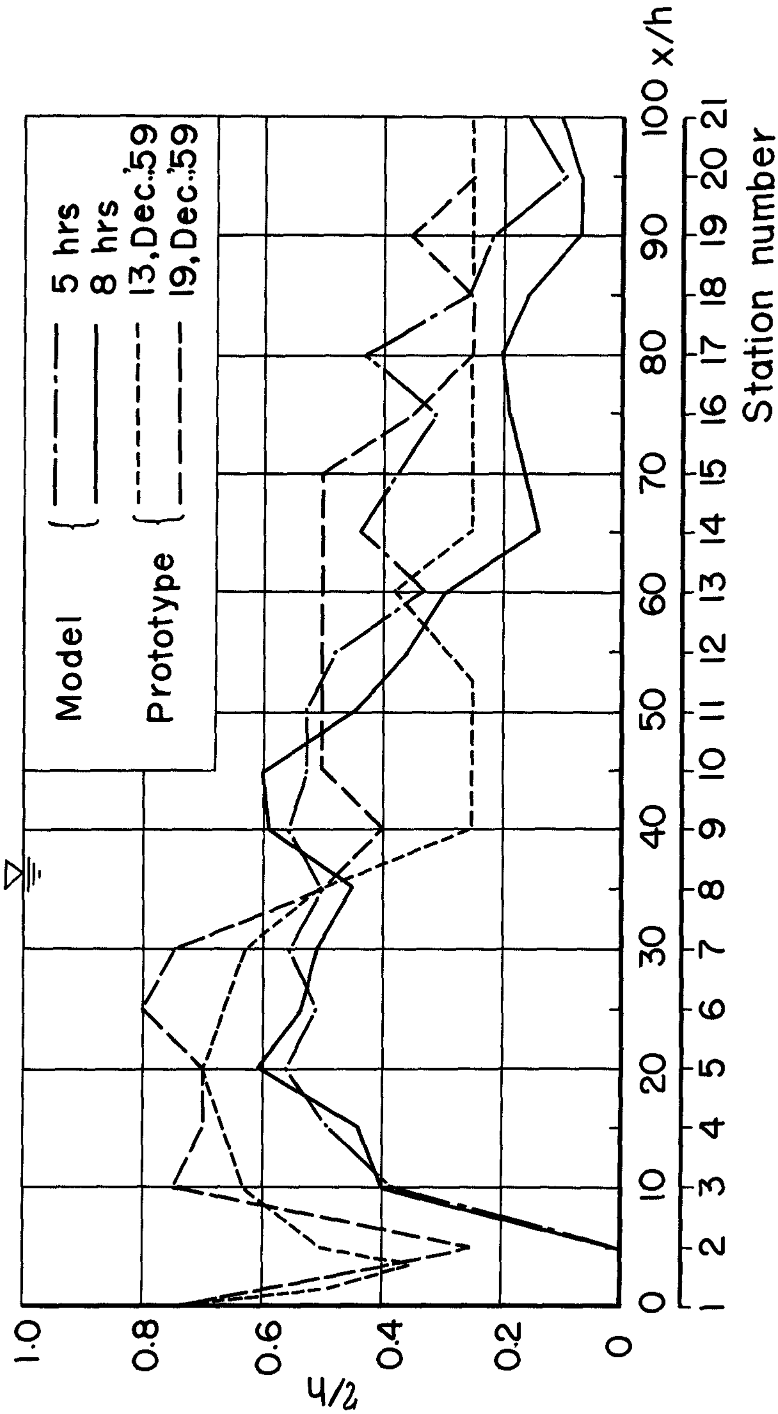

Fig. 10. Comparison between deposition profiles in model and prototype.

