EFFECT OF VERTICAL LOAD ON THE LATERAL BEHAVIOUR OF GROUP OF PILES

Ashish K. Masani[1], Prof. M. G. Vanza[2]

[1]*PG Student, Applied Mechanics Department, L D College of Engineering, Ahmedabad, Gujarat, India*
[2]*Associate Professor, Applied Mechanics Department, L D College of Engineering, Ahmedabad, Gujarat, India*

ABSTRACT

On the response of piles for combined vertical and lateral loads in the laboratory and field test data are limited. The current practice for design of piles is to consider the vertical and lateral loads independent of each other. This paper presents the effect of vertical load on the behaviour of a group of piles under lateral load through laboratory experiments on aluminium pipe piles with outer diameter of 25 mm and internal diameter of 19mm. Pile was driven in poorly graded sand with 60% relative density. Influence of constant magnitude of vertical load (in range of 20%, 40%, 60%, 80% and 100% of Experimental Ultimate Vertical Load) on the lateral response of group of piles for slenderness ratio of 10 and 15 was studied. Pile was instrumented with dial gauges to measure deflection at top of group of piles. The test results have shown a significant increase in the load resisting capacity under vertical loads on the lateral response of group of piles due to increasing length of piles from 250 mm to 375 mm in sandy soil. The test results are compared with the results from the literature and are found to be in favourable agreement. This research of hollow pile foundation will be the most efficient pile foundation technique in terms of economy, stability, construction methods and post settlement problems to transfer very heavy dynamic loads safely to greater depths.

Keywords: - *Pile load test, Lateral load test, Combined load, Lateral load test*

1. INTRODUCTION

Pile foundation are extensively used to support various structures built on loose/soft soils, where shallow foundations would undergo excessive settlements or shear failure. 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 combined loading, the current practice is to analyse the piles independently for vertical loads to determine their bearing capacity and settlement and for the lateral load to determine their flexural behaviour.

The methods of analysing commonly used in predicting the behaviour of piles and pile groups under pure axial loads could be categorized into (1) subgrade reaction method (Coyle and Reese 1996; Kraft et al. 1981; Zhu and Chang 2002); (2) elastic continuum approches (Poulos 1968; Xu and Poulos 2000); and (3) finite-element methods (Desai 1974; Trochanis et al. 1991; Wang and Sitar 2004). Similarly, the methods to study the behaviour of piles and pile groups under pure lateral loads could be categorized into (1) limit state method (Broms 1964); (2) subgrade reaction method (Matlock and Reese 1960); (3) elastic continuum approach (Poulos 1971; Banerjee and Davis 1978); (4) p-y method (Reese et al. 1974); and (5) finite-element methods (Muqtadir and Desai 1995; Yang and Jeremic 2002; Yang and Jeremic 2005).

Studying the interaction effects on group of piles under combined loads would no doubt call for a systematic and sophisticated analysis. The literature availabe in this field is sparse. The limited information on this topic based on analytical investigations (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 investigations (McNulty 1956; Bartolomey 1977; Zhukov and Balov 1978) suggest a decearse in lateral deflection with the combination of vertical loads. S. Karthigeyan, V.V.G.S.T. Ramakrishna and K. Rajagopal (2007) [1] attempted to explain this phenomenon by three-dimensional (3D) finite element analysis and reported that (1) the response of the piles in both clayey and reported that (2) the presnece of vertical loads increases the lateral load capacity of piles in sandy soils by as much as 40% depending on the level of vertical load. Thus experiment model testing would be the most suitable approach to study and anaylse the response of pile under lateral load in the presense of vertical load. Since 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. Besides, the influence of the pile slenderness ratio (L/D) is also an important parameter to be considered in pile design. In view of this, the present paper focuses on the study of group of piles subjected to pure lateral loads and combined vertical and lateral loads through model testing. The details of the numerical model, the validation of the developed model against some field cases, and results from parameteric studies are discussed in the paper.

2. EXPERIMENTAL INVESTIGATION

2.1 Test Programme

Total 12 number of lateral load tests were conducted on sand with no vertical load and with constant magnitude of vertical load (in range of 20%, 40%, 60%, 80% and 100% of Ultimate vertical load).

