Sand Vortices on a Shallow Sea Bottom.

By

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In this article sand vortices such as are often observed at a shallow sea bottom are studied. When waves beat against the shore, vortices of sand are rolled up in many parallel lines at the depth of several dozen cm. The motion of sand vortices being observed in detail, the direction of them looks as if it were contradictory to the laws of hydrodynamics as shown in Fig. 1. So the motion of sand vortices has been studied by taking photographs, an opportunity having been afforded when the aid of the Gakuzyutu Sinkokai was given to the authors for studies on the properties of granular materials. Various methods which were tried in taking the photographs, during stays for studies on the velocity of shocks through sand and the cause of dune formation at Riyamunai in 1935 and Isikari in 1936, resulted in failure due to the imperfectness of stand and other factors. The experiment was repeated by making use of artificial waves in the hydraulic laboratory of Hokkaido Imperial University from Nov. to Dec. 1936 and photographs were obtained some of which are shown in Phot. 1 to 4.

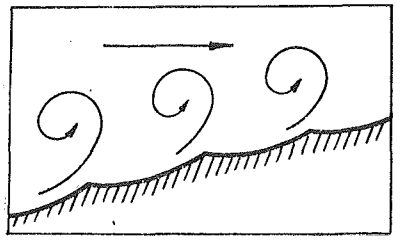


Fig. 1.

Apparatus.

The apparatus used is schematically shown in Fig. 2. At one side

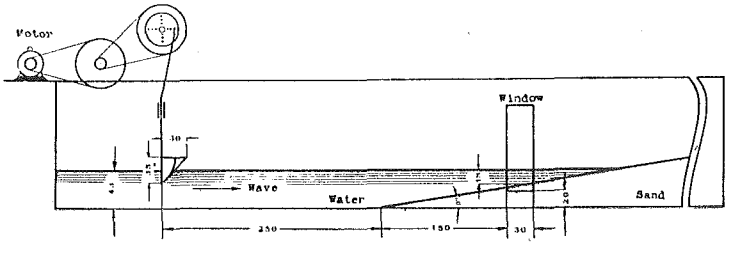


Fig 2.

of a tank of 9.5 m length and 3.5 m breadth in order to make waves a wood pile with a wedge cross section was moved up and down by means of 3 H. P. D. C. shunt motor, pulleys, cranks and connecting rods. At the other side an artificial beach of sand was built of 3 m^3 of sand from the dune at Riyamunai. In the rest of water the depth of water was 43 cm and the slope of the beach about 9^0. Phographs were taken at the depth of about 13 cm. For illumination six incandescent lamps, of which the total consumption of electric power was 2750 watts, were used at the height of about 30 cm above the water surface. Through a window situated at the distance 4 m from the wave-making-apparatus, photographs were taken with Cookes *f*. 2 lens at full aperture.

The mechanism of the formation of vortices.

Fig. 1 shows the imaginary elevation according to the apparent observation from above, while truly withdrawal waves make vortices of sand as shown in Fig. 3 and surf as in Fig. 4 as deduced from the laws of hydrodynamics. Combining the action of these waves, a surf tends

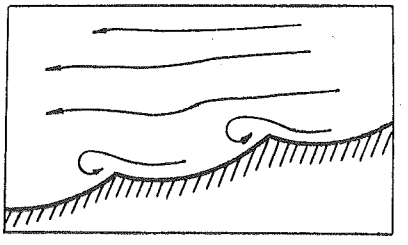


Fig. 3.

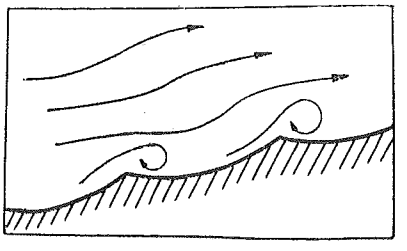


Fig. 4.

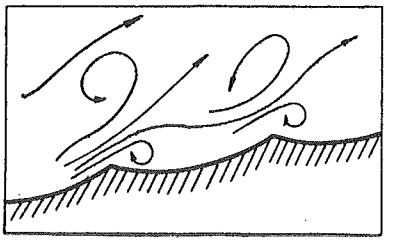
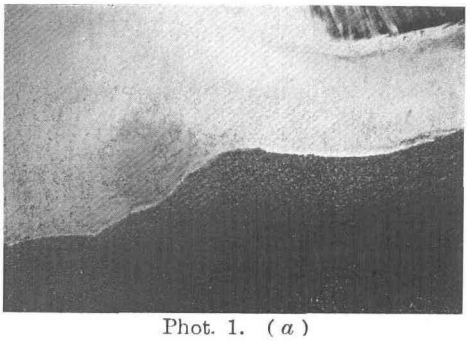
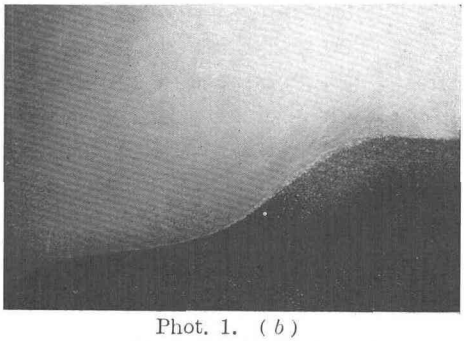


Fig. 5.