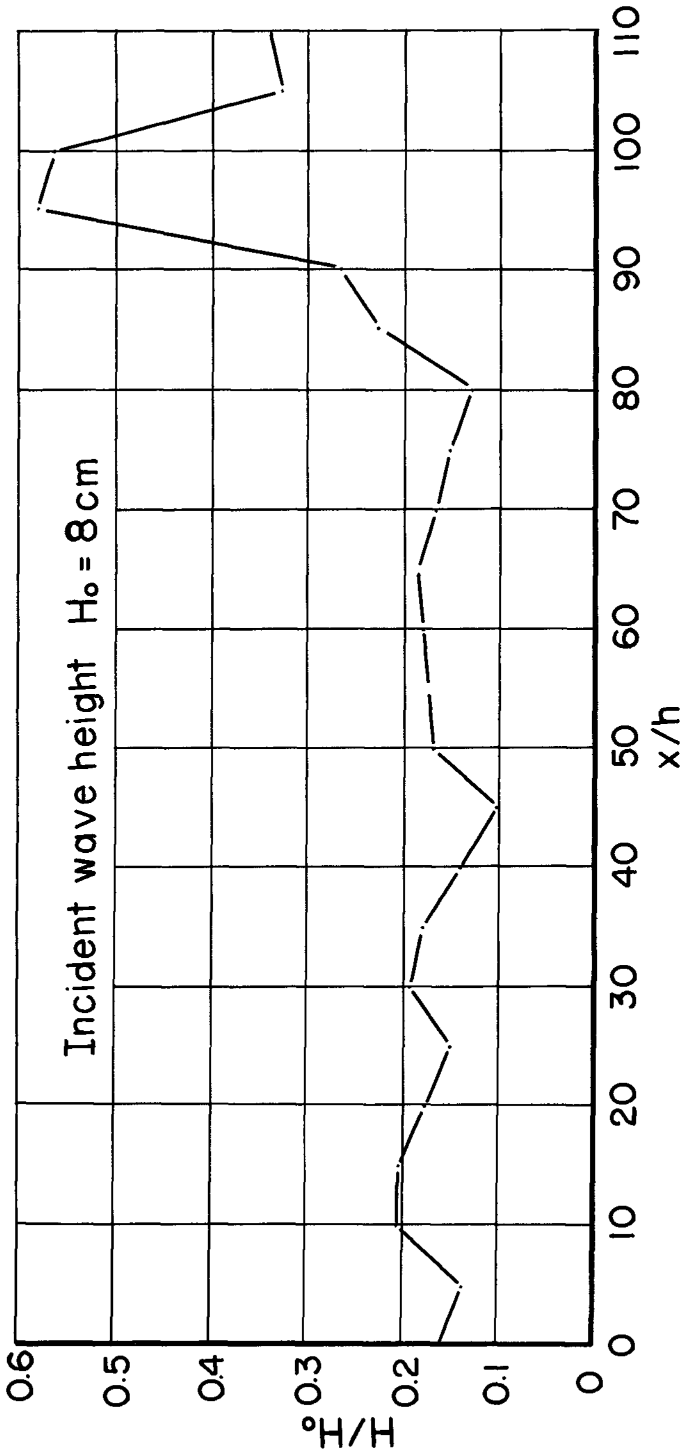

Fig. 11. Change of wave height in the basin.

