Load Test on Batter Piles in Pile Group in Sand

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Abstract: It is common for batter piles to be employed in a pile group which is to be subjected to significant lateral loading. While it has indeed been established that batter piles can reduce lateral deflections due to lateral loading, there may be less favorable effects of batter piles if a group is subjected to vertical loading. The degree of batter is the angle made by pile with the vertical. In this project an attempt is made to study the behaviour of batter pile group in vertical and lateral loading through model pile load test. Poorly Graded sand of medium density is used as a foundation medium. Model Pile load test is conducted on a 3x3 model pile group with a row of batter pile by changing parameters like L/D ratio and batter angles. Load Settlement relationship of pile group of vertical, positive and negative batter piles are compared.

Keywords: *Batter piles, load- settlement,Vertical loading, Lateral loading.*

I. INTRODUCTION

Laterally loaded pile groups should be designed to be safe against structural failure of piles, excessive deflection, and ultimate failure of the soil around the piles. Such large displacements are required to mobilize the ultimate capacity of the soil that soil failure does not control the design in most cases. The lateral resistance of pile foundations is often significant in the design of structures that may be subjected to earthquakes, high winds, wave action, and ship impacts. The inclination in the batter piles are known as the angle of batter which is taken as an angle made by the pile to the vertical alignment of them along their direction.

Batter piles can carry lateral loads primarily in axial compression and or tension while the vertical deep foundation carries load along shear and bending. When the pile group is subjected to loading of both vertical load due to structural loading action and lateral load due to wind, blasts and other impacts from external sources like waves, current and lateral earth pressure, batter piles are employed in the direction of the lateral loading. The influence of batter piles in the vertical capacity is appreciable even though the capacity is assumed to be common in vertical piles for design purpose.

Batter piles are not suitable in all conditions as it is problematic in compressible soil condition, when the settlement imposes lateral loads and bending over the entire length of the pile. The effectiveness of batter pile group involve in prediction of most lateral load direction and the maximum deflection of the piles alongside ultimate lateral capacity of the piles.

From past researches regarding batter pile and laterally loaded piles groups of different configurations. Hirani Anil.D. Verma A.K., Bhatt.D.R.,(2013) conducted CRP vertical load test on the 2x2 batter pile group with batter angles 0˚– 20˚.

M.R.Rahimi, K.Bargi (2010) conducted 3D FEM procedure to study the effect of inclination and position of batter piles on the response of a pile-supported wharf in pile-soil system.

Lv Fan-ren, Yin Ji-ming, Jin Yao-Hua (2011) studied batter pile having batter angle 0˚, 10˚ and 20˚ along the pile head fixed and free. The model experiment indicates that the lateral capacity of the negative batter translational pile is larger than that of the positive batter free pile.

Amr Farouk Elhakim, Mohamed Abd Allah El Khouly, Ramy Awad (2010) utilizes three dimensional finite element modelling to understand the main parameters that affect the response of laterally loaded pile groups 2x2 and 3x3, pile spacing and pile location within the group. The fixity of the pile head affects its load–displacement under lateral loading.

II. EXPERIMENTAL WORK

2.1 Properties of Sand

The soil used as foundation medium was collected from Lalapettai Cauvery river basin, Karur district, India. The soil sample was analysed in laboratory for its index and engineering properties such as specific gravity, particle size distribution, density index and angle of internal friction. The properties of the sample are tabulated in Table 1.

TABLE 1.
INDEX PROPERTIES OF SOIL

Properties	Values
Specific gravity	2.64
Effective Size , D_{10}	0.28mm
D_{30}	0.4mm
D_{60}	0.6mm
Uniformity coefficient of sand, C_u	2.15
Coefficient of Curvature, C_c	0.95
γ_{max}	16.87 kN/m^3
γ_{min}	15.22 kN/m^3
Density index, I_D	45%

As per IS classification the sand is classified as Poorly Graded Sand. The foundation medium is of medium dense condition and the density index of the sand is 45%. The corresponding unit weight of 15.93 kN/m^3 and angle of internal friction 30□.

