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Experimental Modelling of Helical Piles under Axial Loading

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Abstract- **Due to the rapid increase in population, the demand for high-rise buildings is also increasing daily. Researchers have performed various numerical and experimental studies to find out the best foundation type for structure. A helical foundation is one of the most suitable foundation types to be incorporated in the construction of high-rise buildings. In a helical pile, some fraction of axial load is taken by the helix, which increases the load-carrying capacity of the foundation. This study is carried out to determine the settlement and load carrying capacity of the helical pile and helical pile raft cohesion-less soil. For this study, a small-scale model of a helical pile and helical pile raft foundation is prepared and fitted in the rectangular shear box filled with cohesion-less soil (sand). Testing on single helix piles, double helix piles, two helical pile rafts, and four helical pile rafts has been conducted. Instrumentation of the model is carried out using a settlement transducer and load cell to note down the settlement and load applied, respectively. Results provided that the maximum axial load carrying capacity of a single helix pile is almost 1200N at a settlement of 25mm while that is 1750N, corresponding to a 25mm settlement for a double helix pile. Similarly, the maximum load carrying capacity for two helical pile rafts and four helical pile raft are 2700N and 4400N, respectively, at 25mm. These results were compared, and a double helix pile has a greater load-carrying capacity than a single helix pile. Similarly, a pile raft with four helical piles has a greater load-carrying capacity than a pile raft consisting of two helical piles.**

Index Terms-- **Foundation, Helical Piles, Settlement, Number of Helix, Conventional piles**

I. INTRODUCTION

In the design of a foundation, the shallow foundation remains the first choice when the topsoil soil has more bearing strength to support the structure without any settlement failure. But since the last decade, the demand for high-rise buildings is rapidly growing. Subsequently, there is a need for a foundation with sufficient load-bearing capacity and without producing any differential settlement to prevent the structure from excessive damage. Two techniques can be applied to overcome the foundation settlement issue, the ground soil improvement technique and, most importantly, providing a screw pile that transfers structure load to the hard stratum. A helical pile (also known as a screw pile or anchors pile) is designed with a helical plate and frictionless shaft that increases the load-bearing capacity and makes the helical pile the priority to be incorporated in the structure to achieve maximum foundation bearing capacity [1].

In recent decades, helical pile applications in engineering projects have expanded to support and rehabilitate structures under tensile, compressive, and lateral loading [2]. The helical pile is considered one of the most successful advancements in geotechnical engineering [3]. Screw piles are made from high-strength steel comprised of helices and pointed ends, providing excellent installation of helical piles in the ground [4].

Because of its excellent design, the helical pile offers resistance to lateral, compressive, and tensile forces [5]. A helical pile can offer 4-9 times better resistance than a traditional pile with the same shaft and soil condition [6]. The objective of the present study is to experimentally investigate the settlement and load-carrying capacity of the helical pile and helical pile raft in cohesion-less soil. Also, the helical piles modeling is carried out through PLAXIS 3D.

II. METHODOLOGY

A. MATERIALS

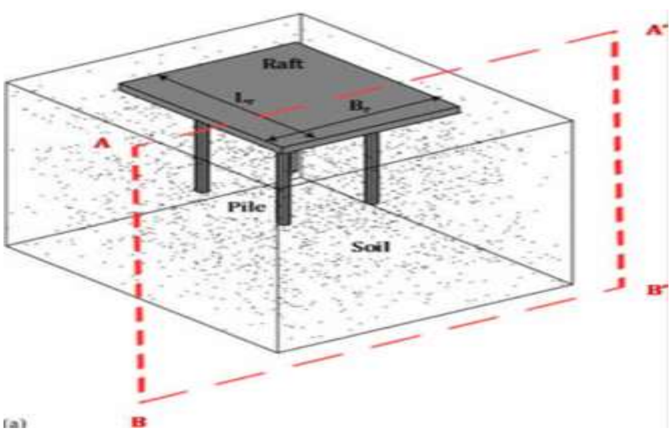
The materials which have been used in this study are (1) Copper rod as a helical pile (length=2ft, diameter=0.75in), (2) Aluminum plate as a raft (1'x1'x0.0196'), (3) Soil box (3.5'x3'x3'), sandy soil and Weights.