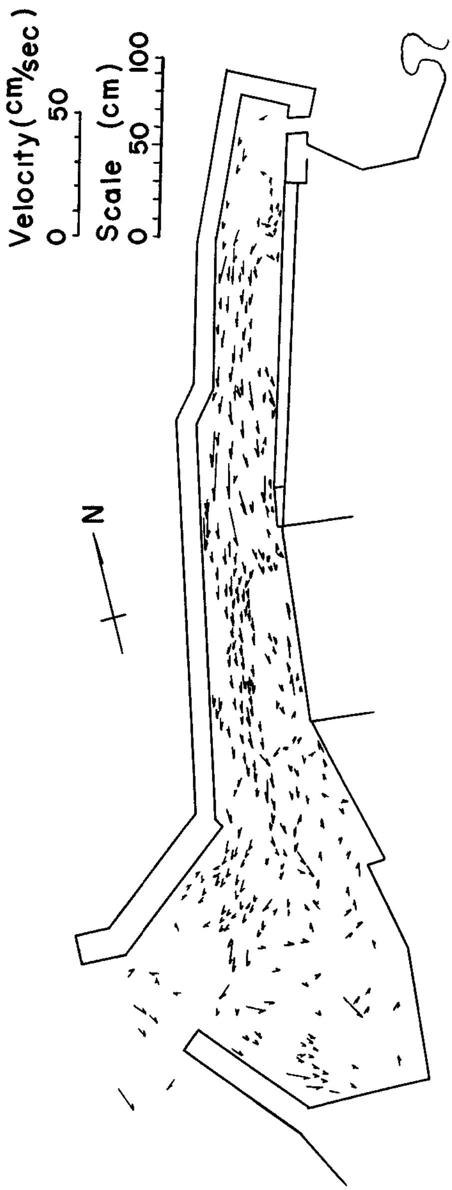

Fig. 12. Direction and velocity of current.

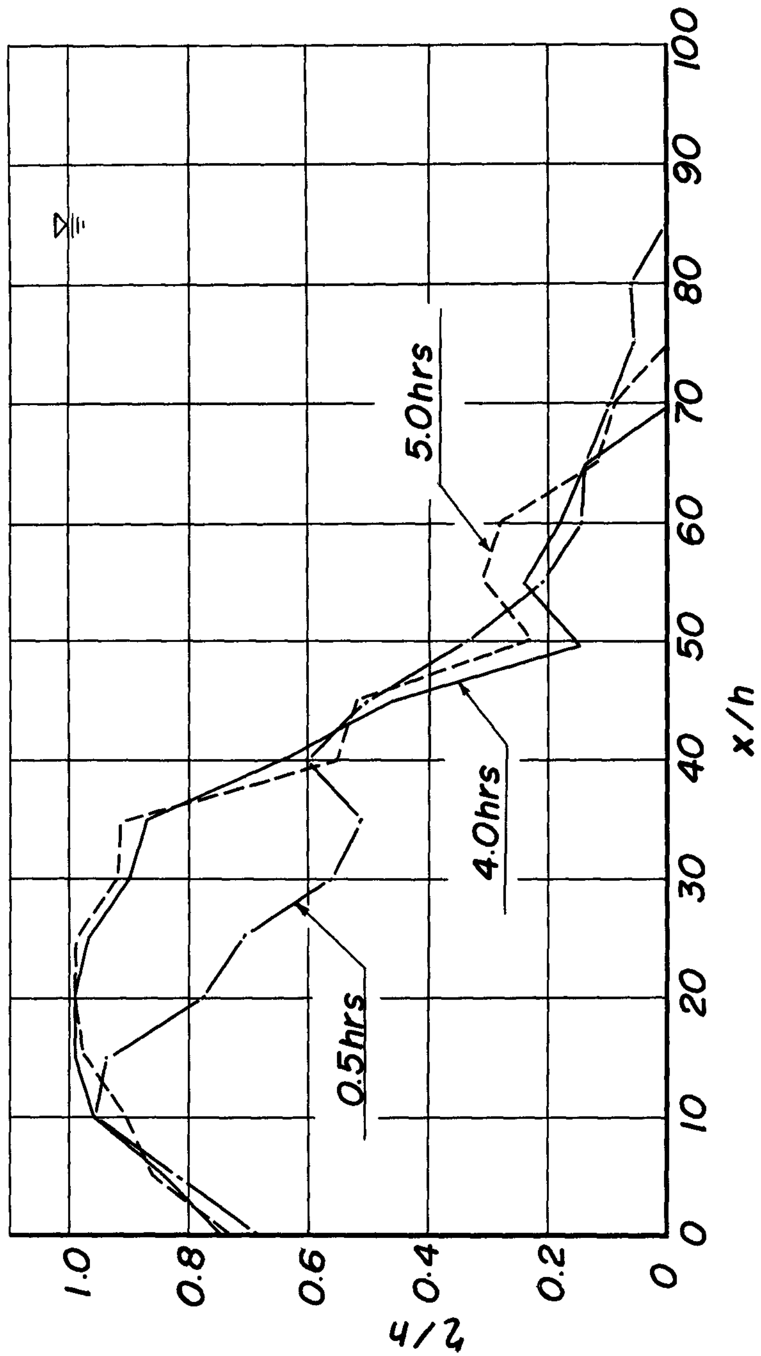

Fig. 13. Dimensionless plots of deposition height (Test. B-1).

