Performance of Pile Group Embedded in Clayey Soil under Vertical and Lateral Loading

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Abstract : When soil of low bearing capacity extends to a considerable depth, piles are generally used to transmit vertical and lateral loads to the surrounding soil media. Pile foundation is used to transmit vertical and lateral loads to the surrounding soil media either as a single / mono pile or group piles. Behaviour of pile group under vertical and lateral loading is examined in clayey soil on steel pipe piles with external diameter and inside diameter of 25mm and 19mm respectively. 300 mm, 400 mm and 500 mm pile length is adopted for experiment work. For this study, pile cap made up of steel plate of size 200mm × 200mm × 20mm is used. The circular R.C.C. model tank with external diameter and inside diameter of 1000mm and 900mm respectively and height of 900mm is used. The dimension of base plate is taken as 1100mm × 1100mm and thickness of plate is 10mm. The effect of slenderness ratio (L/D) of 12, 16, and 20 on a small scale pile group configuration (2×2) is also examined by varying the pile length. The combined vertical and lateral loads were applied in two stages. In the first stage, vertical load was applied and then in the second stage, lateral loads were applied incrementally while keeping the vertical load constant. Results indicate that the load - displacement behaviour is nonlinear. Hollow pile foundation examination will be the most productive pile foundation technique as far as economy, stability, construction methods and post settlement problems to transfer to heavy loads safely to greater depths.

***Index Terms* - Vertical load, Lateral load, Pile group, Slenderness ratio**.

I Introduction

Deep foundations are required when the soil at shallow depth isn't fit for supporting structural loads. Pile foundation will be received if a firm stratum having wanted bearing capacity can't be come to by open excavation. These piles are used to support vertical loads, lateral loads, or a combination of vertical and lateral loads. However, in view of the complexity involved in analysing the piles under the combined loading, the current practice is to analyse the piles independently for vertical loads to determine their bearing capacity and settlement and to determine their flexural behaviour for the lateral load.

Studying the interaction effects on pile group under combined loads would no doubt call for precise and modern analysis. The writing accessible in this field is inadequate. The limited information on this topic based on analytical investigation (Davisson and Robinson 1965; Ramasamy 1974; Goryunov 1975) reveals that for a given lateral load, the lateral deflection increases with the combination of vertical loads. However, experimental (Pise 1975; Sarochan and Bykov 1956; Jain et al. 1987) and field investigation McNulty 1956; Bartolomey 1977; Zhokov and Balov 1978) suggest a decrease in lateral deflection with the combination of vertical loads. The experiment model testing would be the most suitable approach to study and analyse the response of pile under lateral load in the presence of vertical load. Sice the piles are not often adequately designed to resist lateral loads, the response of piles under lateral load in the presence of vertical loads is more critical and interesting for the design engineers. In addition, the impact of the pile slenderness ratio (L/D) is also important parameter to be considered in pile design. In perspective of this, the present paper focuses on study of pile group under pure lateral loads and combined vertical and lateral loads through model testing.

II MATERIAL USED

2.1 Soil

The Clay sample Collected from the Dholka, Ahmedabad, Gujarat.

2.2 Pile and Pile Cap

In this study, Mild Steel material is used as Pile and Pile Cap. Hollow pipes having an outside and internal diameter of 0.025m and 0.19m were used, respectively. The pile cap is of steel plate having dimension of 0.2m * 0.2m * 0.02m was used.

III EXPERIMENTAL INVESTIGATION

3.1 Test Programme

Total 15 number of lateral load tests were conducted on clay with no vertical load and with constant magnitude of vertical load (in range of 25%, 50%, 75% and 100% of Ultimate vertical load).

