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Lateral Load Carrying Capacity of Helical Piles in Sand

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ABSTRACT

In the present study, an attempt is made to evaluate the lateral load carrying capacity of helical pile with varying embedment length and by varying relative density of sand. A series of model tests were conducted on pile with zero, one, two and three helices, with varying embedment depth of 700mm, 600mm and 450mm. The diameter of the shaft and helix is 30mm and 90mm respectively, the spacing of helices is one times the diameter of the helix i.e., 90mm. The pile is driven in both, loose state of sand (relative density = 35%) and medium dense sand (relative density = 50%).The ultimate lateral load increases as the embedment depth increases. The ultimate lateral load increases as L/d ratio (Where L=depth of embedment, d=diameter of shaft;) increases and also increases as the number of helices increases. The ultimate lateral load is more in the helical pile compare to plain vertical pile. The triple helical pile for all the embedment length offer more resistance and carry more load and higher resistance and least load is seen in the plain vertical pile. The ultimate load for all the embedment depth in medium dense sand was found to be more in all cases, than piles driven in loose sand. The increase in lateral load resistance with increase in embedment depth is attributed to increase in passive resistance. A Comparison was made between plain vertical pile and with varying number of helices in a helical pile with varying embedment depth. It was found that the lateral resistance increases even with increase of one helical and it is more as the number of helices increases. Also as the relative density of sand is increased, the lateral resistance was found to increase.

Keywords: Helical Pile, Sand, Lateral Load, Embedment depth, Relative density

1. INTRODUCTION

Modern engineering structures requires a foundation system that provides adequate support by transferring loads to the soil that are imposed on it or resisting vertical and horizontal pullout forces. Pile foundations in some situations are subjected to significant amount of lateral loads besides vertical loads. Lateral forces may be due to impact of ships during berthing and wave action in the case of off shore structures. A helical pile is simply a steel shaft with one or more helices welded to the steel shaft. Helical pile may be of square shaft or circular.

The primary functions of helices are: i) provide the pulling force on the pile by soil to bring the pile to the depth at which the required torque is achieved during the installation of the pile to get required bearing capacity, during & after installation and ii) To transfer the load into the soil by bearing pressure after installation. There are two basic components which contribute to friction: friction on the helix plate and friction on the shaft. The friction resistance on the helix plate increases with an increase in helix diameter. The surface area of the helix in contact with the soil increases with the square of the helix diameter. Mittal and Mukherjee (2013) conducted a series of tests to determine the uplift resistance of helical screw anchors. They found that ultimate pullout capacity of helical screw anchor increases with increase in the embedment depth of the anchor. Ultimate pull out capacity of helical screw anchor increases with increase in the number of helices. Hamdy et.al (2013), conducted the laboratory test by applying the compression and uplift loads at different height within the soil for various helix diameters 5, 6, 7, 8.2 and 10 cm with increasing embedment ratios i.e., D/d 1, 2, 3, 4, 5, 6 and 7 to study the behaviour of helical piles under compression and uplift loads which effect on the helical pile installed into prepared layers of sand until failure. They have noticed that i) as the embedment ratio increases, both compressive load and uplift load increases and ii) as the diameter of helix increases, the compression and uplift loads was found to increase. Mittal et. al., (2010) conducted lateral load capacity of model screw anchor piles embedded in dry sand with different number of helices. Lateral loads were applied at different height above the soil surface with varied embedment length of screw anchor piles to study the behaviour of screw anchor piles under lateral loads. It was found that the ultimate lateral load capacity of screw anchor pile increases effectively with increase in embedment length, number of plates. The percentage increase in lateral load capacity for increase in embedment ratio (L/d) from 14 to 18 is more than the percentage increase in lateral load capacity for increase in embedment ratio (L/d) from18 to22. Nihar Ranjan Patra et al (2004) conducted model tests to find the load-displacement and ultimate resistance of enlarged base piles subjected to axial pulling loads and oblique pulling loads piles, embedded in layered sand and homogeneous sand in a model tank of size 914mm X 914mm X 762mm. It was found that as embedment depth increases, the uplift load was found to increase. The uplift capacity of the pile increases with increase in length, base enlargement. Further the ultimate uplift capacity is higher for medium dense over dense condition.