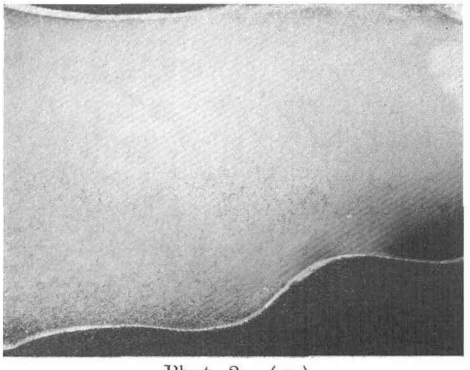
to aid the vortices created by the withdrawal waves as shown in Fig. 5 As a result the sand looks to be rolled up in the surf, while observing from above the vortices due to surf are hidden by the sand vortices created by the preceding withdrawal wave and made large by the surf.



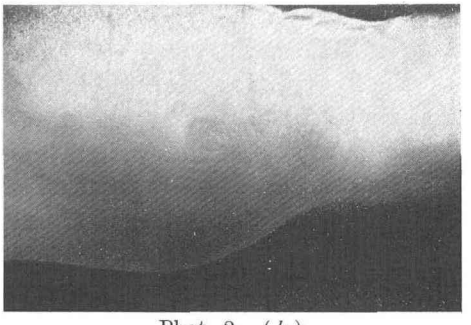
Phot. 1. (*a*)



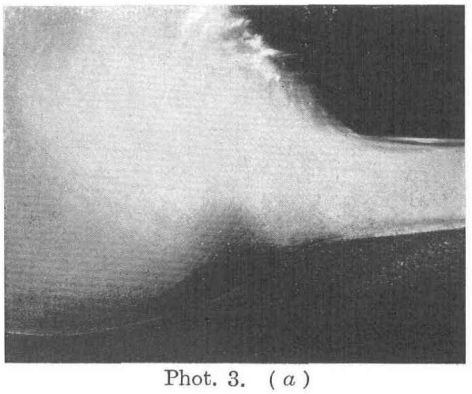
Phot. 1. (*b*)



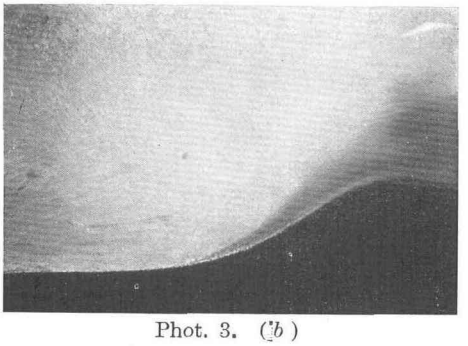
Phot. 2. (*a*)



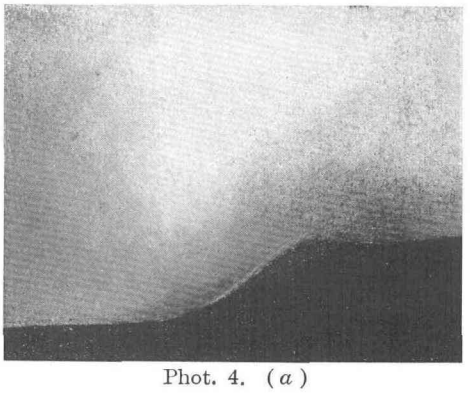
Phot. 2. (*b*)



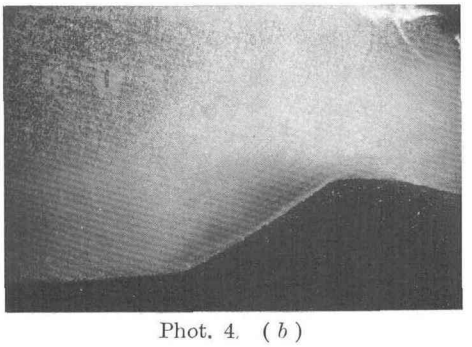
Phot. 3. (*a*)



Phot. 3. (*b*)



Phot. 4. (*a*)



Phot. 4. (*b*)

Photographs: In photographs the shore is situated at the right side. The magnification factor is 1/4.

Photograph 1; the number of waves is 22/min. (*a*) The withdrawal wave comes nearly to an end; at the left of the corner of sand ripple, the vortices are completely formed. (*b*) The surf nearly ends at the left of the corner of the sand ripple, small vortices are formed.

Photograph 2; the number of waves is 22/min. (*a*) The withdrawal wave nearly terminates, nearly the same state as in Phot. 1 (*a*). (*b*) The stage is nearly in the midst of the surf which rolls up the vortices created by the preceding withdrawal wave, the vortices are to be formed at the left of the corner.

Photograph 3; The number of waves is 16/min. (*a*) The initial stage of withdrawal wave. (*b*) Nearly the final stage of the surf.

Photograph 4; The number of waves is 26/min. (*a*) Nearly the final stage of the withdrawal wave. (*b*) The initial stage of the surf.

In conclusion, the writers' sincere thanks are offered to the Gakuzyutu Sinkôkai for financial aid and to Prof. Y. Kuratuka who permitted them to use the Hydraulic Laboratory.