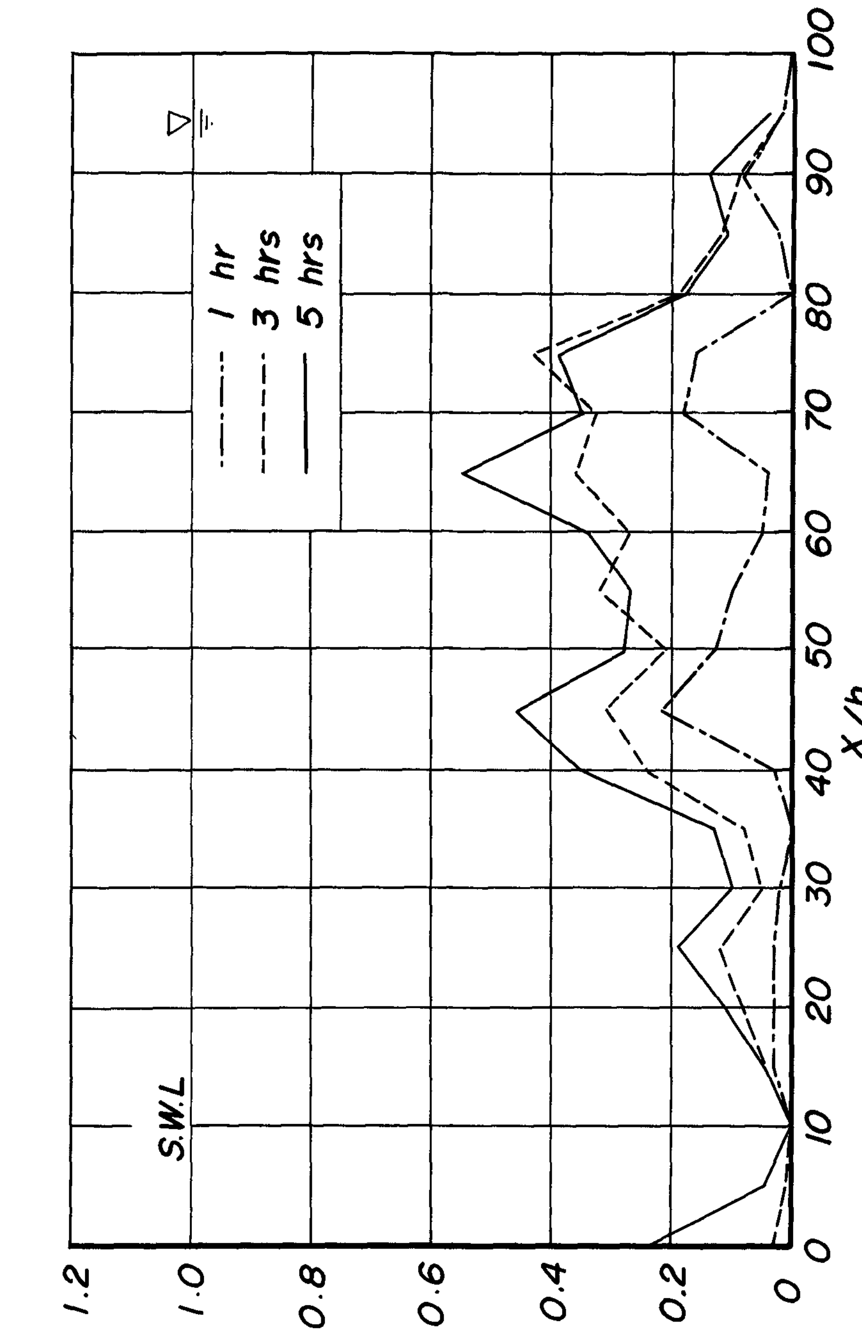

Fig. 14. Dimensionless plots of deposition height (Test. B-II).

