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Experimental study on lateral behavior of step tapered piles in sand

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***Abstract*— Pile foundations are used to account for huge vertical, uplift and lateral loads due to live loads, dead loads, earthquake, wind, impact, waves and lateral earth pressure etc. Uniform cross section piles are commonly used in the practice, increasing loads on these structures has resulted in piles of large diameter and depth at a significantly higher cost. Analysis presented here is intended to provide important information to geotechnical design regarding the behavior of the step tapered piles. Experiments were performed on single step tapered piles embedded in sandy soil under independent lateral loading. The investigations were done by changing the taper length, L/D ratio of pile, and relative density of sand. The results indicate that use of step tapered piles is highly effective in resisting lateral loads due to the enlargement or strengthening of the upper section of piles.**

***Index Terms*— Step tapered pile, Lateral load test**

1. INTRODUCTION

Generally, high rise/tall buildings are supported by pile foundations at sites encountering poor soil conditions at shallow depths. These structures are subjected to large lateral loads and overturning moments due to wind, waves, or both, in addition to vertical compressive load. As a result, the piles supporting these structures have to resist large lateral and uplift loads and moments. If a friction pile subjected to a downward vertical load, has its sides parallel, the transfer of load to the surrounding soil is entirely by the shear at the interface. However, if such a pile is provided with a taper, a part of the downward load is transferred by direct bearing on the sides over the area. This bearing results in an increased normal pressure when compared to the pile without taper, which consequently increases the frictional component of the hearing resistance. Also Significant saving in foundation cost could result from strengthening or enlarging the upper segment of the pile only.

Applications of tapered piles to structures are increasing in the world to accomplish significant saving in foundation cost, e.g. Nabil F. Ismael et al. (2010), M. Hesham et. al., (2000), M. Sakr et. al., (2005) and E I Naggar et. al., (1999). Experimental studies as well as numerical analyses on pile foundation have been conducted, e.g. Poulami Ghosh et. al., (2017), Martin Achmus et. al., (2010), K. Rajagopal et. al., (2015). Number of studies on lateral load tests were reported, e.g. Brown et. al., (1988), McVay et. al., (1998), Narasimha Rao et. al., (1998) and Ilyas et. al., (2004).However, the researches just only investigated the behaviors of tapered piles under lateral loading and the behaviors of step tapered piles have not been fully understood.

This research was carried out to investigate the lateral behavior of step tapered piles with different taper length and L/D ratio.

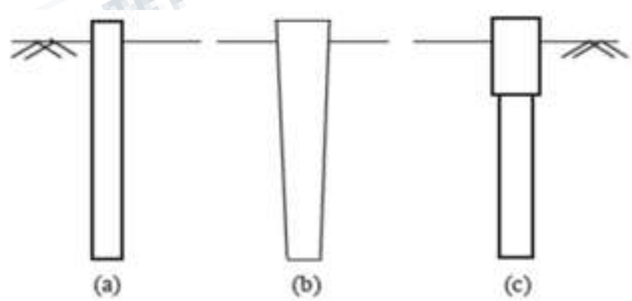

Fig. 1 Types of piles (a) cylindrical (b) Tapered (c) Step tapered

2. MATERIALS USED

The soil used was river sand and it was collected from IES College ground, Thrissur. Air dried soil samples were used for laboratory model study. The test tank used for model tests was a rectangular tank, made-up of galvanized iron sheet having 1 mm thickness. The dimensions of the test tank were fixed based on the criteria by K. Madhusothanan Reddy et.al, (2015). So the sand bed was prepared in a tank

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of inside dimensions 600 mm length, 600 mm width and 700 mm height. The model pile and step tapered piles were casted in mechanical laboratory of IES College of Engineering. To facilitate loading, each pile had a small steel hook, which was welded on the square pile cap of dimension 50 mm x 50 mm and 3 mm thick, to attach the tension load via a steel wire. The length of the pile tested were 270 mm (L/D = 18), 420mm (L/D = 28) where L is the length of pile.

