NOTE ON SAND-BED SCOUR IN OSCILLATING WATER

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NOTE

NOTE ON SAND-BED SCOUR IN OSCILLATING WATER

By Hiroyuki HONJI*

Preliminary observations have been made of sand-bed scour around cylindrical structures submerged in oscillating water in a water tunnel. A movable slider ring seems to suppress effectively sand-bed scour around the structures.

Key words: Scouring, Sand ripples, Oscillating water

1. Introduction

As reviewed by Rooney et al. [1] for example, various methods of protecting hydraulic structures from scouring around them have been developed. When overlying water is oscillating, sand ripples are very likely to develop on the surface of a sand bed. These ripples promote erosive action around structures. Scouring under pulsating jet was investigated by Kubos et al. [2]

A new oscillatory-water tunnel has been constructed at the Sea Safety Research Laboratory in Tsuyazaki, and some exploratory experiments on the formation of various sand patterns have been carried out by using the tunnel. In this note, I will report the results of some preliminary observations of ripple formation and sand-bed scour around cylindrical structures.

2. Experimental methods

Experiments were carried out using a closed-type water tunnel with a test section of $25\times25\times180$ cm, in which tap water was oscillated by a motor-driven piston of 30 cm in diameter. A bird's-eye view of the tunnel is shown in Fig. 1, where the test section equipped with a sand pit is seen on the left side of the picture. The maximum frequency of oscillation of the piston at its maximum amplitude of 33 cm is 0.3 Hz. The oscillation frequency can be increased up to 1.1 Hz as the amplitude is decreased.

Spherical glass beads of 280 μm in mean diameter were used as a bed material, which occupied the sand pit. The thickness of the bed was about 5.5 cm. The surface of the bed was illuminated with a 1 kW flood lamp

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from above, and photographed by a 35 mm camera. The temperature of working water ranged from 15 to 19°C, and the time of exposure for photographing from 1/125 to 1/60 s.

3. Results

When overlying water oscillates harmonically, a flat sand bed deforms in a regular wavy form as shown in Fig. 2, where the mean ripple wavelength is about 7.5 cm. The direction of water oscillation with the amplitude a and frequency f is right and left in all the pictures presented in this note. These sand ripples are fairly two-dimensional, and no effects of side walls are appreciable. Particles constituting the bed-surface are lifted up above the crests of ripples in every stroke of water oscillation. The role of separation vortices in forming sand ripples is discussed in a preceding paper[3].

Sand-bed scour around two vertical circular cylinders has been observed in the water tunnel. One cylinder was an unprotected wooden cylinder of 2.91 cm in diameter d and 26.6 cm in height. The other one was a similar cylinder of the same size, which was protected with a slider ring of 9.35 cm in diameter and 0.32 mm in thickness, as illustrated in Fig. 3. The slider ring made of an aluminum plate was equipped with a cylindrical skirt about 2.3 cm long, in order to inhibit the ring from inclining from the horizontal. The slider ring could be made to move up and down along the axis of the main cylinder, in order to be able to adjust itself automatically to local heaping or erosion of the sand.

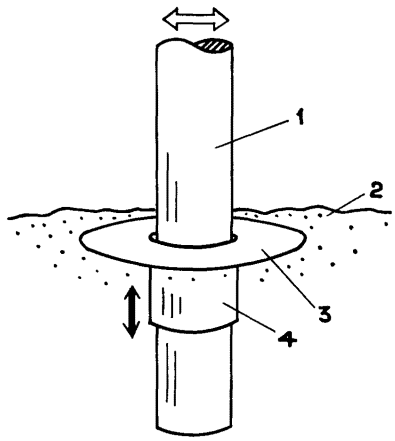

Fig. 3 Cylinder protected with a slider ring. Open arrow indicates the direction of water oscillation, and solid arrow the direction of movement of the slider ring.
1. Cylinder, 2. sand bed, 3. slider ring,
4. cylindrical skirt.

