BEHAVIOR OF PILE GROUP AGAINST CYCLIC LATERAL LOAD UNDER DIFFERENT SOIL CONDITION

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ABSTRACT

As part of a research project to develop a framework for quantifying cyclic effects on piles, centrifuge model tests on single piles and pile groups in dry silica sand have been carried out at the Centre for Offshore Foundation Systems (COFS) in Perth, Australia. The piles were subjected to lateral cyclic 1-way and 2-way loading investigating the vertical and horizontal load displacement behavior. Strain gauges located along the pile shaft provided information about the bending behavior. This Study considers the tests on single piles and highlights the influence of cyclic load amplitude and number of cycles on the observed response. Furthermore, the test results are compared to results from the Extended Strain Wedge Model.Mechanics of the behavior of group of laterally loaded piles is more complex than those of the axially loaded pile group. Pile group behavior under cyclic lateral loading is nonlinear and involves complicated group interaction. Piles in the group subjected to lateral loading are influenced by the existence of similarly loaded nearby piles due to pile-soil-pile interaction. Cyclic loading of pile foundations is of importance in various fields of civil engineering such as offshore and onshore wind turbines or structures for transport infrastructure. The behavior of soils, both fine and coarse grained, under cyclic loading is complex.
Key Words:Pile Group, Cyclic Lateral Load, Soil Condition

I. INTRODUCTION

Pile groups supporting coastal and offshore structures are subjected to lateral loads due to wave action. Theselateral loads are cyclic in nature with different amplitudes and duration. Mechanics of the behaviour of group oflaterally loaded piles is more complex than those of the axially loaded pile group. Piles in the group subjected tolateral loading are influenced by the existence of similarly loaded nearby piles due to pile-soil-pile interaction,leading to reduction in lateral load capacity of the pile group. Pile group behaviour under cyclic lateral loading isnonlinear and involves complicated group interaction. Most of the pile foundations in marine area are constructedin clay deposits. Cyclic loading in clay under untrained condition leads to degradation of stiffness and reduction inshear strength. The problems associated with cyclic lateral loading in clay such as formation of gap at pile-soilinterface, buildup of excess pore pressure and remolding of clay lead to higher deflections and higher bendingmoments than static loading. Cyclic loading of pile foundations is of importance in variousfields of civil engineering such as offshore and onshore windturbines (BSH 2007) or structures for transport infrastructure. Cyclic loading may be caused by wind andwaves (offshore wind turbines) or temperature inducedconstraints (integral bridges without joints and bearings).The behavior of soils, both fine and coarse grained, undercyclic loading is complex. For example,cyclic lateral loads on piles in sand either lead to a densificationor a loosening of the surrounding soil. However, the design of pile foundations under cyclicloading is usually still based on modifications to the moresimplistic monotonic loading conditions. A betterunderstanding of pile-soil interaction during lateral cyclicloading is therefore required to establish more efficient designstrategies for these types of foundations.As part of a research project to develop a framework forquantifying cyclic effects on piles, centrifuge model tests onsingle piles and freestanding pile groups in dry silica sand havebeen carried out at the Centre for Offshore Foundation Systems(COFS) in Perth, Australia.

1.1 Scope of Work

To achieve the objectives of the research investigation, a series of static and dynamic lateral load tests were conducted on two single piles and four pile groups at a test site below the South Temple Street overpass on the Interstate 15 alignment in Salt Lake City, Utah, Work tasks included

(a) Site Characterization,
(b) Cyclic Lateral Load Testing of Single Piles,
(c) Cyclic Lateral Load Testing of Four Free-Head Pile Groups
(d) Dynamic Lateral Load Testing of Two Free-Head Pile Groups,
(e) Cyclic Lateral Load Testing of a Fixed-Head Pile Group.
(f) Data Reduction and Analysis. A summary of each work task is provided below.