B. MODEL PREPARATION

To prepare the model, the helical pile and raft need to be connected, which should be rigid. To ensure this, the first holes of almost 12mm inches in diameter and 6mm in depth are bored in the raft at 1.5 distance from each of the four corners. At the same time, the pile head is also prepared and reduced to less than 12mm. Then a hole was bolted in the pile head having a diameter equal to 6mm up to a depth of 14mm and was threaded with the threading machine. Now bolts of appropriate length were brought and tightened to connect piles with the raft to ensure a rigid pile-raft connection.

C. PILE RAFT FOUNDATION MODEL

The helical pile raft foundation concept is relatively newer and utilizes both helical piles and rafts in resisting the applied load. Here the term pile cap is replaced by raft. Researchers have shown that the minimum contribution of the raft in resisting applied load is 30%. In this system, contact between raft and soil is mandatory. The pile raft foundation 3d view is shown in Fig. 1, and their cross-section view is shown in Fig. 2. The test was conducted on a helical pile raft foundation, as mentioned above in the testing methodology section. The vertical load was applied to the model at an increasing rate, and the corresponding load vs. settlement data was recorded through a data logger.



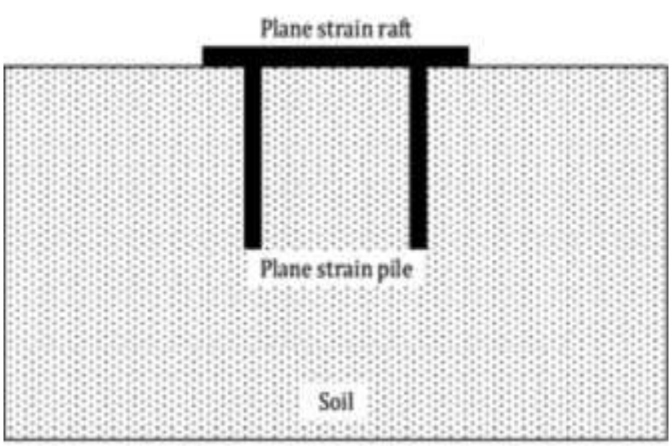


FIGURE 2. cross-sectional view

D.EXPERIMENTAL PROGRAM

A linear vertical displacement transducer is a device that can measure vertical displacement. The linear displacement sensor produces output in signal, which measures the distance covered in millimeter units. It is for a spring-type displacement transducer used in this study. At the same time, there are various electromechanical transducers whose output is an electrical signal like voltage, current or change in resistance that is then converted to the corresponding displacement. Figure 3 shows the linear vertical displacement transducer (LVDT) used in this study during laboratory tests. Two LVDTS are instrumented models of pile raft foundations, each having the capacity of measuring vertical displacement equal to 50mm. These two are attached to the raft of the foundation model at its opposite ends.

The load cell is a device used to measure applied load it converts force into measurable electrical output. The load cell is essentially a strain gauge, and we can easily measure the applied force and load cell through strains. A wheat stone bridge is formed by combining several strain gauges, and an initial voltage has to be provided so that when the load is applied, a voltage difference appears. Hence, through the datasheet, the applied load is calculated. The strain gauge is also used to detect this strain as an electrical signal. A data logger is applied to record data over time. The data logger used in the present study consists of 30 channels that record strain and load. The load cell and strain gauge used in lab are shown in Fig. 4 and 5, respectively.

FIGURE 3 Vertical Transducer

FIGURE 4. Load cell

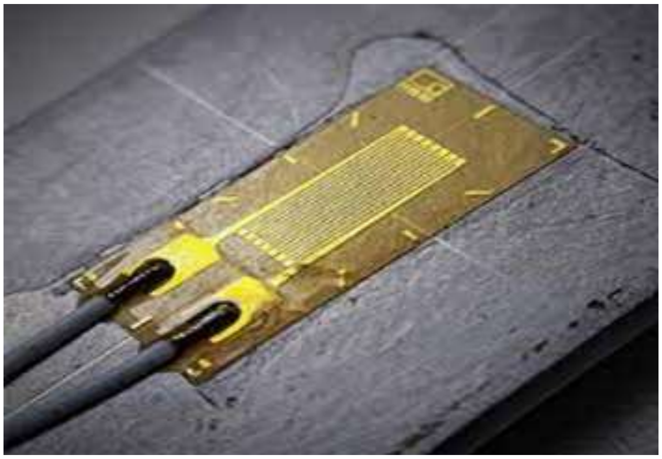


FIGURE 5. Strain Gauge

E. TESTING PROCEDURE

All the tests were carried out in a rectangular steel box as shown in Fig. 6. The box dimensions are 1.524m in height,0.1914m in width, and 1.22m in length. The soil box is filled with sand up to the middle of the box in such a way that it has recommended value of density