Figure 4 shows side views of an unprotected reference cylinder at right and a protected cylinder at left each embedded in a sand bed. The distance between the two circular cylinders is 28.4 cm. For viewing the scoured section of the bed clearly, the edge of a slider ring attached to the protected cylinder was cut away. Figure 4 (a) shows the flat sand surface before the start of water oscillation. Figure 4 (b) shows the eroded surface at $t=1.5$ min, where t is the time passed from the start of water oscillation. Local scour around the right unprotected cylinder is more conspicuous as compared with that around the protected one. A large amount of sand particles lifted up from the foot of the unprotected cylinder is seen clearly.

A similar comparison is made also in Fig. 5, where the close-up views of sand-bed scour around an unprotected circular cylinder (Fig. 5a) and a protected one (Fig. 5b) are shown. A slider ring for the protected cylinder was made of a brass plate of 3 mm in thickness, which was enough to inhibit the ring from inclining from the horizontal and no cylindrical skirt was necessary in this case. The depth of a scoured hollow around the unprotected cylinder reached about 2 cm at $t=2$ min, while no appreciable depression of the sand level was observed around the protected cylinder. This indicates that the slider ring is effective for suppressing vigorous scouring of sand around a cylindrical structure in oscillatory flow.

Figure 6 shows that a horizontal circular cylinder suspended transversely over a sand bed disturbs the formation of regular sand ripples. Figure 6(a) shows regular two-dimensional ripples, and Fig. 6 (b) an irregular sand surface below the cylinder, which was about 2.5 cm apart from the sand surface. A vertical scale may indicate the relative positions of the sand bed photographed.

Sand-bed scour around a square cylinder took place in much the same way as around a circular cylinder, as shown in Fig. 7 where the square cylinder is at left. Between the two cylinders no regular sand ripples formed as seen from the figure. Sand-bed scour around a small wooden prism of $5.5 \times 5.5 \times 8.2$ cm in size was also observed. Sand ripples formed irrespective of the embedded prism. A similar feature was observed around a prismatic anchor block used in a shallow sea.

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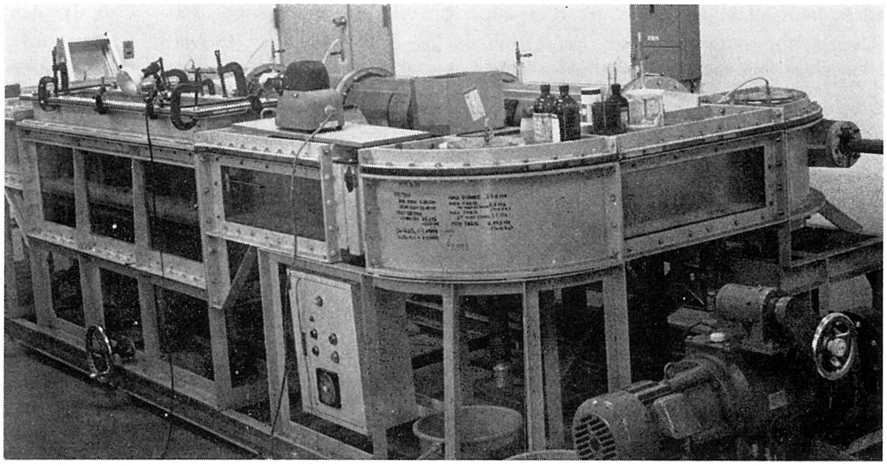


Fig. 1 Oscillatory water tunnel.

