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***Journal of Scientific and Engineering Research*, 2018, 5(5):330-338**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Experimental Investigation of Single Pile and Pile Groups Models Subjected to Lateral Load in Dry Sand under Multilayered Condition

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Abstract The behavior of laterally loaded piles can be studied in the laboratory on small scale models. The research was conducted and investigate through a series of twenty eight tests on single pile and pile groups at various spacing .This research presents the behavior of pile model embedded within cohesionless soils of different relative density arrangement and different pile group configuration under lateral load movement rate equal to 2.5mm/min acted at pile cap and at different spacing to outer diameter of pile S/D=3, 4, 5. The load-displacement diagrams and bending moment with respect to depth were drawn to study the effect the density of sand and how it effect on bending moment and lateral load level during the test. It was found that the lateral load level and bending moment of piles increases with increase the sand relative density and with increase of S/D of pile group.

Keywords pile group; maximum lateral load; sand relative density; pile group's configurations; multilayered soil

Introduction

When a soil of low bearing capacity extends to a considerable depth, piles are generally used to transmit vertical and lateral loads to the deeper and surrounding soil media. The Piles that are used under tall chimneys, towers, sky scrapers, high retaining walls, offshore structures, etc. are normally subjected to high lateral loads. These piles or pile groups should resist not only vertical movements but also lateral movements. Several methods are available for predicting the lateral load capacity of piles in cohesionless soil. Numerous tests have been carried out on model piles and pile groups to study the efficiency of pile under lateral loading. Gandhi and Selvam (1997) studied fixed head pile group pile with different pile group configuration through laboratory experiments on aluminum pipe piles in cohesionless soil. They made comparison between the behaviors of single bored pile with that of a driven pile [1].

Ranjan and Jagannath (2001) investigated pile groups with different configuration subjected to lateral loads, in dry Ennore sand. They conducted the load-displacement response, ultimate resistance, and group efficiency with spacing and number of piles in a group [2].

Kim et al. Vol. 14 [2009], Bund. P 2 (2004) the research carried out under monotonic lateral loadings, the test model of the piles embedded in Nak-Dong River sand, located in South Korea. The study included the lateral resistance of piles, the effect of the installation method, and the pile head restraint condition. The study has led to recommendations of the load–transfer curves (p–y curves) for laterally loaded piles [3].

Boominathan and Ayothiraman (2006) carried out tests on model aluminum single piles embedded in soft clay to study its bending behavior. Static lateral load tests were conducted on piles with length to diameter ratios of 10, 20, 30 and 40 using rope and pulley arrangement up to failure and the load_ deflection response was recorded [4].
Albuhlale (2015) studied eighty model in the laboratory on small scale models within cohesionless soils of different particle size distributions under the following parameters: lateral loading conditions (static & cyclic) It is found that when the static lateral load levels are increased, an increase in the lateral displacement and bending moment occurred. But, these increments are varied depending on the difference in grain size distributions [5].

Experimental Work

Soil Used

This research presented to study the effect of multilayer soil with different relative density arrangement for varies pile group configuration by using dry sand taking from middle of Baghdad city, and the physical properties are shown in Table 1.

Table 1: Properties of the sand used

Index Property	Value		Specification
Effective sizes ,(mm) D_{10} , D_{30} , D_{50} , D_{60}	0.14, 0.18, 0.22, 0.24		**ASTM D 422 and ASTM D 2487 (2007**
Coefficient of uniformity (Cu)	1.7		**ASTM D 422 and ASTM D 2487 (2007)**
Coefficient of curvature (Cc)	0.96		**ASTM D 422 and ASTM D 2487 (2007)**
Specific gravity (Gs)	2.66		**ASTM D 854 (2006)**
Maximum dry unit weight (kN/m^3)	16.7		**ASTM D 4253 - (2000)**
Minimum dry unit weight (kN/m^3)	13.8		**ASTM D 4253 - (2000)**
Maximum void ratio	0.93		**-----------------**
Minimum void ratio	0.59		**-----------------**
% Relative density (RD)	60%	75%	**-----------------**
Dry unit weight (γ_d) kN/m^3	15.5	15.93	**-----------------**
Void ratio,(e)	0.72	0.67	**-----------------**