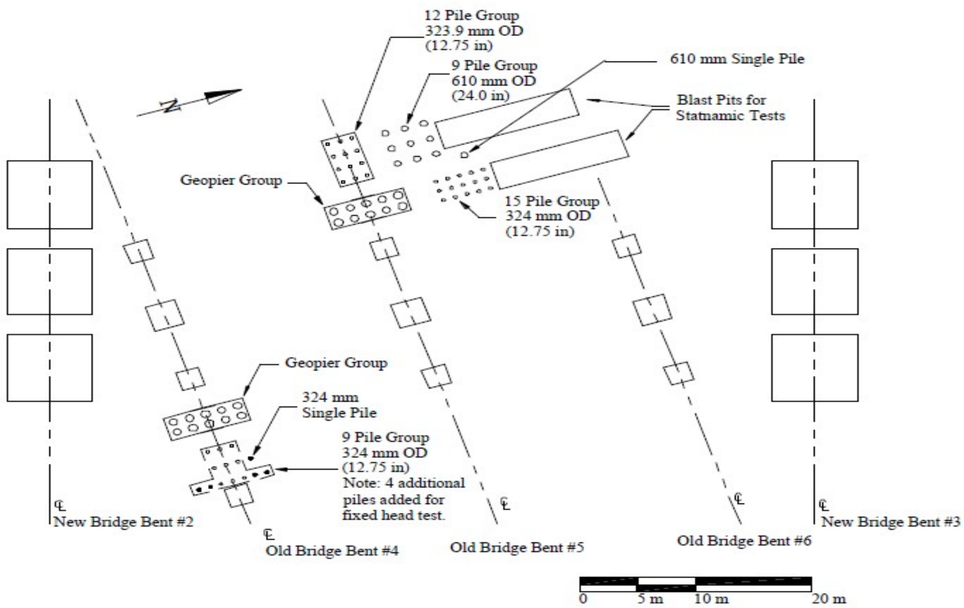

Fig 1 Layout of two single test piles and four pile groups at site

II. LITERATURE SURVEY

Previous research conducted on the lateral response of pile groups has involved full-scale tests, centrifuge model tests, 1-g models tests and numerical analyses. This chapter contains are view of previous research, a discussion of the limitation of existing research and a discussion of the need for further research.

Brungraberet. al. (1976) A comparison of the Group I (1.2 meter spacing) and Group II (0.9 meter spacing) resultsrevealed that an increase in spacing between the rows increased the lateral load resistance of thegroup. At a given load, the deflection of the Group II piles was twice that of the Group I piles.This increase in deflection in Group II was a result of decreased soil resistance because of groupinteraction effects. In addition, the reduced soil resistance led to greater bending moments inGroup II.The cyclic loading of the group resulted in increased deflections as the cycles progressed.

Summary:

The soil resistance decreased as the soil was moved and gaps formed around the piles. For loadsup to 59 kN (13 kips) the increase in deflection was about 29%. For subsequently greater loadsthe increase was only about 4%. Similar increases were noted in the bending moments.

Meimon, Yet. al (1986)A double-acting hydraulic jack was used to apply the lateral load to the pile cap. Thelateral displacement of the pile group was measured with two gauges that were attached to theexcavated wall. Bending moments were calculated based on measurements obtained from strain gauges located along the entire depth of four of the piles. The testing also included two longtermcreep tests and five cyclic tests. The three-pile diameter spacing resulted in pile-soilinteraction, which reduced the soil resistance. In addition, the time between the driving of thepiles and the testing was different for the group and the single pile. Nine months had passedbetween the driving and testing of the single pile. The time between the driving and the testingof the pile group was only one month.

Summary:

The cyclic tests were composed of 1,000 to 10,000 cycles. The displacement at the top of the pile group was about 40% greater than the single pile,which can be attributed to several factors.

