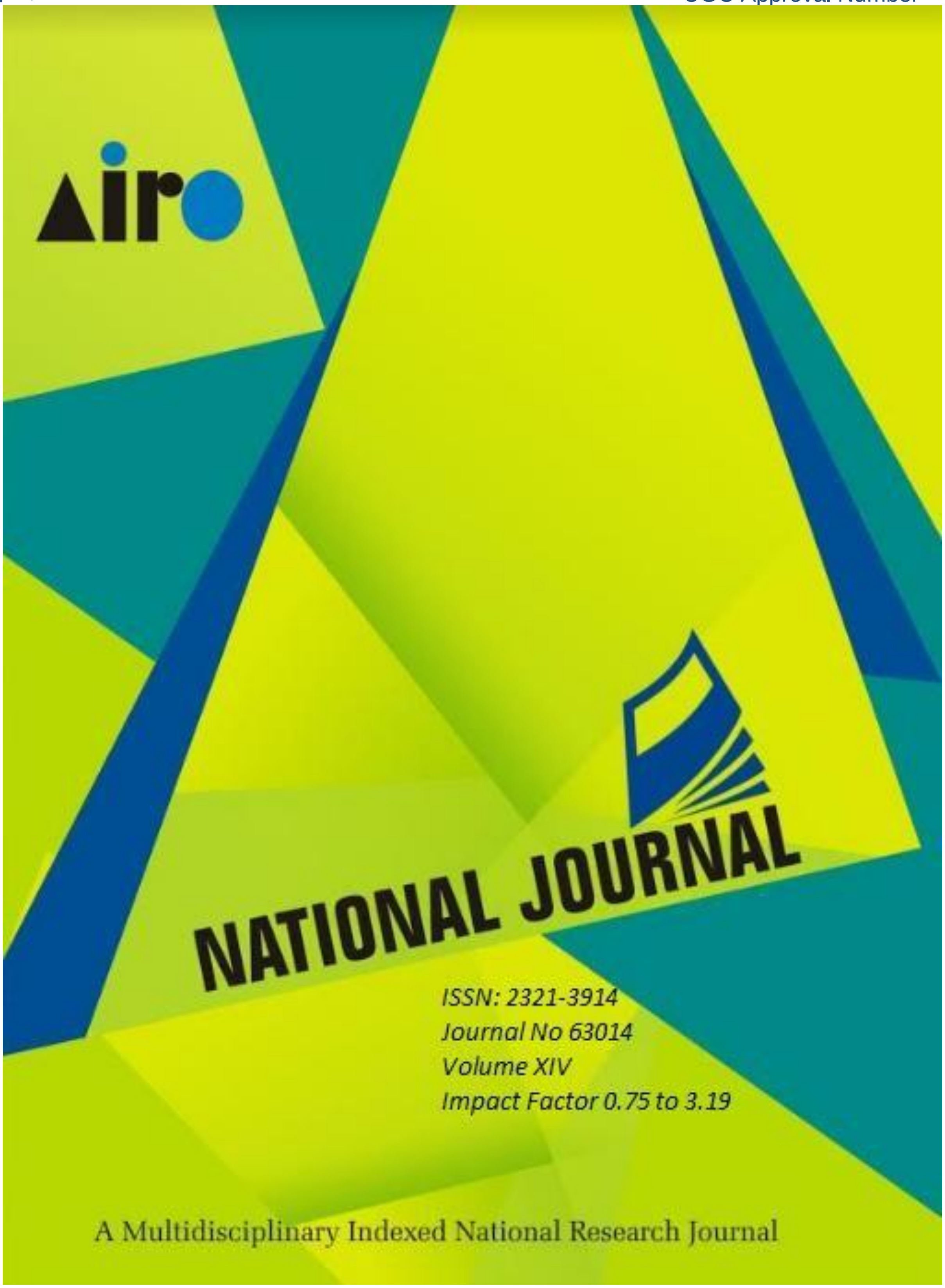
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Behavior of Open and Closed End Pile Groups Subjected To Vertical Loading: A Comparative Study

