CHAPTER 111

BLOCK SUBSIDENCE UNDER PRESSURE AND FLOW

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Abstract

The block subsides gradually into sandy bed under water pressure fluctuation. In actual coast the oscillatory flow also acts on the block. The block subsidence is reproduced qualitatively in a laboratory. The subsidence occurs even under the oscillatory flow. Under some combinations of water pressure fluctuation and oscillatory flow, the subsidence is larger than any of the subsidence under the pressure fluctuation only and the subsidence under the oscillatory flow only.

Introduction

In sandy coast armour blocks gradually subside into the bed. Fig.1 shows an example of the block subsidence and dispersion of an offshore breakwater off the west coast of Niigata facing the Japan Sea(Nakata, H. et al., 1991). There are several mechanisms proposed : for example, the rocking of the block and the porewater flow in the sand bed under the block.

One more explanation for this phenomenon is that the porewater pressure fluctuates due to the wave pressure, the vertical effective stress decreases at each wave trough phase, the block subsides slightly and it is repeated wave and wave. Already the subsidence was reproduced under a water pressure fluctuation in a laboratory(for example, Zen et al., 1990. See Fig.2). The behaviour of a sand bed during a block subsidence was observed in a laboratory(Nago et al., 1993. See Fig.3).

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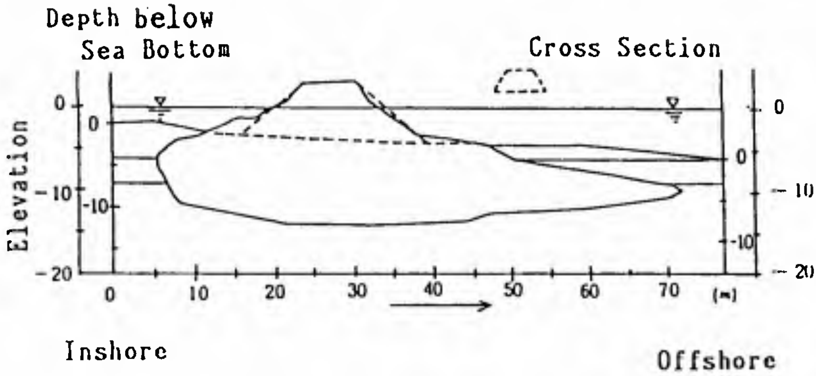

Fig.1 Subsidence and dispersion of block of offshore breakwater(Nakata, H. et al., 1991)

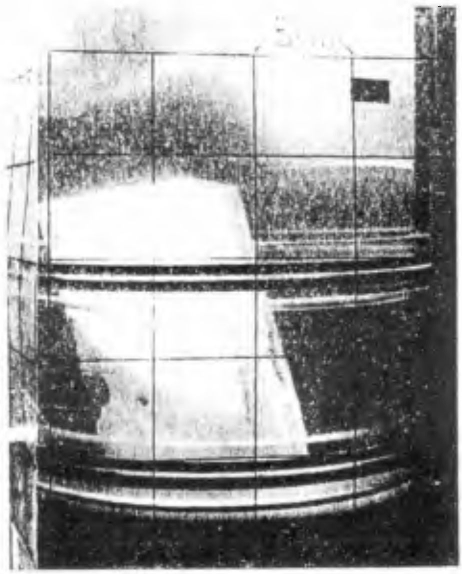

Fig.2 Reproduction of block subsidence due to water pressure fluctuation(Zen, K. et al., 1990)

In actual coasts, however, the oscillatory flow is also induced by waves and the scour around the blocks occurs. Here the subsidence of a model block on a sand bed is reproduced under a simultaneous action of a water pressure fluctuation and an oscillatory flow by a laboratory experiment. The effects of the pressure and flow on the block subsidence are examined qualitatively.

