Helical Pile Subjected to Vertical Loading: Theoretical Study

Mohammad Hamza[1] Dr. S.M Ali Jawaid[2]
[1]Assistant Professor [2]Professor
[1,2]Department of Civil Engineering
[1]Government Engg. College, Kannauj, Uttar Pradesh India
[2]M.M.M.U.T, Gorakhpur, Uttar Pradesh, India

Abstract— The use of pile foundation is increasing day-by-day due to non-availability of suitable land for construction. Heavy multi-storyed buildings are being constructed, and load from these structures cannot be directly transferred to ground due to low bearing capacity and stability issues of the buildings. So, demand for use of pile foundations are increasing day by day. Due to this demand of pile foundations, there have been many improvements in pile foundation technology. Helical pile is a newly developed structural foundation member used to transfer the vertical loads coming on the structure. This paper present a detailed investigation of helical pile subjected to vertical loading. Two piles made up of steel and concrete, are being tested using a field setup. The helical pile used, were having three helix plates and the concrete pile was casted in the same trench made by steel pile, and tested after 28 days. The results of the field load test were compared with theoretical solutions using conventional theories.

Key words: Pile Foundation, Helical Steel Pile, Helical Concrete Pile, Helix Plates, Vertical Loading, Bearing Capacity of Soil

I. INTRODUCTION

Pile foundations are widely used in construction. They are used in cases when the top layers of soil are weak and stronger soils are relatively deep. Reinforced concrete piles are most often used. Since in many occasions weak soils are to be found and frequently an uneven settlement of building foundations occurs, which causes the deformations of the buildings, cracks in the structure in such cases helical piles are better alternatives.

Helical piles are nothing but manufactured steel deep foundation element consisting of a central steel shaft with one or more helical bearing plates welded to this shaft. The helix plates round the shaft to formed into a ramped spiral. When rotated into the soil, the helix shapes provides thrust along its longitudinal axis thus it prove to be helpful in pile installation. After the installation, the plates transfers axial load into the soil through bearing. The number of helix plates is limited only by the capacity of shaft to transmit the load to the soil. Helical piles have several advantages in comparison of other piles: they can be screwed easily to the ground which is important in places where heavy technology operation is needed such as in the basements under the bridges etc. the installation of helical pile foundation causes practically no vibration. There is no problem during installation near the, existing foundation. These features make the helical pile foundations attractive on sites that are environmentally sensitive.

During loading the load applied to the pile sis transferred to the surrounding soil. Thus ultimate capacity of pile is dependent upon the strength of the soil. Solis derive their strength and ultimate load carrying capacity from several characteristics like the internal friction angle φ, the adhesion factor α, the unit weight γ and the un-drained shear strength of the soil.

II. TEST PILE CONFIGURATIONS

Pile Type	Diameter of Shaft	Diameter of Helix	Nos. of Helixes	Length	Material
Helical Pile	76.20 mm	203.2 mm	3	76.2 cm	Mild Steel
Helical Pile	76.20 mm	-	-	76.2 cm	Concrete

Table 1: Description of Test Piles

III. TESTING FACILITIES AND PREPARATION

The load testing program was conducted at location of Madan Mohan Malaviya University of Technology, Gorakhpur. The soil at site composed of layers of clayey and sandy silts followed by sand. Laboratory tests were carried out on the selected soil samples indicated that the dry unit weight was 17.36kN/m³. A summary of typical soil properties is presented in Table 2. Results of tri-axial compression test on undisturbed soil sample indicate a frictional angle of 18°.

The steel pile was placed at site in such a way that to ensure centric alignment. The pile was slightly embedded in soil such that total embedded depth of pile would be completely inside the soil. The surface of the soil was leveled and rigid plate is placed over the pile head and then hydraulic jack is put on the rigid plate. The reaction frame was then put on the jack. The reaction beams were positioned in such a way that it maintains equal spacing between pile head and anchored to the ground with the help of anchoring screws.

The arrangements for applying loads to the test pile involved the use of a 200kN capacity hydraulic jack and the same capacity load cell. The Reaction of the jack is borne by the reaction frame which is anchored to the ground with the help of reaction beams. Load applied in equal increments using hydraulic pump. Each load increment is kept for sufficient time till the rate of settlement becomes lower. The corresponding settlements are recorded with the help of digital indicators. Fig. 1 shows the layout of the site.