2.2 Model Pile Group

The model batter pile group used in this study consist of 9 model pile groups. The pile is of 3x3 piles with a row of batter piles in positive and negative directions and a vertical pile group. The material used for pile cap is Mild Steel plate of plan dimension 100mmx100 mm and thickness of 8mm. Mild steel rod of 8mm diameter is used as pile and the length of pile. The angle of batter is taken as 10□ for positive and -10□ for negative batter piles. Different pile group are casted by varying the L/D ratio 7.5, 15, 22.5 for each set of pile groups.

2.3 Load Test on Pile Group

As per IS 1888-1982 (Method of load test on soils), the width of tank was selected as five times the width of footing. A mild steel tank of plan dimension 1000mmx1000 mm and depth 800 mm is used as model tank. Load cell of 50kN capacity is used for determining the load taken by the pile group placed at the center of pile cap. The Linear Variable Displacement Transducer (LVDT) is used for measuring displacement with accuracy of 0.01mm placed at two ends of the pile cap. The loading setup for vertical loading and lateral loading are shown in Figures 1 and 2.

Figure 1. Vertical loading arrangement of n batter pile group

Figure 2. Lateral loading of positive batter pile group

The model batter pile group load test is based on the Maintained Load Test (MLT) procedure as per IS: 2911 PART 4 – 1985and the test is continued until the pile group achieves ultimate capacity. Each load increment is measured by load cell of capacity 50kN and their corresponding settlements are measured using two LVDTs. The test is repeated for all pile groups and corresponding load – settlement is recorded.

2.4 Vertical Load Test Procedure

The final load is taken as one of the following for the vertical load testing on batter pile group:

- Final load at which the total displacement attains a value of 25 mm unless otherwise required in a given case on the basis of nature and type of structure.
- Two-thirds of the final load at which the total displacement attains a value of 40 mm.

2.5 Lateral Load Test Procedure

The final load is taken as one of the following for the lateral load testing on batter pile group:

- Final load at which the total displacement corresponds to 5mm.
- Fifty percent of the final load at which the total displacement increases to 12mm.
- Load corresponding to any other specified displacement as per performance requirements.

III. RESULTS AND DISCUSSION

The model pile group is of 8mm thick pile cap, the pile group fails at nearly 30mm for vertical loading and at nearly 8mm for lateral loading. In case of the vertical load test procedure the final load is taken for 25mm settlement. In case of the lateral load the final load is taken as the load corresponding to the 5mm settlement.as the pile groups fails after those specified settlement. The safe loads taken by each pile group are tabulated in table 2 and table 3.

From the model load test it is evident that the load carrying capacities on both vertical and lateral loading increases with increase in the L/D ratio of the pile group. As the pile length influences the shaft resistances therefore increase in length increases the load carrying capacities at both loading condition.

Table 2.
Vertical Load Carrying Capacity of Model Pile Groups

Batter Angle	L/D ratio		
	7.50	15	22.50
	Load (N)	Load (N)	Load (N)
0□	424.57	418.06	636.96
+10□	477.54	503.55	737.67
-10□	416.97	442.67	681.06

Table 3.
Lateral Load Carrying Capacity of Model Pile Groups

Batter Angle	L/D ratio		
	7.50	15	22.50
	Load (N)	Load (N)	Load (N)
0□	93.05	119.61	149.14
+10□	85.74	106.17	135.18
-10□	103.37	130.45	181.71

The comparative load – settlement graph for batter pile group carrying vertical load for each L/D ratio are shown in Figures.3 to 5.

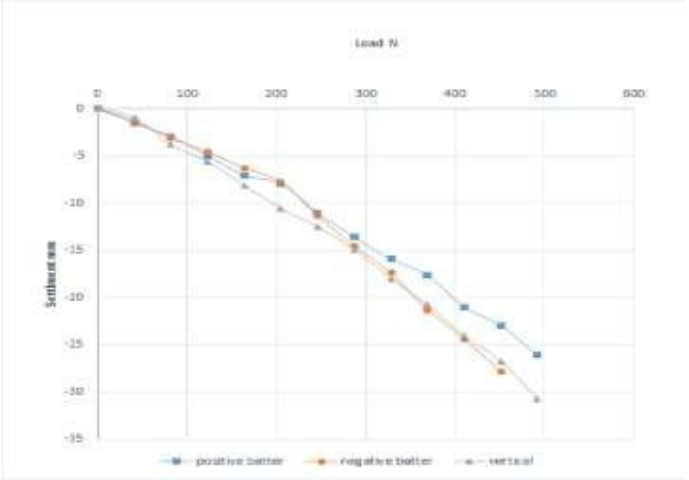

Figure 3. Load Settlement relationship of pile group with L/D = 7.5 under vertical loading