Brown, D.A. et. al.A double-acting hydraulic cylinderapplied the lateral load, and pin connection load cells transferred the load from the frame to thepiles. The loading was cyclic and bi-directional with 5 series of load applications (100 to 200cycles per series). Two linear potentiometers spaced 1.5 m (5 ft) apart monitored both deflectionand rotations.The deflection in the group was significantly greater than the deflection of the single pilewhen subjected to the same average load per pile. As the load increased the group effect increased. At large loads the group effect was significantly more apparent and a “collapse” loadfor the group would most likely appear at a significantly lower load per pile than would occur forthe single pile.Bending moments in the piles located in the group were greater and occurred at deeperdepths than those experienced by the single pile. The largest moment occurred in the front rowat a shallower depth than those of the trailing rows. This was due to the group effect. As thepiles interacted with the soil the resistance in the upper layers decreased.

Summary:

The clay was excavated to a depth of 2.9 m (9.5 ft)and backfilled with medium dense sand. The sand was compacted in 0.15 m-thick lifts to arelative density of about 50%.

Rollins, K. M.et. alA difference in pore water pressures seems to be the explanation for the increased loadcarrying capability of the back row. During the lateral movement of the pile group the materialright behind the pile would be in tension resulting in negative pore water pressure in soft clays.This negative pore water pressure would increase the soil resistance and strength in the trailingrow. In stiff over consolidated clays positive pore water pressure would have been developed andtherefore a decrease in strength would be observed. For sands the pore water pressure woulddissipate quickly and have little effect on the strength of the soil.

Summary:

Bending moments for piles in the group were significantly higher than those of theisolated single pile for the same average load. Increases between 50 and 100 % were observed.

Dunnavant, T.W.et. al. The proposed BEM method saves computational effort compared to more sophisticated codes suchas VERSAT-P3D, PLAXIS 3D and FLAC-3D, and provides reliable results using input data from astandard site investigation. The reliability of this method was verified by comparing results from datafrom full scale and centrifuge tests on single piles and pile groups. The line-by-line reduction factors that are used in GROUP version 4.0 (Reese and Wang, 1996) are based on work by Cox et al (1984) that was formalized by Dunnavant and O'Neill (1986). Cox et al (1984) studied pile behavior with 25 mm diameter model piles.

Summary:

The results of the proposed method are shown to be in good agreement withthose obtained in situ.

Mahdi O. Karkushet. al. The impact of soil contamination on the behavior of a pile group driven into clayey soils is the subject of this study. A mechanical model had been manufactured to study the behavior of pile group (2×2) subjected to one-way cyclic lateral loading, and embedded in contaminated soils. The tests were performed on a free headed pile group with two ratios of eccentricity to embedded length (e/L) equal to 0.25 and 0.5. The intact soil samples were obtained from Al-Musayib city in the center of Iraq, while the industrial wastewater is a byproduct discharged from Al-Musayib thermal electric power plant, which is located in the same region where the soil samples have been obtained.

Summary:

The industrial wastewater discharged from Al-Musayib thermal electric power plant has negative effects on the ultimate lateral load capacity and total lateral displacement of the pile group subjected to cyclic lateral loading.

S. K. Haighet. al In this research, centrifuge modeling of a pile group subjected to cyclic lateral loads has been conducted to investigate the interaction effect in pile groups and the influence of cyclic lateral loads on the performance of pile groups. Different pile installation methods were also applied to capture the full range of construction-induced soil conditions available in the field. Lateral permanent displacements of the pile group were seen to be induced by one-way cyclic lateral loads but not by two-way symmetric cyclic lateral loads. The lateral secant stiffness of the pile group increases slightly with increasing number of cycles, and leading piles attract greater loads than trailing piles. Furthermore, permanent settlements of the pile group accumulate, which can be attributed to the swaying motion of the pile cap induced by cyclic lateral loads.

Summary:

When the spacing of individual piles is four times the pile diameter, interaction effects on the pile group are significant.

Karsan R. Hiraniat.el. Towers and offshore structures are usually subjected to overturning moments due to wind, wave pressure and ship impact. These overturning moments transferred to the foundation of the structure in the form of horizontal and vertical loads. The type of foundation usually recommended for such loading conditions is combination of vertical and batter piles. In practice piles are used in groups and are connected by a cap at the pile heads. The spacing between the piles, arrangement of piles, their batter, and direction of load has an important role in the assessment of load deformation behavior of pile groups under lateral loads. The behavior of batter pile group buried in sand and subjected to lateral loads is investigated.