2. MATERIALS AND METHODS

The model tests were conducted in a model test tank, having inside dimensions of 1.2x0.75 m in plan and 1.5 m in depth, the soil chosen was dry sand, and pile shaft was made up of aluminium. The pile shaft with and without helices solid were driven in medium dense and loose state of sand. Tank is provided with glass window to ensure the sand is being filled uniformly & also it is being in level. The photograph showing model test tank, lever hoist and proving ring arrangement are shown in Fig.1.

Fig. 1: Photograph of Model Test Tank, Lever Hoist, and Proving Ring and LVDT arrangement with Sand Pouring Box

Table 1 Properties of Sand Used for Present Study

Properties	Sand
Type of sand	Dry clean sand
Specific Gravity (G)	2.61
Uniformity coefficient(Cu)	2.91
Coefficient of curvature(Cc)	1.05
D10, D30, D60.	0.24, 0.42, 0.7
Maximum Unit Weight(γ_{max}),e_{min}	17.044kN/m^3,0.502
Minimum Unit Weight(γ_{min}), e_{max}	14.237kN/m^3,0.798
Relative density in loose and medium dense condition	35% & 50% respectively
Dry density in loose and medium dense condition	15.0 & 15.6 kN/m^3 respectively
Angle of internal friction Φ(phi)for loose and medium dense case	32^0 , 36^0respectively

3. EXPERIMENTAL SETUP AND PROCEDURE

Pile of 700mm, 600mm and 450mm embedment length with zero, single, double and triple helical plates were used in this experimental investigation. The diameter of the anchor plate or helix is 90mm. The anchor plates are welded on to the pile by giving the equal spacing of one time the diameter of the anchor plate (90mm). The pile is driven vertically in the sand bed using wooden block to maintain the verticality. Lateral load is applied to the pile through a pulley arrangement with steel wire attached to the hook provided to pile, and displacements are monitored for applied load with the help of L.V.D.T. Fig.2 shows the schematic sketch of experimental set up and Fig.3 shows the model piles used in the present study.

