II -144 POREWATER PRESSURE AND LOCAL SCOUR AROUND A BRIDGE PIER UNDER ABRUPT CHANGE OF WATER PRESSURE

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ABSTRACT
Local scour development around bridge piers is a common natural problem in the river hydraulics. It is essential to have a design method for the estimation of maximum depth of local scour for the economic and safe construction. The investigation of the dynamic behavior of bed material subjected to water pressure variation is important for taking account of the failure due to local scour. To examine such a phenomenon, a laboratory wave flume model was studied. In this connection, the model was used to clarify the effect of the variation of water pressure and to determine the collapse mechanism of bridge pier due to abrupt change of water pressure. The fluctuation of the effective stresses in different layers and the depth of local scour around the pier were observed. The effective stress of the layers was decreased by an increase in excess pore water pressure, as a result a quick removal of bed material occurred.

INTRODUCTION
Nago (1981) investigated the dynamic behavior of sand bed under the oscillating water pressure with a view of the collapse of hydraulic structures due to sinking, sliding and scouring during floods or storm waves. Nago et.al. (1984) also studied the effect of water pressure variation on the scour around bridge pier. When waves are transmitted into the bed, they give rise to horizontal and vertical pore water pressure gradients, which encourage the liquefaction (Zen and Yamakazi, 1993). The liquefied state of the bed is much more susceptible to erosion by waves and currents because of the reduction of shear stress. The aim of this investigation is to study the variation of local scour with time and the effect of pore water pressure on the bed stress around the bridge pier under the abrupt change of water pressure acting on the bed surface.

EXPERIMENTAL WORKS
The experiments to study the influence of pore pressure on the bed stress and the development of scour hole around circular bridge pier model were conducted in a flume 16 m long, 0.60m wide and 0.40m deep, with a longitudinal slope of 1/500 located in the Hydraulics Laboratory of Okayama University, Japan. The working section, 1.0m long, 0.60m wide, and 0.57m deep was located 8.0m downstream from the entrance of the flume where the pier was located. Fig.1 indicates the positions of pressure transducers. A uniform sediment of 0.25mm in mean particle size and a cylindrical pier of 6cm in diameter were used in the experiment. Table.1 indicates the detail of the experiments. At first, steady clear-water flow conditions were established and the scour depths (d_s) were recorded against time. To investigate the effect of pore pressure and the effective stress on local scour around the pier, the depth of flow was risen relative to the initial depth. The sudden drops were allowed at a stage when the equilibrium local scour depth around the pier was almost reached.

TABLE 1. Experimental details for abrupt change (drop) of water pressure

Exp. No.	Pier type	Sand size d_{50} (mm)	Pier width D (mm)	Q (l/s)	Initial depth h_0 (cm)	U/U_c	Scour before drop (cm)	Drop size (cm)	Scour depth due to drop (cm)	Scour depth increased (%)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
D1	Circular	0.25	60	35	20	0.928	7.1	10	7.8	9.9
							7.3	15	8.0	9.6
D2	Circular	0.25	60	40	20	1.060	7.1	10	7.8	9.9
							7.4	15	8.3	12.2
D3	Circular	0.25	60	25	15	0.914	7.3	10	8.0	9.6
							7.2	15	8.2	13.9

Key words: Local scour, Bridge pier, Liquefaction
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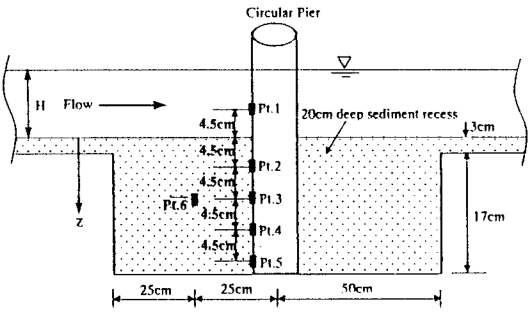

Fig.1. Location of sensors for pore pressure

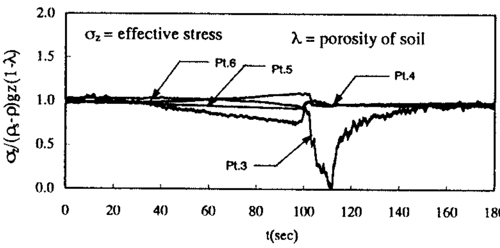

Fig.4. Effective stress

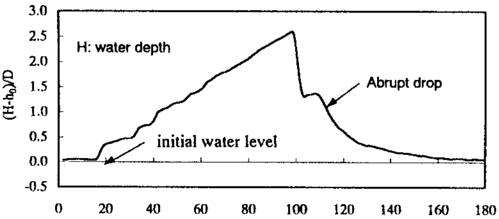

Fig.2. Variation of water surface profile

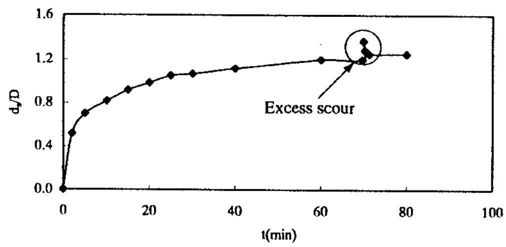

Fig.5. Variation of scour depth with time

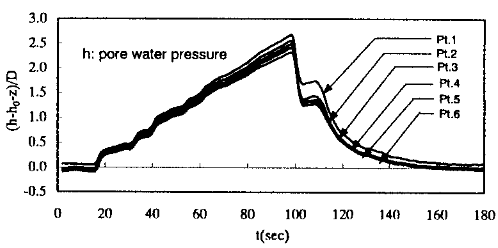

Fig.3. Pore water pressure variation

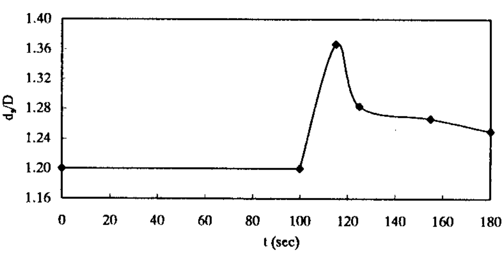

Fig.6. Excess scour developed due to pressure drop; shown in a large scale for the position of circle in fig.5

RESULTS AND CONCLUSIONS

Fig.2 represents the variation of water surface profile of 15cm drop for experiment D3. Fig.3 indicates response of pore water pressure at each layer of the model and Fig.4 illustrates the corresponding effective stresses decreased in the layer. The effective stress in the bed material decreases notably as the pore water pressure increases due to the abrupt change (drop) of pressure. Fig.4 reveals that the liquefaction factor $[\sigma_z/(\rho_s-\rho)gz(1-\lambda)]$ reached to zero in the near surface layer of Pt.3, which indicates no bearing capacity at all in the layer of the bed. Fig.5 is the representation of the variation of scour depth, where the encircled position indicates the excess scour developed due to the abrupt change of water pressure. Because of the weakening of the bed, a significant amount of bed material removed out very quickly (Fig.6). The local scour around the pier was increased by 10%-14% more than that of steady flow.

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