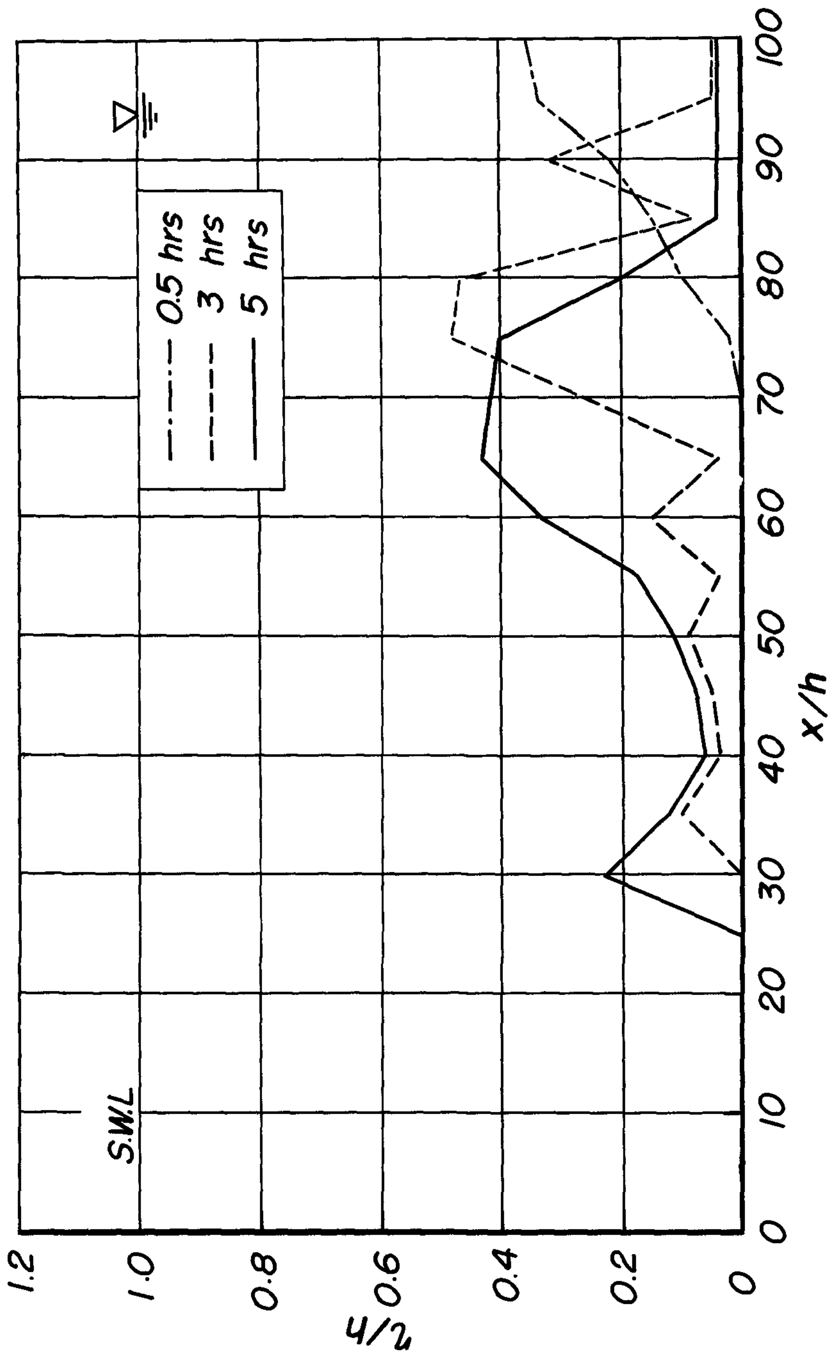

Fig. 15. Dimensionless plots of deposition height (Test. C-I).