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Abstract-*Steel pipe piles are extremelystrong, offerconsistentsubstance, have slighter construction period and can be n driveinto such medium where other piles can't like boulder medium. Steel pipe piles are economical for long piles into deeps loose soil. Till now most of research has been directed towards the response of individual piles to vertical loads. Equally the driving response and fixed bearing capability of open-ended piles are unusual by the soil plug that forms classified the pile during pile driving. In order to investigate the effect of the soil plug on the static and dynamic response of an open-ended pile and the load capacity of pipe piles in general, field pile load tests were achieved on instrumented open- and closed-ended piles driven into sand. For the open-ended pile, the soil plug length was continuously measured during pile driving, allowing calculation of the incremental filling ratio for the pile.*

Keywords- Pile Foundation, pile cap, bearing capacity, pile group

I. INTRODUCTION

Pile foundations have been used as load carrying and loadtransferring systems for many years. Pile foundations are the part of a structure used to carry and transfer the load of the structure to the bearing ground located at some depth below ground surface. The main mechanisms of the foundation are the pile cap and the piles. Piles are long and slender members which transfer the load to deeper soil or rock of high bearing capacity avoiding shallow soil of low bearing capacity. The main types of materials used for piles are Wood, steel and concrete Steel pipe piles are highly durable, provide reliable foundation, have shorter construction period and can be driven into such medium where other piles can't like boulder medium. Steel pipe piles are economical for long piles into deeps loose soil. Because of the comparative strength of steel, steel piles allow driving pressure well and are usually veryconsistent end bearing members, although they are found infrequent use as friction piles as well. The common types ofsteel piles have rolled H, rectangular and circular cross-section (pipe piles).At the earlier time, the capacity of pile groups was taken as equal to the sum of the capacities of the individual piles. But, in practice, when piles are locatednear to each other, the pressures transmitted to the soil through neighboringpiles will overlaps, resulting in a considerable change of the group capacity [1, 2].A method by which the load capacity of the individual piles in a group embedded in sand could be assigned. According to this method, the capacity of a pile is reduced by 1/16 by each adjacent diagonal or row pile. Based on this method, different loads will be assigned to different piles in the group [1] .CumaraswamyVipuianandan, Daniel Wong, and MichaelW. O'Neill, ,(1990) Methods available for estimating the bearing capacity of piles installed with vibratory drivers are inadequate and do not explicitly incorporate important variables, such as soil parameters and in situ stresses. The influence of relative density (65% and 90%), particle size (0.2mm and 1.2 mm), and in situ horizontal stress (10 psi and 20psi) on the load-movement relationship and bearing capacityof vibro-driven displacement piles in sand is investigatedusing a large scale laboratory testing system. The test results indicate that, among the variables investigated, the most important parameter influencing the rate of penetration and the bearing capacity of the vibro-driven piles is the initial relative density of sand deposit. Based on pile capacity tests andanalytical study, several models are proposed to predict thenonlinear unit load-transfer curves, load-movement relationships and bearing capacity of vibration driven displacement piles. The model parameters are related to the important test variables investigated in this study. The model predictions are in agreement with the experimental results.Performance of vibration driven piles is compared with that of impact-driven piles. The bearing capacity of open-ended piles is affected by the degree of soil plugging, which is quantified by the incremental filling ratio .There is not at present a design criterion for open-endedpiles that explicitly reflects the effect of IFR on pileload capacity. In order to investigate this effect, model pile load tests were conducted on instrumented open-ended piles using a calibration chamber. The results of these tests displaythat the IFR increases with increasing comparative density and increasing horizontal stress. It can also be seen that the IFR increases linearly with the plug length ratio ~PLR and can be estimated from the PLR. The unit base and shaft resistances surge with decreasing IFR. Based on the results of the model pile tests, new empirical relations for plug load capacity, annulus load capacity, and shaft load capacity ofopen-ended piles are proposed. The proposed relations areuseful to a full-scale pile load test achieved by the authors.In this load test, the pile was fully instrumented, and the IFRwas continuously measured during pile driving. A comparisonbetween predicted and measured load capacities shows that the recommended relations produce satisfactory predictions [3].The results from an experimental investigation were designed to examine the effect of soil-core growth and cyclic loading on the shaft resistance developed by open-ended piles in sand. An instrumented open-ended model pile was installed either by driving or jacking into an artificially-created loose sand deposit in Blessington, Ireland. The tests provided constant measurements of the soil-core development and the radial effective stresses during installation and subsequent load tests. The equalized radial effective stresses developed at the pile-soil interface were seen to be dependent on the degree of soil displacement (plugging) experienced during installation, the distance from the pile toe, and the number of load cycles practiced by a soil element adjacent to the pile shaft. A new design method for estimating the shaft capacity of piles in sand is proposed and compared with measurements made on prototype field-scale piles [4]. While many studies have been done to investigate the axial performances of open-ended piles in sands, few studies have been reported for weak clayey silts. To develop reliable models for the design of open-ended steel-pipe piles driven into 29-mthick varied clayey silt deposits, a series of full-scale field load tests including large-strain dynamic tests and static cyclic axial-compression-load tests was accompanied on two groups of instrumented piles. Through analysis of the test data, soil parameters were back-calculated for estimation of pile capacities using the static-bearing-capacity formulas and coneresistance-based methods. The comparisons between the calculated results and the field load test data demonstrated that the following considerations can be adopted in the design of static compression capacities of an open-ended pipe pile penetrating through thick varied clayey silts to end-bearing in dense cohesion less soils: (1) a fully plugged condition can be assumed, (2) cone resistance with an upper limit of 4,788 kPa(100 ksf) can be used for unit base resistance on the soil plug, and (3) exterior unit shaft resistance can be estimated using two-thirds of the total unit shaft resistance [5] .

