Effect of Length to Diameter Ratio on the Load-Deflection Characteristics of Laterally Loaded Driven Piles in Sand

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Abstract

Lateral load analysis for different structures has become a subject of interest to researchers in recent years. In this study, experiments were conducted on a small scale model of driven piles in sand. Steel pipes having outer diameter of 26.7 mm and wall thickness of 2 mm were used as model piles. A concrete tank having dimensions of 1m height, 1m width and 1m depth was filled in by using the locally available sand. While filling the model tank layer by layer with sand, special care was taken to ensure the same density of sand in each layer. Two pile group and three pile group configurations were used in this study. In addition to the pile group, tests on single pile were also conducted so that a comparison could be made with the group piles. The embedment length (L) to diameter (d) ratios (L/d) were chosen to be 14 and 16 with center to center pile spacing of 3d to perform these experiments. Static lateral load was applied to the piles and the lateral displacement was measured by using the dial gauge for each increment of applied load. Load-deformation characteristics were examined for different L/d ratios. It is observed that L/d ratio has significant influence on the load-deflection characteristics of lateral loaded driven piles in sand. The lateral load carrying capacity of pile increases with the increase of L/d ratio. The deflection of pile decreases with the increase of L/d ratio for a given load and the differences intensify as the load increases.

Keywords: *Lateral Load, Length to Diameter Ratio, Driven pile, Sandy soil.*

1 Introduction

Perturbation due to load on an infrastructure is restrained by pile foundation. Pile is a robust mean to face the structural load and raise the compatibility to ensure an unquestionable ambient for a structure by conveying the loads to the region regarded as almost impregnable explored under the structure. To figure out the lateral load resistance capacity, impact of soil and pile parameters, various theoretical, experimental and analytical means were triggered. The prerequisites such as: (i) immunity to the lateral load resistance, (ii) bridled deflection of the piles must be met for the aforementioned foundations experiencing lateral and cyclic loading due to multiple forces and hazards or calamities.

Meyerhof et al. (1972) fingered central oblique loads on single and group piles in homogeneous sand and proposed a semi-empirical relationship to consider elliptical discrimination in ultimate resistance under axial to lateral load. To determine shadowing impact, Brown et al. (1988) carried out large scale pile tests on group pile and isolated single pile under two way cyclic lateral loadings. Franke (1988) conducted model tests on bored piles in laboratory. The consequences of bored pile, test triggered by Franke (1988), tried to establish that the displacement of pile group for a spacing was less than 6d, which was more than a single pile. Impact of soil stratification in ultimate pile capacity was found out by Laman et al. (2011) and Kam et al. (2018), respectively. Meyerhof et al. (1988) detailed lateral loading tests on pile groups and flexible model piles in loose sand and coined that the ultimate lateral resistance can be showed in terms of equivalent rigid pile by considering an effective embedment depth. McVay et al. (1995) maneuvered the centrifuge tests on single and 3x3 pile groups at 3d and 5d pile spacing which indicated that group efficiency is independent of soil density. Patra et al. (2001) formulated the experimental process for single and pile groups on smooth and rough piles and demonstrated that rough piles have a better resistance than smooth piles. Kim et al. (2001) wagered a compatibility factor for different pile set up and different pile head restraining means by considering present devices.

This paper delineates various tests maneuvered on group piles for various test set up to observe the consequences under static lateral loads. To observe the geotechnical properties, several experiments of sand were carried out. The impact of length to diameter ratio (L/d) for different pile-group configurations on the laterally loaded driven piles in a homogeneous sandy soil were studied and the load-deflection characteristics were reported in this paper.

2 Experimental Program

As stated earlier, small scale model tests were performed in homogeneous sand considering different configurations for driven pile groups. The experimental programs to carry out the model tests were reported in the subsequent sections.

2.1 Properties of Sand

Properties of sand obtained from different laboratory tests were presented in Table 1.