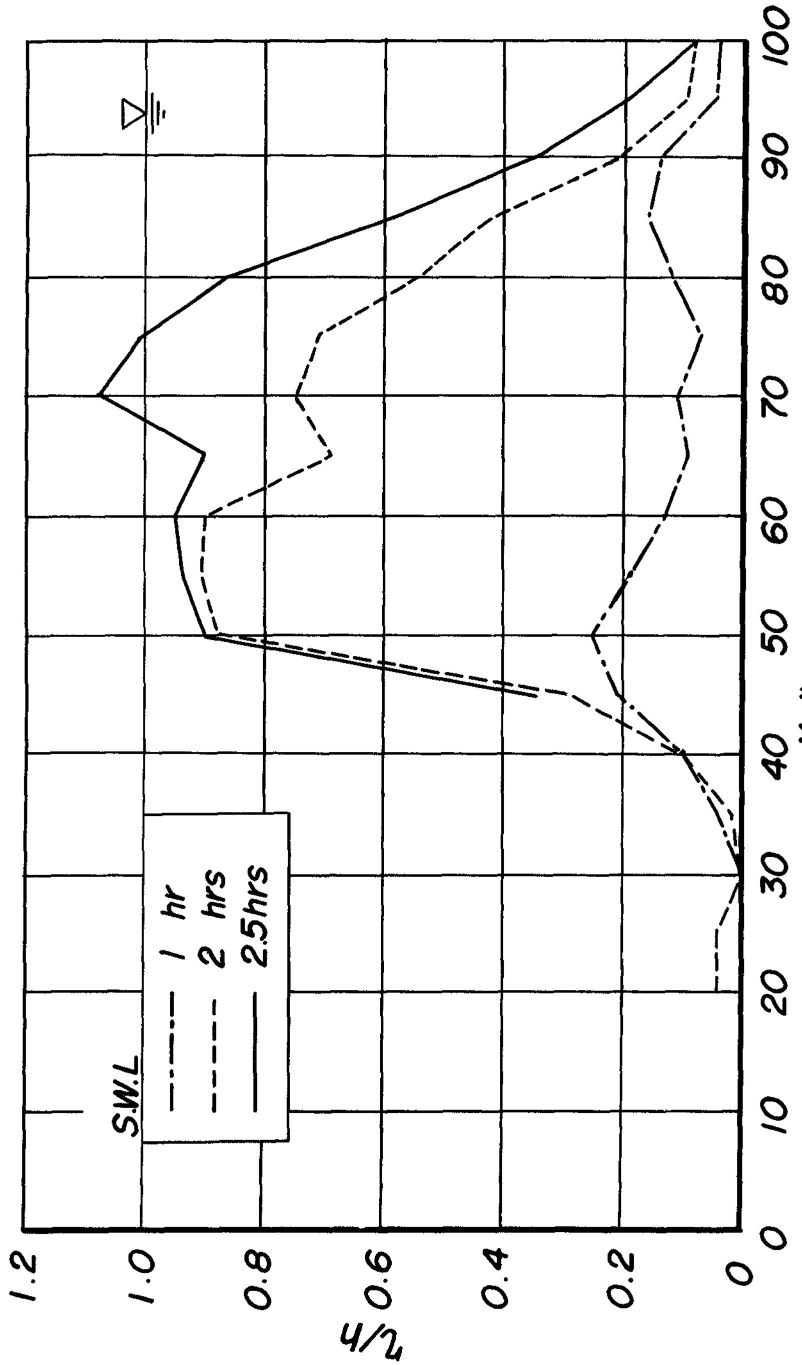

Fig. 16. Dimensionless plots of deposition height (Test. C-II).

