The Inclined Uplift Bearing Capacities of Screw Piles in Sand

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***Abstract*—Screw piles differ from traditional piles in that they are most commonly made of high strength steel consisting of helices which are fixed to the shaft at specific spacing. They are installed in ground by screwing and have a pointy toe to allow for better installation into the ground. Screwed piles have the advantage that their vertical bearing capacity increases because of the resistance of the wing portion. In this study, the inclined uplift load capacity of screw anchor piles is examined through an experimental investigation carried on model piles embedded in sand using a model tank. The angle of inclination of load on screw pile was varied to study the behaviour of screw anchor piles under inclined loads. The experimental program was conducted on piles loaded at 15, 30, and 45° with respect to the vertical and installed into medium dense sands. The ultimate uplift load capacity increases with increase in inclination angle and the settlement decreases with increase in the inclination angle.**

Keywords—Screw pile; Pulling resistance; Model test; Inclined uplift capacity

I. INTRODUCTION

A screwed pile is a steel pipe pile with a wing plate around its tip. Such piles can be installed in the ground with low noise, little vibration and without excavating the soil. Furthermore, screwed piles have the advantage that their vertical bearing capacity increases because of the resistance of the wing portion. Screwed piles are also effective for pull-out loads because of the extra resistance provided by the wing plate [4].

Screw piles differ from traditional piles in that they are most commonly made of high strength steel consisting of helices which are fixed to the shaft at specific spacing and have a pointy toe to allow for better installation in to the ground. There are various dimensions of screw piles specific to certain conditions under which shaft and helix diameters, helix spacing and embedment depths prove to be points of difference [1].

Screw piles were initially used mostly as anchors, and hence, were centred on tensile loads such as transmission tower sand buried pipelines .However, their use has been expanded to structures subjected to compressive and lateral loading. Screw piles offer structural resistance to tensile, compressive and lateral forces along with overturning moments. Helical foundation systems are ideal foundation alternative for weak soils, expansive soils, high ground-water projects, hillsides, creek sides, bay mud. Recently, screwed piles have been used in structures such as a high-rise building subjected to seismic and wind loads, a low-rise building at a site with a high ground water level, and a mega solar facility. In-situ pull-out loading tests have elucidated the pulling resistance of screwed piles. Such studies have shown that the pulling resistance depends on how the pile is embedded and the diameter of the wing.

The helical anchor systems have been widely used in our construction site for resisting the tension load. However, the increasing of using the helical screw anchor system was slow down by the reasons of the lack of techniques to estimate the uplift capacity of helical anchors accurately and consistently. The inaccurate and inconsistent estimating of uplift capacity of these anchors caused by the uncertainties in the failure mechanism and some geometry factors of these anchors. To solve this problem, a number of researches and theories have conducted to estimate the ultimate uplift capacity of anchor in various types of soil during the last twenty years. Therefore, a literature review has carried out to indicate the theories proposed by several researchers to design the helical anchor subjected to pullout forces.

In this study, inclined uplift loading tests on screwed piles is performed and focusing on how the angle of inclination effect the performance of screw pile. The various inclination angles used for the study of uplift capacity of the screw pile are 15˚, 30˚, 45˚. The load settlement behaviour of screw pile in cohesion-less dry sand is studied and finally the inclined pull out resistance of the screwed pile is to be evaluated.

II. EXPERIMENTAL WORK

A. Experimental Setup

A rectangular tank with 1000mmx 1000 mm and 700 mm height and is sufficiently thick and rigid enough to prevent any lateral deformation of the side walls was used to conduct the experimental investigation. The internal dimensions of the tank were taken so as to eliminate the boundary effect. According to Satyendra et al. (2010) the plan dimensions for the tank to avoid boundary effect which was considered to be minimal of three times the diameter of the helix. Height is fixed such that the sand bed extends to 100 mm under the model screw pile. Loading frame consisting of horizontal steel angle attached to a strong vertical fixed frame. Two pulleys is to be attached to the horizontal frame. Steel wire running over the pulleys is used to apply inclined tensile loads by placing the cast iron weights over the load hanger.

B. Model of Screw Pile

Mild steel pipes of 20 mm diameter with total length of 600 mm are used as model piles in this study. In order to form the helixes, two steel circular plates 3 mm thickness with 100 mm diameter, are welded to the hollow steel pipe at specified locations and directions Dimensions are fixed considering following factors L/d=30 ; 2.5<D/d<7.5; P=d. Fig. 1 shows the model pile [2].