3.2 Soil Properties

Table 1 IDETIFICATION OF SOIL PROPERTIES

Sr. no.	Test	IS Code	Symbol	Determination
1	Soil Classification	IS 1498-1970	-	CL
2	Specific Gravity	IS: 2720 Part 3	G	2.8
3	Liquid limit	IS: 2720 Part 5	LL	34
4	Hydrometer	IS: 2720 Part 4	Clay Silt	27% 65%
5	Plastic limit	IS: 2720 Part 5	PL	25%
6	Plasticity Index	IS: 2720 Part 5	PI	9%
7	Shrinkage limit	IS: 2720 Part 6	SL	11.34%
8	Swell Index	IS: 2720 Part 40	FSI	18.48%
9	Standard Proctor Test	IS: 2720 Part 7	OMC MDD	15% 18.30 kN/m^3

3.3 Test setup

Model pile load test was conducted on low plastic clay the Geotechnical Laboratory, Applied Mechanics Department, L.D. College of Engineering, Ahmedabad. The experimental test were performed on model pile group in a RCC circular tank of Internal diameter = 0.9m and External Diameter = 1.0m with Height of tank = 0.9m as shown in fig. 1. The boundary of the tank affect the stress and displacement fields in the soil therefore general clearance of minimum five times the pile-diameter was maintained between the bottom of the tank and bottom surface of mild steel hollow pile, also dimensions of the tank provides a minimum lateral clearance of five times the pile diameter. The soil model was prepared by compacting the clay in layers, each of 0.1m thick up to 0.75m height. The clay bed was prepared at OMC = 6% and MDD = 1.63gm/cc. Sufficient time was allowed for the clay to regain its original shear strength before commencing the tests, which depends on the degree of disturbance during pile installation and thixotropic nature of the clay.

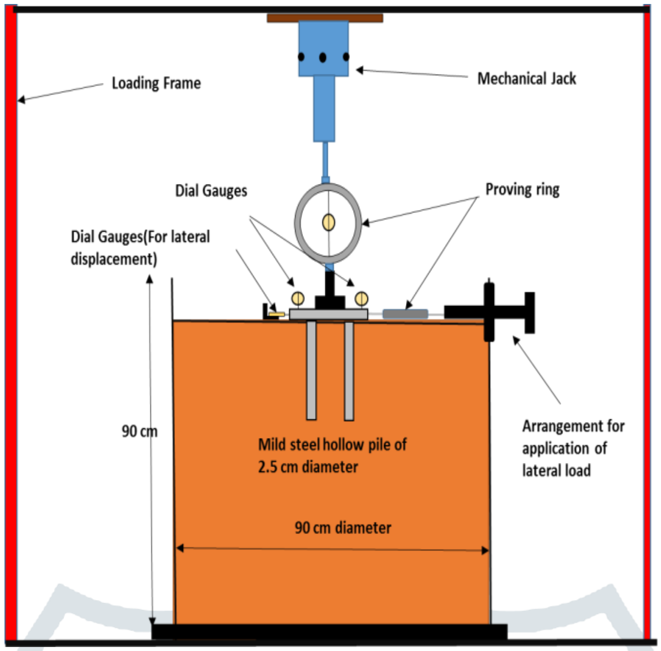

Fig. 1 Schematic Diagram of Test Setup

3.4 Instrumentation

Piles were instrumented for measuring displacement at the top of the pile. The dial gauge tip was rested on pile cap.

Fig. 2 Experimental setup for the test

3.5 Pile Installation

The pile group was placed with the tip resting on the clay surface in the test tank. A 5 mm thick plate was placed over the pile cap. The pile group were gradually driven into the clay bed by gentle blow with a small weight on the steel plate. The verticality of pile group the pile group was checked with a plumb. The pile of 300 mm, 400 mm and 500 mm length was driven to a depth of 270 mm, 370 mm and 470 mm separately from the clay surface because the pile top head was kept 30 mm over the clay surface to influence provision for application of lateral load.

3.6 Test Procedure

A series of 15 tests were carried out on pile group with different magnitude of constant vertical load. Lateral load tests were carried out on pile group for no vertical load and for 25%, 50%, 75% and 100% of the Ultimate vertical load. The vertical and lateral loading was applied using mechanical jack. The horizontal displacement of the pile head was measured using mechanical dial gauge. Each load increment was maintained for a minimum of 30 minute till the displacement stabilized with no movement.

The combined loads are applied in two stages. In the first stage, vertical load were applied and then in the second stage, lateral loads were applied while the vertical load was kept constant. This type of loading is similar to that in field situation such as overhead water tank, pile jetties, transmission line towers, etc. Here, the piles are first under vertical loading from the weight of superstructure. The lateral loading may be caused by wind, wave action, ship impact, etc. while the piles are under vertical loads.