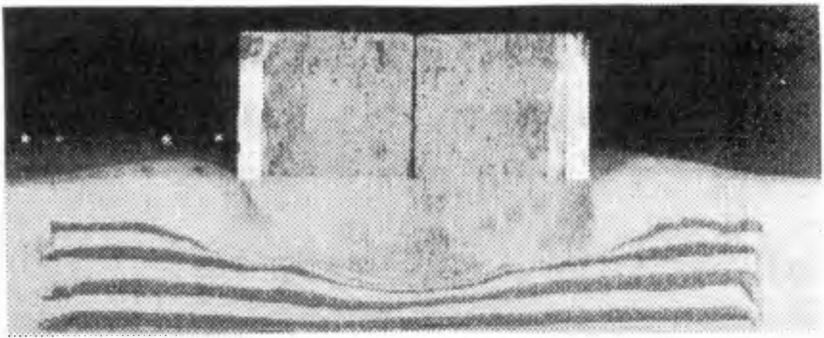

Fig.3 Behaviour of sand bed during block subsidence (Nago, H. et al., 1993)

Experimental setup, procedure and conditions

experimental setup

An oscillatory tank, which can generate a water-pressure fluctuation and an oscillatory flow simultaneously, was used. It consists of a U-shaped tank(30cm x 30cm cross section) with both ends closed and

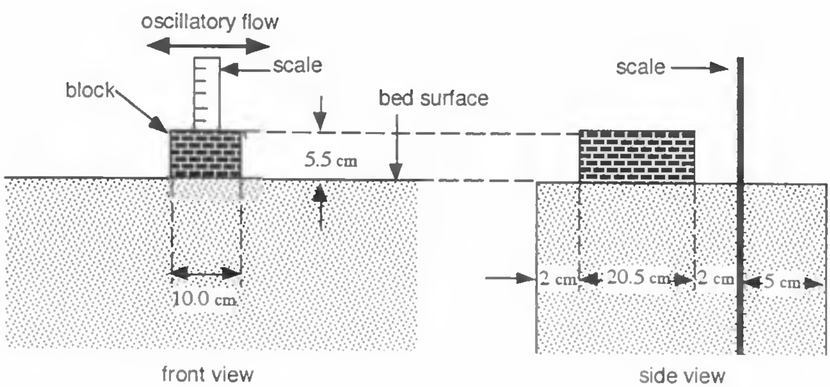

Fig.4 Experimental setup

a sand pit(200cm wide and 100cm deep) attached to the horizontal part of the tank.

The medium grain size of the sand was 0.25mm. A rectangular block(10cm wide, 5.5cm high and 20.5cm long) was set on the sand-bed surface(Fig.4).

experimental procedure and conditions

Three kinds of experiments were done, water-pressure fluctuation only, oscillatory flow only and both water-pressure fluctuation and oscillatory flow simultaneously. The periods of the pressure fluctuation and the oscillatory flow are same(3.0s and 6.0s). Fig.5 shows the combination of the total pressure fluctuation amplitude head and the average oscillatory flow amplitude for the case of wave period = 3.0sec. Fig.6 shows the combination for the case of wave period = 6.0sec. The phase between the pressure and the flow could not be controlled arbitrarily. It varied around 90 degrees. After 100 waves loaded, the amount of subsidence was measured.

The average head of water pressure was about 2.0m, the maximum total pressure-fluctuation amplitude head was 1.3m, and the maximum amplitude of oscillatory flow was 60cm/s. The void ratio of the sand bed was estimated several times during the experiment.

Experimental results

water-pressure fluctuation only

Fig.7 shows an increase of the amount of subsidence for the case of the period = 6.0sec and the total pressure fluctuation amplitude head = 141cm. Even after 300 waves(30min.) the subsidence continues.

Fig.8 shows a relation between the amount of subsidence after 100 waves and the total pressure-fluctuation amplitude head for the period = 3.0sec. The relation between the amount of subsidence and the total pressure fluctuation amplitude is roughly linear. The result for the period = 6.0sec shown in Fig.9 is nearly the same. No clear difference from that of the period = 3.0sec is seen.

oscillatory flow only

Under the oscillatory flow, the block was inclined generally. The amount of subsidence of the gravity center of the block was measured. Fig.10 shows a relation between the amount of subsidence after 100 waves and the average amplitude of oscillatory flow for the period = 3.0sec.

