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Analyzing the Behavior of Micro-Pile in Sandy Soils using Numerical Method

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Abstract- The piled raft has proved to be an economical foundation type compared to conventional pile foundations. The application of piled rafts on soft clay has increased recently. In this research the finite element model for the soil profile was generated. The numerical analysis was based on the Mohr-Coulomb model incorporated in the finite element code; PLAXIS. In this regard, effect of the distance between the micro-piles and length variations of micro-piles has been shown. And the results showed that with increasing distance between micro-piles and length of micro-piles, significant impact on the settlement will occur.

Keywords- micro-piles, finite element method, sandy soil, parametric study

I. INTRODUCTION

The use of Micropiles started in early 1950s in Italy for under pinning application of historic building damaged during war II, Micropiles technology is a reliable pile system that can with stand large capacity axial or lateral loads with minimal disturbance to the existing structures, they become very popular due to their ability to transfer loads efficiently through skin friction and due to their many installation advantage over conventional pile systems. A typical construction sequence is shown in Figure 1.Micropiles are small diameter piles that can be installed in almost any type of ground where piles are required with design loads as small as three tons and has high as 500 tons.

Papadopoulou et al in 2014 were investigated on finite element analyses and experimental investigation of helical micropiles. Within the framework of their research program on the behaviour of a specific type of screw micropile with helical plates of 220 mm diameter, the response in axial and horizontal loadings by the finite element method and full scale in situ tests were investigated. For the axial compressive or tensile loads, the simulation of the helical plates was carried out under axisymmetric conditions as shell foundations.

Moayed and Naeini in 2012 were investigated on improvement of loose sandy soil deposits using Micro piles. Their paper describes a case study in which 350 micro piles of 75 mm diameter and 15-20 m long have been used for the improvement of loose sandy soil deposits. The effect of micro pile injection on liquefaction remedation and improving of soil stress-displacement behavior are evaluated using the results of Standard Penetration Tests (SPT) and Plate Load Tests (PLT) on a real site before and after micro pile installation. The load-displacement responses of micro piles under tensile axial loading are also presented in their paper. The results show that, by using micro piles, the response of loose silty sand soils under surface loading can be significantly improved and the bearing capacity of loose sandy soil increased considerably. Also, the modulus of subgrade reaction of the soil (KS) is increased. The SPT values of soil layers are increased after soil improvement with micro pile installation. Therefore, the liquefaction resistances of sandy soil are also improved.

Sharma and Buragohain in 2013 studied on behavior of micro pile Groups under Oblique pull out loads in Sand. And Bhardwaj and Singh in 2014 studied on influence of load obliquity on pullout capacity of micropile in sand. In their study an experimental study was undertaken to understand the influence of load obliquity on ultimate pullout capacity of pile and it is found that ultimate oblique pullout capacity as well as vertical pullout capacity of micropile decreases as load inclination increases with axis of micropile. To understand the relationship between the two components of oblique pullout load an interaction diagram has been derived from test results which show that horizontal load significantly affects vertical pullout capacity than vice versa. Test results of similar studies on micropiles have been presented through a polar diagram. An attempt has also been made to assess the applicability of existing theories to estimate the ultimate pullout capacity of micropiles under oblique loads.

II. MICROPILE CLASSIFICATION AND DESIGN APPLICATION

A micropile classification system based on two criteria 1) philosophy of behavior (design) and 2) method of grouting (construction). The philosophy of behavior dictates the method employed in designing the micropile. The method of grouting defines the grout/ground bond capacity, which is generally the major constructional control over pile capacity. The classification system consists of a two-part designation: *a number*, which denotes the micropile behavior (design), and *a* letter, which designates the method of grouting (construction).

The design of an individual or group of micropiles differs greatly from that of a network of closely spaced reticulated micropiles. This led to definition of CASE1 micropile elements, which are loaded directly and where the pile reinforcement resists the majority of applied load. CASE2 micropile elements circumscribes and internally reinforce the soil to make a reinforced soil composite that resists the applied load this is to as a reticulated pile network.

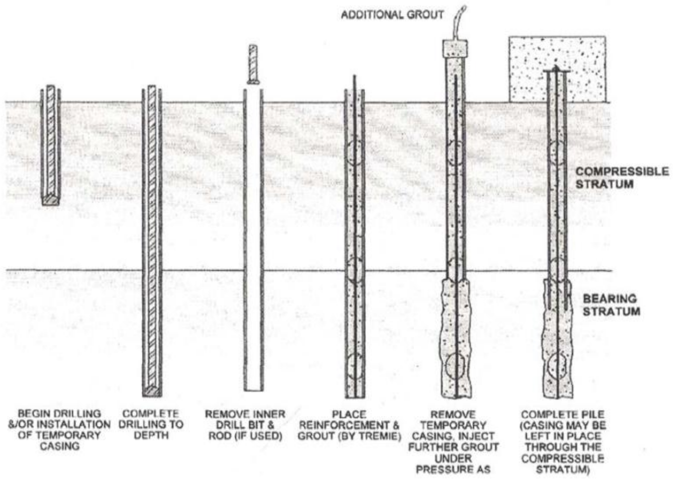

Figure 1. Micropile Construction Sequence (FHWA-SA-97-070)

III. NUMERICAL MODELING

In the analysis using from a uniform silica standard sand known as Fontainebleau sand, that the grain size distribution of Fontainebleau sand is as shown in figure 2.

