A MODEL STUDY ON LATERAL BEHAVIOUR OF MICROPILE UNDER INCLINED COMPRESSIVE LOADS IN SAND

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Abstract - *Micropiles sometimes called Mini-piles are small diameter piles, usually used for structural supports, seismic retrofits, foundation underpinning and even for soil reinforcement. Group and network effect of micropile system provide better performance. Due the extensive use, study of its behaviour under various loading conditions became necessary. In the present study micropile groups having four numbers of micropiles in a group is tested in the laboratory to investigate the lateral behaviour of micropile under inclined compressive load in cohesionless soil. For that square micropile groups with different spacing between the piles (2D, 3D and 4D) and different L/D ratios (20, 30 and 40) are tested under compressive load at inclinations of 15°, 30° and 45°. Results show that as the length and spacing of micropile group increases the lateral capacity also increases but lateral capacity decreases with increase in load inclination.*

***Key Words*: Micropile, Length to depth ratio, Spacing between micropile, Load inclination, Model study.**

1. INTRODUCTION

Micropiles are small diameter piles usually less than 300mm (FHWA, 2005). They were first used in Italy in early 1950's by Dr. Fernando Lizzi in the form of the root pile or palo-radice to restore structures and monuments damaged during World War II (Lizzi, 1982). Later the technology was extensively used and developed. Popularity of the micropile technology has increased in the last 10–15 years. Nowadays micropiles are routinely considered for many projects worldwide. They are now typically used for structural supports, seismic retrofits, foundation underpinning and even for soil reinforcement, especially in locations with poor soil conditions or in congested areas.

Due to the extensive applications of micropile, the study of its behavior under various loading conditions became inevitable. And hence the present work consist of model experimental study of micropile group having four micropiles in a group with different length to diameter ratio and different spacing between the piles in group, inserted in cohesionless dry sand and subjected to different inclined compressive loads. Thus aims to study the load- lateral settlement behaviour of micropile group under inclined compressive loads and understand how it affects factors like length to diameter ratio of micropiles, spacing between micropiles in group and inclination of load with vertical. For that micropile groups with three L/D ratios such as 20, 30 and 40 having three different spacing such as 2D, 3D and 4D are tested under compressive load inclined at 15°, 30° and 45°, thus in total 27 sets of loading was done. The inclined compressive load can be applied in different ways such as inclination is towards the edge of the pile cap or towards the diagonal corner of the pile cap. The direction of load inclination may also have significant effect on the performance and hence to choose more advantageous loading direction pile groups are first loaded with the two different directions at same loading condition.

2. LITERATURE REVIEW

D Su and Y G Zhou (2016): Investigate the effect of loading direction on the behaviour of laterally loaded pile group inserted in sand by model study. For that they loaded both square and rectangular configurations with lateral load along various directions and observed that loading direction have great influence on different factors like load distribution, lateral resistance, bending response etc. It also observed that better lateral resistance will be offered when the group is loaded along its diagonal direction than that along the edge of pile cap.

Kyle M Rollins, Ryan J Olsen, Jeffery J Egbert, Derek H Jensen, Kimball G Olsen and Brian H Garrett (2006): Studied the effect of pile spacing on behaviour of laterally loaded pile group inserted in stiff clay by a full scale cyclic lateral load test. For that they test pile groups have varied spacing and varied number of pile rows in the direction of loading where there were 3 piles in a row. From this it was observed that for a particular deflection more loads will be taken by the first row of piles and it descents to the tailing piles. And for a given load maximum bending moment will occur at the tailing piles than that of leading row piles for small spacing pile group and the trends decreases with increase of spacing.

Soumya Roy, Bikash Chandra Chattapadhyay and Ramendu Bikash Sahu (2013): Evaluated the performance of a vertical pile subjected to inclined compressive load by a model study and compared it with the overall pile behaviour by conventional technical approaches. Pile of various slenderness ratio was tested under various inclination varies from 0° to 90° and ultimate load capacity obtained verses the inclination of load is plotted.

Binu Sharma (2011): Investigate the performance of single micropile of different length to diameter ratios casted in the sand bed of varying relative density and subjected to lateral loading as well as vertical or oblique pull by model experimental study. From the result obtained it was evident that the L/D ratio has a major influence in it. And also relative density of sand bed and angle of inclination of pull have a great influence on failure mechanism.

Singh P K and Arora V K (2014): Evaluate the performance of steel pipe pile group inserted in loose sand under axial loading condition by a model study. For that, pile group having square rectangular and circular configurations were loaded in which the spacing between the piles are kept constant. From that Circular configuration shows a better ultimate capacity than both square and rectangular. But efficiency was maximum for square and minimum for rectangular configuration.