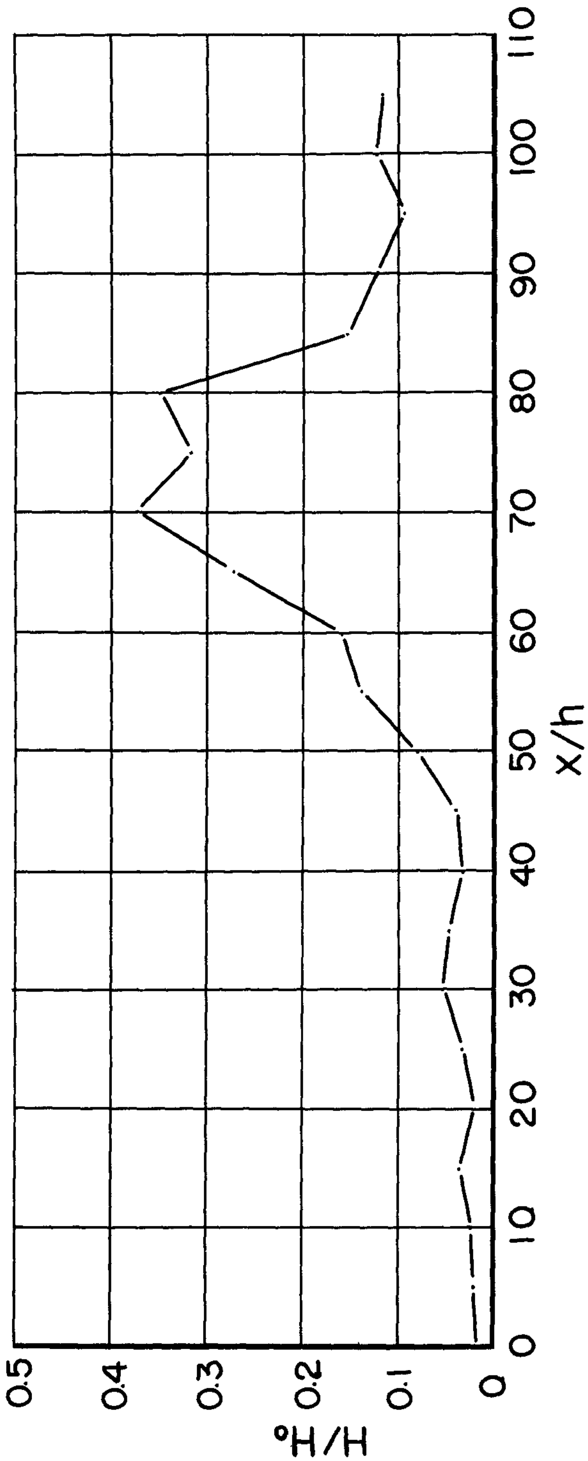

Fig. 17. Change of wave height in the basin.