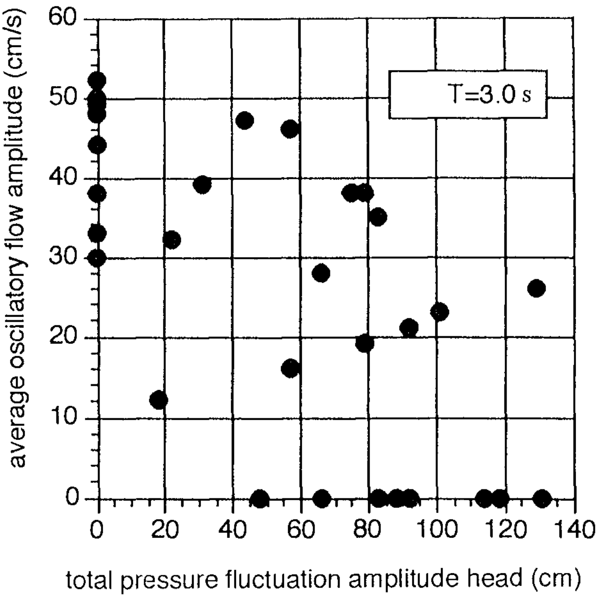

Fig.5 Combination of pressure fluctuation amplitude and oscillatory flow amplitude for wave period = 3.0sec

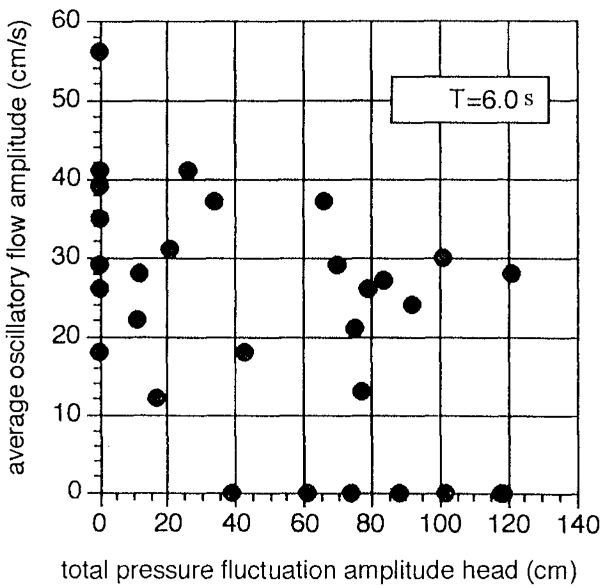

Fig.6 Combination of pressure fluctuation amplitude and oscillatory flow amplitude for wave period = 6.0sec

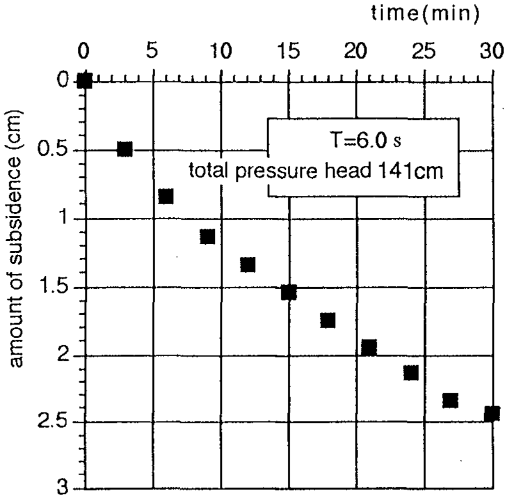

Fig.7 Increase of amount of subsidence in time

When the average oscillatory flow amplitude becomes larger than about 30cm/sec, the block begins to subside. The relation between the amount of subsidence and the flow amplitude is roughly linear. The result for the period = 6.0sec shown in Fig.11 is nearly the same. No clear difference from that of the period = 3.0sec is seen.

pressure fluctuation and oscillatory flow simultaneously

Fig.s 12 and 13 shows the amount of subsidence in the parentheses for the period = 3.0sec and 6.0sec respectively. The data on the horizontal axis are for the case of pressure fluctuation only. The data on the vertical axis are for the case of oscillatory flow only.