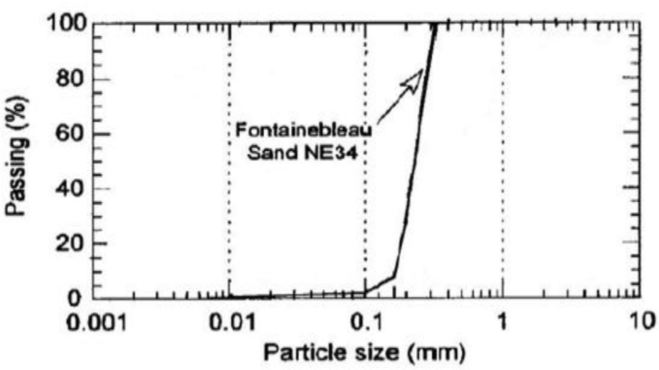

Figure 2. Grain size distribution of Fontainebleau sand

The finite element model for the soil profile was generated. Parameters of soil and micro pile used in the simulation are listed in the Table 1 and 2. Micro piles diameter is 20 cm and length of them is 10 m. The numerical analysis was based on the Mohr-Coulomb model incorporated in the finite element code, PLAXIS. The boundary conditions were set as the typical boundary conditions. The displacements in all directions at the bottom boundary were fixed; the boundaries at both sides can only move in the vertical direction. The mesh discretization with 6-node triangular elements is shown in Fig.3.

TABLE I. MATERIAL PROPERTIES OF SOIL FOR FINITE ELEMENT ANALYSIS

parameter	Friction Angle (o)	Cohesion (KN/m^2)	Unit Weight (KN/m^3)	(Mpa) E	ν
value	39	0	16.77	117	0.3

TABLE II. MATERIAL PROPERTIES OF MICRO-PILE FOR FINITE ELEMENT ANALYSIS

Type of micro-pile	ω (kg/m)	EI (kN)	EA (kN)	ν
TITAN – IBO103/ 78	100	2597	1401582	0.2

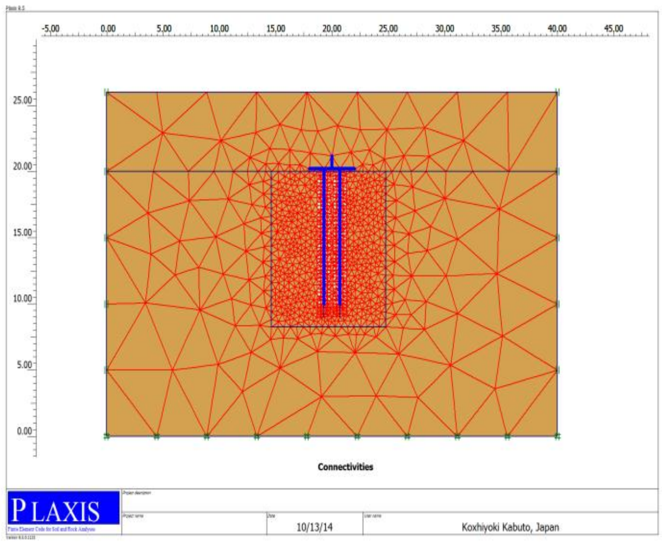

Figure 3. Finite element mesh in analysis

When the geometry and boundary condition setting was completed, the finite element mesh was generated. In order to consider the possible large stress gradient, the mesh was refined at the interface of the soil and the pile.

IV. PARAMETRIC STUDY

In this section, the change in the distance between Micro piles (s), Micro piles length (L), internal friction angle (φ), Loading and injection procedure, have been analyzed.

A. *The effects of the distance between micro-piles*

Figure 4 shows change in the settlement against distance between the micro-piles. As can be seen with increasing distance from each other, the settlement in micro-piles has a decreasing trend. It is important to note that at a depth of about 5 meters, Changes in settlement, compared to the distance, there is a reverse trend.

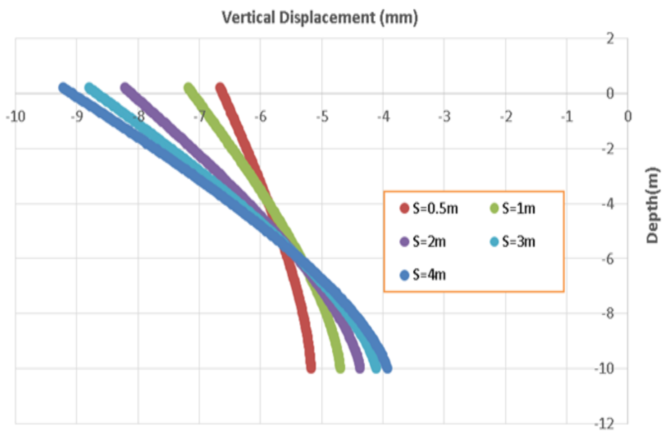

Figure 4. change in the settlement against distance between the micro-piles

Figure 5 shows change in axial force against distance between the micro-piles. As can be seen axial force at the end of micro-pile is closely to zero. Also observed that by increasing the distance between the piles, the axial force is reduced gradually.