2.2 Test Setup

Model pile load test was conducted on sand in the Geotechnical Laboratory, Applied Mechanics department, L.D. College of Engineering, Ahmedabad. The experimental tests are performed on model group of piles in a RCC circular tank of Internal diameter = 0.9 m, external diameter = 1.0 m and Height of tank = 0.9 m as shown in Fig. 1. The boundaries of the tank affects the stress and displacement fields in the soil therefore general clearance of minimum five times the pile-diameter was maintained between the bottom of tank and bottom surface of aluminium 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 sand in layers, each of 100 mm thick up to 750 mm height. The sand was compacted at a relative density of 60%.

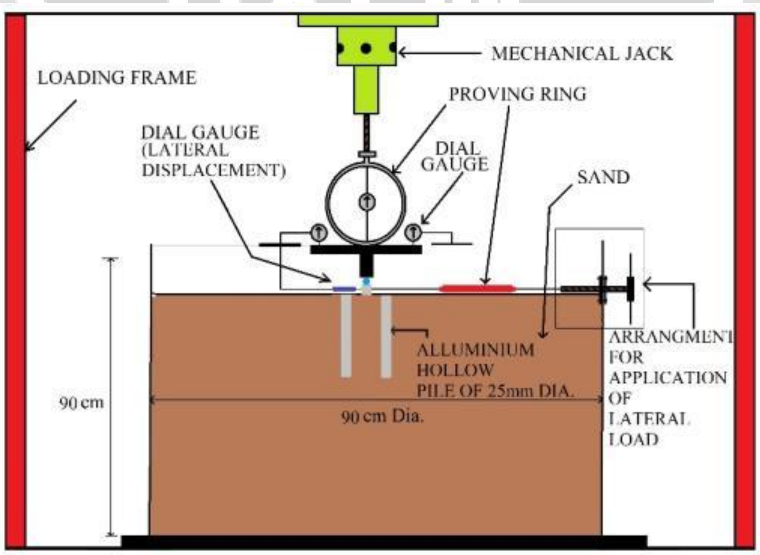

Figure-1: Schematic Diagram of Test Setup

2.3 Properties of Sand

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

For all tests, the sand was placed with a relative density of 60%. To achieve uniform density, the surface vibration technique, with the surface vibrator device was used.

Table 1: Physical properties of sand

Test	Symbol	Determination	IS Code
Soil classification as per IS		Poorly Graded Sand(SP) $C_u = 2.2$ $C_c = 1.25$	IS :1498 - 1970
Specific Gravity	G	2.7	IS :2720 (Part 3)-1980
Relative density	I_d	$I_d = 60\%$ $\rho min = 16.78 KN/m^3$ $\rho max = 18.18 KN/m^3$	IS :2720 (Part 14)-1983
Φ of sand	Φ	36^0	IS :2720 (Part 13)-1997

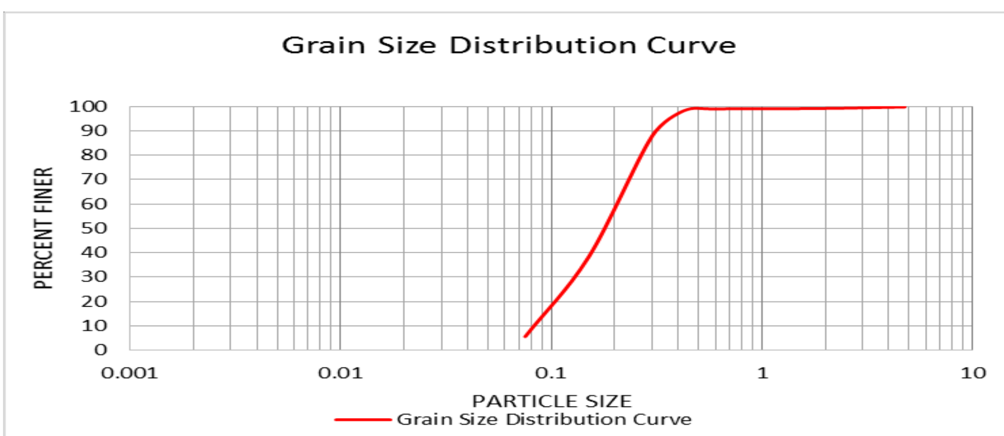

Figure-2: Grain size distribution graph

2.4 Model Piles and Instrumentation

Aluminium pipes with outer diameters of 25 mm and wall thicknesses of 3 mm were used as model piles. L/D ratio was 10 and 15 so the length of pile was 250 mm and 375 mm respectively. Piles were instrumented for measuring displacement at the top of the pile. The dial gauge was kept on pile cap edge. The dial gauge tip was rested on the pile cap.