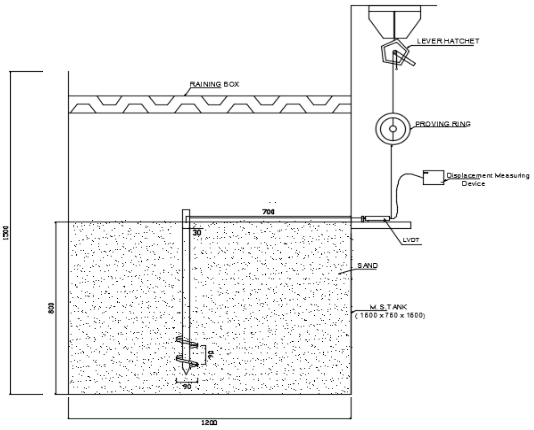


Fig. 2: Schematic diagram of experimental set up

Fig. 3: Model Pile and Helical Piles

The proposed experimental program aims at determining the lateral load capacity of helical pile driven in sand with different embedment length. It consists of mild steel model tank of size 0.75m x 1.2m x 1.5m, in which a pile having 30 mm diameter and L/D ratio 23, 20, and 15 respectively. The tank is filled with Sand (which is Sun Dried or Oven Dried,) using Rainfall Technique which will be achieved by pouring the sand through a Sand pouring box. The height of the sand pouring box is maintained uniformly for subsequent sand filling to achieve the required density, which has been predetermined. The sand is filled up to 800mm from the bottom of the tank. After filling the sand to the required height from the bottom of the tank the pile is driven inside the sand layer. The pile is placed at 700 mm distance away from the boundary to avoid the boundary effect from one side of the tank in the direction in which the horizontal load will be applied and also the three times the diameter of the shaft is kept above from the bottom of the tank. The plain pile (without helical) is driven with the help of a hammer through a pre-drilled wooden block to maintain the verticality with varying embedment length of 700mm, 600mm and 450mm.Lateral pull out force is applied to the pile through steel wire. One end of the wire is connected to the pile with a hook and the other end is connected to the strain controlled proving ring and this proving ring is connected to a manually operated loading jack called lever hoist. The lever hoist is supported by extension at the top of mild steel tank itself. The device called LVDT (Linear Variable Displacement Transducer) is rigidly adjusted to the MS plate which is fixed to the wire rope so as to measure the displacement, and is positioned between the pulley and the face of the MS plate. LVDT is connected to a digital meter from which displacement of the pile is recorded in "mm". The loading is stopped only after it reaches a maximum value and then starts reducing or remains constant for corresponding maximum deformation. During failure, rotation of pile is observed at the top sand surface of the tank. The above procedure is carried out for the double and triple helical pile setup for varying embedment length. Finally, lateral load v/s displacement graphs are plotted from which maximum load is obtained from the graph and it represents the ultimate lateral load capacity of that particular pile corresponding to their number of anchor plates, density of the sand. The results of helical pile are compared with the plain vertical pile.

4. RESULTS AND DISCUSSION

Fig. 4 and Fig.5 shows the load-displacement response for vertical pile shaft without any helical and single helical pile embedded in loose sand. However, all other figures are not presented here in to restrict the size of the article. However, a summary of all the test results are shown in Table.2. It can be observed from figure that the curve is nonlinear and also as the embedment length increases ultimate lateral load increases. Also with inclusion of helices, the lateral load was found to increase.

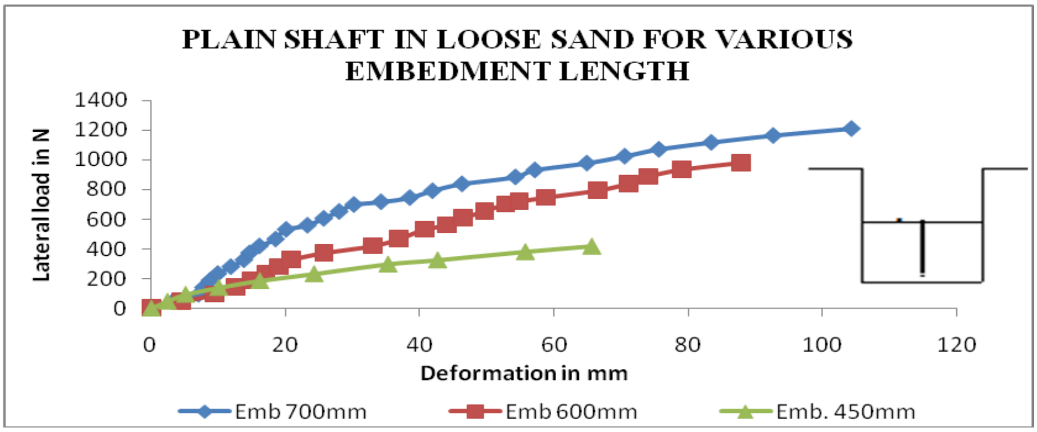


Fig.4: Lateral Load-Displacement curve for Plain Vertical pile in loose sand.