Pile Used

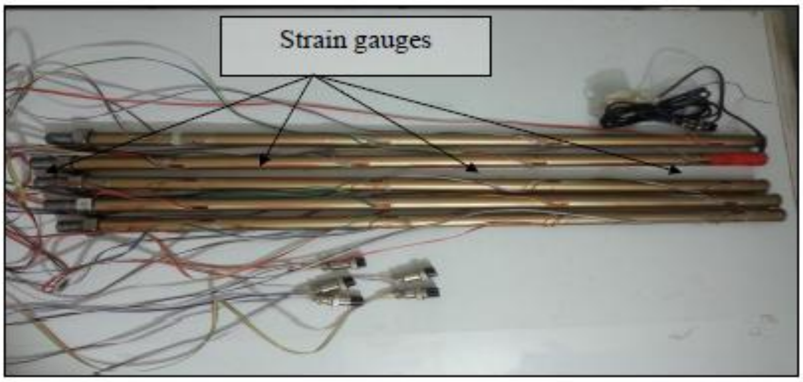

Plate (1): Pile model with strain gauge pasted on pile.

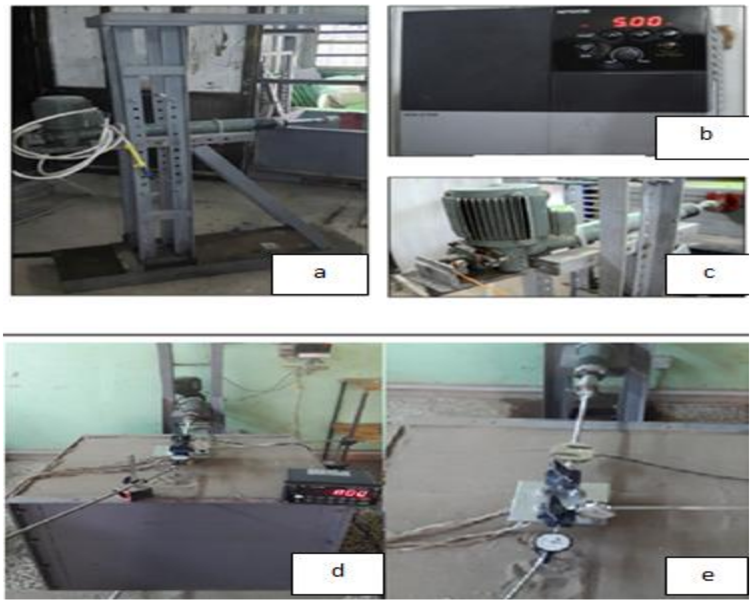

Plate (2):(a) Frame holding hydraulic jack,(b) AC drive,(c) and hydraulic jack,(d, e)System of lateral loading.

The pile used in this research is cylindrical aluminum pipe pile hollow from inside with outer diameter, length and thickness equal to (18,570and 1.5 mm), respectively. The embedded length to outer diameter equal to (L/D=30) with embedded length as shown in plate (1).

The test instrument system consist of: load cell to measure loading level and eight stain gauge (four of them in each side) fixed along the pile shaft to sense and measured the bending moment, and dial gauge used to measure the lateral displacement at pile cap are used. The data acquisitions used are strain indicator and digital weight indicator as shown in plate (2).

Testing Device

The container box used in this research with 750 mm length, width and depth is used for the single pile and pile groups model is made of steel plate of 6mm thickness welded with the frame that holding the lateral load system.

The Lateral Load Movement System

In order understand the effect of relative density arrangement with different configuration of pile groups many tests are carried out. In all cases, the lateral load movement rate is 2.5mm/min and embedded length to outer diameter (L/D=30) with embedded length =540mm.

Preparation Model and Experimental Procedures

The test procedure divided in to three sections. First part is pile installation. The second part is preparation of soil by using handle compactor by dividing the container to equal layer and compacted the soil to desired limit. The last part is the important part in this study which composed of hydraulic jack controlled by using AC-drive which used to induce rate of 2.5mm/min.

Before the device switch on, all data acquisition and wire sensors were checked for reading, when the loading shaft start moving with 2.5mm/min loading rate; the test stopped at 12mm lateral displacement recorded at pile cap.