II. MATERIAL AND METHODOLOGY

The research work was divided into different headings as determination of index belongings of loose sands, procurement of pile cap material, steel piles, sand etc, preparation of test model, testing of pile and pile groups and finally evaluation and comparison of test results.

Material

Sand

Steel pile: It is usually desirable from economical andpractical considerations that the smallest model should beused. At the same time the model pile should be slender and also wide sufficient so that the effect of individual soil grains is negligible. The piles were used having 2 cm diameter and the total length of pile was 50 cm with an embedded length of 40cm.

Mild steel plates: Mild Steel Plates can come in several sizes and grades. Thicknesses available range from 3mm up to as thick as 150mm. The plate used in making of pile caps is of 12mm thickness which is cut according to the required dimension of pile caps.The spacing between the piles in each group was 2.5 times of pile diameter. The size of pile cap varied giving to the number of piles in a group. A minimum cover of approximately half the pile spacing was provided around the outer piles. The length of embedment of piles was kept as 40cm in all the tests. Total thirteen tests were performed in which five circular groups were also tested.

Test Procedure

Single Pile Testing

The single pile was driven into the sand. The proving ring was devoted to the lower end of screw jack. Two dial gauges were fixed at the top of pile cap. These Baty dial gauges (least count0.01 mm and 25 mm travel) were supported on a cross anglesections through magnetic bases.The average of dial gauge readings was taken as the average clearing under a particular load.The load was applied in small increments. Load wasmaintained constant after an increment, till the reimbursement was constant. When there was no movement of dial gauge readings were recorded. Next increment was applied and the process was repeated till failure i.e. when the pile started setting rapidly.

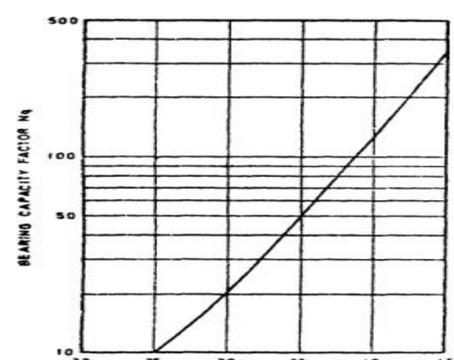

Figure 1 PLOT FOR BEARING CAPACITY FACTOR VS ANGLE OF INTERNAL FRICTION

Pile Group Testing [7]

The proving ring was involved to the screw jack. Two dialgauges were appropriately mounted on the pile cap at oppositecorners. It was checked by tapping that the dial gauges were securely fixed. The load is than applied at the centre of pile cap by turning the screw jack. After each increment, the load was maintained constant till the settlement was constant.After the disbursement was complete, the next increment of load was applied and the process continued till the pile group started sinking. From the recorded readings of showing ring and dial gauges, the values of load settlement were computed.