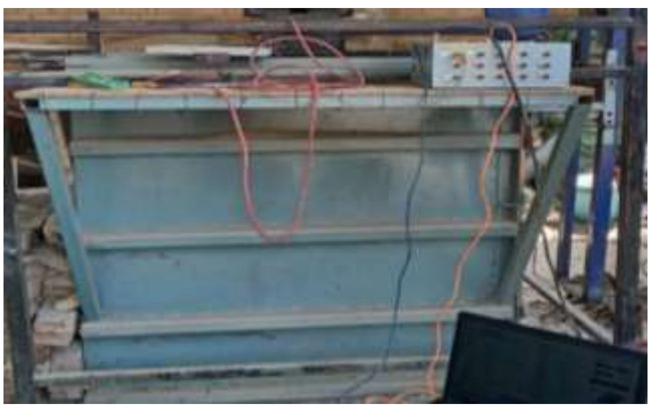


Figure 6. Model container

A copper rod is modeled as a helical pile in research work. The pile length is 2 feet, and the diameter is 0.75inches. The two helices are attached to the piles, as shown in Fig. 7. The position of piles is marked on the soil in the box, so piles remain exactly in the middle of the box. Piles are driven into the soil so that the soil's density is not disturbed. Strain gauges that were attached to the piles are kept in such a way that it may not contribute to the overall bearing capacity of the soil. Now the raft is placed over the pile and in vertical load as shown in Fig. 8 the hydraulic load is applied. Now the strain gauges are attached to the data logger, which is attached to the laptop and the specific data logger file is opened through MATLAB. Which will acquire real data from the applied loads. Now, on that hydraulic load cell, axial loads are applied in incremental values over it. The above process is repeated for the double helical pile's raft foundation and 4 helical pile raft foundations. At the same time, the settlements and load values are noted from the data logger through MATLAB.

FIGURE 7. Helical Pile

FIGURE 8. Actual Experimental model being loaded

III. RESULTS AND DISCUSSIONS

A. DATA ANALYSIS FOR SINGLE AND DOUBLE HELIX PILE

Tables I and II show the settlement and load data for the single helix pile and double helix pile, respectively. Figure 9 shows that the single helix pile model's maximum axial load carrying capacity is almost 1200N at a settlement of 25mm. Similarly, Figure 10 shows that a double helix's maximum axial load capacity is 1750N, corresponding to 25mm settlement.

TABLE I. Actual Data for single helix Pile

Settlement (mm)	Load (N)
0.01	432.2531
2.15	655.14
7.66	1114.36
12.77	1550.399
16.16	1716.92
18.84	1732.38

TABLE 2. Actual data sample for double helix pile

Settlement (mm)	Load (N)
0.01	440.8369
0.325	440.8369
4.2975	698.9625
11.98	931.3369
16.6	1115.888
23.6175	1221.345

