PARAMATRIC STUDY OF VERTICAL AND BATTER PILE GROUPS UNDER THE UPLIFT LOAD IN SAND

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ABSTRACT

Pile foundations are frequently used to transmit the superstructure loads to deeper strata if the subsurface soil is of inadequate strength. In cohesionless soils, the shaft resistance is an important source of pile capacity under axial loading, especially when the pile is subjected to uplift loading. Foundations of structures like transmission line towers, tall chimneys, offshore structures, jetty structures, Mooring system, submerged platform, etc. are subjected to overturning moments due to wind load, seismic effect, wave load, ship impacts, etc. For foundations in such structures, generally a combination of vertical and batter piles are used. Batter piles provide a much stiffer resistance to horizontal and inclined loads than would be possible with vertical piles. Experimental model tests have been conducted on pile groups embedded in sandy soil and subjected to pure axial uplift loading. In the present study an attempt has been made to estimate the uplift capacity of combined vertical and batter pile groups embedded in sandy soil of uniform relative density of 63%. The model piles used in this investigation are mild steel solid shaft. The pile groups consisting of 2x2 piles (2 vertical and 2 batter piles), c/c spacing is 3d (d is diameter of pile) and slenderness ratio (L/d) of 8, 12 and 16. In pile groups the angle of batter piles is varied as 10˚, 20˚, 30˚, 35˚ and 40˚. The influences of pile embedment depth, batter angle on the uplift capacity of piles are investigated. Results indicate that the uplift capacity of pile group increases about 2 to 2.5 times with increase of slenderness ratio from 8 to 12 and 12 to 16. The pull out capacity of these pile groups increases with increasing the batter angle up to the 35˚ and after that it reduces drastically.

Keyword: - *Vertical pile, Batter pile, Tension test, Batter angle, Pullout capacity*

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1. Introduction

Foundations of some structures like transmission towers, mooring systems for ocean surface or submerged platforms, tall chimneys, jetty structures etc. are subjected to uplift/inclined pull out load. In different foundation systems, especially for offshore structures, vertical or nearly vertical driven piles are often used to found structures, e.g. platforms. Normally the axial loading of the pile is predominant. But in special cases, for instance for piles supporting offshore wind energy foundations or conductors, the axial (mostly vertical) load is accompanied by a lateral (horizontal) load. Shaft resistance is a major design factor for piles supporting structures subject to significant uplift forces such as transmission towers, harbour structures, and offshore platforms and for anchor piles.. The behaviour of pile shaft under uplift loading has not yet been completely understood. Many factors affect its behaviour, some of them are related to the characteristics of the pile itself such as type, surface roughness, length and diameter and others are related to the properties of the soil around it such as strength, deformability, and density. In cohesion less soils, the shaft resistance is an important source of pile capacity under axial loading, especially when the pile is subjected to uplift loading. The most studies were conducted on the behaviours of piles, are mainly related to piles subjected to axial compression load, while in many cases due to uplift forces, piles will act in tension. Knowing behaviour of piles under tension as well as parameters effecting on tension bearing capacity of piles is very significant.

2. Methodology

2.1 TEST PROGRAMME

Total 15 number of pullout tests was conducted on combined vertical and batter pile groups with batter angle 10˚, 20˚, 30˚, 35˚ and 40˚ embedded in cohesion less soil of medium-dense subjected to pure axial uplift load.

2.2 TEST SETUP

Model pullout tests were conducted in Geotechnical laboratory, Applied Mechanics Department, L.D. College of Engineering, Ahmedabad. The investigational tests were performed on model pile groups in a precast RCC circular tank of height = 800mm, internal diameter = 900mm and external diameter = 1000mm. The whole pullout assembly is shown in Fig. 1.

