Behavior of grouting pile in sandy soil

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Abstract An old project was built in south of Iraq. This project included housing and buildings for common use. Pile foundations were needed in some parts, where sandy lean clay and medium dense silty sand existed at different depths. Small diameter friction piles were used in this part of the project. Micro piles are used in the same manner as the conventional piles in combination with caps. They can also be used to reduce excessive settlement. In the load test program vertical, tensile and lateral loading tests were performed to study the efficiency of this type of piles. For the current work, Full-scale pile loading testing has been done to examine the field performance of the micro piles subjected to tension, lateral and compressing loads. The observations have provided some conclusion. Installing the micro piling within all soils represents a method of improving procedure done to a ground. Micro piles can be used a normal foundation piles. The work of this paper pointed to, without plunging failing, Butler and Hoy's strategy gives a well estimating of a definitive uplifting limit. This study has shown that, once micro-piles have been provided with a higher casing section, carrying capacity of piles may be increase by more than 90% in comparison with micro-piles that have no case. Tensile loads ratio represents 25% of the compression loads. A final observation is that the micro piles have sensitivity toward the constructing method as well as the drilling bit specification.

Keywords: Micro pile; Sandy soil; Foundation; Grouting; Fuller

1. Introduction

Micro Piling had at first been utilized to fix historical structures which had been harmed at the time of the second World War, 1950's which involved introducing miniaturized such piling by boring via the current establishment along with filling the gaps with cements grout as well as bars made of steel [1]. These days, various sorts of Micro piling can be utilized to give the burden conveying limit of new establishment system [2]. In current practice, the diameter of a micro pile is typically less than 300 mm. Micro piles had been presented for North America during the mid-1980, what's more, their utilizations have been quickly developing from that point onward. Their development strategy has been improved and new development system has been created. The progressions of the drill hardware have brought about the capacity to penetrate via practically any ground state to introduce micro piling at any point with least commotion, vibrating as well as unsettling influence. Additionally, the generally little size of the gear has permitted the supporting of existing establishments even in confined access circumstances [3].
2. Ground conditions

According to the unified classification system, the subsoil profile can be summarized as following:

- The upper layer is fill material with asphalt pavement and subbase material.
- The next layer is brown, grey medium silty clay about (1.0) m thick
- The last layer of boreholes is white, yellow clayey silty sand to fine sand with cemented sand, gypsum and pebbles which extend down to the end of borings.

The results of direct shear are shown in the Table 1.

Table (1). Shear strength parameters for different boreholes

| B.H. No. | Depth (m) | Shear strength Parameters | \(c\) KN/m\(^2\) | \(\phi\) deg. |
|----------|-----------|---------------------------|-----------------|-------------|
| 1        | 9.0-9.5   | 0.00                      | 37              |
| 2        | 15.5-16.0 | 0.00                      | 36.5            |
| 3        | 125-13.5  | 0.00                      | 36              |
| 4        | 3.5-4.0   | 0.00                      | 37.5            |
| 5        | 4.5-5.0   | 0.00                      | 35              |
|          | 6.5-7.5   | 0.00                      | 39              |
|          | 14.5-15.0 | 0.00                      | 35              |

3. Pile installation

Mini reinforcement piles of 30 cm diameter have been installed to depths ranging between 15 and 16 meters and have performed excellently. They were designed in accordance with the specifications for construction of Mini piles published in Ground Engineering Journal, (1987).

In this project water was used as a drilling fluid together with a flight auger. The water carries away cuttings and fine soil to the ground surface level. After forming the hole, the injection tube are placed in the hole. A cement suspension grout is pumped into the hole through the injection tube which reaches to the bottom of the hole. The injection tube has staggered slots spread every 0.5 m in the vertical direction of the tube. The injection is usually carried out starting from the hole base which reduces the possibility of necking in the pile shaft. In granular or fissured ground, grouting increases the frictional resistance of the pile. The used mixes of pure cement suspension have a water cement ratio ranging from 0.4 to 0.5 with a high cement content. The pile construction process is shown in the Figure (1). The grout has a strength of 30 MN/m\(^2\) and prepared by using a sulphate resisting cement.
4. Pile load testing
Micro piles have been tried by the static pivotal loading test of single pile. such testing for the most part include gradual axial load till the piling either continues a foreordained greatest testing loading, arrives at a foreordained constructional axial dislodging breaking point, or arrives at a foreordained ground creep limit. With the pattern towards higher limit CASE 1 piling, failing may happen as the abrupt loss of burden and increment in removal related with constructional failing.

4.1 Load Settlement Behavior
For the purpose of examining the loading settling conduct of the micro piles, modelling investigations had been executed upon individual micro pile as well as groups of micro piles under compression, tensile and lateral loads. To achieve the objective of the study, all necessary tests should be conducted, which we will review in the next section.

4.2 Static Axial Compressive Load Testing
The main purpose of this test is to define the reaction of piles to a statically compression loading done in axial form for the pile. And get a relationship between applied load and pile settlement. The age of tested pile should not be less than 28 days, or the strength of preformed test blocks which has been maintained at the same conditions reaches designed strength, or designer approve to do the test [4]. Equipment installation is shown as in Figure. 2.

4.2.1 Interpreted failure criteria
The failing loading utilizing a digression to the load-settling bend inclining at 0.15 mm/KN, [5] along with [6]. This technique is appropriate for a short pile tried beneath brisk maintaining testing. Such standard is prescribed by FHWA (2005) to Micro piling also could be utilized for check testing.
Ten Micro piles had been burdened till failing so as to assess their final limit. The outcomes of pile testing are stated below, see figure 3. The loading-settling bend appears a failing load at about 56 tons. as a result of breaking the head of the substrate in the case of micro pile without casing, see Figure 4. even though ultimate load had been noticed within same pile with loading equals 93 tons (by using Butler and Hoy) in the case of using casing as shown in Figure 5.