Figure 3. Experimental setup for the test

2.5 Pile Installation

The group of piles was placed with the tip resting on the sand surface in the test tank. A 6-mm-thick steel plate was placed over the pile cap. The group of piles were slowly driven into the sand by gentle blows with a small weight on the steel plate. The verticality of the pile group was checked with a plumb after every 50 mm penetration. The pile of 250 mm and 375 mm length was driven to a depth of 220 mm and 345 mm respectively from the sand surface. The pile cap head was kept 30 mm above the sand surface to make provision for application of lateral load.

2.6 Test Procedure

A series of 12 tests were carried out on group of piles with the different magnitude of constant vertical load. Lateral load tests were carried out on group of piles for no vertical load and for 20%, 40%, 60%, 80% and 100% of the Experimental Ultimate Vertical Load. The lateral load was applied by about 10 equal increments. The horizontal displacement of the pile head was measured using mechanical dial gauges. Each load increment was maintained for a minimum of 30 min till the displacement stabilized with no movement.

The combined loads are applied in two stages. In the first stage, vertical loads 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 situations such as pile jetties, transmission line towers, and overhead water tanks, etc. Here, the piles are first subjected to vertical loading from the weight of the deck or superstructure. The lateral loading may be caused by wind, wave loading, ship impact, etc. while the piles are subjected to vertical loads.

3. RESULTS AND DISCUSSION

The ultimate load carrying capacity of the pile for the compression test is 9933 N from theory. Lateral load-Displacement curves from 12 tests carried out on group of piles embedded in sand with and without vertical load shown in Fig. 4 to Fig. 9. Soil failure occurs before the failure of 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 group of piles subjected to constant magnitude of vertical load was obtained from the lateral load-displacement curves.

The ultimate lateral resistance group of piles subjected to pure lateral load is 800 N.

The lateral load carrying capacity of group of piles is increased when it is subjected to vertical load. The increase in ultimate lateral resistance of pile when subjected to 20%, 40%, 60%, 80% and 100% of ultimate vertical load with respect to pure lateral load test is 2.3 times, 3.6 times, 4.7 times, 5.5 times and 6.9 times respectively.

The comparison of the effect of vertical load on the lateral response of the group of piles for various percentage of constant magnitude of vertical load is shown in the Fig. 9 and Fig. 10. The application of vertical load clearly shows the increase in the ultimate lateral resistance of pile.