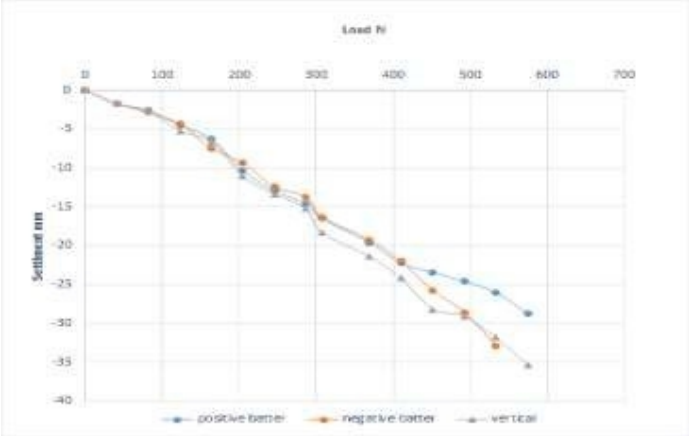

Figure 4. Load Settlement relationship of pile group with L/D = 15 under vertical loading

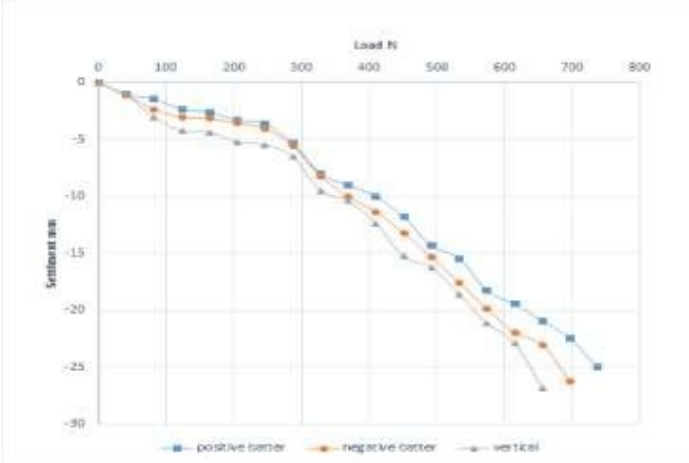

Figure 5. Load Settlement relationship of pile group with L/D = 22.5 under vertical loading

The influence of the batter angles shows predominant changes in the load carrying behaviour of the pile. From the Load settlement relationship for vertical

loading the positive pile groups show elastic behaviour on load sharing but the negative batter pile groups shows two stage behaviour as elastic at initial load condition and plastic under failure stage. The results prove that the positive batter pile groups have better vertical load carrying capacities than of the vertical or negative batter pile groups.

The comparative load – settlement graph for batter pile groups carrying lateral load for each L/D ratio are shown in Figures.6 to 8. Load Settlement relationship under lateral loading shows similar elasto plastic behaviour as the failure takes place gradually. As the direction of loading is in corresponding the batter pile angle positive batter pile groups fails suddenly but negative piles are opposite to the loading direction hence withstand more load than that of vertical pile groups.