Fig. 2 Step tapered piles

Pile Configurations

Table. I Pile Configurations

Length of pile (mm)	270	420
L/d ratio	18	28
Dia of pile (mm)	15	15
Taper dia (mm)	25	25
Taper length (mm)	27, 54, 108, 270	42, 84, 168, 420

Properties of Sand

Table. II Index properties of sand

Parameters	Value
Specific Gravity	2.59
Effective size, D10 (mm)	0.15
D30 (mm)	0.36
D60 (mm)	0.56
Uniformity coefficient, Cu	3.73
Coefficient of curvature, Cc	1.03
Gradation of sand	SP
Maximum density (g/cc)	1.71
Minimum density (g/cc)	1.35
Sand density (35% RD) (g/cc)	1.43
Sand density (50% RD) (g/cc)	1.63
Angle of internal friction (35% RD) (degree)	33.5
Angle of internal friction (50% RD) (degree)	41

3. EXPERIMENTAL PROGRAMME

Lateral load tests were performed in fine loose and medium dense sand bed. In each test, pile was installed by same method at the same embedment depth. Tests were performed in sand bed, which was prepared in metal tank of inside dimensions 600 mm x 600 mm x 700 mm (l x b x h). Each layer was compacted to achieve the desired density. Pile is placed in desired embedment depth and continue the filling of sand till it reaches the top of the pile and level the top surface of sand bed. After sand bed preparation, the static lateral load was applied by means of dead weights placed on a loading hanger connected to center of pile cap via a flexible steel wire, which strung over a pulley which is on the right hand side of the pile for lateral load test. A dial gauge, accurate to 0.01 mm was placed on a flap which is welded on right hand side of pile cap used to measure pile head lateral movement in the loading direction.

(i) Test Procedure for Lateral Load Test

The load was applied laterally through pulley fixed on right side of the tank via a steel wire attached to the centre of the pile head, avoiding any eccentric load. The load was applied incrementally. Each load was kept constant until the difference between two successive displacement readings was less than 0.01 mm per minute. A dial gauge, accurate to 0.01 mm was used to measure pile head lateral movement. The loading was continued until the total deflection of pile head

Fig. 3. Lateral loading test

reached 12 mm. The safe lateral load is taken as least of the following (IS 2911 Part IV-2010) : (a) Load corresponding to a total pile head deflection of 5 mm (b) Half of the load corresponding to a total pile head deflection of 12 mm. (c) Load corresponding to any other specified displacement as per performance requirements.

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4. RESULTS AND DISCUSSION

Safe lateral load of piles in loose and medium dense sand bed:

Lateral load test of piles was conducted in loose and medium dense sand bed, i.e., at various densities such as 35 and 50 %. Figure 4.shows the safe lateral load of piles in loose and dense sand bed under lateral load test. From the above response it is clear that as relative density increases the safe lateral load increases due to increase in passive soil resistance. When the density of sand was increased, the shear strength and stiffness of the sand increased. Therefore lateral deflection of the pile decreased and at the same time, the safe lateral load increased.

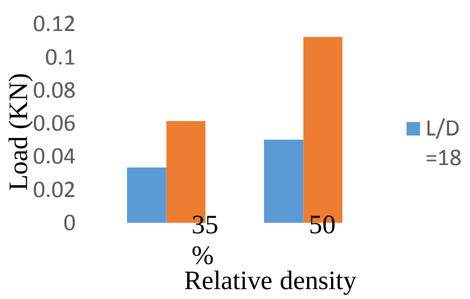

Fig.4. Safe lateral loads of piles in loose and medium dense sand

For a short pile, safe lateral load was increased 1.5 times when the sand relative density changed from 35 to 50 % and for pile with L/D = 28, safe lateral load was increased 2 times. This increase in relative density increases the mobilization of shearing resistance on the pile surface through the interface friction between the pile and sand.

Variation in safe lateral load of short and moderate step tapered piles due to change in taper length in loose and dense sand:

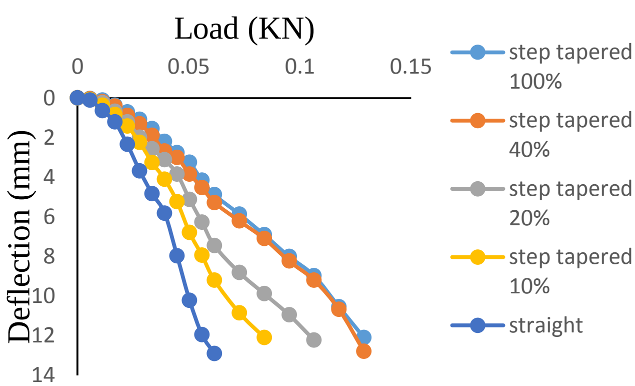

Fig.5. Load deflection Response of Short Step tapered piles in Loose Sand Bed

Fig.5 and 6. indicate that enlarging the upper pile section for the short step tapered piles has significantly increased the ultimate lateral capacity. Thus enlarging the pile diameter from 0.15 to 0.25 m for the upper 40% of the pile length increased the ultimate lateral capacity from 0.0616 to 0.1288 KN. This is a 50% increase. When the full length of the pile has a diameter of 0.25, which corresponds to 100% enlargement, the ultimate capacity was also 0.1288 KN, which indicate no increase in capacity over the 40% enlargement. Similar behaviour was observed in medium dense sand bed condition also. The ultimate lateral capacity increased from 0.0983 to 0.2052 KN.