Discussions

pressure fluctuation only

In the experiment of Zen et al.(1990), the width, height and length of the block were 6.9cm, 19.0cm and 6.9cm respectively(Table 1). The weight per unit area of the sand surface was 52.0g/cm^2 in the experiment of Zen et al., while it was 9.7g/cm^2 in this experiment. The void ratio of the sand bed, the period of pressure fluctuation and the total pressure fluctuation amplitude head were 0.80, 3.0sec and 566cm respectively. The amount of se after 100 waves was 0.5cm.

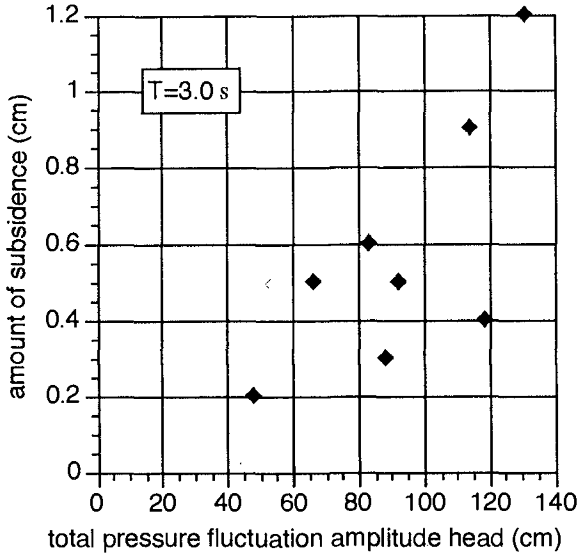

Fig.8 Amount of subsidence after 100 waves under pressure fluctuation only(wave period = 3.0sec)

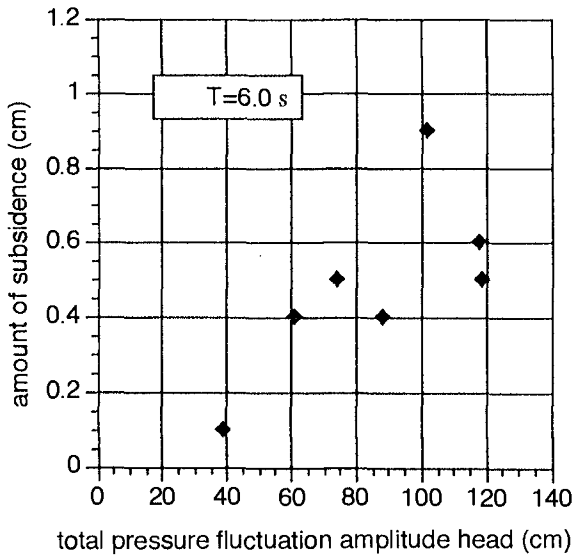

Fig.9 Amount of subsidence after 100 waves under pressure fluctuation only(wave period = 6.0sec)