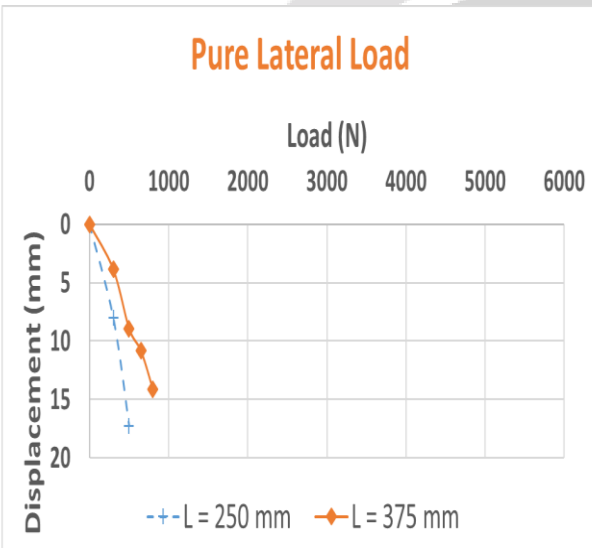

Figure-4: Lateral load vs Displacement graph for NO vertical load

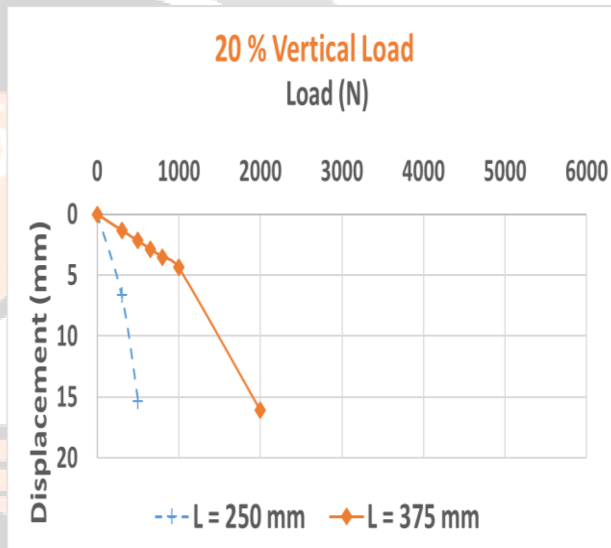

Figure-5: Lateral load vs Displacement graph for 20% vertical load

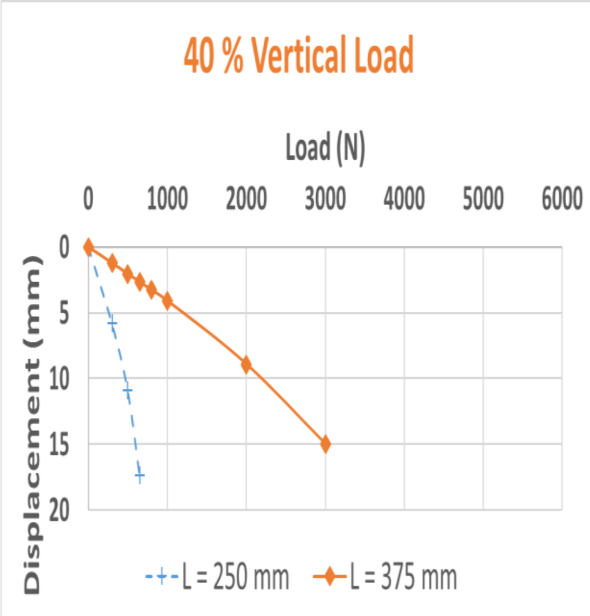

Figure-6: Lateral load vs Displacement graph for 40% vertical load

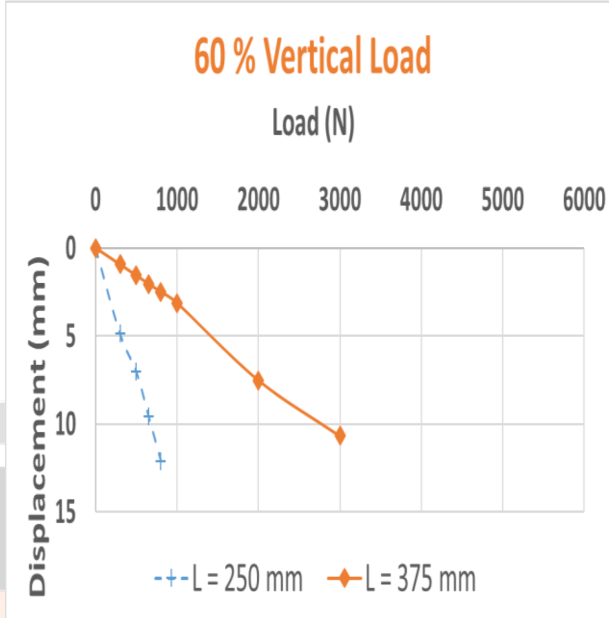