Fig. 1: Model Screw Pile

C. Sand

The sand used in this paper is rated as well graded (SW) according to the Indian Standard Classification System. The specific gravity of the soil particles was determined by the jar method. Three tests were carried out, producing an average value of 2.68. The maximum and minimum dry unit weights of the sand were found to be 17.17 and 15.11 kN/m^3 respectively. The particle size distribution was determined using the dry sieving method according to ASTM D 422 - 63 (2007), and the results are shown in Fig. 2. The angle of internal friction angle of sand is obtained as 32˚ by performing direct shear test. Initial tests such as specific gravity, gradation, relative density, direct shear is done. The geotechnical properties of the sand are given in Table I.

TABLE I. GEOTECHNICAL PROPERTIES OF SAND

Description	***Value***
Specific Gravity	2.68
Grading Zone	1
Classification	Well graded sand (SW)
Coefficient of Uniformity	4
Coefficient of Curvature	1
Sand ()Relative Density	5.2
Angle of Internal Friction Angle	32˚

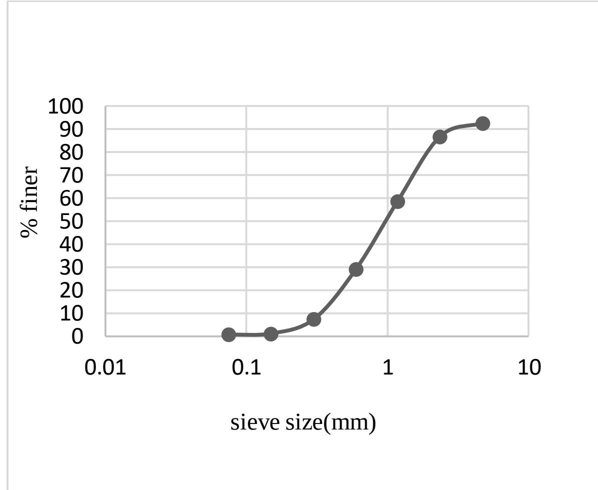

Fig. 2: Grain Size Distribution of Tested Sand

III. TEST PROGRAM

A. Preparation of the Sand Bed

The sides of the test tank was coated with polythene sheets to avoid side friction. Prior to the start of the actual test, a series of trials were conducted to determine the height of fall required to achieve relative density. A calibration chart was prepared by obtaining the maximum and minimum void ratios of sand. All the tests were conducted at a relative density of 50%. The height of fall required to achieve 50% relative density was directly obtained from the chart.

The total height of sand was chosen in such a way that the sand bed extends to 100 mm. The water tight mild steel tank of dimension 1000 mm × 1000 mm × 700 mm is to be filled with sand to the top by raining the sand from a this height. After attaining the desired height of the bed, the fill was levelled using a trowel without disturbing the density of the bed.

B. Experimental Setup

To study the behaviour of inclined loaded helical piles in sand, laboratory tests need to be conducted on a small scale model steel piles of diameter (d) equal to 20 mm. and of length, L, 600 mm. Loading frame consisting of horizontal steel angle attached to a strong vertical fixed frame. Two pulleys is to be attached to the horizontal frame. Steel wire running over the pulleys is used to apply inclined tensile loads by placing the cast iron weights over the load hanger as shown in Fig 3. The load was applied in small increments. Each load increment was maintained at a constant value until the pile deformation has been stabilized. It is worth mentioning that the pulleys should have smooth surface to prevent any friction. Sufficient number of dial gauges were provided to measure the movements of helical pile. The model piles were screwed to the required pre-determined level by applying a torque and adjusted to be in exact vertical position.

Fig 4. Schematic representation of the test setup

IV. Results and Discussions

The behavior of screw piles can better be assessed with the help of the results obtained from the load-displacement curves for screw anchor piles at different inclination angle.

A. Effect of Angle of Inclination of Load

The effect of angle of inclination of load with vertical to the uplift capacity can be understand by loading , screw pile having same L/D ratio and by varying the inclinations as 15°, 30° and 45°.

Fig 5 shows the load displacement curve for inclined pull out load test for an inclination angle 15°. Fig 6 shows the load displacement curve for inclined pull out load test for an inclination angle 30°. Fig 7 shows the load displacement curve for inclined pull out load test for an inclination angle 45°. Figure 8 shows the comparison between the three.

