A Study of the Surface Settlement of Gravel Piles with Different Layouts
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ABSTRACT

A new development for the theory proposed by Seed and Booker (1977), with experimental works by Lee and Albaisa (1974), can be used to illustrate the settlement ratio versus the excess pore water pressure ratio for various time factors. These figures can be used to illustrate when calculating settlements. In order to investigate the best layout for gravel drain, a series of shake table tests was performed with the following dispositions: a gravel wall, square gravel piles and diamond gravel piles. The experimental parameters included different gravel wall thicknesses and gravel pile diameters. For a certain amount of time, the ground-surface settlement for gravel wall and gravel piles were mentioned; in addition, topographic chart software was used to display settlement variations. All studied dispositions efficiently prevented settlements.

It was also found that the area ratio (area of gravel/area of whole system) of the gravel piles or gravel wall could reduce excess pore water pressure after a series of shaking table. Finally, the gravel wall outperformed the diamond and square pile in terms of settlement reduction.

KEY WORDS: Liquefaction, gravel piles, disposition ways, area ratio, excess pore water pressure ratio, settlement ratio.

INTRODUCTION

Liquefaction typically results in a lot of serious damages during or after an earthquake, and some feasible mitigation techniques, including a gravel drain or stone column, have been suggested. Lu and Su (2002) collected many case histories of stone columns construction on difficult ground in Taiwan to illustrate this phenomenon. The results show that the success of a stone column is significantly influenced by the construction sequences. However, many papers discuss cases studies and numerical solutions; the contribution of the construction sequence has not been studied as thoroughly. To understand the availability of a wall or pile disposition, a series of small-scale shaking table test was performed for different distribution, thicknesses and soil densities. In addition surface settlements for each test were measured with an image process and by hand.

LITERATURE REVIEW

Lee and Albaisa (1974) indicated that settlement can induce large volume strain when the soil initially undergoes liquefaction; however, it causes little or no strain in non-liquefaction soils. In addition, the volume strain only reaches 0.5% of the soil thickness, unless the excess pore water pressure ratio is larger than 0.8. The settlement can reach 2%–5% of the soil thickness in the initial liquefaction. Meantime Lee and Albaisa found that the volume strain decreases as the relative density increases, but is independent of the confining pressure.

In 1977, Seed and Booker described excess pore water pressure induced by cyclic loadings, which can be dissipated easily using ground improvement techniques to prevent liquefaction failure. In addition Seed and Booker made several assumptions, including applicability of the Darcy law, and the values of the constant coefficients of k and m, to derive a gravel-drain equation to calculate the generation and dissipation of pore water pressure and the radial flow direction. Finally some design charts were provided as a reference for gravel drain which revealed that the pore water pressure in terms of gravel percentage depends on a time factor $T_{ad}$.

$$T_{ad} = \frac{k}{\gamma} \frac{t_i}{m_i a^2}$$

Where $k$ is the permeability coefficient, $t_i$ is the period of the earthquake, $m_i$ is the volume compression coefficient, and $a$ is radius of the gravelly drain.

Yoshimi and Tokimatsu (1977) studied how grain drain blockage affects the drainage path of excess pore water pressure during dissipation. A high permeability characteristic of gravel pile could affect efficient water emission because of fine grain blockage. The proper selection of gravel size and gradation is very important to maintain efficient drainage. In addition Brown (1977) proposed the value $S_n$ (Suitability Number), which is defined in Equation (2), to determine the proper refill gradation based on experience in the field.

$$S_n = \frac{1.7}{\sqrt[3]{\left(\frac{3}{(D_{60})^3} + \frac{1}{(D_{50})^2} + \frac{1}{(D_{50})^2}\right)}}$$