Figure-7: Lateral load vs Displacement graph for 60% vertical load

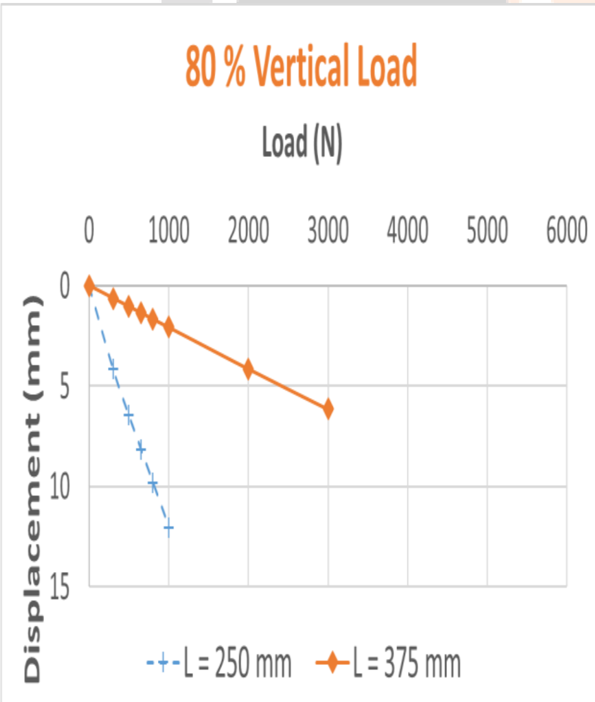

Figure-8: Lateral load vs Displacement graph for 80% vertical load

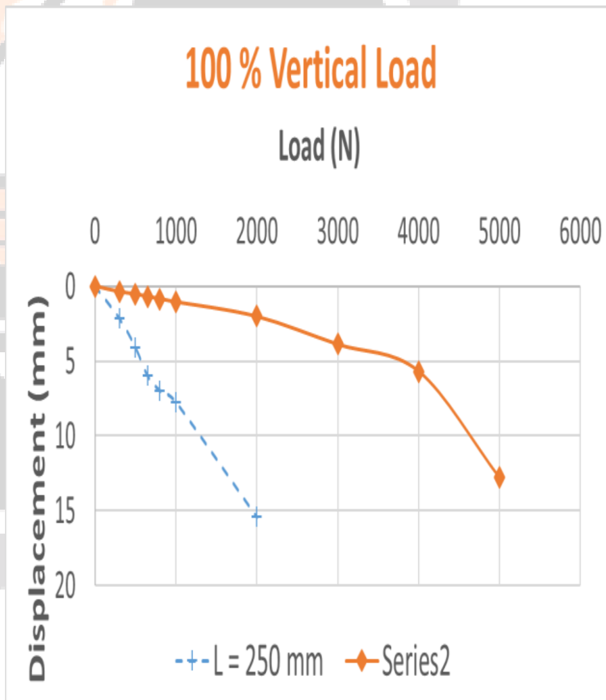

Figure-9: Lateral load vs Displacement graph for 100% vertical load

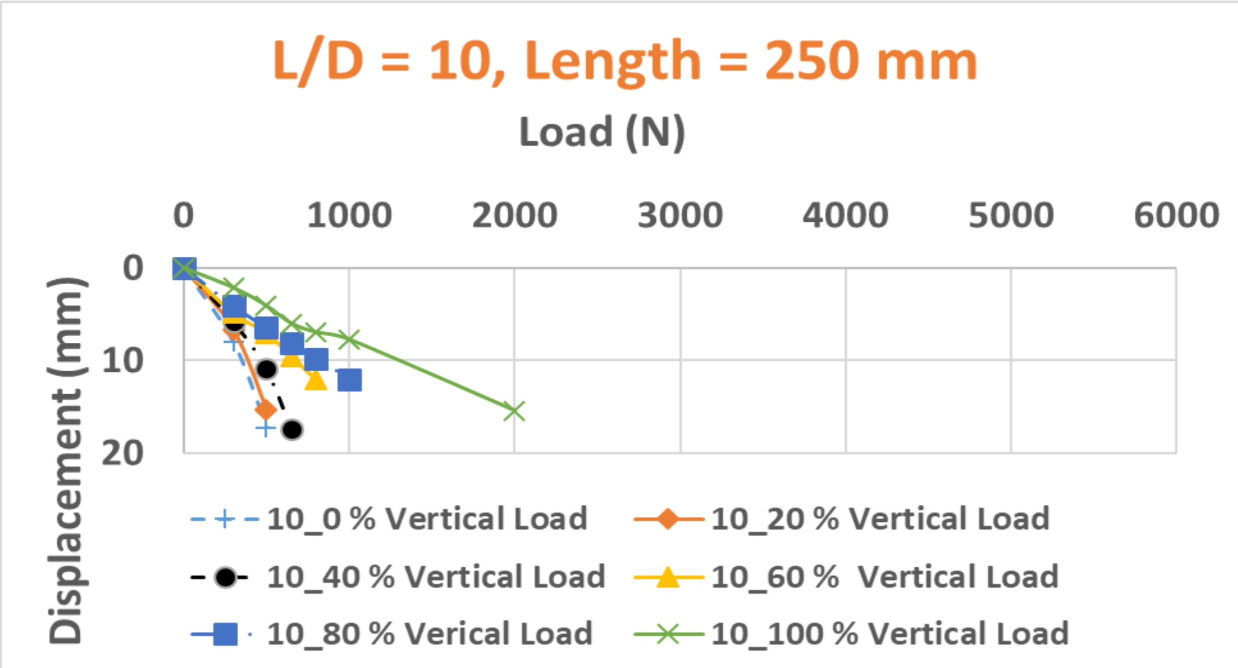

Figure-10: Comparison of Lateral load vs Displacement result for different vertical load