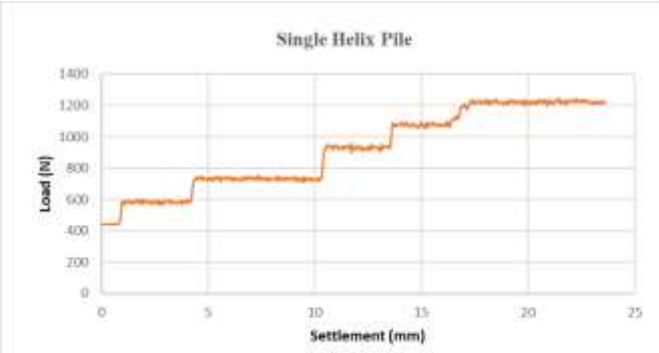


FIGURE 9. Load vs Settlement graph for single helix pile

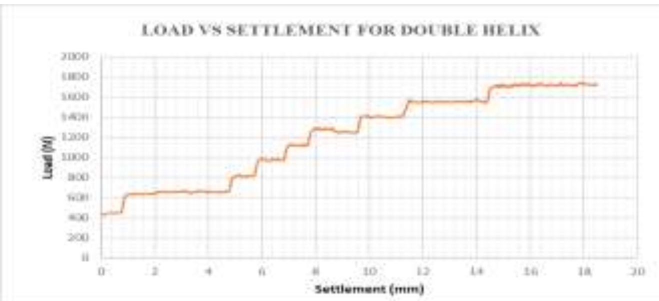


Figure 10. Load vs Settlement curve for double helix pile

B.DATA ANANALYSISOR TWO AND FOUR HELICAL PILES

The experimental data of the pile raft model consisting of two and four helical piles are analyzed in the same manner as was done for single and double helix piles. A graph is drawn between applied load and corresponding settlement shown in Fig. 11 and 12. the maximum load taken by a raft consisting of two helical piles is almost 2700N, corresponding to 25mm. And for raft consisting of four helical piles is 4400N corresponding to 25mm (Table III & IV).

TABLE III.ACTUAL DATA FOR PILE RAFT OF TWO HELICAL PILES

Settlement (mm)	Load (N)
0.01	720
4.24	1330.236
8.9	1864.979
13.34	2753.765
18.54	3212.481
23.78	3705.629

TABLE IV. ACTUAL DATA FOR PILE RAFT OF FOUR HELICAL PILES

Settlement (mm)	Load (N)
0.01	434.7056
2.68	615.5775
6.06	848.565
13.82	1484.989
18.24	1716.137
24.42	2786.653

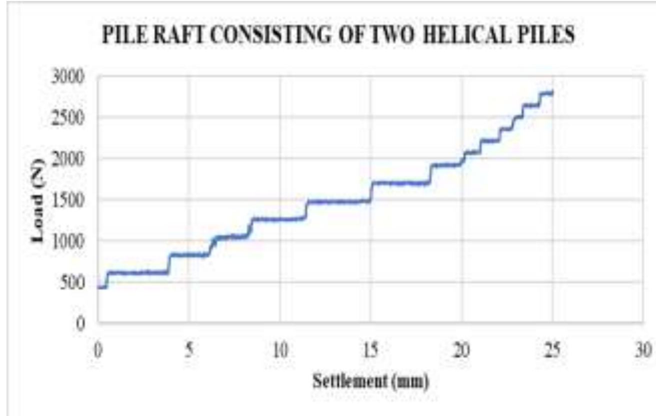


FIGURE 11. Load vs settlement graph for Pile Raft consisting of two helical piles

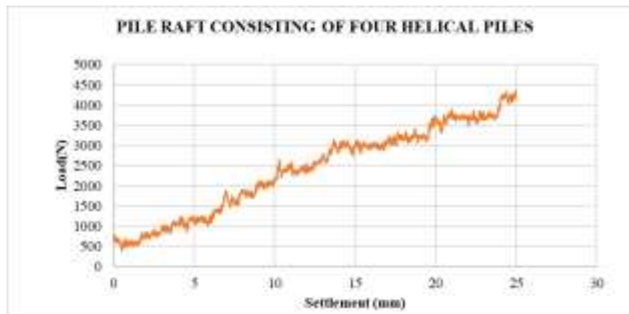


FIGURE 12. Load vs settlement graph for Pile Raft consisting of four helical piles

IV. CONCLUSIONS

When a single helix was added to the conventional pile, the settlement was reduced to 26%, and in a double helix, it was reduced to 30%, so the net conclusion is that the average settlement is reduced to 27%. When two helical piles were used, the settlement was reduced to 33%, and in four helical piles, it was reduced to 36%, so the average net conclusion is that settlement is reduced to 34%. Helical pile axial capacity is much greater than normal traditional piles. The axial capacity of a double helix pile is more than a single helix pile. Four helical pile rafts have more axial bearing capacity than double helical piles. A helical pile raft is more economical to use than traditional piles as the number of piles gets reduced due to the higher value of axial capacity. Helical piles are mostly made of steel or aluminum and hence can be recycled and reused, which is a sustainable approach.

FUNDING STATEMENT

The author(s) received no specific funding for this study.

CONFLICTS OF INTEREST

The authors declare they have no conflicts of interest to report regarding the present study

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