Table 1. Properties of sand used in the model test

Properties of sand	Values
Specific Gravity (G_s)	2.65
Fineness Modulus (FM)	1.20
Max. Unit Weight (γ_{max})	1.53 gm/cc
Min. Unit Weight (γ_{min})	1.20 gm/cc
Uniformity Coefficient (C_u)	1.83
Coefficient of Curvature (C_c)	0.926
Friction Angle (∅)	36.82°
D10, D30, D50, D60	0.159 mm, 0.207 mm, 0.257 mm, 0.291 mm

2.2 Properties of Testing Pile and Pile Cap

Outer diameter and wall thickness of testing piles made of steel were 26.7 mm and 2 mm, respectively. A steel plate having a thickness of 0.64 cm was taken as a pile cap. Flexible steel wire was used to facilitate the application of loads with the help of a frictionless pulley.

2.3 Configurations of Pile Group

In this study, two pile group and triangular pile group systems were used for different L/d ratios. A single pile of equal L/d ratio was considered as well for the comparison of group effect with the single pile. Figure 1 demonstrates the configuration of single pile, two pile group and triangular pile group with the spacing of 3d between piles. To perform the study, L/d ratios were chosen to be 14 and 16. In Figure 1, arrow indicates the direction of lateral load applied to the single or group piles.

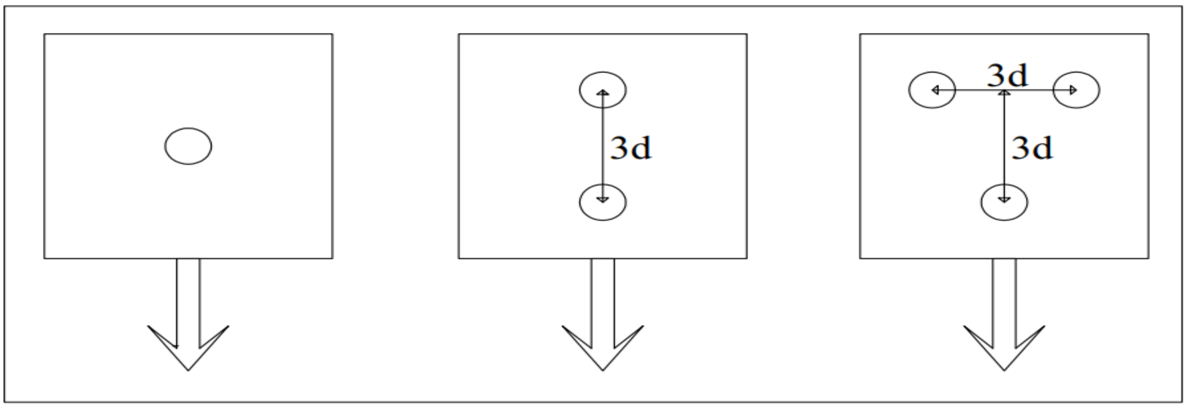

Figure 1. Single and group pile arrangements with the direction of applied load.

2.4 Experimental Setup and Test Procedures

Figure 2 shows different components of a cube shaped model tank having a volume of 1 m^3. Different methods were introduced by different researchers to fill in the model tank by the soil considered in the study. In the present study, compaction technique was adopted. While filling the model tank with sand, the tank was divided into 10 equal layers. Then, each layer was filled in by a certain weight of sand and compacted sufficiently to the layer mark. The next layer was filled in with the same weight of sand. The same procedure was repeated for the subsequently layers. This ensured almost the same density of soil in each layer. After the model tank was filled in completely, the steel pile cap was kept over the top of sand and the steel piles were driven into the sand through the holes already made in the pile cap. Lateral load was applied using a frictionless pulley and weir to the piles. A sensitive dial gage was attached with the pile cap to measure the lateral displacements. Static load was applied on the piles in the order of 0.50, 1.0, 1.50, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10, 12, 14, 16, 18, 20, 22, 26, 30, 34, 38, 40 kg and so on. The same order of loading was adopted for all the experiments. Dial gauge of 0.01 mm sensitivity was taken to measure the displacement of pile head at each increment of load.