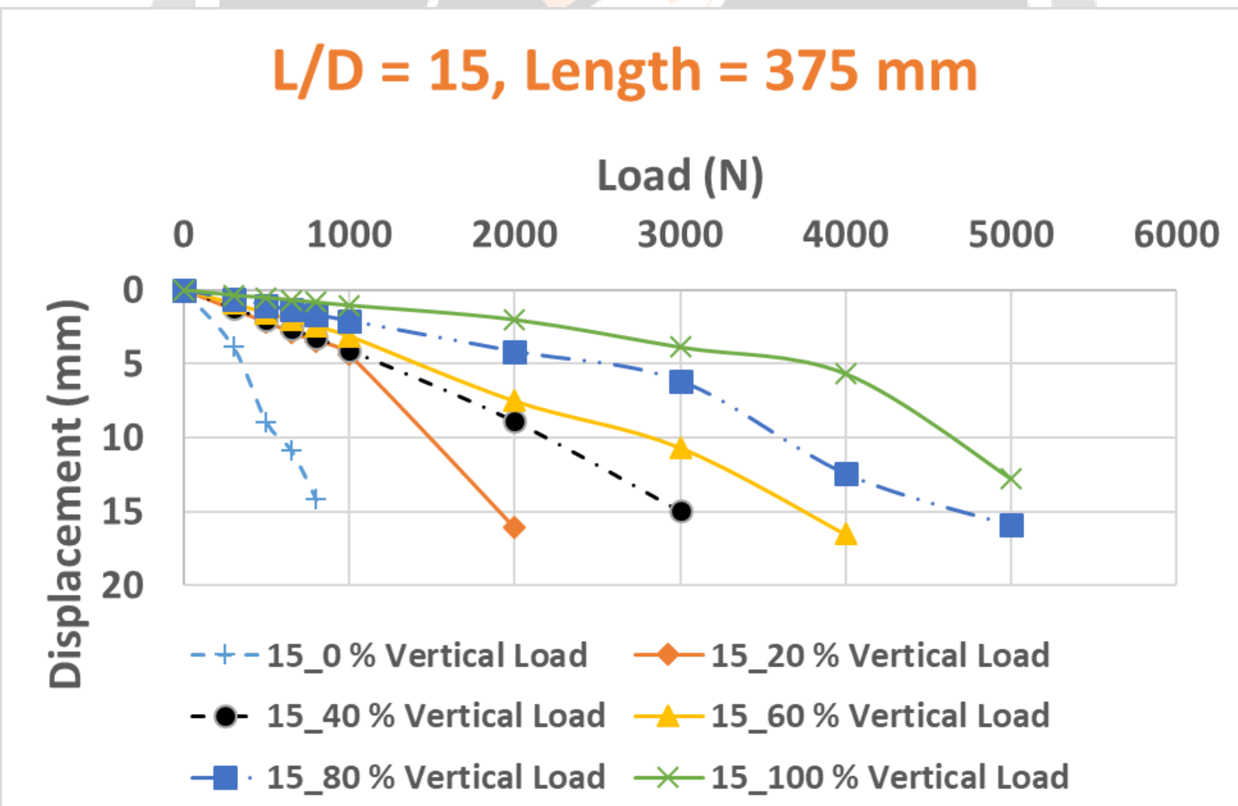

Figure-11: Comparison of Lateral load vs Displacement result for different vertical load

4. CONCLUSION

Model tests were carried out on Aluminium group piles of fixed L/D ratio of 10 and 15. The test results are analyzed and presented in here. Based on the foregoing study, the following conclusions are drawn:

- The vertical load has a significant influence on the response of group of piles embedded in sand as pile induces complex interaction effects due to simultaneous mobilization of passive earth pressure due to a horizontal load and pile skin friction due to vertical load.
- The ultimate lateral resistance of group of piles increases with the increase in the magnitude of vertical load up to 6.9 times with respect to pure lateral load test.

5. ACKNOWLEDGEMENT

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