Analysis of Underpinned Micropile on Existing Foundations

Rose Simon[1], Seemon S[2]

[1]Post Graduate Student of Civil Engineering, IES College of Engineering, Kerala, India
[2]Assisstant Professor, Dept. of Civil Engineering, IES College of Engineering, Kerala, India

---

Abstract - *Micropiles are useful for various range of applications such as underpinning of existing foundation, foundation support of light-weight structures, slope stabilization etc. They are said to be relatively low diameter piles with diameter up to 300mm. Underpinning is the process of strengthening the foundation of an existing building or other structure. Load transfer from the existing foundation to the micropiles is an important mechanism to consider when designing an existing foundation underpinned by micropiles. This study evaluates the effect of load carrying capacity and the settlement behavior of existing foundation underpinned by micropiles. A series of model tests were conducted in the laboratory to investigate the behavior of micropiles in the underpinned foundation under additional loading. Using load settlement curves obtained from tests, the bearing capacity and settlement of micropiles were calculated and compared. The test results showed that the bearing capacity of two piles were equal (helical pile with double helices and waveform pile with 5 waves) and a 29% of settlement reduction was observed in the case of helical pile with double helices.*

***Key Words*: Bearing Capacity, Settlement, Helical Pile, Waveform Pile, Conventional Pile, Plate load Test.**

1. INTRODUCTION

In construction or renovation, underpinning is the process of strengthening the foundation of an existing building or increase the depth of an existing foundation by lowering the footing to allow it to rest on more supportive soil. While oftentimes underpinning is associated with the remediation of deficient or failing foundations, it is also used in cases where the use of a building has changed, floors are being added to upper stories, or additional depth is desired in subsurface spaces, such as basements or cellars. The most common among the many reasons for foundation underpinning are seismic retrofit and prevention of harmful settlement. Micropiles are typically used for underpinning, whereby a separate load transfer structure is often provided between the micropiles and the existing superstructure.

Micropiles are small diameter (less than 300 mm), drilled and grouted non-displacement piles that are typically reinforced. The main difference between pile and micropile is that in case of conventional pile, most of the applied load is resisted by the reinforced concrete, while in case of micropile structural capacities rely on high-capacity steel elements which resist most or the entire applied load. Micropiles are generally used in underpinning of existing structures, seismic retrofitting of foundations, stabilization of slopes, for excavation support and resisting uplift loads. The installation process of micropiles cause minimal disturbance to adjacent structures, soil and environment. Micropiles can be installed in all type of soils and ground conditions with restricted access.

Micropiles can be subjected to significant uplift resulting from seismic loading. The overturning moment caused by the seismic lateral force to the pile cap is typically resisted by the axial resistance of the micropiles. Some structures, like transmission towers, mooring systems for ocean surface or submerged platforms, tall chimneys, jetty structures, etc., are constructed on pile foundations, which have to resist uplift loads. Micropile underpinning is the process of creating small diameter drilled and grouted friction piles.

2. SCOPES AND OBJECTIVES

The concept of micropile is showing a tremendous growth in the present times. One of the basic applications of micropiles is underpinning of existing foundations as they are said to transfer loads efficiently through skin friction and they also have an advantage of installation over other conventional piles that are now in use. The installation of micropiles also cause very minimum ground disturbance hence results in no damage to the surrounding structures during underpinning of existing foundation.

The project aims at achieving the following objectives:

- To evaluate the type of micropile suitable for underpinning
- To find the effect of number of waves and number of helices in micropiles
- To compare the settlement behaviour of wave form and helical pile
- To determine the bearing capacity of micropiles

3. MATERIALS

The materials required for the experiment includes Sand, Model Tank, Piles and Footing. The details regarding the materials are given below.

3.1 Sand

The sand chosen for the study was a river sand obtained from Pattambi. The sand was air dried for conducting all the laboratory tests. The grain size distribution was found using IS: 2720-part 4.

