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CHARACTERISTICS OF SANDY GROUND IMPROVED BY SCP DURING EARTHQUAKES

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INTRODUCTION

The sand compaction piles (SCP) method has been used widely to prevent the damage of liquefaction. Its reliability is confirmed by the several case histories. In the actual design, the degree of compaction and extent of compacted area need to be determined. Because the characteristics of the compacted ground are influenced by the adjacent uncompacted ground during earthquakes, it is relatively difficult to determine the suitable degree and extent of compaction. The object of this study is to investigate the typical factors influencing on the compacted ground and clarify the characteristics of sandy ground improved by SCP during earthquakes, using the effective stress analysis method.

OUTLINE OF EFFECTIVE STRESS ANALYSIS METHOD

Two dimensional finite element analysis program NUP2 (Nonlinear u-p formulation in 2 dimension) is developed based on the two-phase mixture theory of Biot, which can take into account the generation and dissipation of pore water pressure during earthquakes. The Newmark's time integration scheme is adopted and the constitutive model used for the present study depends on Iai *et al*'s proposal[1]. This model is composed of two parts: a stress-strain relation for shear mechanism and a mechanism for generating excess pore water pressure. The stress-strain relation for shear mechanism is multiple mechanism model composed of simple shear mechanisms in arbitrary directions. This model can represent realistic hysteresis loops rather than those given by Masing's rule. The mechanism for generating excess pore water pressure is given by a function of plastic shear work and shear stress ratio.

NUMERICAL ANALYSES AND DISCUSSIONS

With the numerical procedure above, simulation analyses are performed for shaking table tests of the sandy ground improved by SCP[2]. As shown in Fig. 1, the model ground is made of saturated sand of the depth of 80 cm and of the width of 150 cm. Four sand compaction piles in the direction of motion are constructed by the same procedure as in-situ to simulate the construction process of sand compaction piles. Dynamic analyses are conducted under drained condition. The side boundaries are assumed to be the repeatability condition. Input motion used in the tests is sinusoidal wave with the frequency of 5 Hz and maximum acceleration of 100 gal. Fig. 2 shows the time histories of imput motion and excess pore water pressure at the depth of 40 cm in uncompacted and compacted model grounds. A good agreement between experimental and computed values is indicated. Fig. 3 shows the distribution of excess pore water pressure ratios at two transient times for another compacted model ground in which the width-to-depth ratio of the compacted area (l/h) and h are equal to 2.5 and the depth of the ground (H) respectively. In spite of the existence of the compacted area, the compacted ground still gradually liquefies depending on the present degree and extent of compaction. However, the numerical results show slow accumulation of excess pore water pressure in the compacted area and sharp accumulation in the uncompacted area. After the excess pore water pressures reach the peak in the uncompacted area, they start dissipation. The results obtained here indicate that the compacted ground against liquefaction gradually liquefies due to the seepage flow from the adjacent liquefied ground. From Fig. 3(b) it can be obtained that the angle between line AB and line BC is approximately equal to 35° if the most part of compacted ground does not liquefy. Here the line AB is the bounday of compacted and uncompacted grounds and the line BC appears as the critical line corresponding to the contour line of 0.5. The compacted zone surrounded by the triangle ABC can be considered to easily liquefy because of the influence of the adjacent liquefied uncompacted ground. This result is basically consistent with the experimental result reported by Iai *et al*[3]. Fig. 4 shows the relationships between the maximum excess pore water pressure ratio at the different depths of the center of the compacted ground and the width-to-depth ratio of the compacted area. It can be pointed out that the excess pore water pressure ratio of the compacted ground decreases with increasing width ratio. Although the data is limited, it can be seen that there may exist an optimum compaction width for design purposes.

ACKNOWLEDGMENT

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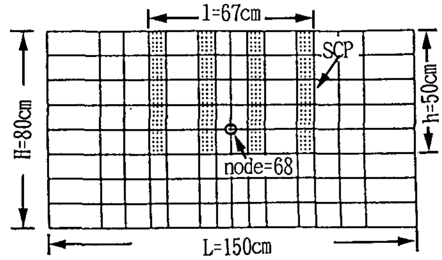


Fig. 1 Finite Element Model

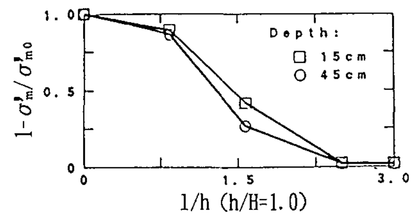
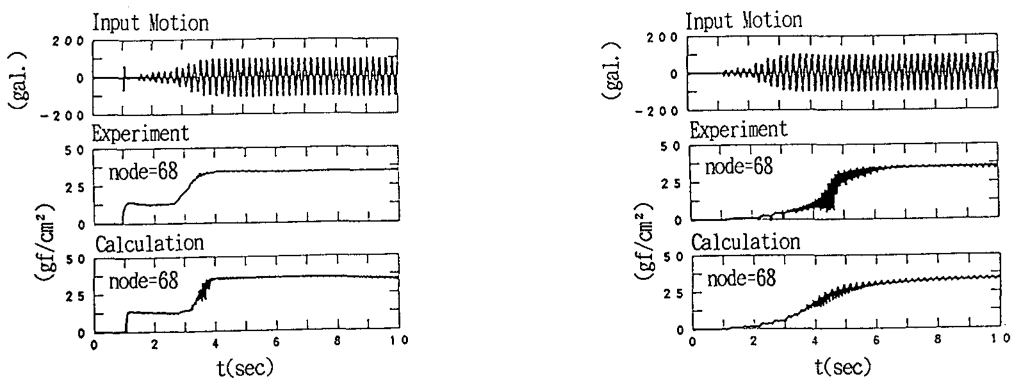


Fig. 4 Maximum Excess Pore Pressure



(a) Uncompacted Model

(b) Compacted Model

Fig. 2 Time History of Excess Pore Pressure
(l/h=1.34, h/H=0.625)

(a) t=4sec

(b) t=10sec

Fig. 3 Distribution of Excess Pore Pressure Ratio
(l/h=2.5, h/H=1.0)