On the Movement of Sand along the Model of Breakwater

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Abstract: The movement of sand in the uniform field of current is discussed from the viewpoint of the friction between sand grains and water. Therefore the absolute value of the velccity of the current is of importance for solving this problem. But in the non-uniform field of current it seems that stress gradient due to pressure plays an essential role in the movement of sand. The experiments were carried out by using a small water tank and models of breakwaters.

1. Introduction

There are many breakwaters having the shape of Γ-type. In the sandy beach, such a construction is likely to cause erosion at its base and sedimentation of sand in the near places. In the river, as the stream is nearly uniform, the movement of sand at its bottom depends on the velocity of stream, while in the sea, the stream along the breakwater is subjected to time and spacial variations of pressure. The former will be represented by waves and the latter by littoral current or tide at the corner or ends of the breakwater. In this article the effect of littoral current along the breakwater only is discussed.

In such a non-uniform field of current, stress gradient due to the pressure variation will play an essential role in the movement of the sand. In the laminar flow, the variation of pressure will cause variation of velocity as following

$$dp = -vdv.$$

Even in the turbulent flow it may be considered that dp is a fuuction of dv and v. Therefore the influence of velocity is connected directly to that of pressure and the one cannot be separated from the other. The distribution of velocity is indicated by the conformal representation in the laminar flow. In the practical case, if the distribution of velocity is known by any means, the distribution of pressure can be estimated approximately. When the pressure gradient is approximately obtained, it may be expected to explain on what the form of contour lines depends.

II. Apparatus and Method

In order to obtain an invariant flow with respect to time and space a small circulating water tank is prepared. The apparatus is shown in Fig. 1. The flow is generated by a 16-blades wheel 30 cm in diameter. The part where the flow is uniform and steady is used as waterway for this experiment; in this part the bottom of tank is covered uniformly with sand. The velocity of the flow is 14cm/sec and 18.5 cm/sec. The depth of water is 6.0cm in case of the thick layer of sand and 6.9cm in case of the thin layer of sand.

The models of breakwaters are made from transparent celluloid board, which permits the taking of photographs from sidewall. Two types of model are used; the one has the shape of Γ -type: two rectangular plates are glued at one common edge perpendicularly to one another. The model is placed so as to make the common edge stand vertically and to fix one of the plate at a right angle perpendicularly to the wall. The height is 7cm, the length of the side parallel to the wall 10cm, and the length of the perpendicular side 5cm, The other model is the one shown in the preceding article by Prof. Y. IKEDA, placed in such a way that the x-axis coincides with the wall and the point from where the flow along the curve has constant velocity is located at ($x = 1$, $y \doteqdot 4$). The height of the model is the same as that of the first model.

These experiments are performed by taking photographs of the path lines of the flow and movement of sand near the model vertically from above and from the side through the window of the tankwall.

In order to obtain the path lines, powder of aluminium was suspended in the water and the path lines are photographed. Specially the solution of $AgNO_3$ in NH_4OH was poured into the water near the corner of the model for investigation of the turbulent area caused by the separation of the boundary layer.

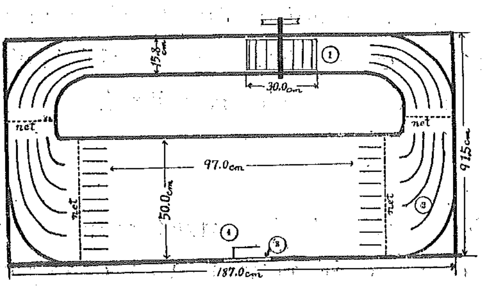


Fig. 1. Schematic diagram of the apparatus
1 waterwheel,
2 guide vanes,
3 window of the sidewall,
4 the field that is used in these experiments.

As the atmospheric pressure is considered to be constant, the height of the free surface may vary in accordance with the variation of the velocity. Therefore the pressure distribution at the bottom is affected by this variation of height. A glass plate was used to cover closely the surface of the flow so that the flow may be treated two dimensionally. Other conditions being kept to invariant the flows having the free surface are photographed in order to compare with the "two dimension" case.