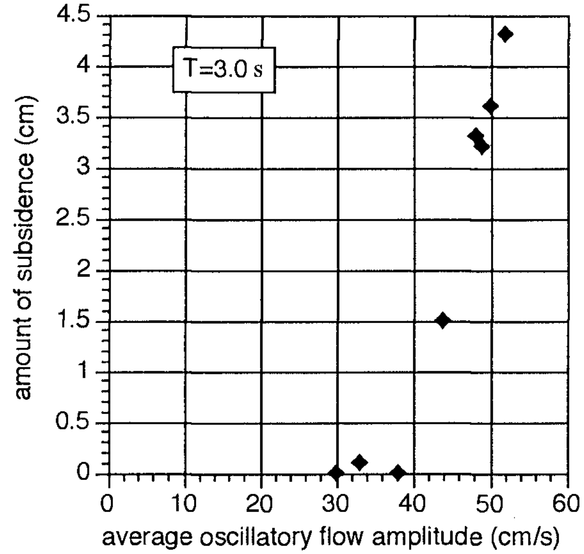

Fig.10 Amount of subsidence after 100 waves under oscillatory flow only(wave period = 3.0sec)

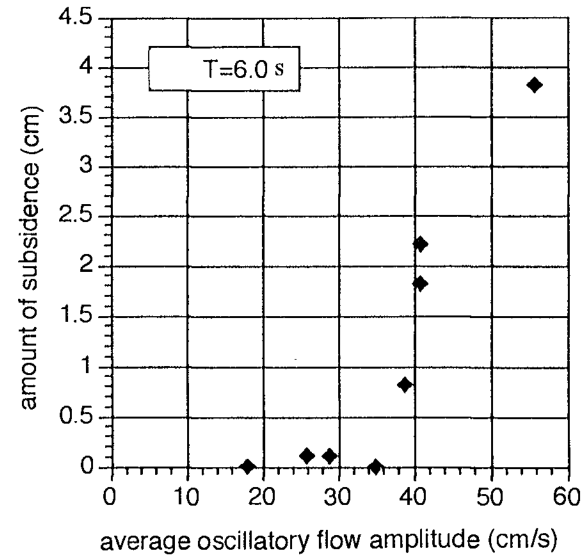

Fig.11 Amount of subsidence after 100 waves under oscillatory flow only(wave period = 6.0sec)

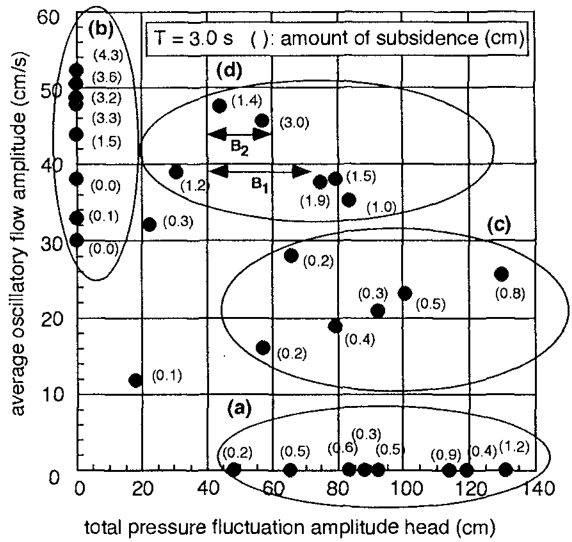

Fig.12 Amount of subsidence after 100 waves under both pressure fluctuation and oscillatory flow (wave period = 3.0sec)

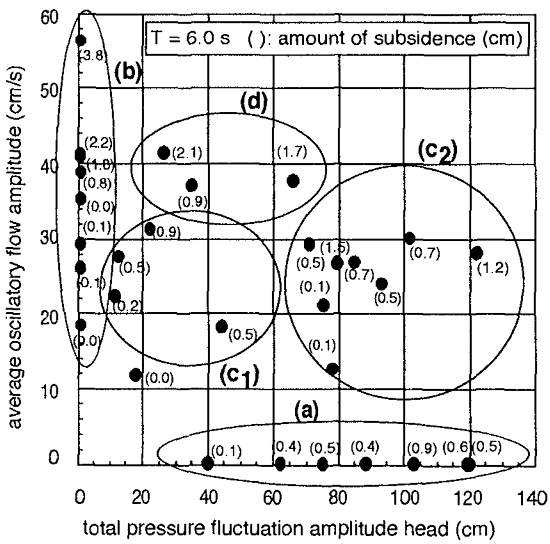

Fig.13 Amount of subsidence after 100 waves under both pressure fluctuation and oscillatory flow (wave period = 6.0sec)