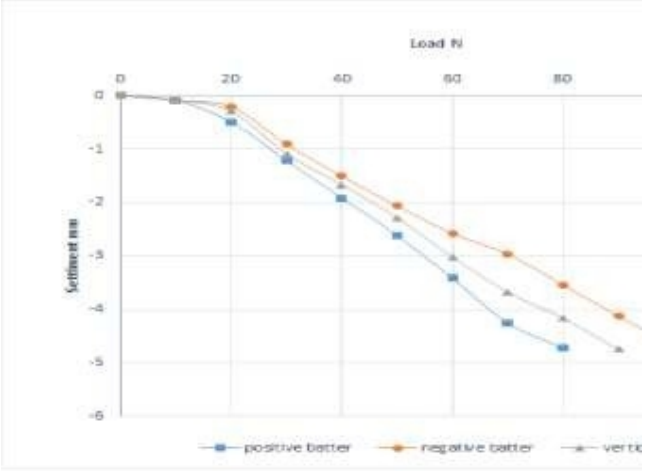

Figure 6. Load Settlement relationship of pile group with L/D = 7.5 under lateral loading

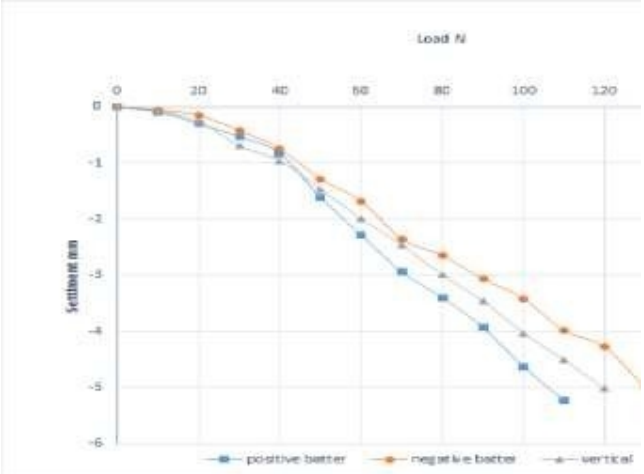

Figure 7. Load Settlement relationship of pile group with L/D = 15 under lateral loading

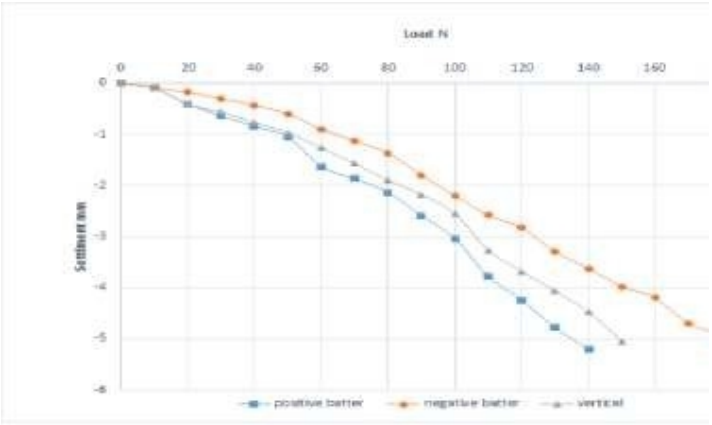

Figure 8. Load Settlement relationship of pile group with L/D = 22.5 under lateral loading

The lateral load capacities of the negative batter pile are comparatively high while considering the positive batter and vertical pile groups. As the negative batter piles are against the lateral loading direction it can resist more load than other pile groups.

IV. CONCLUSION

From the laboratory model study, the following conclusions were made

2.6 Vertical load

1. The positive batter pile group takes load as vertical pile group but towards the end it withstands about 15% to 20% of safe load than vertical pile group.
2. For negative batter piles the initial load capacity is high and it fails in same manner as the vertical pile group. The vertical load carrying capacity of negative batter pile group is about 10% -15% high compared to vertical pile group.

2.7 Lateral load

1. The initial load carrying behaviour of the pile groups is same as the loads are taken by the pile cap.
2. Positive batter piles capacity decreases due to influence of pile sinking as the load acting in same line of the inclination.
3. In case of negative batter piles the lateral capacity increases about 10% - 12% than vertical pile groups.

- The L/D ratio is having an influence over the pile group capacity in all cases of batter piles.
- The load carrying capacities of pile group increases as the L/D ratio increases.
- The difference is about 1% to 4% for both vertical and lateral loading conditions.
- The negative batter pile groups proves to be well behaving in combination as it shows 12% increase in vertical loading and 20% increase in lateral load compared to the vertical pile group.

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