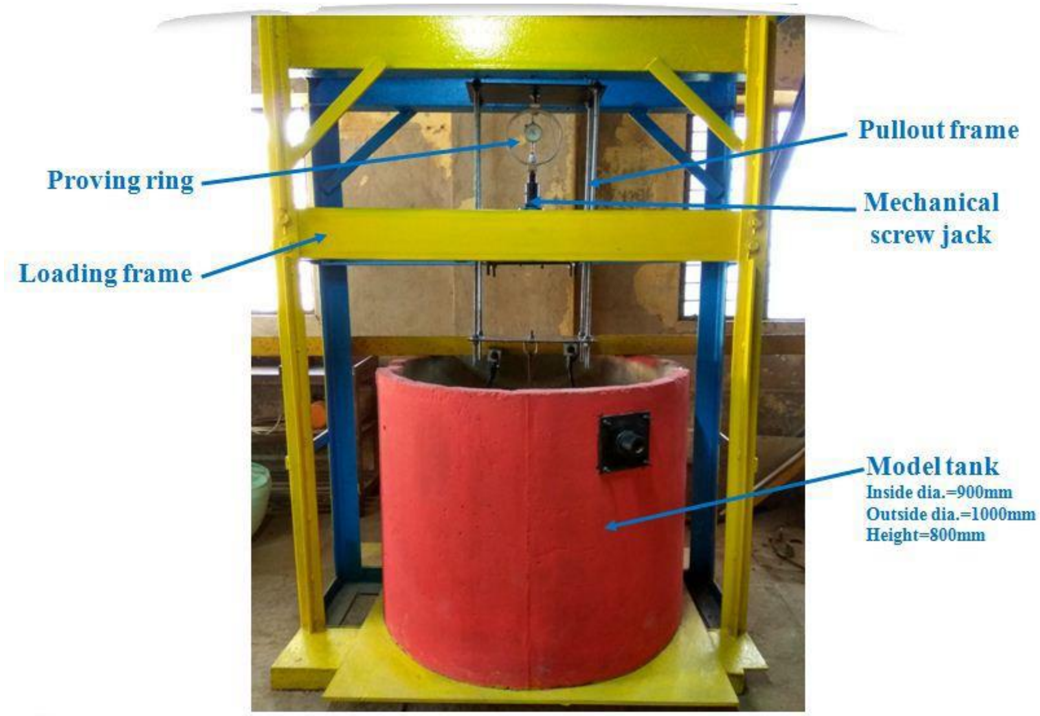

Fig -1: Test setup for pullout test

2.3 PROPERTIES OF SAND

The dry sand used was poorly graded with the gradation shown in Fig. 2. The index and engineering properties of sand used for this study are shown in Table-1.

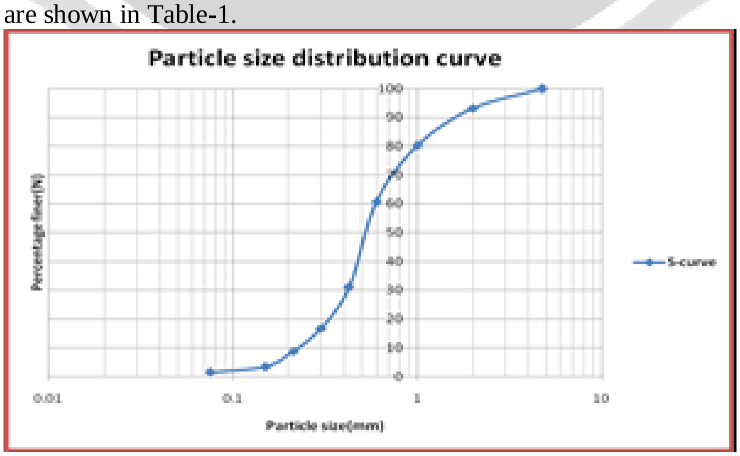

Fig -2: Particle size distribution curve

Table -1: Physical properties of sand

Sr. No.	Properties of sand	Value
1	Coefficient of uniformity,Cu	2.5
2	Coefficient of curvature,Cc	1.23
3	IS soil classification	SP
4	Specific gravity,G	2.67
5	Angle of internal friction,Φ	34°
6	Cohesion,C	0kg/cm^2
7	Minimum density,$\gamma_{d\ min}$	1.48gm/cm^3
8	Maximum density,$\gamma_{d\ max}$	1.97gm/cm^3
9	Experimental density,γ_d	1.76gm/cm^3
10	Relative density,I_d	63%

(β = Batter angle)
Fig -3: Model pile groups

2.4 TEST PROCEDURE

Initially the sand was filled in the tank in the layer of 150mm and each layer was compacted using small surface vibrator. It was vibrated for 4 minutes. All the tests were conducted at a relative density of 63% (Medium-dense condition). The sand was filled up to 200mm below the level in circular tank for testing the pile groups. The surface of sand mass was levelled using spirit level. Marking on the center of sand bed is done with help of plumb bob from center of lower plate. Then after on center line pile group was placed on marking and inserted with help of hammer until pile head is up to bed level of sand. Pile cap is levelled using spirit level. S-shape hook is connected with high-tension bolt and hook connected with bottom plate. Dial gauge for measurement of displacement in the vertical direction of load is attached firmly with loading frame with help of flexible magnetic base. Vertical resultant displacement of pile head is measured by using dial gauges of 0.01mm sensitivity. Two dial gauges on pile cap at 180 degree apart was kept to measure uplift displacement as shown in Fig. 4. An estimated load was applied by opening screw jack and progressive displacement was measure until there is no further displacement of pile head.