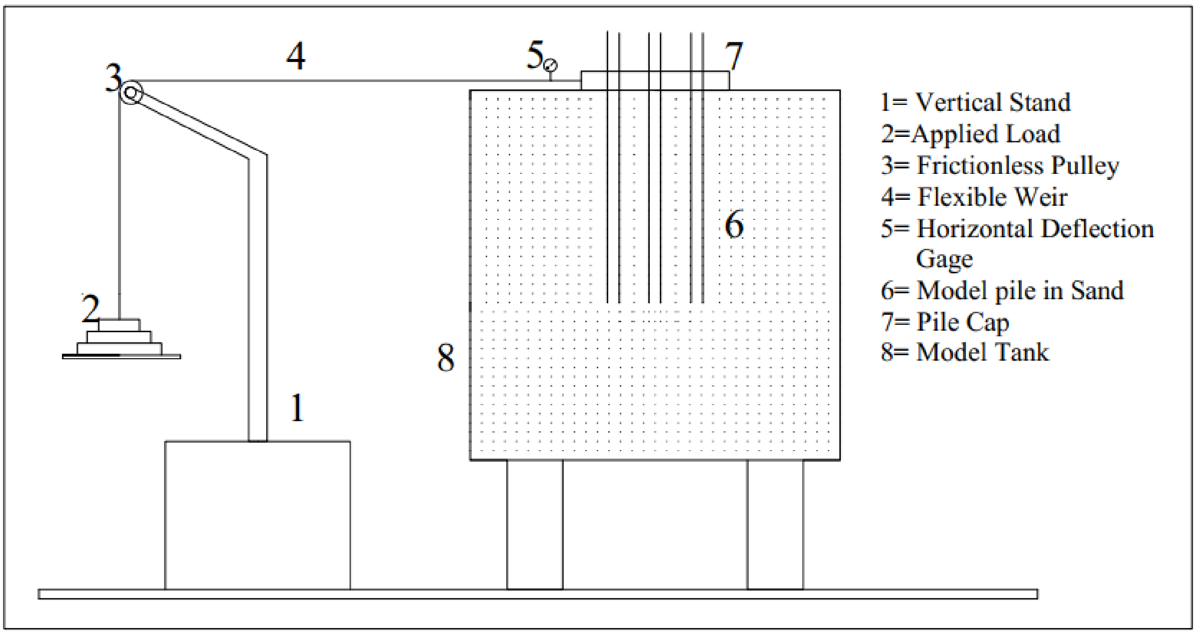

Figure 2. Side view of the experimental setup.

3 Results and Discussion

3.1 Effect of Length to Diameter Ratio

Several tests were conducted to investigate the effect of length to diameter (L/d) ratio to the load-deflection characteristics of laterally loaded driven piles in sand. Figure 2 depicts the effect of L/d ratio on the load deflection characteristics of single, two pile group and the three pile group, respectively. It is noticeable that the load-deflection behaviors are non-linear in nature. The lateral load carrying capacity of pile increases with the increase of L/d ratio regardless of the configurations of pile group used. It should also be noted that the slope of the load deflection curve is getting stiffer as the L/d ratio increases. From Figure 3, it is observed that the deflection of pile decreases with the increase of L/d ratio for a given load and the differences intensify as the load increases. This behavior is factual whatever the configuration of pile group may be. It is interesting to note that the stiff behavior of load-deflection curve is noticed only at the small strain level. The ratios of lateral end deflection at a given load and condition for L/d =14 and L/d=16 is almost same regardless of the configuration of the pile group.

3.2 Effect of the Configuration of Pile Group

The effect of configuration of pile group on the load-deflection characteristics of laterally loaded driven piles in sand for different L/d ratios is depicted in Figure 4. The initial slope of the load deflection curve changes as the configuration of pile group changes. The slope of the load deflection curve becomes stiffer as the number of piles increases. L/d has a significant role in increasing the slope of the load deflection curve regardless of the configuration of the pile group subjected to the lateral load. The evolution tendency of load-deflection curve for group pile is almost same as the single pile except their reduced values of deflection for a given load.

