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Vertical Load Carrying Capacity of Batter Pile Group

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ABSTRACT

The pile group in loose to medium dense sand has found vast application world-wide. The behavior of batter pile group enclosed in sand and subjected to vertical loads is investigated. This paper is an attempt to examine the effect of batter angle of a pile group on its ultimate vertical load carrying capacity and load deflection behavior for different batter angle. The results are compared with vertical pile group, and optimum battered angle will be found out. For the study fabricate a model of steel plate as pile cap and steel pipes as a pile, pile load test carried out using maintain load test (MLT) as per IS-2911-IVin medium dense sand-bed on a hydraulic loading frame in the laboratory[10]. Ultimate load found out by tangent intersection method from the load Vs displacement graph as per the experiment results.

KEYWORDS: Batter pile group, batter angle, medium dense sand, model test, ultimate vertical bearing capacity

INTRODUCTION

The rapid growth of main offshore structures in the last few decades all over the world led to a rapid increase in the number of offshore structures even in unfavorable ground condition. The foundation of offshore structures on such unfavorable sub ground presents a challenge for both geotechnical and structural engineers. Pile foundations are generally preferred when heavy structure loads have to be transferred through weak subsoil to hard strata. These foundations in some situations are subjected to significant amount of lateral loads besides vertical loads. Lateral forces may be due to impact of ships during berthing and wave action and vertical load due to superstructure constructed in the case of off shore structures.

Piles are commonly used to support bridge structures, tall buildings, and transmission line towers. Towers and offshore structures are usually subjected to overturning moments due to wind, wave pressure and ship impact [7]. 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 [9].

The spacing between the piles, arrangement of piles, and their batter angle has an important role in the assessment of load deformation behavior of pile groups under vertical loads [11]. When the piles are inclined at an angle to the vertical they are called as batter piles. Batter piles are quite effective for taking lateral load and also in vertical load. The usual assumption in design of a batter pile is that the pile is capable of resisting the same axial load as a vertical pile of the same type and size and driven to same stratum.

Literature survey

Ultimate vertical resistance of pile groups Analytical techniques

The bearing capacity of a pile depends primarily on the type of soil through which and/ or on which it rests, and on the method of installation. It also depends upon the cross-section and length of the pile. The pile shaft is a structural column that is fixed at the point and usually restrained at the top. The elastic stability of piles, or their resistance against buckling, has been investigated both theoretically and by load tests (Bjerrum, 1957)[9]. By static analysis Meyerhof (1959) and Vesic (1967) proposed certain failure surfaces for deep foundations [8]. Vesic conclude that only punching shear failure occurs in deep foundations irrespective of the density index of the soil, so long as the depth to width ratio is greater than 4 (habitually so for pile foundations). As per wave equation method [7]. The dynamic process of pile driving is analogous to the impact of a concentrated mass upon an elastic rod. The rod is partially restrained by end bearing at the tip and partially by skin friction. This system can be approximated by lumped mass elastic model (Ramot, 1967) [7]. Engineering news formula (Wellington, 1886) [7], Danish formula and Hiley's formula are commonly used pile formula in the dynamic pile driving formula [7].

Past research studies

Kyle. M. Rollin, et al.[1] studied pile spacing effect on lateral pile group behavior. Sayed M. Sayed, et al.(1992)[2] proposes new formula to evaluate efficiency of axially loaded pile group. It is based on three-dimensional geometry of the pile group and the strength and type of the embedding soil. Zhang. L, et al.(1998)[3] worked on centrifuge testing on vertically loaded fixed head batter pile group in sand. Ashraf Nazir, et al.(2012)[4] worked on pullout capacity of batter pile in sand. Yin jiming et al.(2011)[5] Studied load-displacement behavior of batter pile under vertical load by model experiment. Ahmed W. Abdeldayem et al.(2011)[6] worked on the Effect of Pile Group Arrangements on Local Scour Using Numerical Models.

SCOPE OF STUDY

Laboratory model tests on batter pile group (2×2) have been carried out in uniform sand-bed under vertical loads to find out ultimate load. By performing experiments for various batter angles also to find out optimum load by load-displacement curve at which bearing capacity is more than plumb pile group.

EXPERIMENTAL SET UP AND TESTING PROGRAMME

A. Foundation

Dry local river sand was used as foundation medium in modal tank of size 740mm x 740mm x 600mm deep. The specific gravity and uniformity coefficient of sand were 2.43 and 1.75 respectively. The placement density of sand during testing was 1.62 g/cc, corresponding to relative density of 46.11% and angle of shearing resistance Φ was 36.86°.