Nihar Gogoi, Sanandam Bordoloi and Binu Sharma (2014): Conducted a model study to determine the behaviour of micropile groups in sand under axial loading condition. Ultimate axial resistance of group was observed to be increases with the L/D ratio, which is non-linear and also the settlement decreases with increase of L/D but only before the ultimate capacity. Efficiency seems to be increases with spacing and maximum efficiency is obtained for 4D spacing.

Harish C and Manjunatha M (2016): Investigate the performance of single and group micropile in black cotton soil subjected to axial loading by a model study. And the result shows efficiency increases with increase in spacing but decrease with increase in length of micropile.

Doohyun Kyung and Junhwan Lee (2017): Conducted field load test as well as finite element analysis for inclined single and group micropiles subjected to lateral load. And the result obtain shows a trend that the lateral capacity increases with inclination for a load from right side to left and a opposite trend for left to right loading. For group micropiles, lateral capacity increases with the inclination of pile due to the fixity effect. Passive failure zone and the skin friction developed along the pile are the factors that contribute to the lateral load carrying capacity of inclined micropiles.

3. MATERIALS

The materials required for the experiment includes foundation medium, model tank, model pile and model pile cap. The details regarding the materials are given below.

3.1 Foundation medium

In the present study cohesionless dry sand is choose as the foundation medium and it was collected from the Bharathapuzha river in Palakkad district. And the properties are determined as per IS specifications. The result obtain are shown in Table – 1.

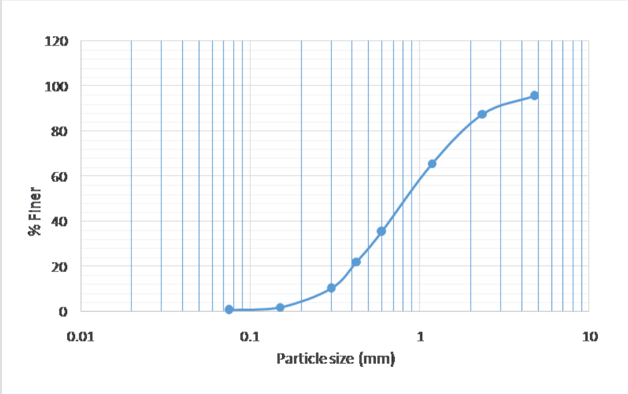

Chart -1: Grain size distribution curve of sand

Table -1: Properties of sand

Properties	Values
Specific gravity, G	2.60
Dry density,	1.76 g/cc
Coefficient of permeability	1.36×10^{-2} cm/s
Uniformity coefficient, Cu	3.33
Coefficient of Curvature, Cc	1.00
Angle of internal friction	33°
Cohesion, C	0

3.2 Model tank

Model micropiles are tested in a model tank constructed with mild steel plates by considering the effective stressed zone of soil around the pile. In the present study hence a tank of 100 cm X 100 cm X 75 cm is prepared to minimize the boundary effects. The tank is constructed with a provision of erecting the loading frame to apply the inclined loads to the micropile group.

3.3 Model micropiles

The micropiles are casted by using 53 grade ordinary Portland cement and 4.75 mm IS sieve passing sand in a ratio of 1:1 with water cement ratio 0.4 with a 2 mm diameter center mild steel tendon. The diameter of the micropiles are taken as 12mm, thus micropiles with different length satisfying L/D equal to 20, 30 and 40 are casted and cured it for seven days.

Fig -1: Casted micropiles.

3.4 Model pile cap

Pile cap is designed such that at least half the spacing between the piles is provided as the effective cover and hence a mild steel plate of 10 cm × 10 cm × 1 cm is taken as micropile cap in this study.

4. METHODOLOGY

The water tight mild steel tank of dimension 100 cm × 100 cm × 75 cm was filled with cohesionless dry sand to the top by raining the sand from a constant height, by arranging the micropile group with the cap vertically and centrally in the soil. Micropile groups are arranged in both way to load the group with inclination towards the corner and edge. A semicircular loading frame capable of applying compressive load at various inclination ranging from 0°to 90° was erected in the model tank. This has a semicircular guide bar and an alignment guide bar for the exact application of inclined load. A proving ring of 2.5 kN capacity is arranged in the loading frame to apply the load which is loaded by rotating a load application arm. The load transferring arm transfers the load from proving ring to micropile group. Sufficient numbers of dial gauges are arrange to measure the lateral settlement of the micropile group.

Fig -2: pictorial view of Experimental setup

5. RESULT AND DISCUSSION

The tests were conducted and the load taken by the micropile groups corresponding to each lateral settlement were tabulated. Then the load verses lateral settlement curves are plotted. And study effect of each factors considered in the study from the graphs.