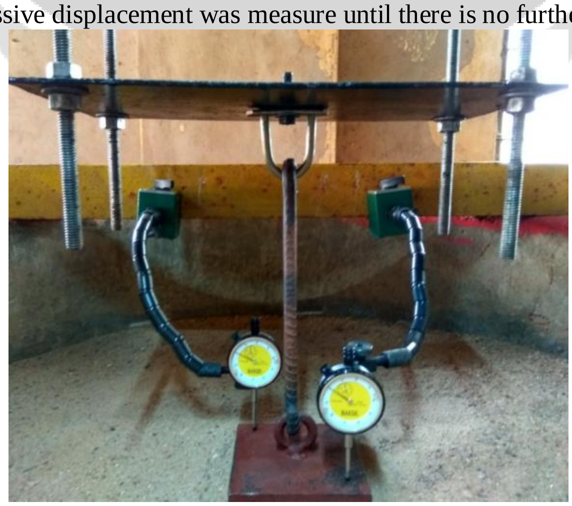
Fig -4: Arrangement of dial gauges

3. Results and Discussion

The pullout load - resultant pile head displacement characteristics of pile group of combined vertical and batter pile groups: 2x2 piles (2 vertical and 2 batter piles) for 160mm, 240mm and 320mm length and constant diameter of 20mm, batter angles 10˚, 20˚, 30˚, 35˚ and 40˚ and 3d (d=diameter of pile) spacing in between pile subjected to pure axial uplift load are shown in Fig. 5 to 9. It can be observed from figures that as pull out load increases the resultant pile head displacement increases linearly initially turns into non-linear with concave downward and become again linear with progress of loading. It can be observed that with increase in pile length the pullout load carrying capacity also increases.

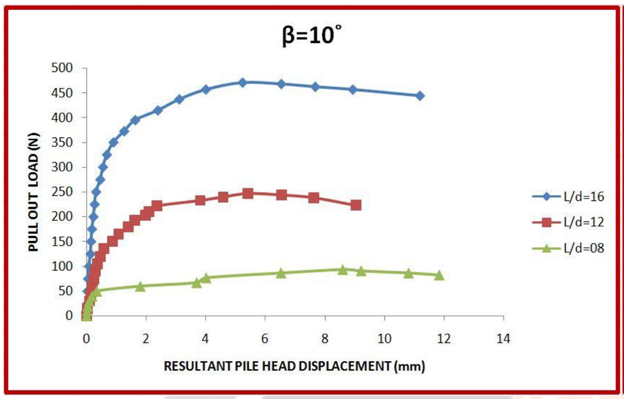

Fig -5: Pullout Load vs Displacement (β=10°)

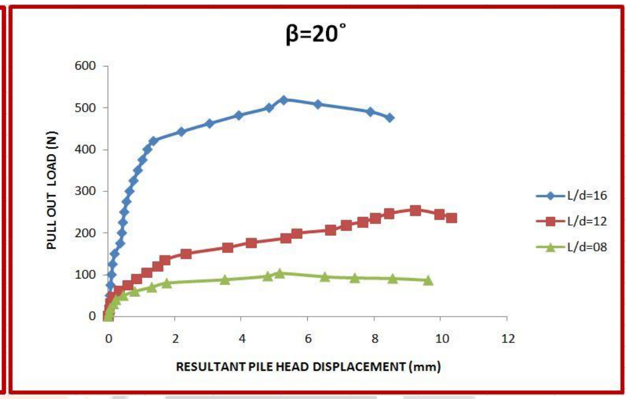

Fig -6: Pullout Load vs Displacement (β=20°)