IV RESULTS and DISCUSSION

Lateral load – Displacement curves from 15 tests carried out on pile group embedded in clayey soil with and without vertical load as show in fig. 3 to fig. 7. Soil failure occurs before failure of the pile. Hence, the lateral response of pile will be governed by the ultimate lateral load carrying capacity of the soil. The ultimate lateral resistance of pile group under constant magnitude of vertical load was obtained from the lateral load-displacement curves.

The ultimate lateral resistance of pile group under pure lateral load is 600 N, 800 N and 1000 N for 0.3m, 0.4m and 0.5m.

The lateral load carrying capacity of pile group is increased when it is subjected to vertical load. The increase in ultimate lateral resistance of pile when subjected to 25%, 50%, 75% and 100% of the ultimate vertical load with respect to pure lateral load test is 1.33 times, 1.67 times, 2.5 times and 3.33 times respectively for L/D = 12. For L/D = 16, the increase in ultimate lateral resistance of pile when subjected to 25%, 50%, 75% and 100% of the ultimate vertical load with respect to pure lateral load test is 1.875 times, 2.5 times, 3.125 times and 3.125 times respectively. For L/D = 20, the increase in ultimate lateral resistance of pile when subjected to 25%, 50%, 75% and 100% of the ultimate vertical load with respect to pure lateral load test is 2 times, 2.5 times, 235 times and 4 times respectively.

The comparison of the effect of vertical load on the lateral response of the piles for various percentage of constant magnitude of vertical load is shown in the fig. 8 to fig. 10. The application of vertical load clearly shows the increase in the ultimate lateral resistance of pile.

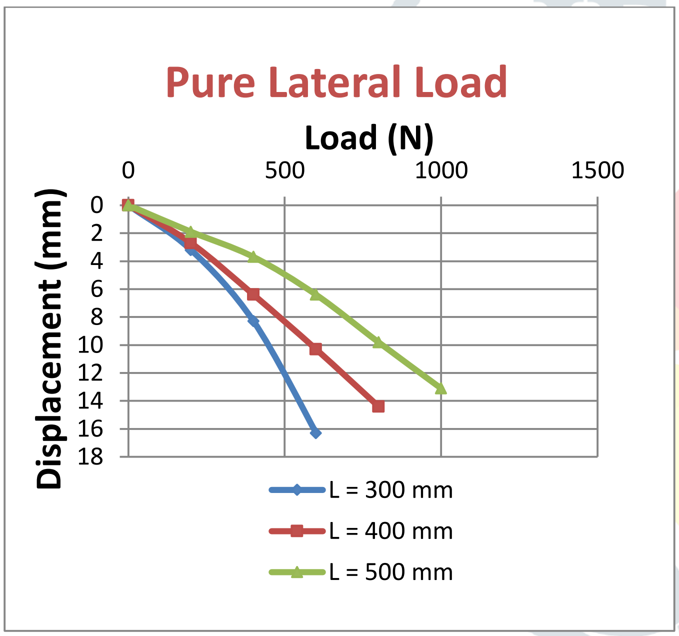

Fig. 3 Lateral load – Displacement curve (NO vertical load)

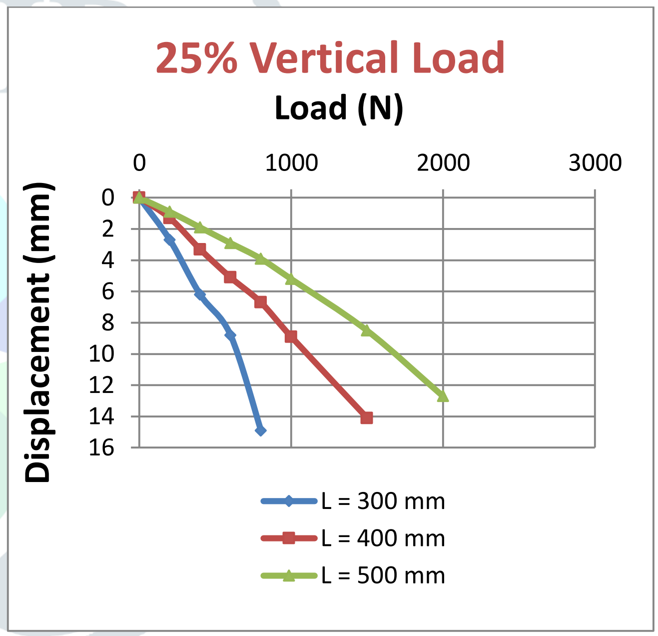

Fig. 4 Lateral load – Displacement curve (25% vertical load)