**Figure 2.** Axial compression load application (study site)

**Figure 3.** Load settlement curve for load test of micro pile.

**Figure 4.** Pile load test without casing.

**Figure 5.** Pile load test with casing.
When comparing the results of examination of micro substrates with substrates of pre-castings (0.3x0.3 cm and 15 m length) we observe the results very close to some as shown in figure 6.

![Figure 6. Load settlement curves for the casing micro pile and precast piles.](image)

4.3 Static Axial Tensile Load Testing

The main purpose of this test is to define the reaction of piles to a statically tension loading done in axial form for the pile. And get a relationship between applied load and pile settlement [7].

Load applied to pile by hydraulic jack(s) (figure 7) acting between the reinforced testing beam with a reacting framing fixed to the pile’s center over the test pile.

4.3.1 Loading-displacement curve

Each micro pile was subjected to load till failing load happened, the peak loading cannot be preserved associated with a great increment in displacement ratio. The curves of the loading-displacement to the micro piles which were tried in tension are shown in figure 8 below. According to figure 8, each micro pile showed very nearly similar behavior. However, the maximum movement is 30 mm for pile no. TP1. The behavior approves the observing done at the time of the drill that a shallow filling layer, extending just about 2 m to 3 m alongside the micro pile shaft. While other three micro piles, TP2, TP3 and TP4, exhibited maximum average settlement at about 22 mm.
In order to analyze the lateral force effect on the Mini pile. The usual method of carrying out lateral load tests is to use a pair of piles and jack their heads apart [8]. An arrangement was developed in this study. A schematic diagram of horizontal loading test setup is shown in Figure 9. The lateral deflection of the pile head is measured with a dial gauge at the same level of the applied load. The method presented here is based on [9] assumptions: one: neglects the dynamic earth pressing performing upon the pile’s back, two: no influence of the pile shape on the ultimate soil distribution pressure, and three: the full lateral resistance is mobilized at the considered movement [10].

**4.4 Lateral Loading Test**

In order to analyze the lateral force effect on the Mini pile. The usual method of carrying out lateral load tests is to use a pair of piles and jack their heads apart [8]. An arrangement was developed in this study. A schematic diagram of horizontal loading test setup is shown in Figure 9. The lateral deflection of the pile head is measured with a dial gauge at the same level of the applied load. The method presented here is based on [9] assumptions: one: neglects the dynamic earth pressing performing upon the pile’s back, two: no influence of the pile shape on the ultimate soil distribution pressure, and three: the full lateral resistance is mobilized at the considered movement [10].

**4.4.1 Results analysis**

Eight Micro piles have been subjected to load till failing for evaluating their upmost lateral limit. Figure 10 shows the outcomes of lateral pile testing. The loading-settlement curves appears a failing load at about 4.5 ton which is a result of breaking the head of the micro pile in the case of micro pile without casing, see Figure 11. Whereas ultimate load had been noticed in the same pile by a load equals 14 tons in the case of the use casing as shown in Figure 12.
Figure 9. Horizontal loading test setup (study site).

Figure 10. Lateral load versus horizontal movement.

Figure 11. Lateral pile load test without casing.

Figure 12. Lateral pile load test with casing.
5. Conclusion:

Within the current work, full-scale pile load testing was performed for investigating the field performing of the micro piles under tension, lateral as well as compression loads. The observations have provided some conclusion summarized below.

1. Installing the micro piles within any soil represents a method of ground improving technique.
2. Micro piles can be used as normal foundation piles.
3. The investigation pointed out that, without plunging failing, Butler and Hoy’s technique gives a well estimating of the upmost uplifting limit.
4. This study has shown that, once micro-piles get provided by an upper case section, the carrying capacity of piles may be increase by more than 90% in comparison with micro-piles which having no case.
5. Tensile loads ratio represents 25% of the compression loads.
6. A final observation is that the micro piles have sensitivity toward the constructing method along with the drilling bit specification.

6. References

[1] Federal Highway Administration (FHWA) 2005 *Micropiles Design and Construction*.

[2] Lizzi F 1985 *Pali radice’ (root piles) and ‘reticulated pali radice.* (In Thorburn S & Hutchison JF (eds) Underpinning. Surrey University Press. Glasgow and London: 84– McLean, VA: US Department of Transportation

[3] Bruce D A DiMillio A F Juran I 1995 *Introduction to Micropiles* (an international Perspective, Foundation Upgrading and Repair) ASCE Geotechnical Special Publication no. 50, pp. 1-26

[4] ASTM D1143 / D1143M – 2013, for Deep Foundations under Static Axial Compressive Load.

[5] Butler H D and Hoy H E 1977 *The Texas Quick – Load Method for Foundation Load Testing* (user’s manual, FHWA) – p77 – 8, December.

[6] Fellenius B H 2006 *Basics of Foundation Design* (Electronic Edition. www.Fellenius.net) p275.

[7] ASTM D3689 / D3689M 2013 *Standard Test Methods for Deep Foundations under Static Axial Tensile Load*.

[8] ASTM D3966 / D3966M, 2010 *Standard Test Method for Piles under Lateral Loads*.

[9] Broms B 1964 *Lateral Resistance of Pile in Cohesion less Soils* (Journal of the Soil Mechanics and Foundations Division), ASCE, Vol. SM3, pp123-156.

[10] Poulos H G 1980 *Comparisons between theoretical and observed behavior of pile foundations* (Australia-New Zealand Conference on Geomechanics) pp95-104.