In the course of experiment, the sand of the bottom may be disturbed and the thickness of the sand layer can not be uniform. Consequently the condition of two dimension cannot be held. Therefore a thinner layer of the sand may be desirdble. Thus the experiments are undertaken in two cases having thick or thin layer of the sand.

In most cases the phenomena were photographed three times; 2.5 min, 5 min. and 15 min. or 0.5 min, 2.5 min. and 5 min. after the flow began. As the first stage of the flow is considered to be of prime importance, the movie camera was used each 1/20 sec.

III. Experimental Results and Discussion

The velocity of the flow is considered to be largest at the corner of the Γ -type breakwater. In actual case, however, the position where the velocity is largest, will remove downward of the flow owing to the friction of the breakwater wall and to the existence of turbulent area. Consequently the result obtained from the conformal representation may not be useful in strict sense, but it may supply useful suggestions for this problem. In comparision with the equi-velocity line, the equi-gradient line of pressure appears in the upperward of the flow.

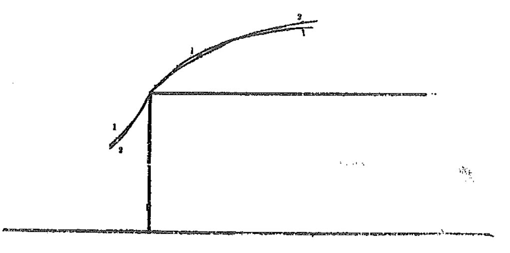


Fig. 2B. Examples of the boundary of turbulent area.
1 is the case of free surface, and 2 the case of glass covered surface. The velocity of flow is 18.5cm/sec..

If the path lines appearing in two cases, where the surface is covered with glass and where it is left free, are obviously different from one another, the problem is too complicated to warrant any conclusion. Fortunately as is shown in Fig. 2B, a difference in the states of path lines can scarcely recognized.

As shown in Fig. 3, the sand ridge observed from the window of the sidewall indicates the process of sedimentation of sand. If static pressure is alone considered to act in the turbulent area, it may be concluded that the pressure gradient plays an essential role in the movement of sand.

Photographs of the movement of the sand are taken in the following four cases: when the sand layers of the bottom are thin and thick, and when the surfaces of water are left free and covered with glass plate. They are sketched from the photographs and shown in Fig. 4. As reference, the one of the photographs is shown in Fig. 5.