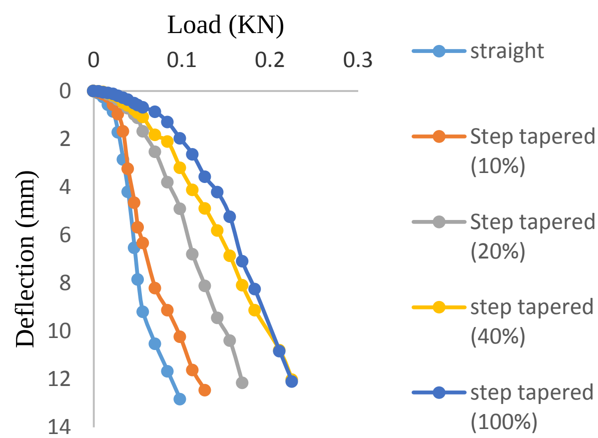

Fig.6. Load deflection Response of Short Step tapered piles in Dense Sand Bed

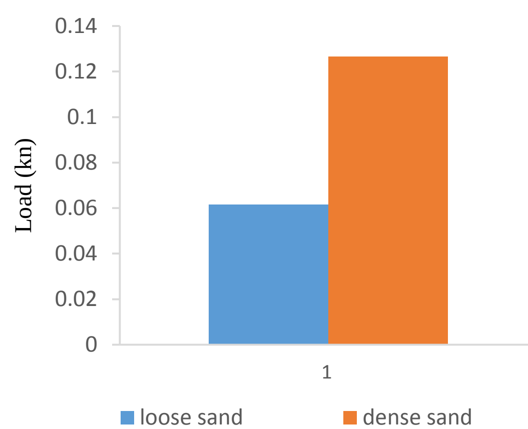

Fig.7. Safe lateral load of Short Step tapered piles in Loose and Medium Dense Sand Bed

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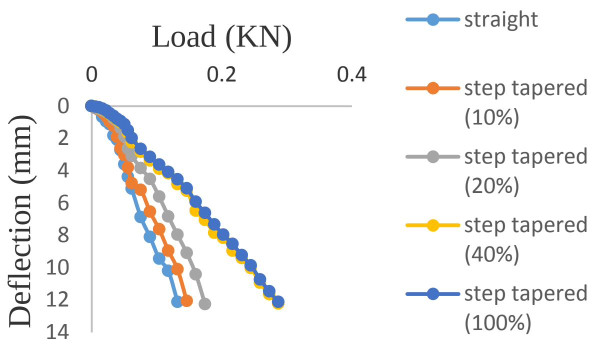

Fig.8. Load deflection Response of Moderate Step tapered piles in Loose Sand Bed

Fig.8 and 9. indicate that for medium pile length step tapered piles enlarging the pile diameter from 0.15 to 0.25 m for the upper 40% of the pile length increased the ultimate lateral capacity from 0.1321 to 0.2872 KN in loose sand bed. In dense sand bed the ultimate lateral capacity increased from 0.2252 to 0.3662 KN. This is a 60% increase.

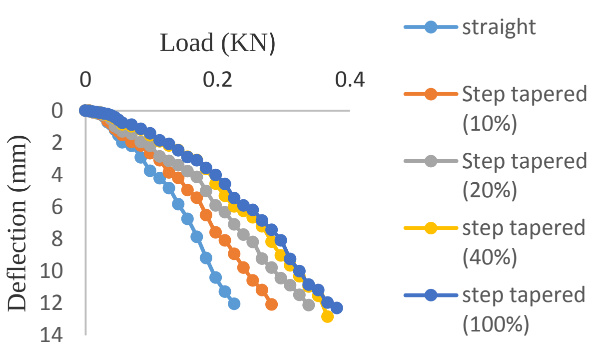

Fig.8. Load deflection Response of Medium Step tapered piles in Medium Dense Sand Bed