After the testing of steel piles, the pile extracted from the ground and the concrete piles was casted in the same trench made by the steel pile and has been tested for their axial load carrying capacity. Plain cement concrete of grade M25 (1:1:2) was used for the construction of concrete pile.

The soil at site consists of silty sand (ML or SM) followed by sand (SP) and having following properties:

S. No.	Property	Value
1.	Cohesion, C_u	10.76 KN/m²

2.	Unit weight, γ	17.36 KN/m³
3.	Internal friction, φ	18°

Table 2: Soil Parameters

Fig. 1: Test setup of pile loading

IV. METHODOLOGY

The Capacity of piles are dependent on the strength of soil, the projected area of helix plates, depth of helix plates of piles. There are several calculation methods of helical piles load bearing capacity: the Latvian building code LBN 214-03 "Geotechnical pile foundation and footings" A.B.CHANCE company calculation method and the 'Canadian building engineer large capacity screw piles calculation methods' (Mitsch and Clemence 1985; Narasimha et al.1991). If we look at all three helical piles calculation methods conclusions are very difficult and hard to compare. The Latvian building code LBN 2014-03 applies to screw piles with one capacitive plate; however the "A.B.CHANCE" calculation method and the large capacity screw piles calculation method developed by Canadian building engineers are used for calculation of screw piles with one or several capacitive plates. Here we are discussing about Canadian building engineer's method and "A.B.CHANCE" calculation methods.

A. The ultimate compression capacity of helical screw pile according to Canadian building engineer calculation method:

Methods for estimating pile ultimate capacities were proposed by Narasimha Rao (Narasimha et al.1991) for the design of screw piles in cohesive soils and (Mitsch and Clemence 1985) for the design of screw piles in non-cohesive soils. The total failure resistance can be summarized as follows:

$$Q_c = Q_{helix} + Q_{bearing} + Q_{shaft} \dots (i)$$

Where:
Qc = Ultimate pile compression capacity
Q helix = Shearing resistance mobilized along the cylindrical failure surface
Q bearing = Bearing capacity of pile in compression
Q shaft = Resistance develop along steel shaft

For a cohesive soil the ultimate compression capacity of the helical pile using a cylindrical shearing method as proposed by the Mooney and Narasimha (Narasimha et al.1991) is:

$$Q_{helix} = S_f.(\pi.D.L_c).C_u \dots (ii)$$

$$Q_{bearing} = A_h.C_u.N_c \dots \quad (iii)$$

$$Q_{shaft} = \pi.d.H_{eff}.\alpha.C_u \dots (iv)$$

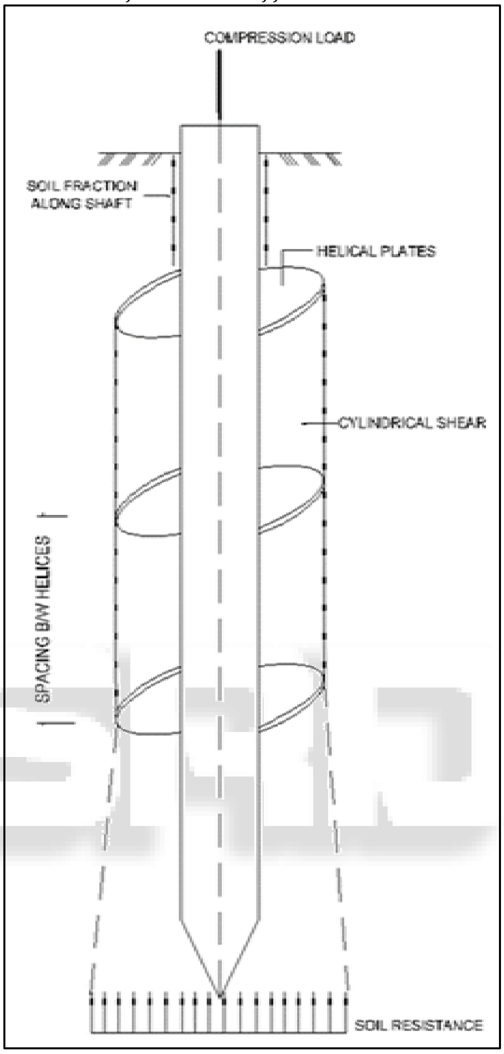

Fig. 2: schematic of a typical helical pile foundation section

Where: Qc = Ultimate pile compression capacity, D = Diameter of Helix, Lc = distance between top and bottom helical plates, Cu = Un-drained shear strength of soil, Ah = Area of bottom helix, Nc & Nq = Dimensionless bearing capacity factors, d = Diameter of shaft, Heff = Effective length of pile, α = Adhesion factor, Sf = spacing ratio factor, γ = Unit weight of soil, Ks = Coefficient of lateral earth pressure, φ = Soil angle of internal friction