Table -1: Basic Properties of Sand

Properties	Values
Specific gravity	2.65
Uniformity coefficient, Cu	2.4
Coefficient of curvature, Cc	0.77
Gradation of sand	SP
Max. dry density (g/cc)	1.819
Min. dry density (g/cc)	1.777
Soil friction angle, ø	33°
Permeability (cm/s)	7.24×10^{-4}

3.2 Footing Plate

The footing plate used for plate load testing which has dimensions 30cm × 30cm × 1cm.

3.3 Tank

The test tank was fabricated using GT plated sheet of thickness 1.2mm. The dimensions of the test tank were 850mm x 850mm x 900 mm length, width and depth respectively. The dimensions of the tank were fixed by considering the dimension of pile and their influence zone.

3.4 Model Piles

Three sets of mild steel pile models of length 400mm and 16.7mm diameter were selected in the present study. One is used as the conventional pile without providing bulb portion. Other two model pile fabricated as helical pile and waveform pile. Fig. 1 shows the helical and waveform pile.

Fig -1: Helical and Waveform pile

4. METHODOLOGY

Tests were carried out in 2 sections. In first section preliminary tests were conducted to study the basic properties of sand. The study includes determination of index properties of sand. Index properties are the properties which are used for the identification purposes. The various index properties of the sand include Specific gravity, Relative density, Sieve analysis, Direct shear test and permeability test. All the index properties of sand were estimated in accordance with the Indian Standard (IS) procedure. Second section comprised of conducting plate load tests on footing placed on the micropiles. Micropiles include conventional pile, waveform pile with 3, 5 waves and helical pile with single, double helix.

Large scale model tests are designed to represent the actual three-dimensional field conditions. As per IS: 1882-1962, for conducting plate load test in the field the width of the test pit should not be less than five times the width of the plate so that the failure zones are freely developed without any interference from sides. The dimensions of the test tank for large scale model testing are fixed based on these criteria. In order to avoid the boundary effects, the sides of the tank are taken as five times the width of largest model footing. Under static plate load tests loads and vertical settlements were studied and it is obtained by using proving ring and dial gauges respectively.

4.1 Filling of Test Tank

The test tank was marked to equal layers. The quantity of sand was calculated for each layer corresponding to the required relative density. Then filled this predetermined quantity of sand in each layer with compaction using rammer. The sand was filled in layers up to the level where the tip of the piles was rest. Then pile was kept in correct embedment depth and position. Then filling of sand was continued till it reaches 2cm below pile cap bottom. The gap is provided for avoiding frictional resistance of bottom face of footing during loading. Then the top surface of sand bed was levelled.

4.2 Setting Load Measurement

After preparing the test tank, the hydraulic jack was clamped to the reaction frame and its hose was connected to the lever system. The load was applied to the footing by using rigid reaction frame through the hydraulic jack and proving ring. A calibrated proving ring of 100 kN and dial gauge of 25 mm capacity with sensitivity of 0.01 mm are used for measuring loads and pile displacement respectively. Fig. 2 shows the experimental set up before testing.

The proving ring and dial gauge are set to zero before the testing was started. The test was started by applying load using hand operated hydraulic jack. The pile was loaded at a constant loading rate until an ultimate bearing state was reached. The behavior of pile was obtained by plotting the graph between vertical displacement and axial load. Final load at which the group pile stops taking further load is taken as the ultimate axial load capacity of the footing.

Fig -2: Loading setup

5. RESULTS

In this study, the axial compressive loading of piles was considered. The loads applied at the footing and the corresponding displacements were recorded during tests. Ultimate bearing capacity of piles were estimated using load displacement curves obtained from the plate load test.

Chart. 1 shows the applied axial load versus settlement curves obtained for the waveform piles having 3 and 5 number of waves.