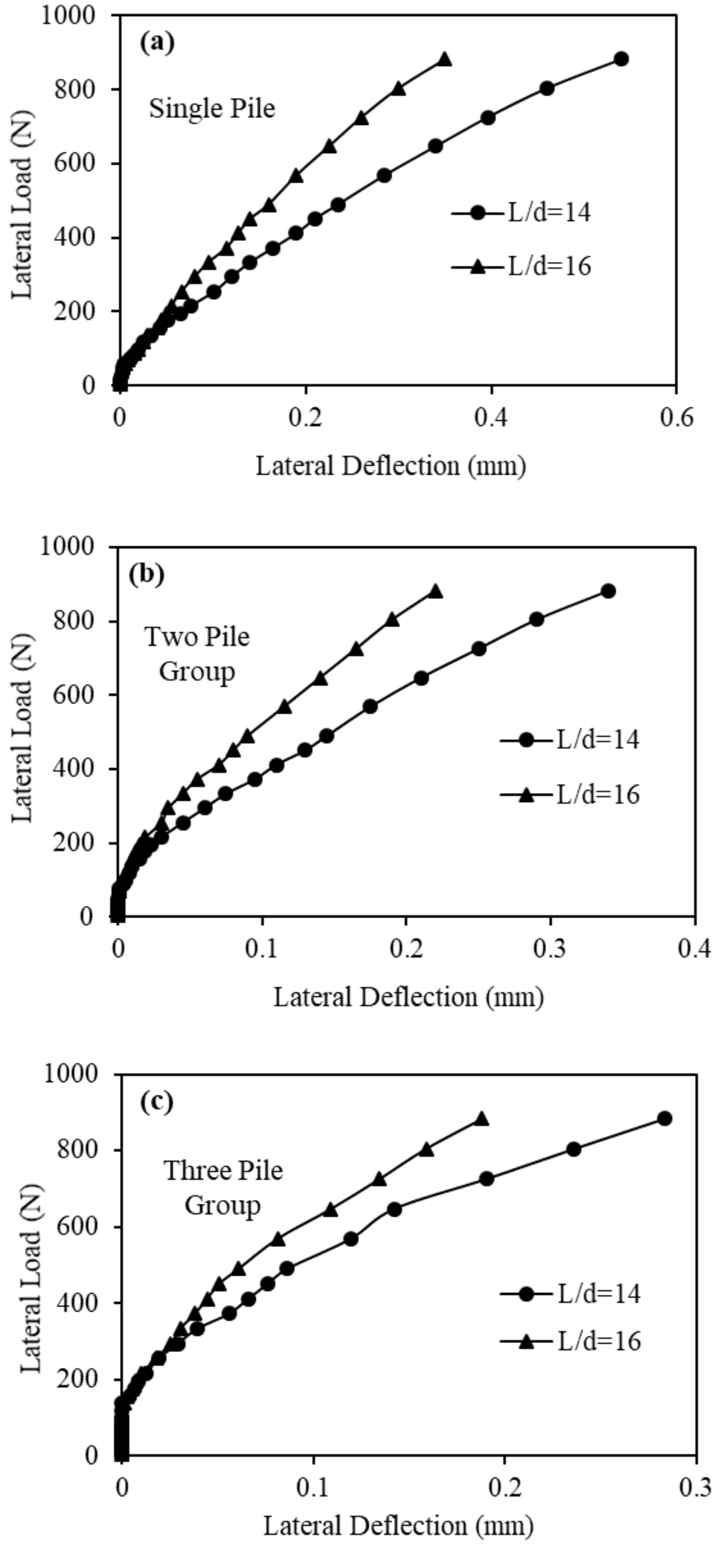

Figure 3. Effect of L/d ratio on the load-deflection characteristics of laterally loaded driven pile in sand: (a) for single pile (b) for two pile group and (c) for three pile group