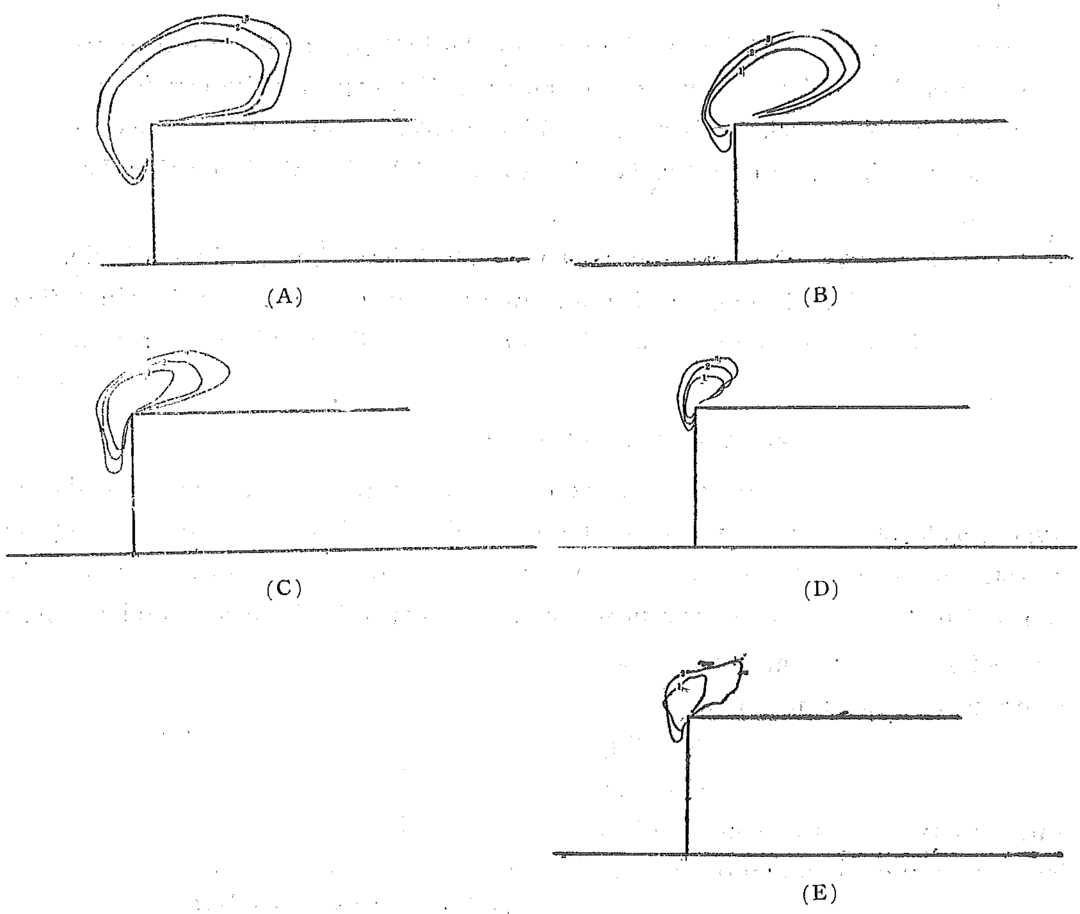


Fig. 4. The contour lines of the movement of the sand.

(A) In case of free surface and thick layer of sand.

(B) In case of free surface and thin layer of sand.

In these cases the velocity is 18.5cm/sec and intervals 1; 2.5 min, 2; 5min, 3; 15 min. after flow began.

(C) In case of glass covered surface and thick layer of sand.

(D) In case of glass covered surface and thin layer of sand.

In these cases the velocity is 18.5 cm/sec and interval 1; 0.5mim, 2; 2.5 min, 3; 15 min. after flow began.

(E) The case is the same as case (D), but the velocity is 14 cm/sec.

The form of contour lines in Fig. 4. are compared and it is concluded that 1) the movement of sand is most conspicuous in the case (A), where the sand at the bottom is thick and the surface is left free, which indicates the actual three dimensional state; 2) the movement of sand is remarkably little in the case (D), where the sand layer is thin and the surface of water is covered with glass plate, which indicated the two dimensional state. It seems that the form of the contour lines in the latter case resembles that of equi-gradient line of pressure more than that of the equi-velocity line.

Difference of movement of sand due to the variation of velocity is recognized only in the quickness of the progress of procedure. Though it is not wise to attempt to draw conclusions from these results, the form of the contour line seems invariable. However, as the boundary of turbulent area varies with the variation of velocity, it will be deformed in the case of larger differences of velocities.

For the second model breakwater the path lines of the flow are the same as shown by the conformal representation since the turbulent area does not appear, therefore the condition of constant velocity is satisfied. Indeed, the movement of sand as influenced by this model is very small.

The form of contour line of sand after a long time is shown in Fig. 8; the movement of sand is recognized at the point where the pressure gradient is large, and not at the point where the velocity is maximum, a little forwards from the position where the velocity begins to be constant.

As is shown in Fig. 6, the difference of path lines in the two cases where the surface is left free and where it is glass-covered is not recognized, but the dimensions of the sand ripples appearing of the end of the breakwater are different from one another as shown in Fig. 7. This is also an evidence to show that the movement of sand depends on the pressure gradient more than on the velocity of the flow.