B. Model piles

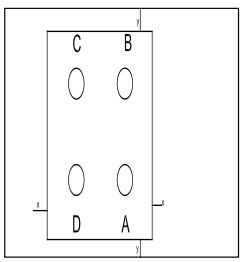
Stainless steel pipe piles of 32mm outer diameter and 1.45mm wall thickness were used as a model piles. The embedment length-to-diameter ratio of vertical pile was 11.pile cap is of steel plate, length of the pile L is 360mm, spacing between piles 3D. EI of the pile is 2.1074 x1011N-mm2. Where, D is diameter of pile, E is modulus of elasticity of pile, I is inertia of the pile

C. Angle fixing plate

To make optimization in fabrication for experimental program one types of angle fixing vertical plates were fabricated to change the batter angle between00 to 200 for the piles. Figure1 show angle fixing plates and its arrangement.

D. Model tank and loading arrangement

For the model study on battered pile group(2x2) with 3D spacing of vertical piles subjected to vertical loading, a rectangle tank of size 0.74m×0.74m×0.60m deep is fabricated with mildsteel. The tank was placed centrally in a reaction frame fabricated from angle section and channel section. Vertical load is applied gently by hydraulic pressure. Dial gauges of capacities of 25mm with sensitivity of 0.01mm are used to measure settlement of pile head. The test were carried out in medium dense sand (RD=46.11%).



Plan

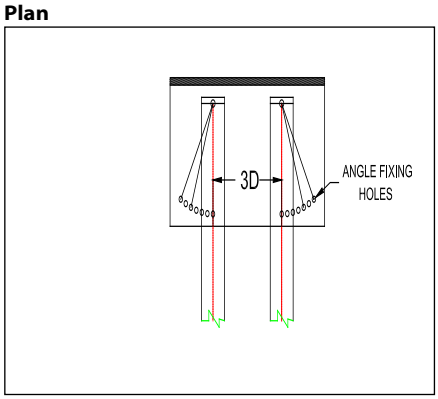


Fig-1 Plan- Section /Angle fixing plate

E. Experimental Procedure

Initially the sand is filled in the tank from the height of 40cm to achieve density. Pile groups are first kept in tank and then sand is filled in tank. They are kept in the center of tank and by taking care that they remain vertical. Dial gauge for measurement of displacement of the pile cap is attached firmly with pile group and taking care of that the displacement is to be measured at surface of sand bed. As per IS-2911(part 4), maintained load test (MLT) or constant rate of penetration (CRP) method is used for routine test. In MLT method application of increment of test load and taking of measurement or displacement in each stage of loading is maintained till rate of displacement of the pile top is either 0.1mm in first 30 minutes or 0.2mm in first one hour or till 2 hr whichever occur first. This load is taken incremental load [10]. Procedure is repeated till the maximum load is achieved. Results will be recorded for load and settlement from proving ring and two deflection gauges, which were fitted diagonally, respectively. Then load Vs settlement curve will be plot using appropriate computer software and from that ultimate load will be found out using tangent intersection method. Fig-2 show a testing arrangement and Table 1 show a testing program.

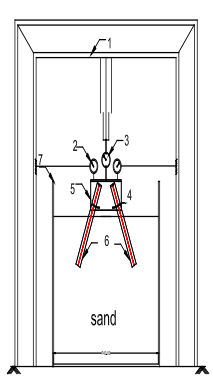


Fig-2 testing arrangement

1. Loading frame
2. Dial gauge
3. Proving ring
4. Holes for angle variation
5. Angle fixing plate
6. Batter piles
7. Test tank

Table-1	Angle of Pile Inclination			
Combination	A	B	C	D
1	0^0	0^0	0^0	0^0
2	5^0	0^0	0^0	0^0
3	5^0	5^0	0^0	0^0
4	5^0	5^0	5^0	0^0
5	5^0	5^0	5^0	5^0
6	10^0	0^0	0^0	0^0
7	10^0	10^0	0^0	0^0
8	10^0	10^0	10^0	0^0
9	10^0	10^0	10^0	10^0
10	15^0	0^0	0^0	0^0
11	15^0	15^0	0^0	0^0
12	15^0	15^0	15^0	0^0
13	15^0	15^0	15^0	15^0
14	20^0	0^0	0^0	0^0
15	20^0	20^0	0^0	0^0
16	20^0	20^0	20^0	0^0
17	20^0	20^0	20^0	20^0