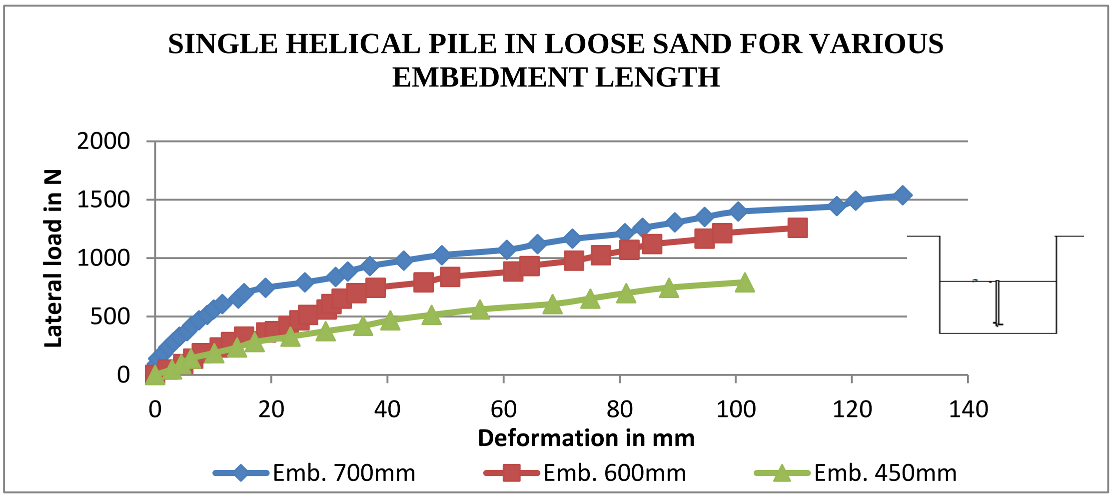
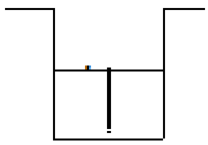
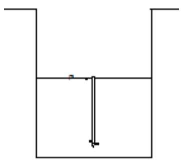
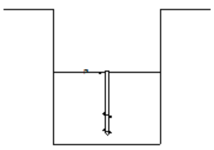
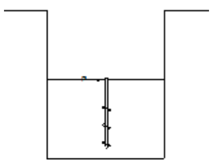


Fig.5: Lateral Load-Displacement curves for Single Helical pile in loose sand

TABLE 2: Ultimate load and displacements values for various embedment length corresponding to vertical plain shaft and varying number of helices in loose and medium dense sand

Sl. No	Type of Pile	Embedment length in mm	Ultimate load "N"		Displacement "mm"	
			Loose sand	Medium dense sand	Loose sand	Medium dense sand
1		700 600 450	1211.54 978.55 419.38	1491.12 1118.34 698.96	99.93 87.87 65.64	117.45 86.80 58.76
		700 600 450	1537.72 1304.73 792.16	2050.29 1537.72 978.55	128.76 119.78 101.59	103.77 100.72 76.51
3		700 600 450	2003.69 1630.91 1025.15	2376.47 1957.10 1258.13	136.65 138.87 94	108.2 108.2 78.85
4		700 600 450	2329.88 1910.5 1304.73	2795.85 2236.68 1630.91	132.14 142.8 98.89	144.22 92.16 100.63

5. CONCLUSIONS

The lateral resistance of helical pile was influenced by embedment depth, number of helices and relative density. The ultimate lateral load carrying capacity of helical pile driven in loose and medium dense sand increases with an increase in embedment depth. When compared to loose state of sand, medium dense state offers more lateral resistance in all the cases. The lateral load carrying capacity of helical pile also depends on number of helices and L/d ratio (Where L=depth of embedment and d = diameter of pile shaft). Also as the number of helices increases in a helical pile, the lateral resistance was found to increase. The model experiment indicates that the ultimate lateral capacity of the triple helical pile in loose sand is 1.92 times, 1.95 times and 3.1times more than the plain vertical pile for L/d ratio 23, 20 and 15 respectively. Ultimate lateral capacity of the triple helical pile in medium dense sand is 1.9 times, 2 times and 2.3 times more than the plain vertical pile for L/d ratio 23, 20 and 15 respectively. The model experiment indicates that the lateral capacity of the triple helical pile in medium dense sand is 1.2 times more than the triple helical pile in loose case for L/d ratios 23, 20 and 15 respectively. The model experiment indicates that the lateral capacity of the single and double helical pile in medium dense sand is 1.2 times more than the single and double helical pile in loose case for L/d ratios 23, 20 and 15. As compared to plain vertical pile, pile with varying number of helices offers more lateral resistance for all the cases in loose and medium dense state of sand.

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