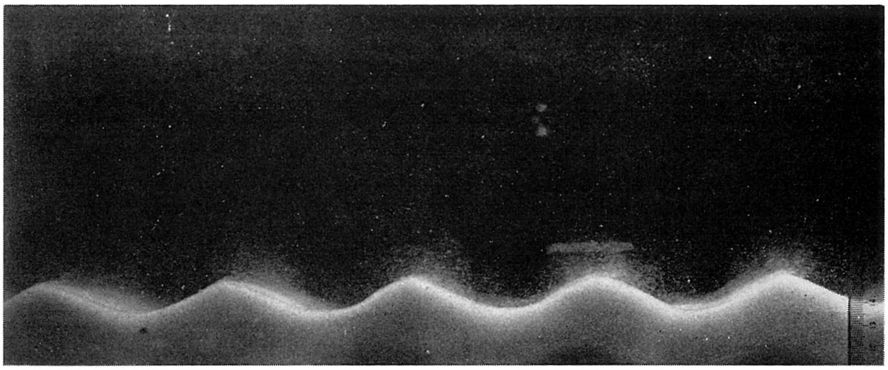
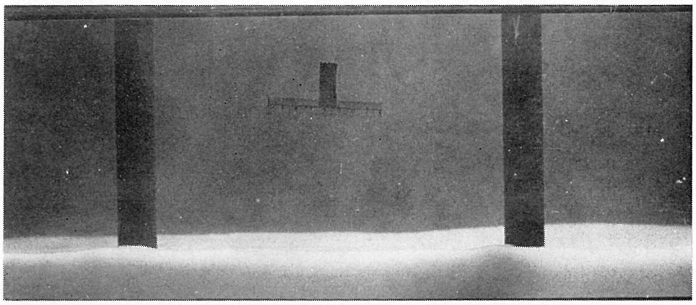
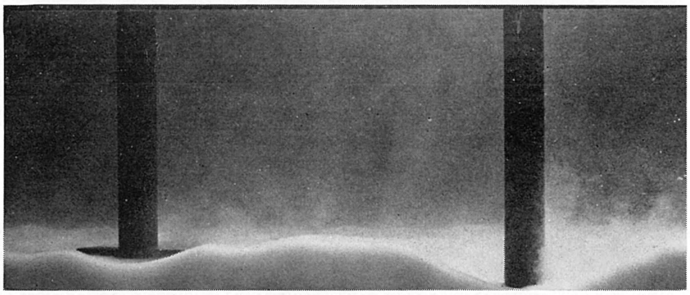


Fig. 2 Ripple mark of glass beads. $a=6.59$ cm, $f=0.556$ Hz.

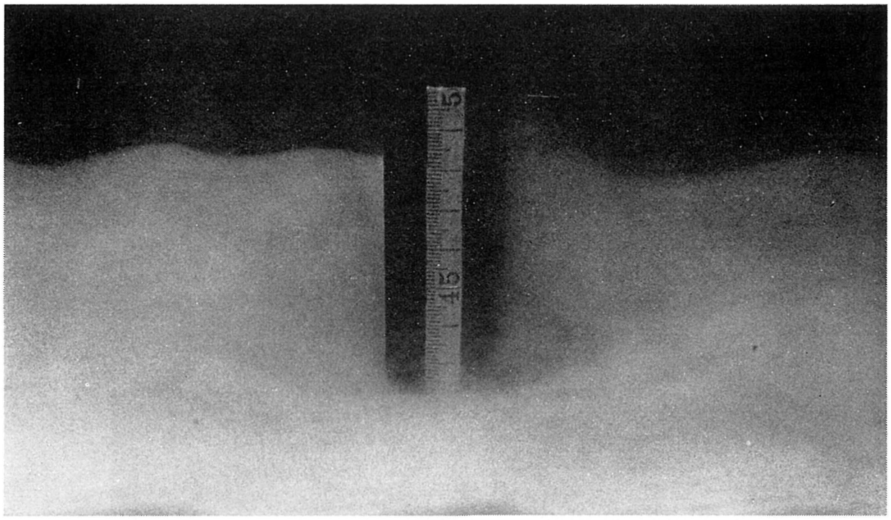


(a) $t=0$ s.