5.1 Effect of direction of load inclination

The better direction of load inclination was selected by loading micropile groups with two different directions, one with inclination towards edge and other with inclination towards corner at same loading conditions.

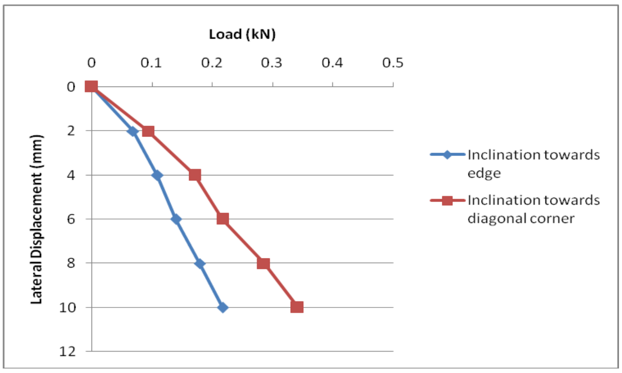

Chart -2: Load verses settlement curve for L/D=20, spacing= 2D and inclination= 15°

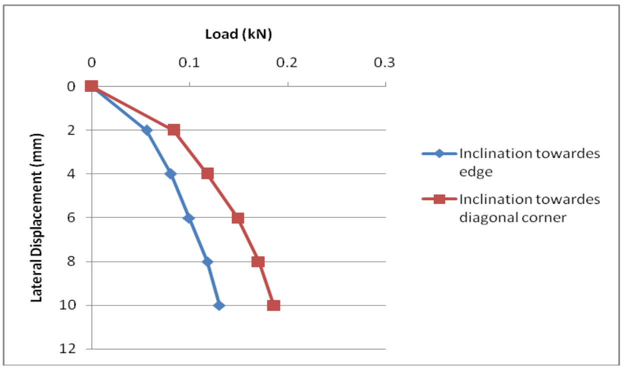

Chart -3: Load verses settlement curve for L/D=40, spacing= 4D and inclination= 45°

From the above curves it was inferred that loading such that direction of inclination towards the diagonal corner of the micropile group provide more lateral capacity than that loaded toward the edge. And hence inclination towards the corner can be use to evaluate effect of other factors.

5.1 Effect of L/D ratio

The effect of L/D ratio of the micropile in its lateral settlement behaviour under inclined compressive load can be understand by varying the L/D ratio for same loading conditions and by analyzing the resulting p-y curves.

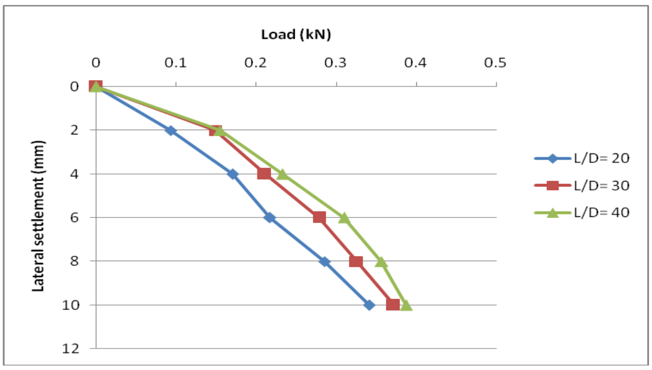

Chart -4: Load verses settlement curve for spacing= 2D and inclination= 15°

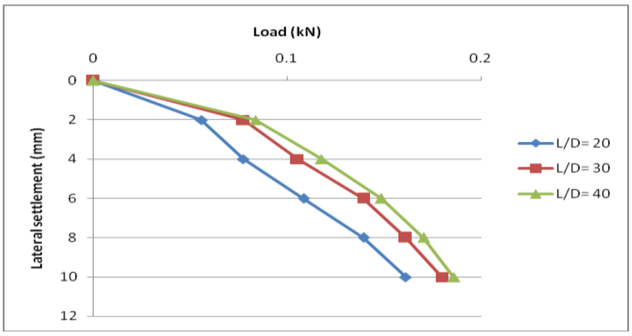

Chart -5: Load verses settlement curve for spacing= 4D and inclination= 45°

Lateral capacity of the micropile group are seems to be increases with the increase of L/D ratio. This may be due to the fact that for micropiles loads are carried by friction rather than end bearing; hence as the length increases frictional resistance also increases. This passive resistance along the pile length provides better lateral capacity.

5.1 Effect of spacing between micropiles in a group

To understand the effect of spacing, micropile groups with spacing 2D, 3D and 4D were tested.