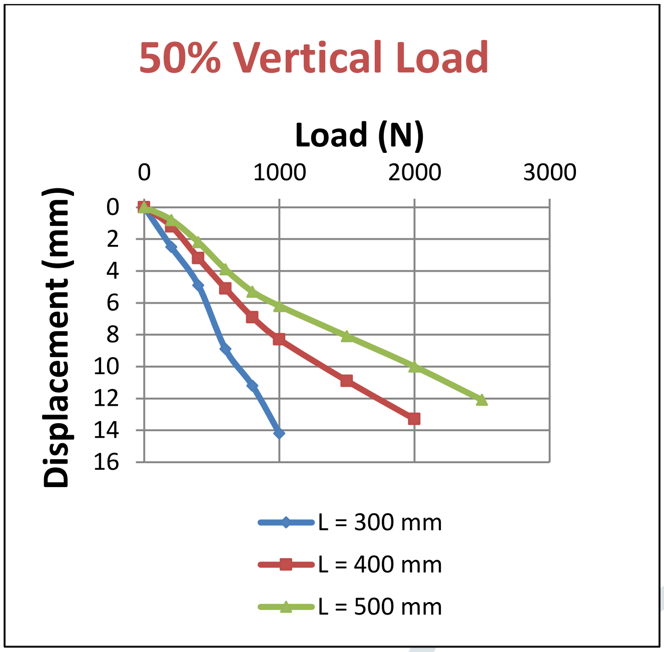

Fig. 5 Lateral load – Displacement curve (50% vertical load)

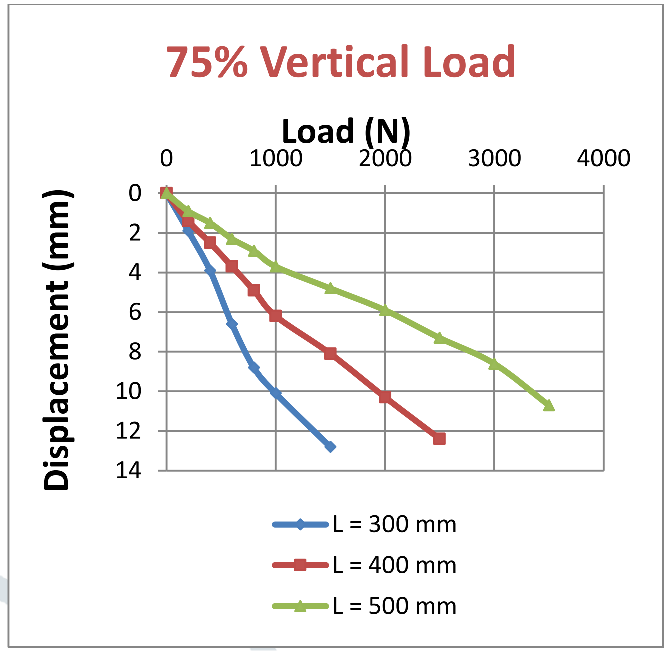

Fig. 6 Lateral load – Displacement curve (75% vertical load)