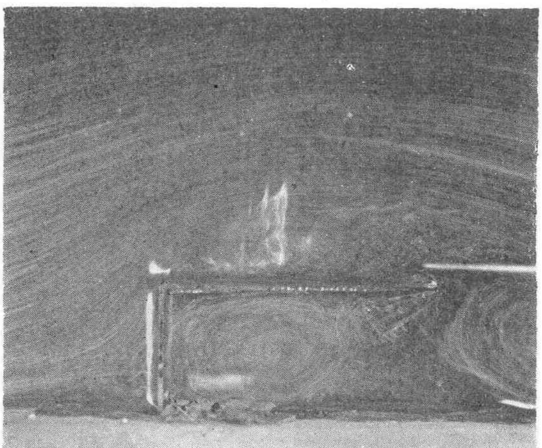


Fig. 2. A. The path lines of free surface

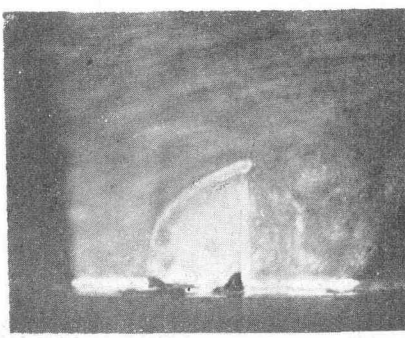


Fig. 8. The state after 2 hours flowing. In this case, the surface of water is covered with glass plate and the sand layer is thin. The velocity was 18.5 cm/sec.

Fig. 3A. Glass Covered surface.
15 min. after flow began.

Fig. 3B. Free surface.
5 min. after flow began.

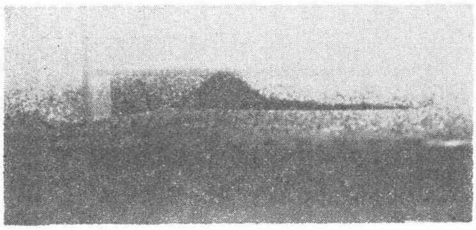


Fig. 3C. Free surface.
10 min. after flow began.

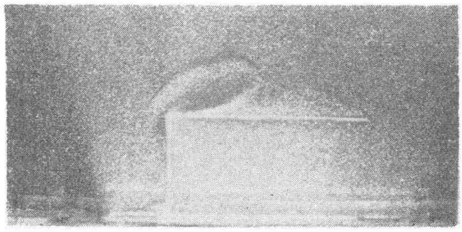
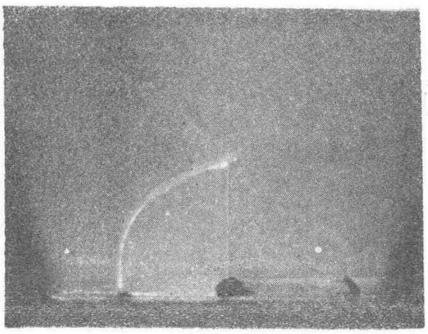
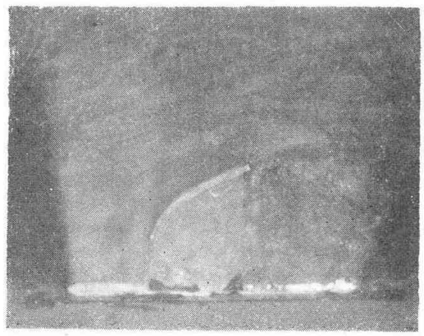


Fig. 5. A photograph of contour line formed by the movement of the sand. This state is the same as Fig. 3A.

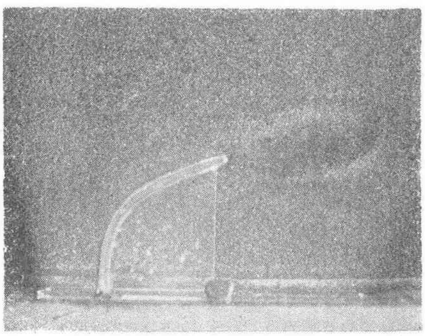


(A)

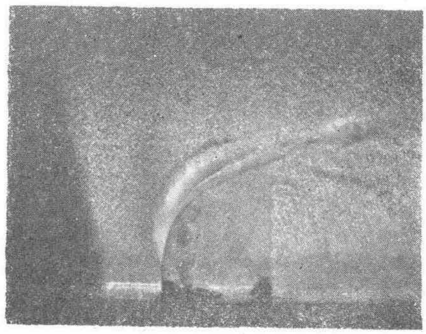


(B)

Fig. 6. The path lines in the flow formed by second model.
(A) In case of free surface. (B) In case of glass covered surface.
The velocity is 18.5cm/sec.



(A)



(B)

Fig. 7. These photographs show the movement of the sand.
(A) In case of free surface. (B) In case of glass covered surface.
The velocity is 18.5cm/sec, and the sand layers are thick.

IV. Acknowledgement

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