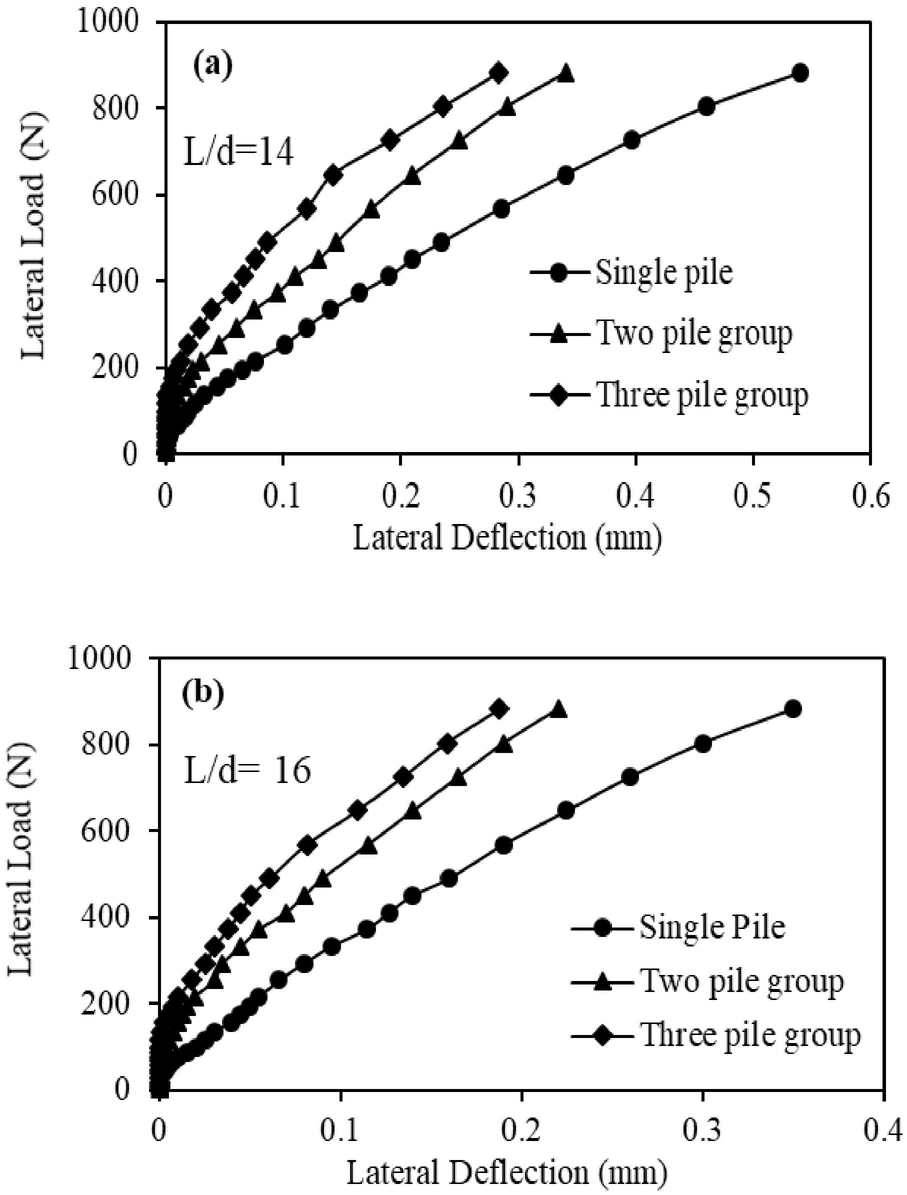

Figure 4. Effect of configuration of pile group on the load-deflection characteristics of laterally loaded driven pile in sand: (a) for L/d=14 and (b) for L/d=16

4 Conclusions

In this study, an effort has been made to understand the load-deflection characteristics of the piles subjected to lateral loads for different length to diameter ratios in sand considering different configurations of pile group. For this purpose, a small scale model similar to real problem was prepared and a series of experiments were conducted. The steel piles were driven into the sandy soil and the pile head deflection were measured for each increment of load. Two pile group and three pile group were considered in the study to evaluate the role the configuration of pile group in addition to the length to diameter ratio. It is noted that load-deflection behaviors are non-linear in nature. The length to diameter ratio of driven pile in homogeneous sand has significant effect on the load deflection characteristics. The lateral load carrying capacity of pile increases with the increase of L/d ratio regardless of the pile group configurations. The initial slope of the load deflection curve increases with the increase of the L/d ratio regardless of the configuration of the pile group. The stiffening of the load-deflection behavior is observed only at the beginning stage (at very small strain level) of the curve and the stiffening of the load-deflection reduces rapidly as the load increases. The deflection of pile decreases with the increase of L/d ratio for a given load and the differences intensify as the load increases.

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