Loading Direction of Piles and the Arrangement of Soil Relative Density in Tank of Test

this section include the load direction at pile cap according to it configuration ,as shown in Figure (1) and the arrangement of relative density with in tank as in Figure (2) the arrangement of relative density in tank divided as flow (a_1,a_2) present the uniform state where the container fill with same relative density dense and medium, respectively . However; (b_1, b_2) presented by dividing the container in to two equal halves of upper layer and lower layer ((b_1) present medium over lay dense relative density M/D and (b_2) present dense over medium relative density D/M).

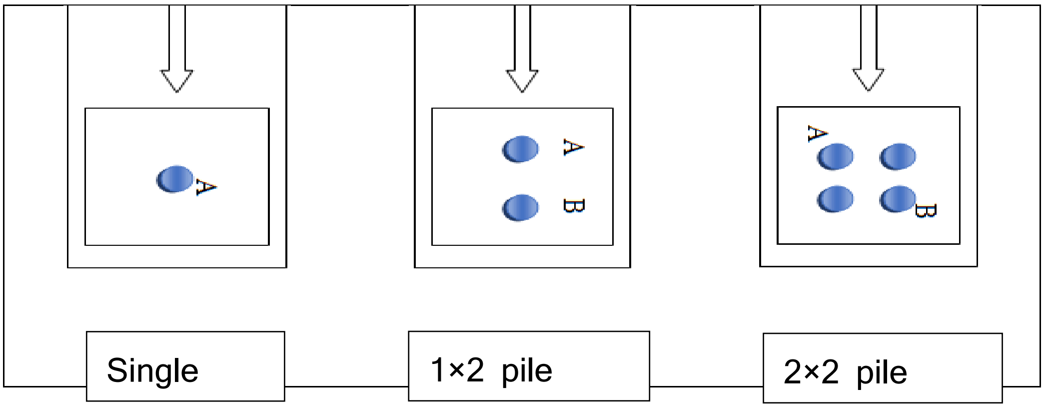

Figure 1: Load direction at pile cap

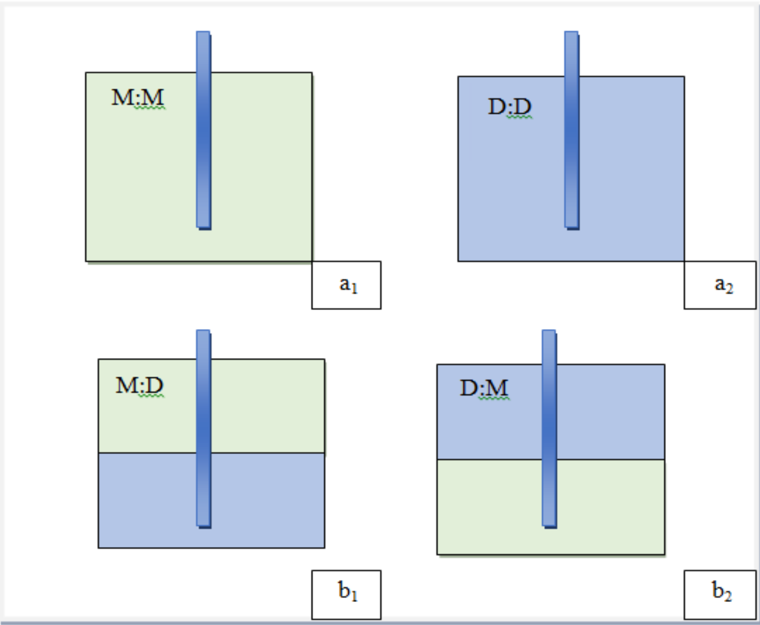

Figure 2: Arrangement relative density of soil in tank of test

Results and Discussion

