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Experimental research of spatial variation of compaction effect on vibratory probe compaction method for ground improvement

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Abstract

In order to demonstrate effectiveness of vibratory probe compaction at silt deposit, a self-developed vibratory probe with cross section and compaction equipment were adopted to treat silt deposit at Suqian-Xinyi Expressway liquefiable site in China. Field pilot tests were conducted to study spatial variation of compaction effect. It is shown that strength increase at vibration point is largest after ground improvement, while a small increase occured at 1m, but not 2m from vibration point. The radial influence range and effective reinforcement radius are 2m and 1m. The largest settlement is in a zone within a radius about twice the probe diameter. The major settlement occurred immediately after compaction, slightly increased with time.

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Keywords: vibratory probe compaction; vibratory probe with cross section; spatial variation

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1. Introduction

Vibratory probe compaction is a new concept for deep compaction of granular soils, a specially designed steel probe, to the top of which is clamped a heavy vibrator, which can generate vertical oscillations. The soil is compacted as a result of repeated insertion and withdrawal of the probe, which takes advantage of the amplified ground response, which occurs when a soil layer is excited at a resonant frequency. This can be achieved by adjusting the vibrator frequency to one of the resonant frequencies of the soil-probe system. At resonance, the probe achieves an optimal transfer of vibration energy to the surrounding soil. The greatest advantage of the method lies in the speed and low cost compared with other deep compaction methods. The two most common applications of vibratory probe compaction are the improvement of reclaimed land for infrastructure projects (e.g. ports and airports) and the mitigation of liquefaction risk in seismic areas.

Based on comprehensive study of the mechanism of the rearrangement of soil particles and corresponding densification[1],a set of deep vibratory compaction equipment with frequency-variable piling vibrator was developed in this research. This equipment is designed to insert a self-developed probe with cross section into the soil which needs to be densified[2]. Details of the equipment will be discussed later.

Assessing the effect of vibratory compaction on silt soil treatment always from several aspects such as physico-mechanical characteristics indices of soil layer, safety factor and liquefaction probability, spatial variation of cross section vibratory probe compaction effect are less researched[3~6]. Strength change and ground surface settlements give reliable indication of the achieved densification. Brown[7] researched the effect of cone resistance after Tri-Star probe compaction as a function of increasing distance, the results show that the obtained densification was the largest at the densification point same as grid centre point, while a small increase occurs at 1m, but not 2 or 3m from the densification point, the Tri-Star probe has a zone of influence of about 2m radius. Some scholars investigated settlements of different points after compaction such as densification point, center point of grid and increasing distances away from densification point[8~12]. Mitchell[13] found that the largest settlements can be expected in a zone extending to about twice the probe diameter. Jonson[14] observed that settlements at the ground surface can be observed up to a distance of about half the probe penetration depth. The average settlements range between 5 and 10% of layer thickness[15~17]. This study investigates spatial variation of compaction effect after cross section vibratory probe compaction based on experimental research.

2. General Introduction of the Test

2.1. Construction equipments

The vibratory pile driving apparatus consists of a 50-ton crawler crane, mounted with a 7-ton vibrator. The vibrator is attached to the top of a 0.6-m wide and 15-m long probe. The probe is provided with circular openings of 0.1m in diameter and 0.8m apart aiming to reduce probe impedance and provide better contact with soil. The probe is driven to the designed depth of compaction by a vibrator which frequency range is 840 cycles per min-1200 cycles per min with the normal operating frequency 1000 cycles per min. The max centrifugal force and eccentric moment for the vibrator is 530 kN and 430 Nm, respectively. The compaction process consisted of lowering the probe to designed depth at a rate of 2.5 m/min, followed by a steady state phase in which the probe was vibrated at a constant, but lower frequency. The probe was then withdrawn to ground at a rate of 1.2 m/min.

2.2. Soil conditions

The soil consisted of a maximum thickness of 25 m Yellow River alluvial silt on a natural deposit of dense sand. The ground water level was located approximately 3.8m below the ground surface. The geotechnical properties of the soil deposit were investigated by extensive field and laboratory tests. Typical test results are summarized in Table 1.

Table 1. Typical geotechnical properties of major typical soil layers.