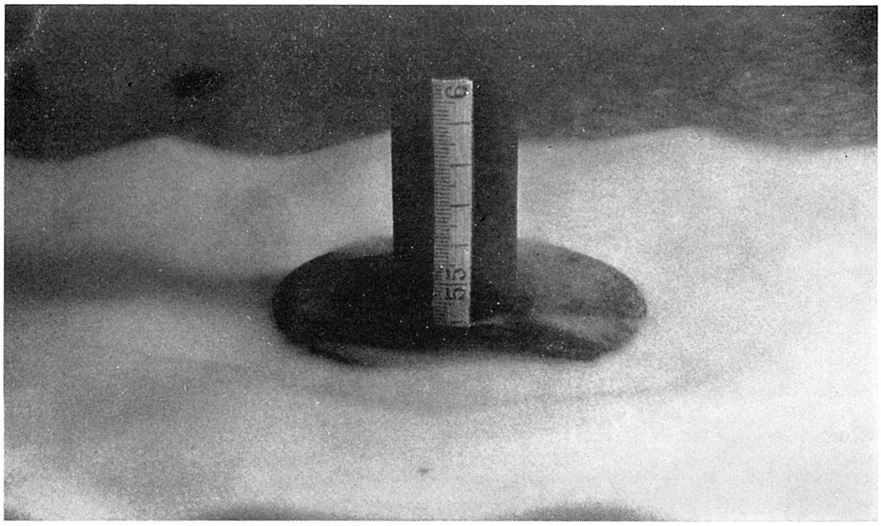


(b) $t=44$ s

Fig. 4 Comparison of sand-bed scour between unprotected (right) and protected (left) cylinders.
$a=15.9$ cm, $f=0.389$ Hz, $d=2.91$ cm.

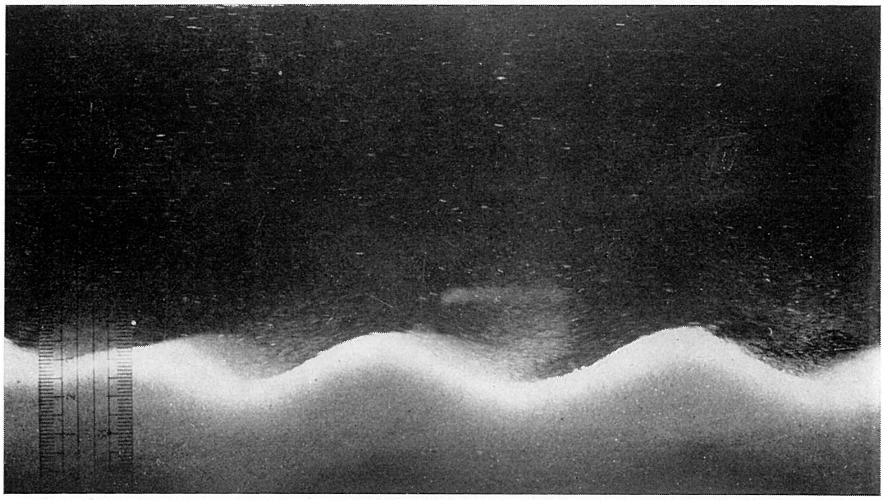


(a)

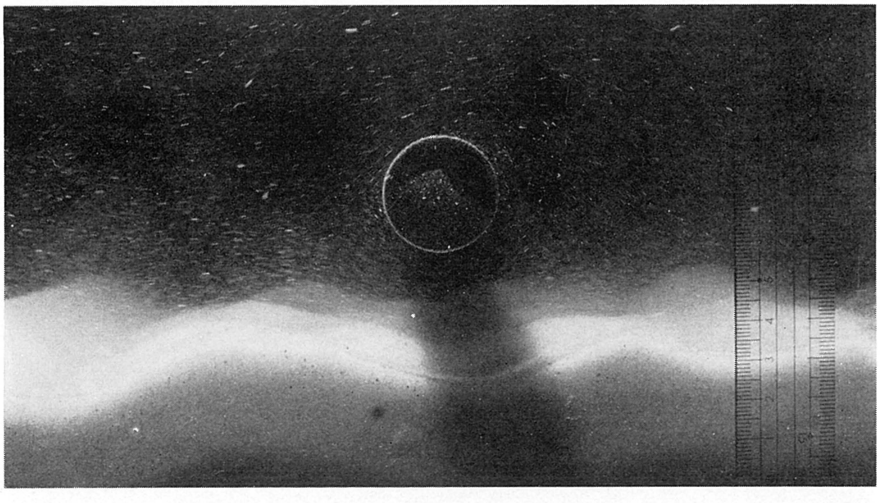


(b)

Fig. 5 Close-up views of the sand bed around an unprotected cylinder (a), and a protected cylinder (b) at $t=1$ min: Scale unit in cm. $a=15.9$ cm, $f=0.336$ Hz.