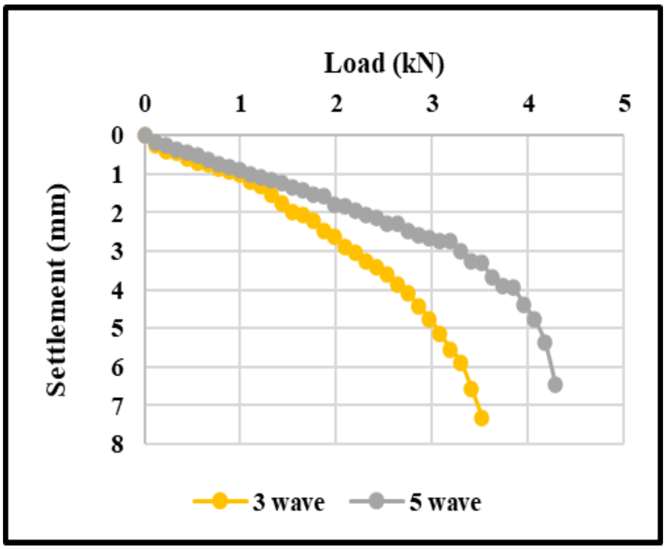

Chart -1: Load Settlement curve for waveform piles

In the case of waveform pile with 3 waves, the settlement was 7.32mm for an applied axial load of 3.52kN. For waveform pile with 5 waves settlement was equal to 6.46mm for an applied axial load of 4.29kN.

Chart. 2 shows the load settlement curves for helical piles with single and double helices.

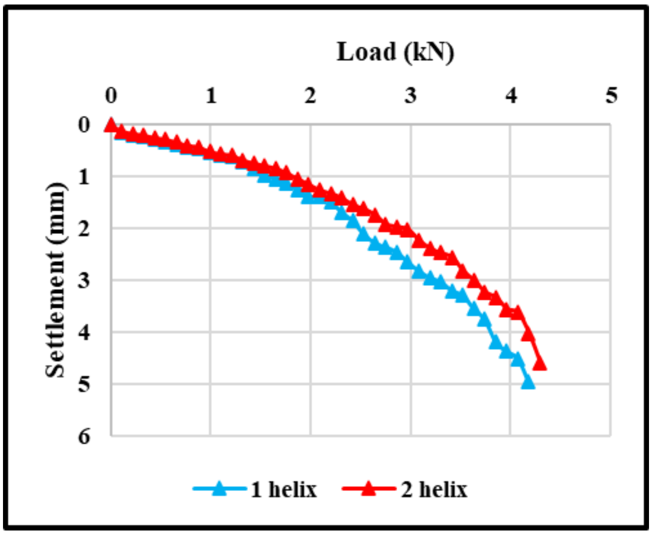

Chart -2: Load Settlement curve for helical piles

For the single helix the settlement was 4.95mm at an applied axial load of 4.18kN. And in the case of double helices the settlement was 4.58mm for an applied load of 4.29kN.

From the above results it was clear that in the case of waveform pile, pile with 5 waves shows better performance than 3 waves and in the case of helical pile, pile with double helices shows better results than the single helix. So, the chart. 3 shows the comparison of load settlement curve of these 2 piles (waveform pile with 5 waves and helical pile with double helix) with the conventional pile.

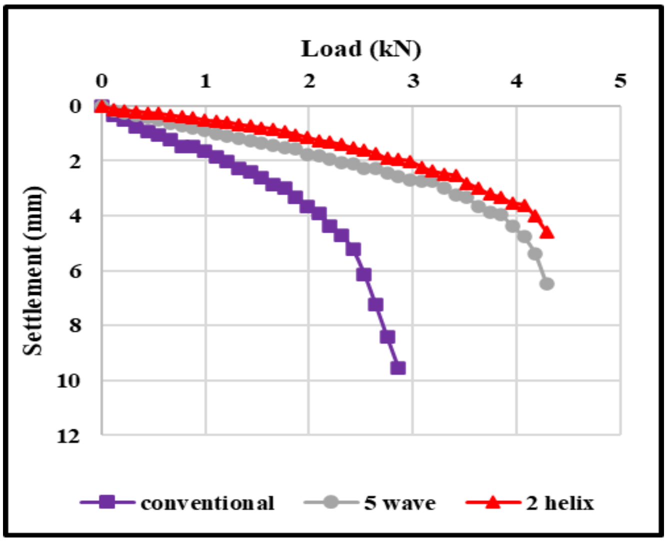

Chart -3: Load Settlement curves for micropiles

Finally, it was found that the bearing capacity of both piles were equal but the helical pile with double helices shows slight reduction in settlement than the waveform piles with 5 waves.