TEST RESULTS

Vertical load Vs displacement diagrams

The observation from the test were applied to plot graph of vertical load Vs vertical settlement for different arrangement in medium dense sand-bed are shown in fig-3 to 6

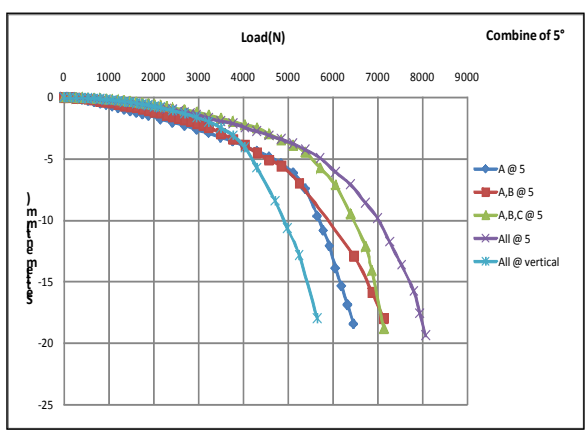


Fig-3 comparison between vertical pile group and when different piles at 5^0.

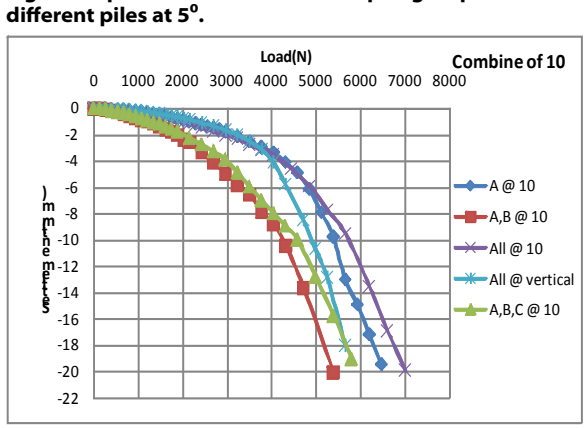


Fig-4 comparison between vertical pile group and when different piles at 10^0.

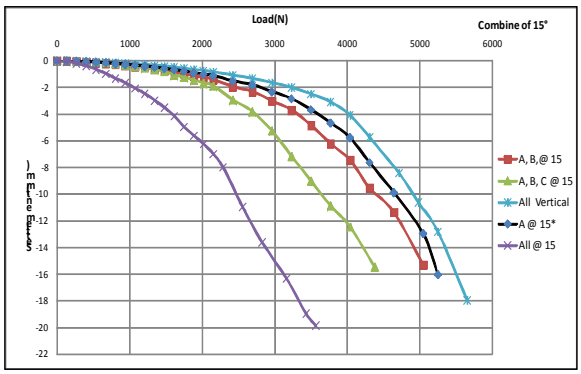


Fig-5 comparison between vertical pile group and when different piles at 15°.

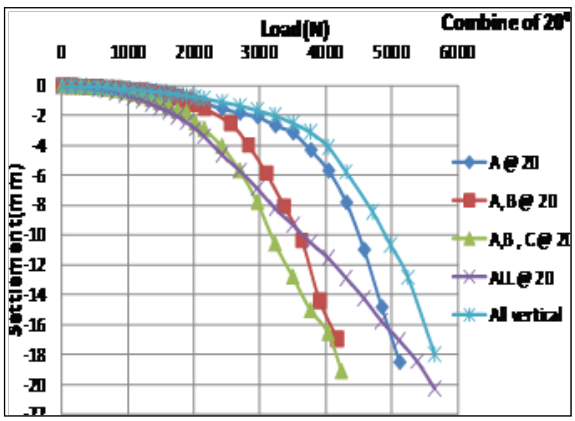


Fig-6 comparison between vertical pile group and when different piles at 20°.

Comparison of results

The results are compared with Vertical pile group. Finding out ultimate vertical load from the graph by tangent intersection method.

CONCLUSION

The following conclusions are drawn from the present study:-

1. The load Vs displacement curves are practically non-linear under vertical loading.
2. When all piles are placed at 5° battered angle it offers 40% - 50% more resistance compared to plumb pile group.
3. When all piles are placed at 10° battered angle it offers 9%-11% more resistance compared to plumb pile group.
4. Optimum angle of battered pile group under for vertical loading is 5°.

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