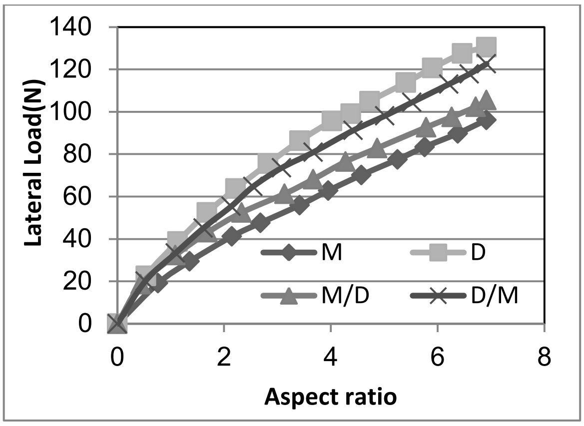

Figure 3: Variation of aspect ratio with lateral load of single pile

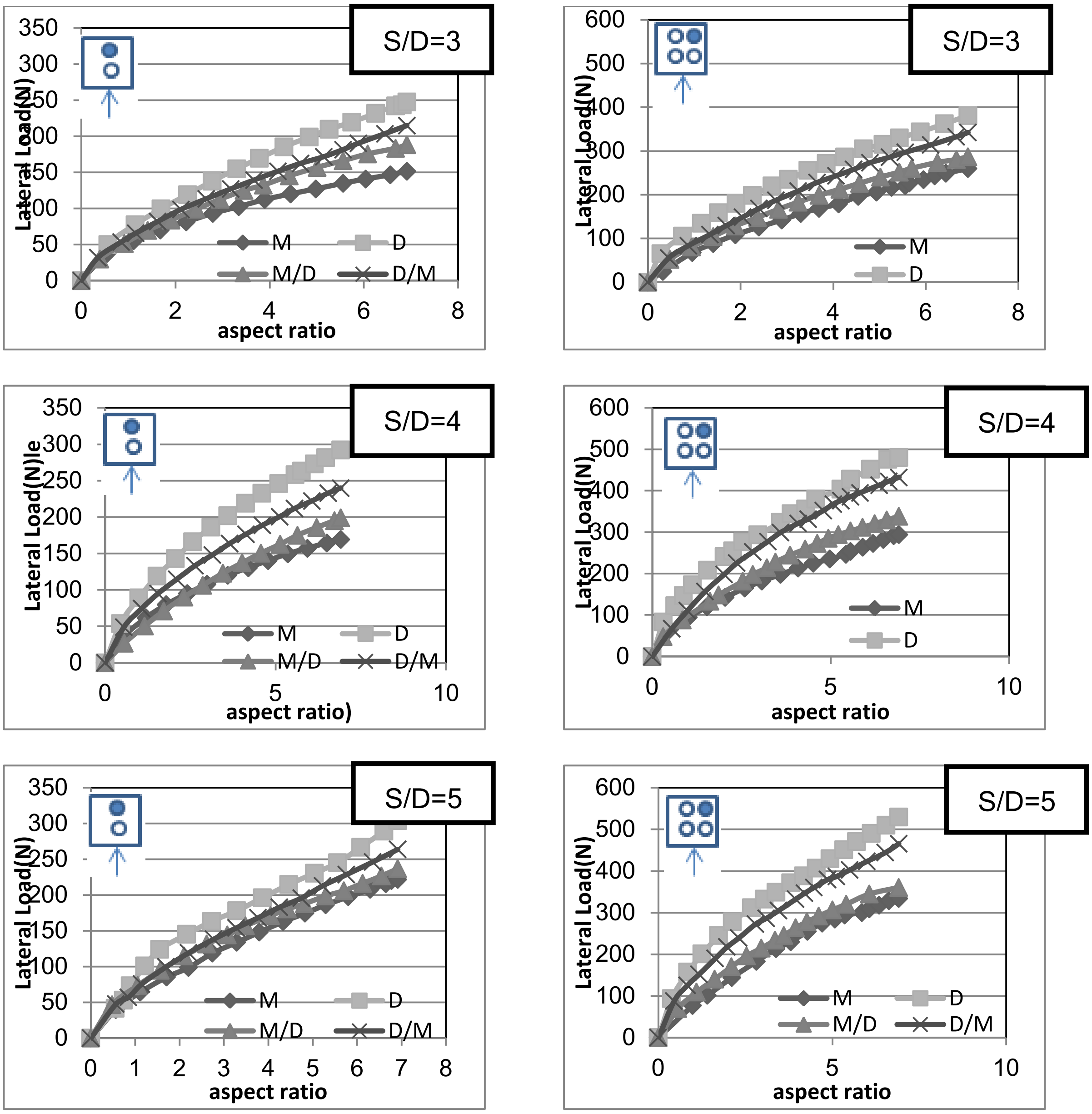

Figure 4: Variation of aspect ratio with lateral load of pile group

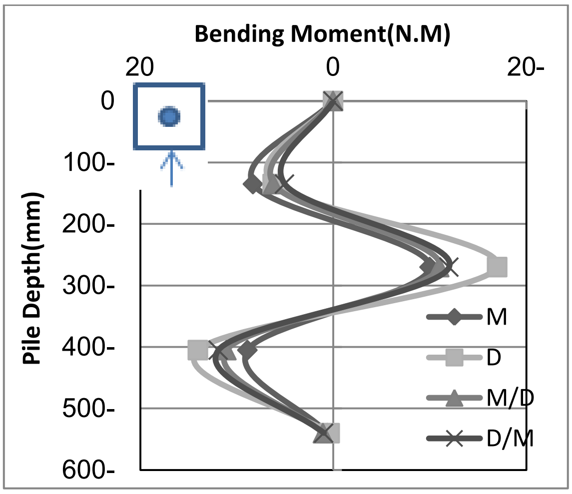

Figure 5: Bending moment development with depth for single pile

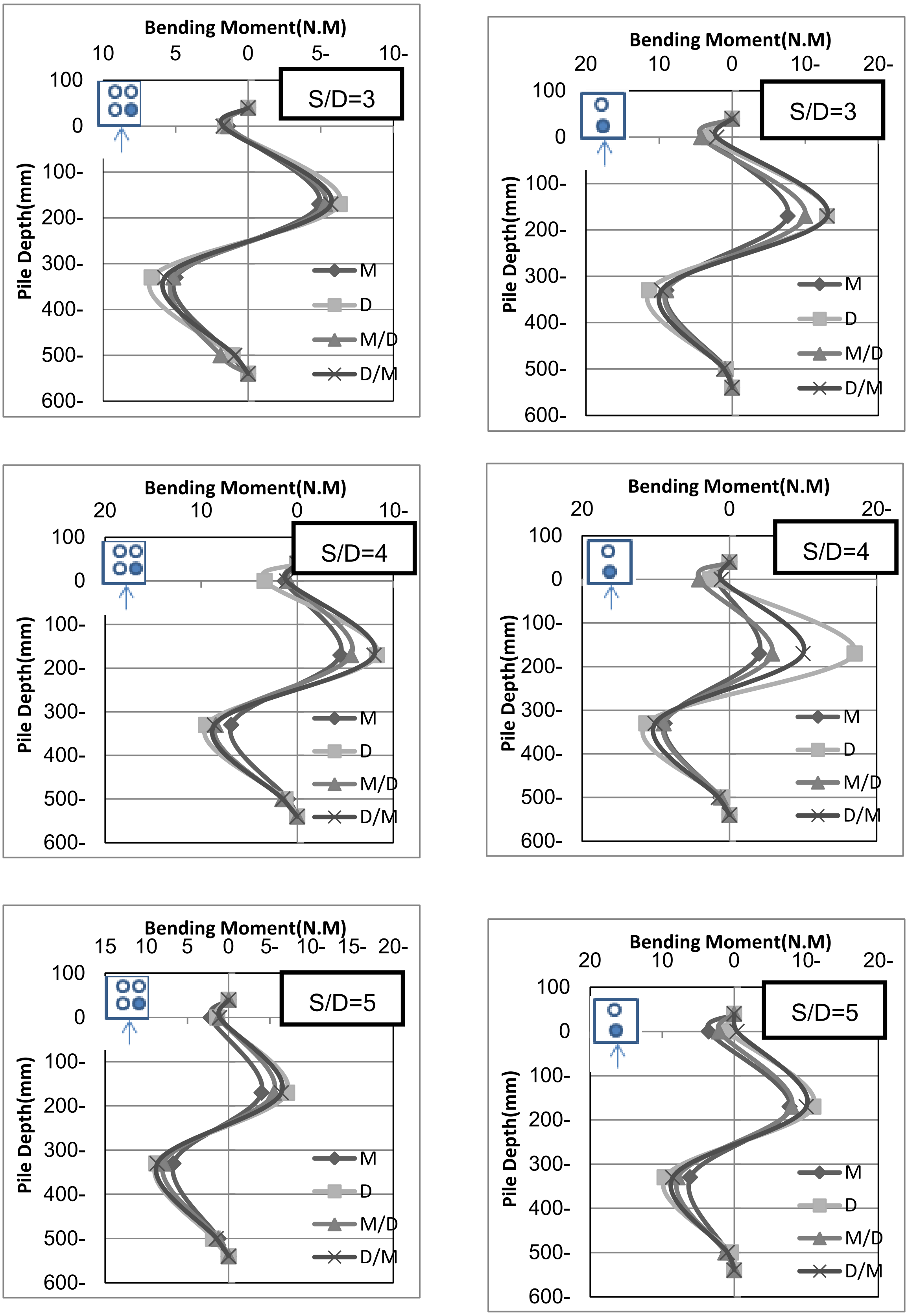

Figure 6: Bending moment development with depth for front pile (A) 2×2 and 1×2 pile group.