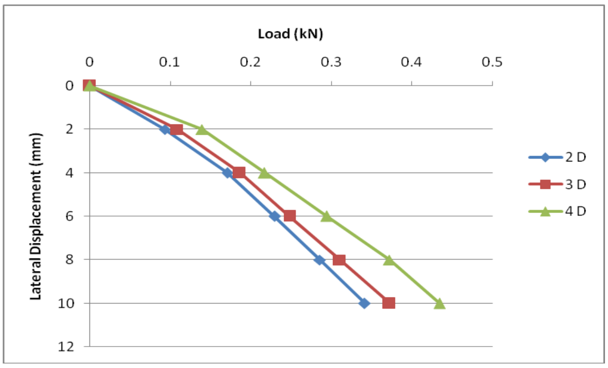

Chart -6: Load verses settlement curve for L/D= 20 and inclination= 15°

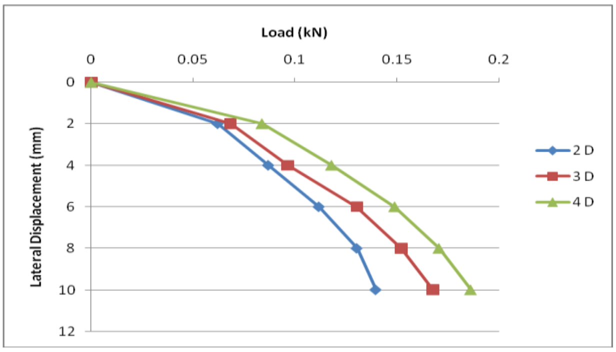

Chart -7: Load verses settlement curve for L/D= 40 and inclination= 45°

The resultant curves show similar trend that is, as the spacing between the piles in a group increases the lateral capacity also increases. This could be due to the decreased overlapped stress zone at large spacing.

5.1 Effect of load inclination.

The effect of angle of inclination of load with vertical to the lateral capacity cab be understand by loading , micropile groups having same L/D ratio and spacing are by varying the inclinations as 15°, 30° and 45°

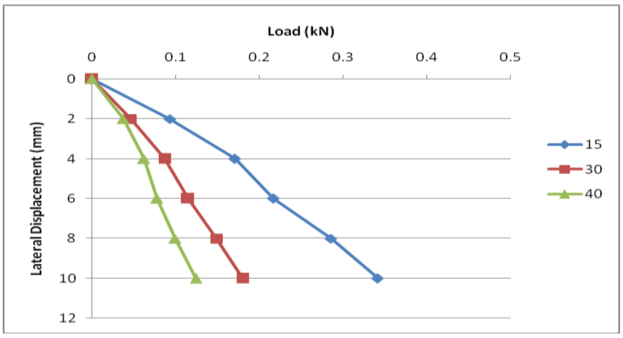

Chart -8: Load verses settlement curve for L/D= 20 and spacing= 2D

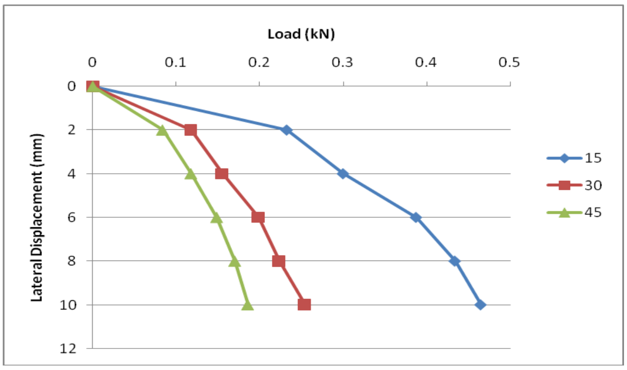

Chart -9: Load verses settlement curve for L/D= 40 and spacing= 4D

Unlike the other factors, lateral capacity of the micropile decreases with increases in inclination of load from vertical. It could be due to the increased lateral load component at larger inclinations.

6. CONCLUSIONS

- The load settlement behavior of micropile group in cohesionless dry sand under inclined compressive load is non-linear
- The direction of inclination of compressive has a significant effect on lateral behavior of micropile group. Group loaded with compressive load inclined towards the diagonal corner of the pile cap provides better capacity than that towards the edge of pile group.

- The lateral capacity of the micropile group increases with increase in length. This may be due to the increase of frictional resistance with length.
- As the spacing between micropiles in a group increases also the lateral capacity increases. This could be due to the reduced overlapped stressed zone for pile group having larger spacing.
- The value of lateral capacity shows a decrease with increase of load inclination. This could be due to the greater lateral component as the inclination increases.

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