(a) $t=11$ min



(b) $t=9$ min

Fig. 6 Deformation of sand surface without cylinder (a) and with cylinder (b): Scale unit in cm. $a=6.59$ cm, $f=0.556$ Hz, $d=3.00$ cm.

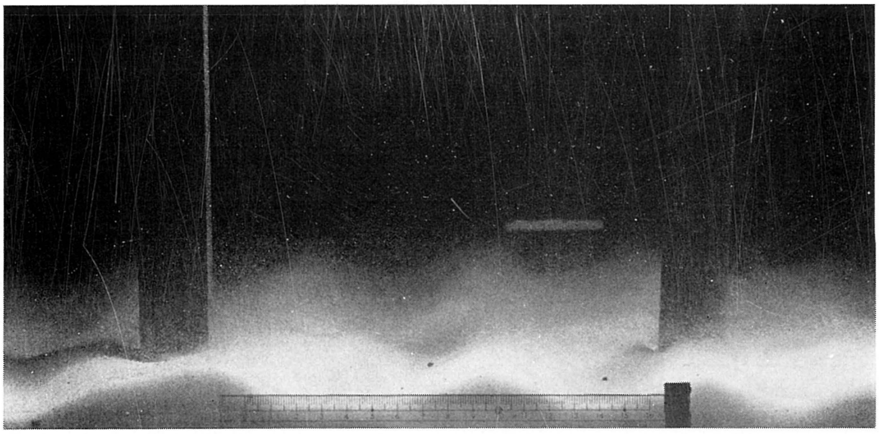


Fig. 7 Sand-bed scour around a square cylinder at left with the side 3.00 cm long. Distance from a circular cylinder at right is 23.0cm: Scale unit in cm. $a=6.59$ cm, $f=0.714$ Hz.

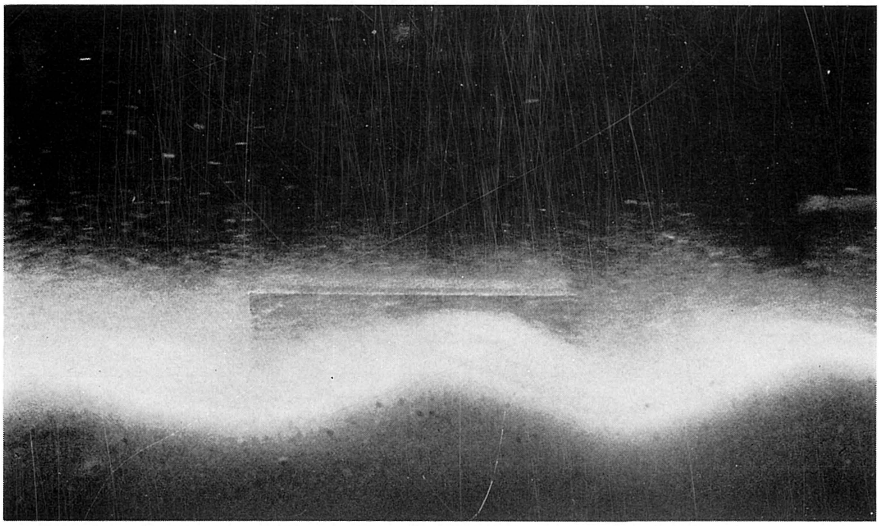


Fig. 8 Deformation of sand surface around a prism 8.20 cm long. Initial height of the prism above sand level was 1.5 cm. $a=6.59$ cm, $f=0.556$ Hz, $t=3$ min.