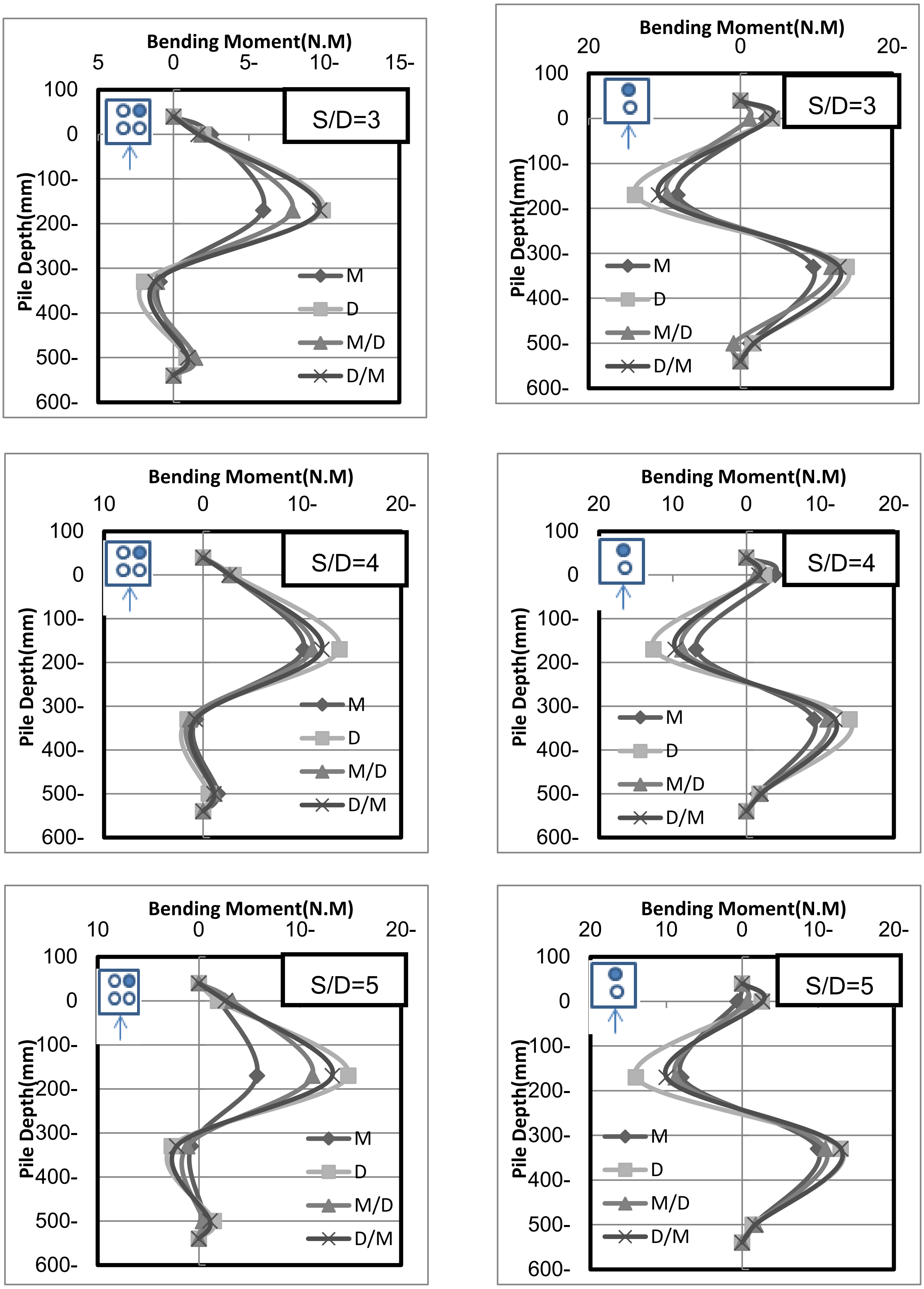

Figure 7: Bending moment development with depth for rear pile (B) 2×2 and 1×2 pile group

A total of 28 tests were carried out on laterally loaded aluminum pipe piles has closed ends embedded in dry sand deposit. The response of laterally loaded aluminum pipe piles investigated under the effect of sand relative density, (s/d) of spacing between pile in group(s) / diameter of aluminum pipe pile (d), and piles configuration.