Table 1 Comparison with Zen et al.s experiment(1990)

	Zen et al.(1990)	this study
width(cm)	6.9	10.0
height(cm)	19.0	5.5
length(cm)	6.9	20.5
weight/bottom area (g/cm^2)	52.0	9.7
void ratio	0.80	0.93
degree of saturation	high	low
period(sec)	3.0	3.0
total pressure amplitude head(cm)	566	131
subsidence(cm)	0.5	1.2

In this experiment, the amount of subsidence under total pressure fluctuation amplitude head of 131cm is 1.2cm. In the experiment of Zen et al., the amount of subsidence is less than half of that of this experiment under about 4 times larger pressure fluctuation. The void ratio of the sand bed of this experiment was 0.93 and fairly larger than 0.80 of the experiment of Zen et al. This is one reason of the large amount of subsidence of this experiment.

One more possible reason may be the low degree of saturation of porewater. The lower the degree of saturation of porewater, the larger the attenuation and the phase lag of the porewater pressure(Zen et al., 1990). It induces the larger decrease of the vertical effective stress under the wave trough.

<u>pressure fluctuation and oscillatory flow simultaneously</u>

For convenience' sake, the data in each figure of Fig.12 are divided into several groups. The group (a) consists of the data for the case of pressure fluctuation only. The group (b) consists of the data for the case of oscillatory flow only.

The scatter of data is large, but the following can be said. In the case of 3.0sec, the amount of subsidence under the pressure fluctuation and the oscillatory flow, the average flow amplitude of which is less than 35cm/sec, group (c), is roughly the same as that of group (a). In other words, under the average flow amplitude less than 35cm/sec, in which no subsidence occurs in group (b) of oscillatory flow only, there is no effect of oscillatory flow on group (c).

In group (d), in which the average flow amplitude is larger than 35cm/sec, the amount of subsidence is larger than that of group (a) for the same pressure fluctuation amplitude. Some data show the amount of subsidence larger than any of those of the cases of the same pressure fluctuation only and the same oscillatory flow only.

In the case of 6.0sec shown in Fig.13, the similar trend is seen. There are the data in which the average flow amplitude is less than 35cm/sec and the total pressure fluctuation amplitude head is less than 40cm, group (c_1). In the case of 3.0sec, there is no such data. Under the average flow amplitude less than 35cm/sec, in which no subsidence occurs in the case of flow only, the amount of subsidence is lager than that expected from the pressure fluctuation amplitude. This is one of the additive effects of the pressure fluctuation and the oscillatory flow.

Conclusions

The amount of subsidence of a model block(10.0cm wide, 5.5cm high and 20.5cm long) on a sand bed was measured after 100 waves under a water pressure fluctuation and an oscillatory flow in a U-shaped oscillatory tank. The tank generated a water pressure fluctuation and an oscillatory flow simultaneously. The maximum total water pressure fluctuation head was 1.3m. The maximum average oscillatory flow amplitude was 60cm/sec. The period was 3.0sec and 6.0sec.

(1) Under the water pressure fluctuation, the relation between the fluctuation amplitude and the amount of subsidence is roughly linear and independent on the period.

(2) The amount of subsidence under the water pressure fluctuation is fairly large compared with that of Zen et al.(1990). This is thought to be due to the larger void ratio and the lower degree of saturation of the porewater.

(3) Even under the oscillatory flow, the subsidence occurs. The relation between the flow amplitude and the amount of subsidence is roughly linear and independent on the period.

(4) Under both the water pressure fluctuation and the oscillatory flow simultaneously, the subsidence is larger than any of the subsidence under the pressure

fluctuation only and the subsidence under oscillatory flow only for some combinations of the pressure and the flow.

Acknowledgment

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