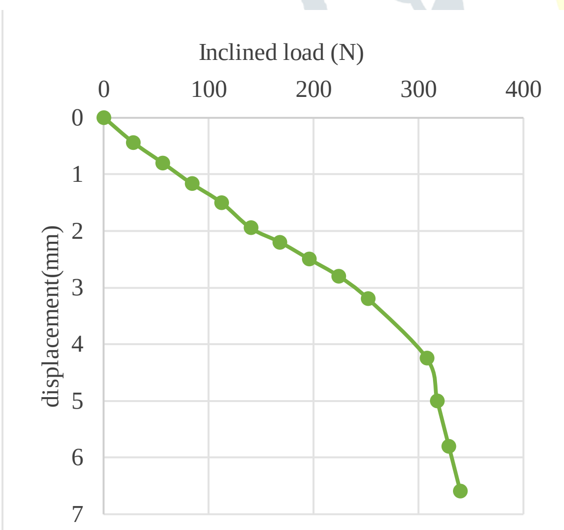

Fig 5. Load – Displacement Curve for 15˚load

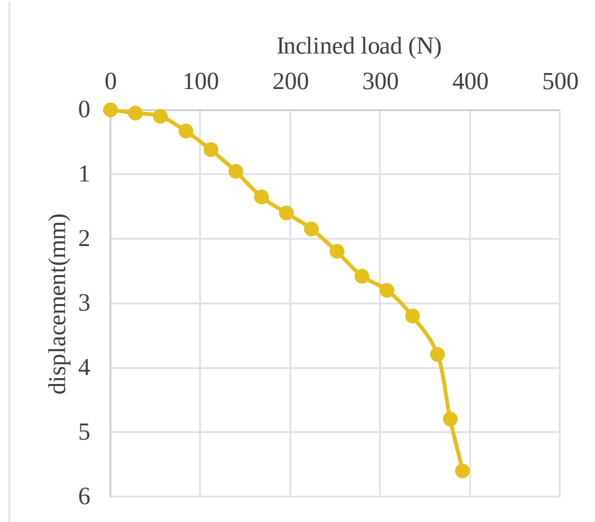

Fig 6. Load – Displacement Curve for 30˚load

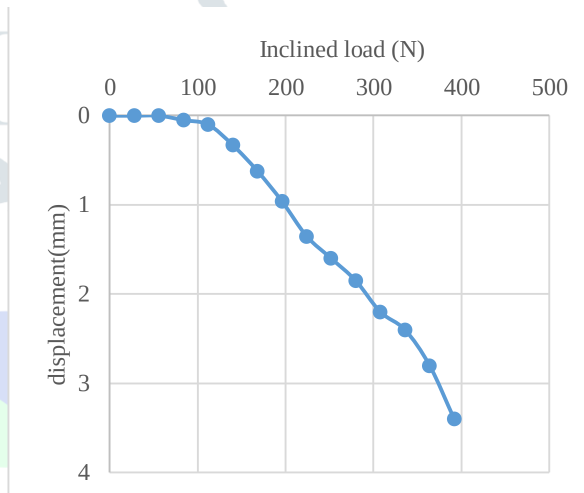

Fig 7. Load – Displacement Curve for 30˚load

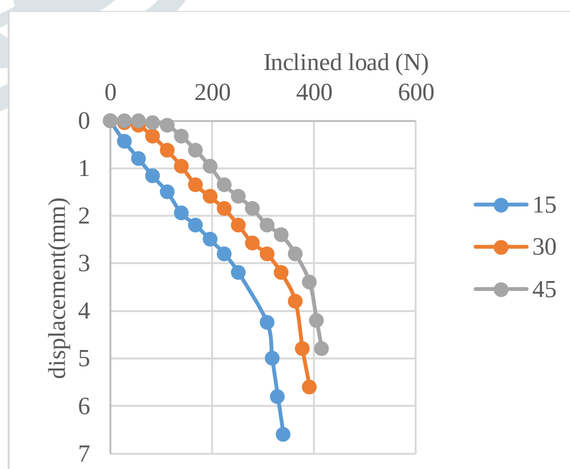

Fig 8. Variation of inclined load with displacement

From the results obtained it is clear that the uplift capacity of screw piles increases with an increase in the inclination angle and the settlement decreases with the increase in inclination angle. The ultimate load for 30˚ shows a 15% increase with respect to 15˚ and the ultimate load for

45˚ shows a 27% increase with respect to 15˚. The tabulated results are shown in Table II.

TABLE II. PULL OUT LOAD TEST RESULTS

Angle of Inclination	Ultimate Load (N)	Settlement (mm)
15°	308	6.5
30°	364	5.6
45°	392	4.2

V. CONCLUSION

The load settlement behaviour of screw pile in cohesion-less dry sand under inclined tensile load is non-linear. For inclined pull out load test the ultimate load increases with increase in inclination angle and the settlement decreases with the increase in inclination angle. The ultimate uplift load for an angle of inclination 30˚, shows a 15% increase with respect to the ultimate load for an angle of inclination 15˚. The ultimate uplift load for an angle of inclination 45˚, shows a 27% increase with respect to the ultimate load for an angle of inclination 15˚.

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