The lateral displacement reads from dial gauge of 0.001 accuracy attached to pile cap and lateral load reads sensed and recorded by using load cell and digital weight recorder, the lateral displacement with lateral load applied at pile cap are drawn but the lateral displacement (L.d) of the piles is expressed in non-dimensional form in terms of outer pile diameter (D) as aspect ratio (L.d/ D).the lateral movement is previously fixed at 12mm lateral displacement and the test stopped as this point. Figures (3) and(4)show the variation of aspect ratio of pile cap for single pile and pile group with lateral load at different relative density and at S/D=3,4 and 5.

It can be seen that lateral load increase as relative density increase for uniform case and lateral load increase as relative density of upper layer increase from 60% (medium(M)) to 75% (dense (D)), but at specific lateral load intensity it observed that aspect ratio decrease as relative density and S/D increases and the value of aspect ratio of single pile higher than 2×2pile group by twice. This behavior may be due to the increase of relative density of top layer from medium to dense and that lead to increase in the load resistance of soil in top layer because of the soil passive resistance mobilized in front of pile. Also due to the fact that shear strength of sand increases as it become denser by Salini & Girish [6] and it can be see that lateral load increased as S/D increased that due to interaction effect of pile group decreased with S/D increased.

In order to find the effect of relative density arrangement and effect of spacing between pile S/D on the location and magnitude of maximum bending moment, eight strain gages fixed at different depth along the pile and the distance between two adjacent followed strain gages is equal to 170 mm, bending moment values that sensed and from strain gages and strain logger is drawn with respect to depth.

Figure (5), (6) and (7) illustrated the variation of bending moment with respect to pile length. It observed that both negative and positive bending moment, are occurred and the negative bending moment showed at upper part of pile depth.

Generally, it can be observed that bending moment increase as relative density increase corresponding to flowing arrangement (M, M/D, D/M, and D) that due to shear strength of sand increases as it become denser .in additional to that bending moment no significant differences in magnitude as S/D increases from 3 to 5.

It can be see that negative bending moment for font pile (A) higher than for rear pile while positive bending moment of front pile is higher than for rear pile this may be back to that the lateral load subjected at pile cap causing tilting to pile cap that making the front pile to up lift and the rear pile to compression this behavior making bending moment to decrease.

Also, it can be seen this behavior due to the increase of interaction effect of pile group where the pile in front is works as active piles making the rear pile having the largest bending moment.

It worth to mention that position of maximum bending moment occurred approximately at midpoint of pile shaft and generally, bending moment of single pile is higher than for pile group.

Conclusion

Based on the experimental analysis of 28 small scale pile model of single pile and pile group subjected to lateral load at pile cap it can be as flow:

Relative density of upper layer has huge effect on pile response.

Lateral load increase as relative density increases corresponding to flowing arrangement (M, M/D, D/M and D) and it increase as spacing (S/D) between piles in group increased from3to5.

The aspect ratio also affected by relative density of upper layer and it decrease as relative density increases corresponding to flowing arrangement (D, D/M, M/D and M) and aspect ratio decrease as S/D increases.

Bending moment effected by relative density and it increased as relative density increased corresponding to flowing arrangement (M, M/D, D/M and D), and spacing to diameter ratio has small effect on bending moment.

Both negative and positive bending moment occurred and negative bending moment for font pile (A) higher than for rear pile while positive bending moment of front pile is higher than for rear pile, and position of maximum bending moment occurred approximately at midpoint of pile shaft.

Acknowledgements

I would like to express the greatest and sincere thanks to my supervisor *Assist. Prof. Dr. Mohammed A. Mahmoud Al-Neami Assist. Prof. Dr.* Zeena W. Samueel for the full support, valuable advice and guidance.

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