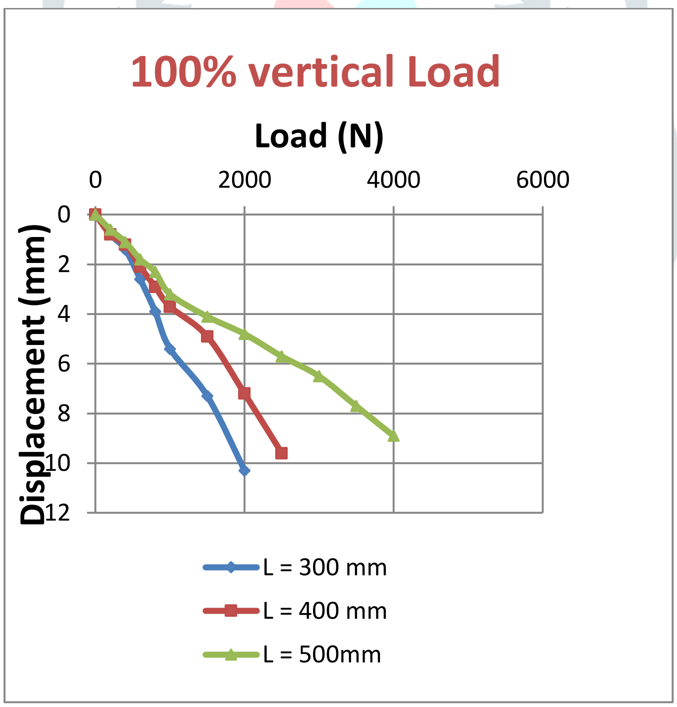

Fig. 7 Lateral load – Displacement curve (100% vertical load)

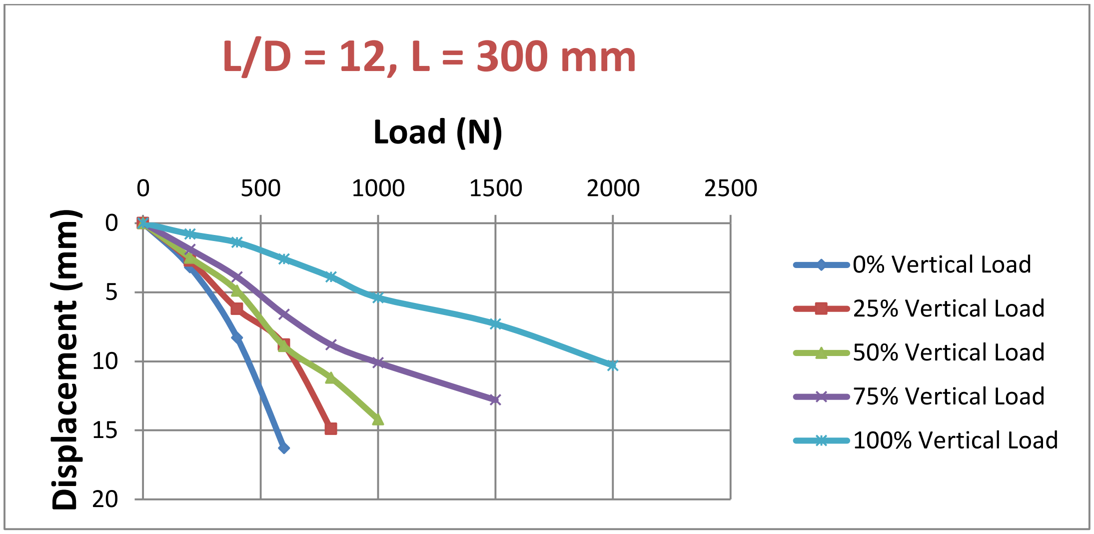

Fig. 8 Comparison of lateral load – Displacement results for different vertical load