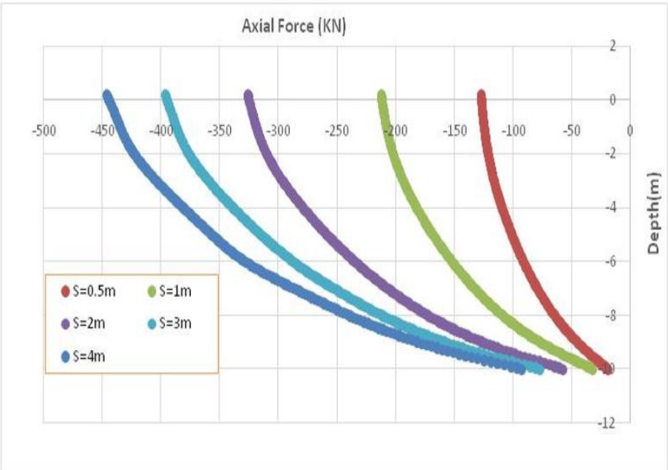

Figure 5. change in axial force against distance between the micro-piles

B. The effects of micro-piles length

Figure 6 shows change in the settlement against length variations of micro-piles. In this figure, micro-piles with lengths of 4, 6, 8, and 10 meters are modeled. By increasing the length of micro-piles, surface settlement reduced, because involvement of the soil and micro-piles will be greater. Also trend of increasing in settlement, from 10 m to 15 m, decreased. And this implies that an increase over 15 meters, there is little effect in reducing in settlement.

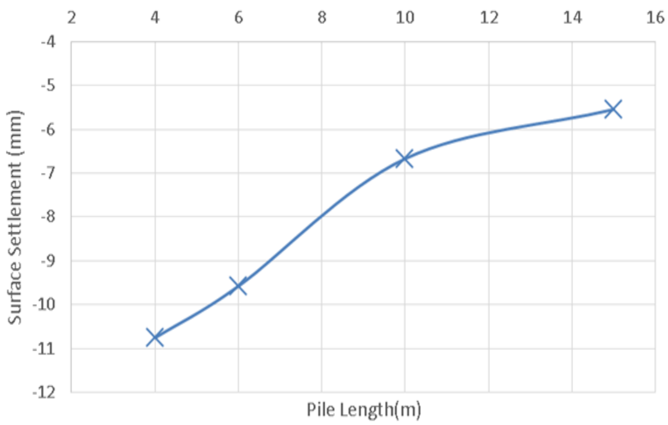

Figure 6. change in the settlement against length variations of micro-piles

Figure 7 shows change in maximum axial force against length variations of micro-piles. The results show that, with increasing length of micro-piles, the force on the head increased. Also within just 10 to 15 meters, tilt-shift, has increased dramatically. And the lowest change occurred at intervals of 6 to 10 meters.

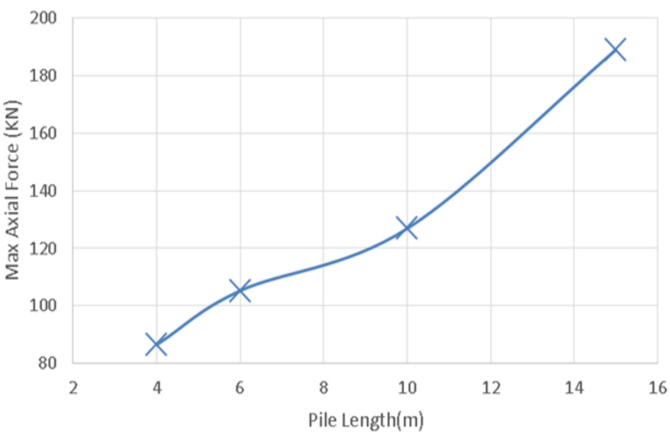

Figure 7. change in maximum axial force against length variations of micro-piles

V. CONCLUSION

The results of this study have shown the beneficial effects of Micropiles. Therefore, On the basis of literature survey carried out following concluding remarks are made:

1- With increasing distance between micropiles, the settlement in micro-piles has a decreasing trend. It is important to note that at a depth of about 5 meters, Changes in settlement, compared to the distance, there is a reverse trend.

2- Axial force at the end of micro-pile is closely to zero. Also observed that by increasing the distance between the piles, the axial force is reduced gradually.

3- Micro-piles with lengths of 4, 6, 8, and 10 meters are modeled. By increasing the length of micro-piles, surface settlement reduced, because involvement of the soil and micro-piles will be greater. Also trend of increasing in settlement, from 10 m to 15 m, decreased.

4- With increasing length of micro-piles, the force on the head increased. Also within just 10 to 15 meters, tilt-shift has increased dramatically. And the lowest change occurred at intervals of 6 to 10 meters.

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