Theoretical Pile Group Efficiency

The efficiency of pile groups were calculated by using the pile group efficiency equation. There are many pile groupequations. These equations are to be used very cautiously, and may in many cases be no better than a good guess. The Converse-Labarre Formula is one of the most widely usedgroup-efficiency equations which is expressed as

$$\eta = 1 - \alpha \frac{(n-1)m + (m-1)n}{90mn}$$

Where:
η= Group efficiency
m= no. of rows.
n= no. of columns.
α= tan−1(□/□)
s= centre-centre spacing of piles.
d=Pile diameter.

Experimental Pile Group Efficiency

The spacing of piles is typically predetermined by practical and economical considerations. The design of a pile foundation subjected to vertical loads consists of

1. The determination of the ultimate load bearing capacity of the group Qgu.
2. Determination of the settlement of the group, Sg,under an allowable load Qga.

The ultimate load of the group is usually different from the sum of the ultimate loads ofindividual piles *Qu*.

Eg = QguΣQu

is called group efficiency which depends on parameters such as type of soil in which the piles are embedded, method of installation of piles. The efficiency of pile groups obtained by using this formula.

Test Result and Interpretation

The data obtained from tests on single pile and pile groups at various spacing's is presented and interpreted in the following sections.

Failure load

loadsettlement methods almost vertical tangent when the pile start sinking rapidly. The load corresponding to rapidsinking of the pile is taken as the failure load of the pile. Thefailure loads for the pile groups have been obtained in thesimilar manner.

Comparison of Experimental Failure Load with Other Theories

The final bearing capacity (Qu) of piles in granular soils is given by the following formula:

$$Q_u = A_p \left(\frac{1}{2} D_\gamma N_r + P_D N_q\right) + \sum_i^n K P_{Di} \tan\delta A_{si}$$

where *
A_p = cross-sectional area of pile toe in cm2;
D = stem diameter in cm;
γ = effective unit weight of soil at pile toe in kgf/cm3;
P_D = effective overburden pressure at pile toe in kgf/cm2;
N_r and N_q = bearing capacity factors depending upon the angle of internal friction ɸ at toe.
summation for n layers in which pile is installed;
K = coefficient of earth pressure;
P_{Di} = effective overburden pressure in kg/cm2 for the ith layer where i varies from 1 to n;
δ = angle of wall friction between pile and soil, in degrees (may be taken equal to ɸ)
A_{si} = surface area of pile stem in cm2 in the ith layer where i varies from 1 to n.

NOTE 1 — N_r factor can be taken for general shear failure asper IS: 6403-1981*.

NOTE 2 — N_q factor will depend, apart from nature of soil on the type of pile and its method of construction, for bored piles,the value of *N*q corresponding to angle of shearing resistance are given in Fig. 1. This is based on Berezantseu's curve for *D*/*B* of 20 up to = 35° and Vesic's curves beyond = 35°.

NOTE 3 — The earth pressure coefficient *K* depends on the nature of soil strata, type of pile and its method ofconstruction. For bored piles in loose medium sands, *K* values between 1 and 3 should be used.

NOTE 4 — The angle of wall friction may be taken equal to angle of shear resistance of soil.

NOTE 5 — In working out pile capacities using staticformula, for piles longer than 15 to 20 pile diameter,maximum effective overburden at the pile tip shouldcorrespond to pile length equal to 15 to 20 diameters.

III-CONCLUSION

From the model tests approved out on vertical pile groups of
rectangular, square and circular in loose sand following conclusion have been drawn:-

1. The pile group load increases as number of piles in agroup are increased.
2. The efficiency of determined pile groups in sand isextreme in square collection and lesser in rectangulargroup.
3. The experimental efficiency of pile groups is morethan the efficiency obtained by converse-Labarreformula.
4. The efficiency obtained by the experiment in loosesand is more than 1.
5. The ultimate bearing capacity of rounded groups ismore in comparison of other two groups.
6. The experimental failure loads for pile groups arehigher than the failure loads obtained using I.S codemethod.

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