B. The Ultimate Compression Capacity of Helical Screw Pile According To "A.B.CHANCE" (USA) Method:

The ultimate theoretical capacity of a multi helix foundation equals the sum of all individual helix capacities. To determine the theoretical bearing capacity of each individual helix the following equations should be used:

$$Q_t = \sum Q_h \dots \dots (v)$$

Where:
Qt = Total ultimate multi helix pile capacity
Qh = Individual helix capacity

The ultimate capacity of an individual helix is evaluated by using the following equation. An upper limit for this capacity is based on the helix mechanical strength.

$$Q_h = A_h[c.N_c + \gamma.D_f.N_q] \le Q_s \dots\dots (vi)$$

Where:
Qh = individual helix bearing capacity
Ah = Projected helix area
C = Soil cohesion
γ = Unit weight of the soil
Df = Depth of foundation
Qs = Capacity upper limit, determine by helix mechanical strength

For a cohesive soil the determination of helix ultimate bearing capacity is accomplished by using the following equation:

$$Q_h = A_h c N_c = A_h c 9 \dots\dots (vii)$$

Where:
Ah = projected helix area
C = Soil cohesion
Nc = Bearing capacity factor for cohesive component of soil = 9

The Nc bearing capacity factor when applied to helical piles is often taken as equal to 9

V. Results

A. *Theoretical Results:*

Base on the above theories the ultimate capacities of the piles are determines as follows:

Pile type	Method	Capacity
Helical pile (Steel)	A.B.Chane (USA) method	8.10 KN
Helical pile (Steel)	Canadian method	6.36 KN
Helical Pile (Concrete)	A.B.Chane (USA) method	8.10 KN
Helical Pile (Concrete)	Canadian method	6.36 KN

Table 3: Theoretical capacities of different piles

B. *Experimental Results:*

The field results are in the form of loads and the corresponding settlements. According to IS: 2911 (part-4) the safe load on single pile for the initial test is equal to two-third of the final load at which the total settlement attains a value of 12 mm. So, for both piles the load-settlement graphs are plotted in order to get the safe load for the piles. The load settlement graphs are shown below:

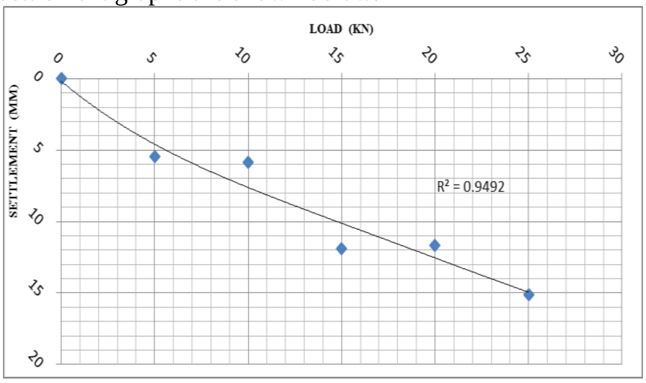

Fig. 3: Steel Pile

C. *Concrete Pile:*

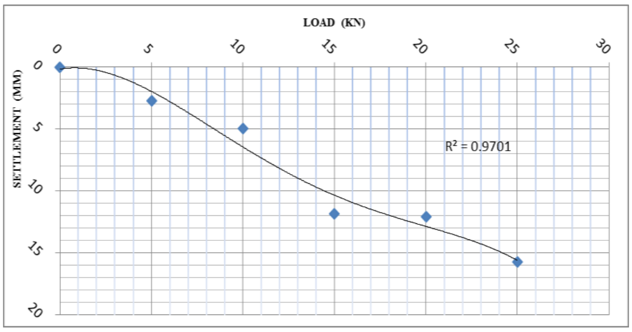

Fig. 4: Concrete Pile

Note: The R-Square value of the load-settlement curves indicates the degree of best fitted curve.