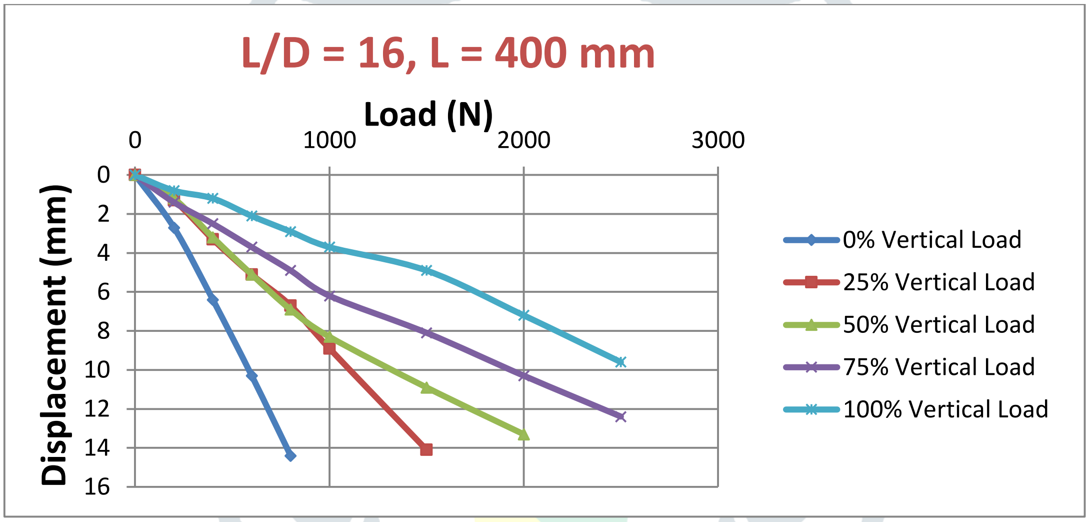

Fig. 9 Comparison of lateral load – Displacement results for different vertical load

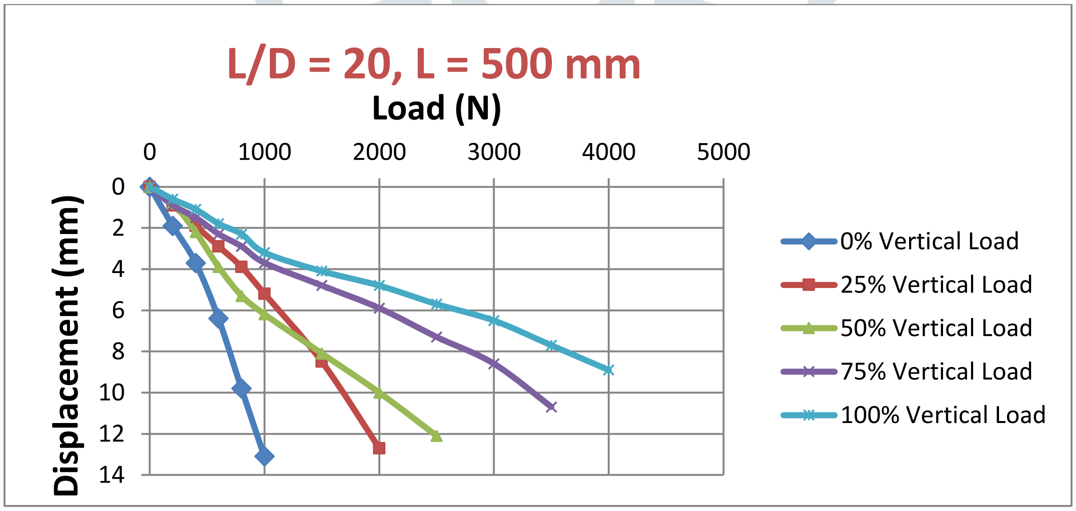

Fig. 10 Comparison of lateral load – Displacement results for different vertical load

V CONCLUSION

Model tests were carried out on Mild Steel pile group of fixed L/D ratio of 12, 16 and 20. For various slenderness ratio of the pile the lateral reaction of the group of piles was considered. Similarly the impact of vertical load (25%, 50%, 75% and 100%) on the lateral reaction of the group of piles for various slenderness ratio (12, 16 and 20) was likewise considered.

The test result are analysed and presented here:

- The increase in ultimate lateral resistance of pile when subjected to 25%, 50%, 75% and 100% of the ultimate vertical load with respect to pure lateral load test is 1.33 times, 1.67 times, 2.5 times and 3.33 times respectively for L/D = 12.
- For L/D = 16, the increase in ultimate lateral resistance of pile when subjected to 25%, 50%, 75% and 100% of the ultimate vertical load with respect to pure lateral load test is 1.875 times, 2.5 times, 3.125 times and 3.125 times respectively.
- For L/D = 20, the increase in ultimate lateral resistance of pile when subjected to 25%, 50%, 75% and 100% of the ultimate vertical load with respect to pure lateral load test is 2 times, 2.5 times, 235 times and 4 times respectively.

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