6. CONCLUSIONS

In this study, in order to understand the behaviour of micropiles embedded in sand several plate load tests were performed. Based on the results of model tests, the following conclusions are drawn:

- The addition of micropiles beneath the central area of the footing increases the load bearing capacity of the group piles.
- Wave form Pile with 5 wave results 16% increase in bearing capacity and 12% reduction in settlement while comparing with 3 waves.
- Helical pile with double helices shows a slight increase in bearing capacity and 7% reduction in settlement when compared with single helix.
- Even though there was 29% of reduction in settlement for helical pile with double helices, the bearing capacity of 2 piles (waveform pile with 5 waves and helical pile with double helices) were equal
- So, both piles are effective in underpinning because of their high load carrying capacity.

REFERENCES

[1] Binu Sharma, and Zakir Hussain, “Behaviour of Batter Micropiles Subjected to Vertical and Lateral Loading Conditions”, Journal of Geoscience and Environment Protection, 2019.

[2] Bushra S. Albusoda, and Hassan O. Abbase, “Performance assessment of single and group of helical piles embedded in expansive soil”, International journal of Geo Engineering, 2017.

[3] Chengcan Wang, Jin-Tae Han, and Young-Eun Jang, “Underpinning of an Existing Foundation”, MDPI, 2019.

[4] Fatnanta F., Satibi S., and Muhardi, “Bearing capacity of helical pile foundation in peat soil from different, diameter and spacing of helical plates”, Materials Science and Engineering Journal, 2018

[5] Jang Y. E., Kim B., Wang C., and Han J. T., “Prediction of vertical bearing capacity of waveform micropile”, ICE, 2019.

[6] Kyle Kershaw, and Ronaldo Luna, “Scale model investigation of the effect of vertical load on the lateral response of micropiles in sand”, Taylour & francis, 2018.

[7] Makarchian M., (2001). “An experimental study of foundation underpinning by piles.” IJE.

[8] Mohammad Hamza1 and Dr. Ali Jawaid S. W., “Helical Pile Subjected to Vertical Loading: Theoretical Study”, IJSRD, 2017.

[9] Pengcheng Jiang, Xu Wang and Yanjie Zhang, “Analysis of the bearing behavior of a screw-pile foundation in silt soil”, ICE, 2018.

[10] Shyma Jose, Vishnu M Prakash and Hanna Paul, “A Model Study on Lateral Behaviour of Micropile Under Inclined Compressive Loads in Sand”, IRJET, 2018

[11] Soumya Sadhukhan and Nirmali Borthakur, “Behavior of Single Micropiles And Micropile Groups Subjected to Uplift Loading”, IGC, 2015.

[12] Walid El Kamash and Jie Han, “Numerical Analysis of Existing Foundations Underpinned by Micropiles”, ASCE, ISSN 1532-3641, 2016.

[13] Young-Eun Janga and Jin-Tae Han, “Field study on the axial bearing capacity and load transfer characteristic of waveform micropile”, Canadian geotechnical journal, 2017.

[14] Zeyad H. Elsherbiny and M. Hesham El Naggar, “Axial Compressive Capacity of Helical Piles from Field Tests and Numerical Study”, Canadian geotechnical engineering, 2013.

[15] Zhengyang Guo and Lijun Deng, “Field behaviour of screw micropiles subjected to axial loading in cohesive soils”, Canadian Geotechnical Engineering, 2018.