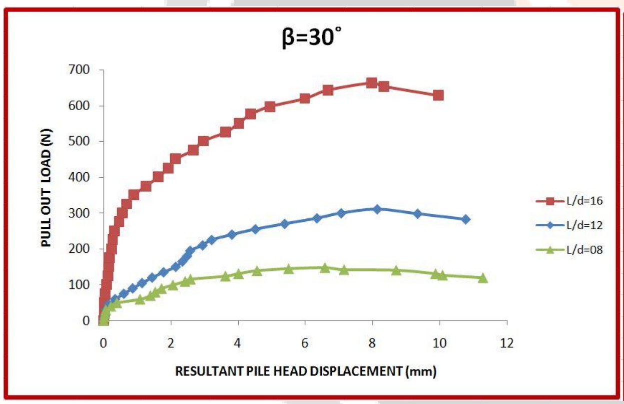

Fig -7: Pullout Load vs Displacement (β=30°)

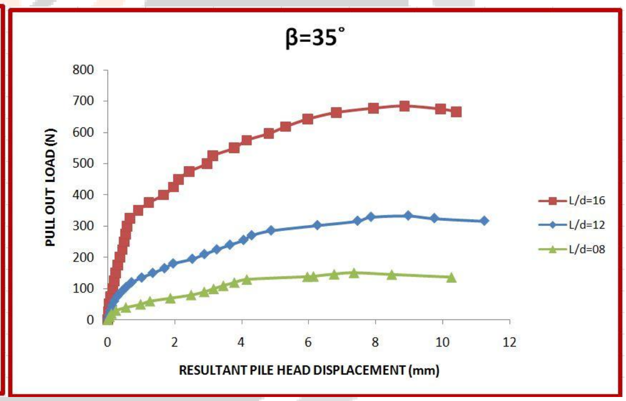

Fig -8: Pullout Load vs Displacement (β=35°)

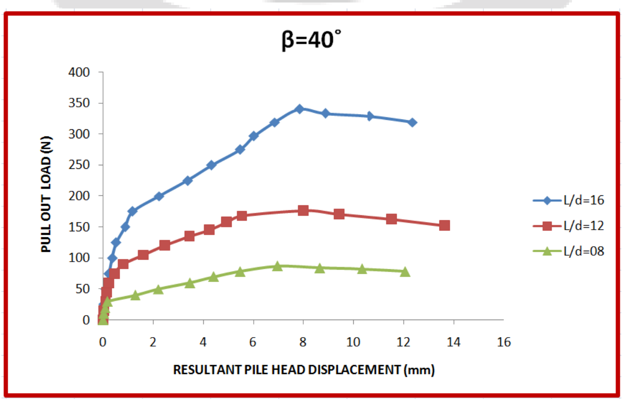

Fig -9: Pullout Load vs Displacement (β=40°)

Table -2: Experimental results

SR. NO.	L/D RATIO	BATTER ANGLE, β (Degree)	ULTIMATE UPLIFT CAPACITY (kg)	TOTAL VERTICAL DISPLACEMENT (mm)
1	16	10˚	48.4	11.18
2	16	20˚	52.5	8.47
3	16	30˚	66.3	9.96
4	16	35˚	69.0	10.41
5	16	40˚	34.5	12.34
6	12	10˚	25.0	9.04
7	12	20˚	26.4	10.34
8	12	30˚	31.0	10.76
9	12	35˚	34.2	11.23
10	12	40˚	17.5	13.64
11	08	10˚	9.84	11.83
12	08	20˚	10.6	9.63
13	08	30˚	13.2	11.28
14	08	35˚	14.5	10.26
15	08	40˚	7.5	12.05

4. CONCLUSIONS

- The ultimate pullout capacity of a combined vertical and batter pile groups that constructed in medium density sand increases about 5%-9% , 17%-27% and 4%-10% as going from the batter angle of 10˚ to 20˚, 20˚ to 30˚ and 30˚ to 35˚ respectively.
- The ultimate pullout capacity of a combined vertical and batter pile groups that constructed in medium density sand decrease about 43%-48% and 48%-50% as going from the batter angle of 30˚ to 40˚ and 35˚ to 40˚ respectively.
- For each batter angle, the ultimate uplift capacity of pile groups of slenderness ratio(L/d) = 12 is 2.5 times that of the slenderness ratio(L/d) = 08
- For each batter angle, the ultimate uplift capacity of pile groups of slenderness ratio(L/d) = 16 is almost twice that of the slenderness ratio(L/d) = 12

5. ACKNOWLEDGEMENT

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6. REFERENCES

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