Summary:

This paper is an attempt to examine the effect of batter angle of a pile group on its ultimate lateral load carrying capacity and load deflection behavior. The results are compared with vertical and batter pile group, and optimization for battered pile group is done

III OBJECTIVES OF PROPOSED RESEARCH WORK

The driven pile research described in this report had the following objectives:

- To examine the index properties of different soil conditions and the influence of pile diameter on lateral load resistance
- Determine the effect of cyclic loading and gap formation in clays on the measured group
- Examine the effect of cyclic loading and gap formation in clays on the measured dynamic resistance. (soil liquefaction)
- Evaluate the effect of pile diameter and stiffness for pile groups for above lateral load and cyclic load combination
- Evaluate the effect of uplift and compression on the lateral resistance of pile groups.
- Provide well-documented case histories and validation for use in evaluating and calibrating computer and physical models

III. GAPS IN THE RESEARCH AND MOTIVATION FOR NEW RESEARCH

- The pile group in loose to medium dense sand has found popular application world-wide.
- The lateral total and permanent displacements and lateral load capacity of pile group have been investigated under cyclic lateral loading in contaminated soil samples.
- A comparison is presented between measured and computed data on a laterally loaded fixed-head pile group composed by reinforced concrete bored piles.
- The reduction in soil resistance in the top layers also increased the depth at which the maximummoment occurred. This finding of greater moments at deeper occurrence is similar to previousfindings.
- This difference in time was an uncontrolled variable in the experiment and introduced some uncertainty into the results.

IV. CONCLUSION

This paper investigates literature of the behaviour of pile group against cyclic lateral load. The findings of this study is Mechanics of the behaviour of group of laterally loaded piles is more complex than those of the axially loaded pile group. Piles in the group subjected to lateral loading are influenced by the existence of similarly loaded nearby piles due to pile-soil-pile interaction, leading to reduction in lateral load capacity of the pile group. Pile group behaviour under cyclic lateral loading is nonlinear and involves complicated group interaction.

The pile group was composed of six piles hinged in a rigid cap and aligned in two rows spaced three pile diameters apart centre-to-cytocentrifuge modelling of a pile group subjected to cyclic lateral loads has been conducted to investigate the interaction effect in pile groups and the influence of cyclic lateral loads on the performance of pile groups.

V. REFERENCES

[1] Brungraber, R.J. and Kim, J.B. (1976). “Full-scale lateral load tests of pile groups.” Journal of Geotechnical Engineering. ASCE, Vol.102, No. GT1, pp. 87-105.

[2] Meimon, Y., Baguelin, F. and Jezequel, J.F. (1986). “Pile group behavior under long term lateral monotonic and cyclic loading.” Proc., Third Int’l Conf. on Numerical Methods in Offshore Piling, Inst. Francais Du Petrole, Nantes, p. 286-302

[3] Brown, D.A., Resse, L.C., and O’Neill, M.W. (1987). “Cyclic lateral loading of a large-scale pile group.” Journal of Geotechnical Engineering. ASCE, Vol.113, No. 11, pp.1326-1343.

[4] Rollins, K. M., Peterson, K. T., and Weaver, T. J. (1998). “Lateral load behavior of full-scale pile group in clay.” J. of Geotechnical and Geoenvironmental Engineering, ASCE, Vol. 124, No.6, p. 468–478.

[5] Dunnavant, T.W. and O’Neill, M.W. (1986). “Methodology for analysis of laterally loaded pile groups,” Third Intl. Conf. on Numerical Methods in Offshore Piling, IFDP/LCPC, Nantes, France, p. 303-316.

[6] S. K. Haighet. al “The response of pile groups under cyclic lateral loads”

[7] Karsan R. Hirani at. el.“Lateral load carrying capacity of model pile groups.”National Conference on Recent Trends in Engineering & Technology

[8] TouréYoussoufat. el. “Force Performance Analysis of Pile Behavior of the Lateral Load” MPDI 28 March 2019