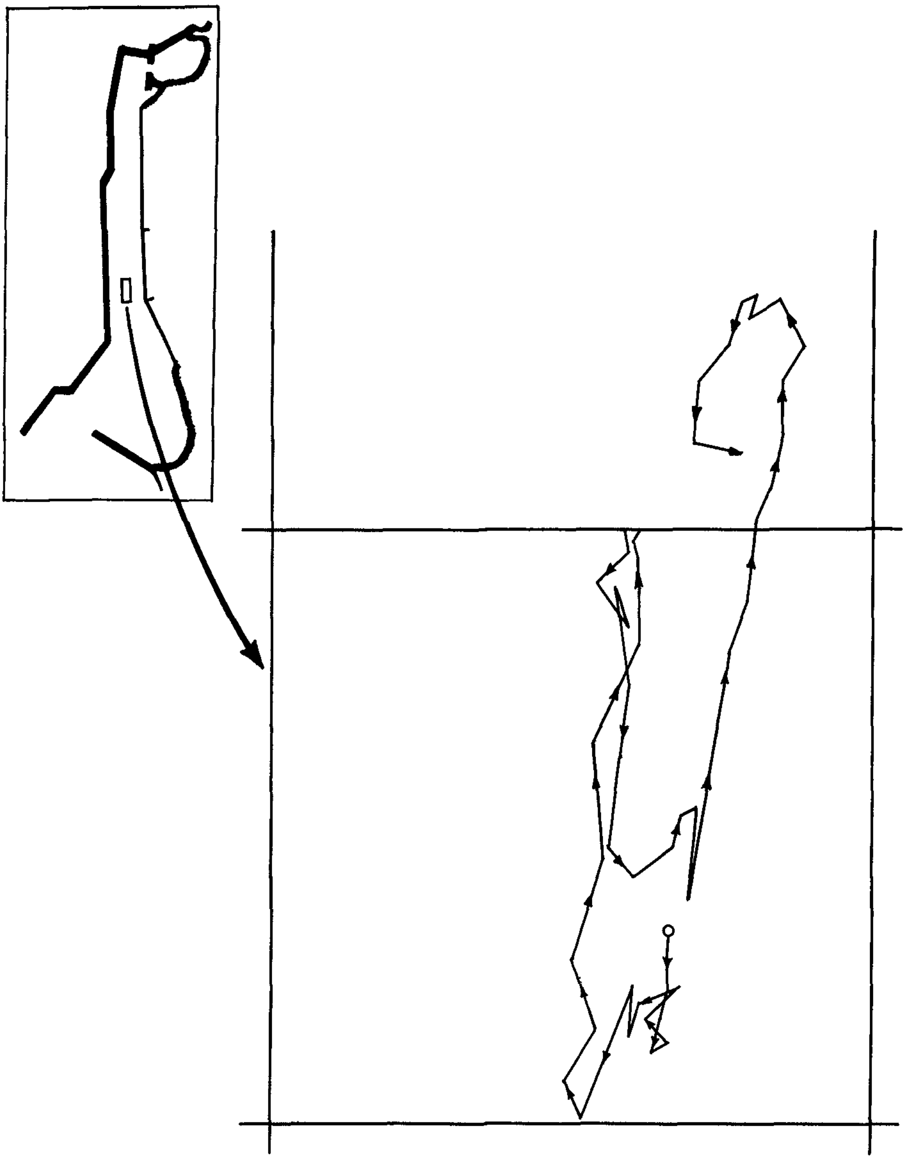

Fig. 18. Locus of a particle.

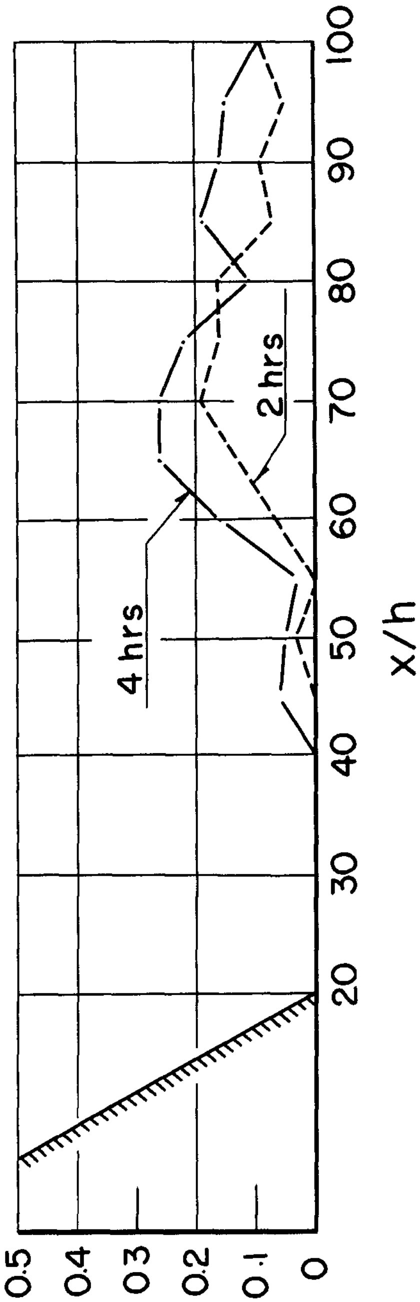

Fig. 19. Dimensionless plots of deposition height (Test. C-IV).

Table 1. Conditions of Experiments.

Test No.	Shape of the harbor	Water depth in the basin	Bed condition		Measurement
			Tray I	Tray II	
Test A	Fig. 9(a)	4 cm	movable	mobable	deposition height
Test B	Fig. 9(a)	4 cm	fixed	fixed	wave height, current velocity and direction
Test B-I	Fig. 9(a)	4 cm	fixed	movable	deposition height
Test B-II	Fig. 9(a)	4 cm	movable	fixed	deposition height
Test C-I	Fig. 9(b)	4 cm	movable	fixed	deposition height
Test C-II	Fig. 9(c)	4 cm	movable	fixed	deposition height
Test C-III	Fig. 9(c)	4 cm	fixed	fixed	wave height, current near the bottom
Test C-IV	Fig. 9(d)	6 cm	movable	fixed	deposition height