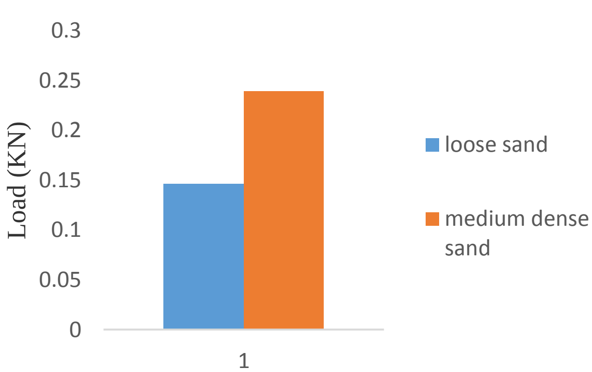

Fig.9. Safe lateral load of Medium Step tapered piles in Loose and Medium Dense Sand Bed

From the bar diagrams 7 and 9 it is clear that as relative density increases the safe lateral load increases due to increase in lateral confining earth pressure and increase in passive soil resistance.

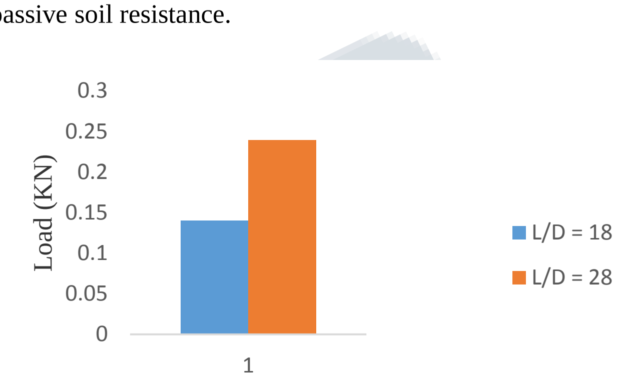

Fig.10. Safe lateral load of small and medium pile length Step tapered piles in Medium Dense Sand Bed

Fig.10. shows that the measured safe lateral capacity of small and medium pile lengths (L/D = 18 and 28). It is found from Fig. that the ultimate lateral capacity increases with an increase in pile length. This could be due to increase of the passive resistance with the increase in pile length.

5. CONCLUSION

A series of lateral load tests on straight and step tapered piles were carried out in both loose and medium dense sand bed. Based on the laboratory tests, the following conclusions were reached.

1. For a medium length pile, safe lateral load was increased 2 times when the sand relative density changed from 35 to 50 %.
2. The use of step tapered bored piles is highly effective in resisting lateral loads.
3. By enlarging the pile diameter from 0.15 to 0.25 m for the upper 40% of the pile length increased the ultimate lateral capacity from 0.2252 to 0.3662 KN in medium dense sand. This is a 60% increase.
4. No further increase in ultimate lateral capacity is observed over the 40% enlargement of pile section in both small and medium pile lengths.
5. The ultimate lateral capacity increases with increase in pile length. So step tapered pile with medium pile length in medium dense sand exhibits higher lateral capacity

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REFERENCES

1. Nabil F. Ismael "Behavior of Step Tapered Bored Piles in Sand under Static Lateral Loading" Journal of Geotechnical and Geoenvironmental Engineering. ASCE/ 669, May 2010.
2. K. Madhusudan Reddy and R.Ayothiraman "Experimental Studies on Behavior of Single Pile under Combined Uplift and Lateral Loading" J. Geotech. Geoenviron. Eng. ASCE 2015.
3. Brown, D. A. "Lateral load behavior of pile group in sand." J. Geotech. Engg., ASCE, 114(11), 1261-1276, 1988.
4. Narasimha, R. S., Ramakrishna, V. G., and Babu, R. M. "Influence of rigidity on laterally loaded pile groups in marine clay." J. Geotech. Geoenviron. Eng., ASCE, 124(6), 542-549. 1988
5. M. Hesham EI Naggar, Jin Qi Wei "Uplift behaviour of tapered piles established from model tests" Can. Geotech. J. 2000.
6. M. Sakr, M.H EI Naggar, M. Nehdi "Lateral behaviour of composite tapered piles in dense sand" Can. J. Geotech 2005.
7. Martin Achmus, Klaus Thieken "On the behaviour of piles in non-cohesive soil under combined horizontal and vertical loading" Springer 2010.
8. Poulami Ghosh, Sibaproya Mukharjee "Behavior of single pile under combined uplift and lateral loading" Indain Geotech. Conference 2017