VI. Comparison

As we see load-settlement curves, the load corresponding to 12mm settlements are recorded as 15kN for both piles, as per IS: 2911(part 4) the safe load on single pile for the initial test should be two-third of the final load at which the total settlement attains a value of 12 mm. so, if we apply this factor of safety to these piles we get the values as 10kN.

Pile type	Theoretical Capacity	Experimental Capacity	Safe Load
Steel pile	6.36 kN /8.10kN	15kN	10kN
Concrete pile	6.36 kN /8.10kN	15kN	10kN

Table 4: Comparison between theoretical & experimental results

$$\text{Percentage Error} = \left[\frac{10 - 8.10}{8.10} \times 100\right]$$
$$= 23.45\%$$

VII. Conclusion and Discussion

The results of the study are shown in tables. One of the main important factors affecting the axial behavior of pile is its settlement. To sum up all the results, we can see that the plates has an essential influence on the load carrying capacity of helical piles also it can be concluded that if the embedded depth and the effective area of the helix plates is enlarged, the capacity enlarges in a direct proportion. By comparing steel pile with concrete one it can be concluded that there is a rapid settlements occurs in steel as compared with concrete pile. For the same load of 5kN the settlement in the steel is 5.47mm while in concrete pile it is only 2.71mm. The safe load for the above piles are much higher than the theoretical capacities thus the results comes from the theoretical solutions are also satisfied with the experimental solutions and shows the percentage error of 23.45%.

References

[1] Andina S, and Leonids P, Helical pile behavior and load transfer mechanism in different soils. 10th International Conference on Modern Building Materials, Structures and Techniques, 2010, Riga LV-1048 (pp. 1174-1180)
[2] Ben Livneh and M. Hesham EI Naggar 2008, Axial testing and numerical modeling of square shaft helical piles under compressive and tensile loading. NRC Research Press, (pp. 1142-1155)

[3] CHANCER Civil Construction Helical Anchor/pile bearing capacity C-2006, Hubbell power systems, Inc.
[4] IS: 2911 (part 4)-1985; Indian Standard Code of Practice for Design and Construction of Pile Foundations UDC 624.154.1:624.042:006.76
[5] Meyerhof, G.G., and adams, J.I, 1998.The Ultimate uplift capacity of foundations. Canadian Geotechnical Journal, 5(4): (pp. 225-244)
[6] Meyerhof, G.G., 1976, Bearing Capacity and settlement of pile foundations, journal of the Geotechnical Engineering Division, Proceedings of the American Society of Civil Engineers, Volume 102, No. GT3, New York City, New York.
[7] Mitch, M.P; Clemence,S. P. 1985, The Uplift Capacity of Helix Anchors in sand. Uplift Bhavior of Anchor Foundation in soil ASCE. New York, 26-47.
[8] Narasimha Rao, S. Prasad, Y.V.S.N, Shetty M.D.1991. The behavior of model screw piles in cohesive soils, soils and foundations 31(2): 35-50
[9] Narasimha Rao, S. Prasad, Y.V.S.N, Shetty M.D, 1991, Estimation of uplift capacity of helical anchors in clays. Journal of Geotechnical Engineering, 199: 352-357.
[10] Narasimha Rao, S. Prasad, Y.V.S.N, Shetty M.D and joshi V.V, 1989, Uplift capacity of screw anchors. Journal Geotechnical Engineering, 20: 139-159.
[11] Narasimha Rao, S. Prasad, Y.V.S.N, Shetty M.D and Veeresh C. 1993, Behavior of embedded model screw anchors in soft clays. . Journal Geotechnical Engineering, 43: 605-614.
[12] Prakesh, S., and Sharma, H.D. 1990. Pile foundation in engineering practice. John Wiley and Sons, New York.
[13] Sharma, H.D., and Joshi, R.C. 1988, Drilled Pile behavior in granular deposits. Canadian Geotechnical Journal, 25: 222-232.
[14] Terzaghi, K. 1942, Discussion of the progress report of the committee on the bearing value of pile foundations. Proceedings of the American Society of Civil Engineers, 68 311-323.
[15] Zhang, D.J.W.1999, Predicting capacity of helical screw piles in Alberta soils. M.Sc., Thesis, university of Alberta, Edmonton, Alta.