Comparative Study and Analysis of the Lateral and Vertical Loads Of Pile Foundation

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Abstract *Pile foundations are common foundations for bridge abutment, piers and buildings resting on soft soil strata. Piles are structural members that are made of steel, concrete, or timber. They are used to build pile foundations. Despite the cost, the use of piles often is necessary to ensure structural safety. piles are used in construction work, depending on the type of load to be carried, the subsoil conditions, and the location of the water table The objective of the current study is to carry out parametric analysis of a group of piles by analyzing using finite element method & comparing the results obtained using empirical equations(Brom s method and Vesics method) . The piles are modelled as linear elements. The effect of soil structure interaction is taken into account by assuming it as vertical and horizontal soil spring (winkler soil spring) . Lateral subgrade modulus and vertical subgrade modulus of soil (KH and kv) is calculated as per is code 2911. The pile group is subjected to both vertical and horizontal forces.*

Keywords — *Spring Constants, Pile Foundation, Static Analysis, Staad Pro.*

I. INTRODUCTION

Pile foundations are adopted commonly for various types of multi-storeyed structures when the founding soil is weak and soft; and also in industrial structures, bridges, offshore structures. With increasing infrastructural growth and seismic activities, designing the pile foundations for load bearing conditions and soil conditions is of considerable importance for the efficient function of the structures especially, the lifeline structures like bridges etc. Several studies were conducted by various researchers on the lateral and verticial loaded analysis and design of the pile foundations and evolved different theories on the same. Codes of practice available in different countries suggested some procedures for find lateral and vertical loaded design of pile foundations. This paper presents a short discussion on the various theories evolved on load calculation pile performance concepts followed by outlines of suggested procedures by selected international and Indian codes on the subject. A soil profile is selected from Gangavaram, Vizag area as an exemplary case to demonstrating the load design of pile foundations. From this paper it can be summarised the points that need to be amended to Indian codes of practice to meet the state of the art developments in the subject. Presented in this research paper are the results of a competetive and Analysis of Laterally and Vertically Loaded of Pile foundations. compressive clay soil comparasion in cohesive soils, cohesiveless soils change parameters of pile (Length) depth in meter considered as primary parameter. Analysis is performed both for a single pile and a pile group. It was observed that lateral and vertical loaded pile foundation analysis.

II. SOIL INVESTIGATION

The overall purposes of this study are to investigate the stereography at the site, perform a detailed liquefaction susceptibility analysis for the site, and to develop geotechnical recommendations for design and construction of foundations for the proposed building and associated facilities. Static cone penetration tests to get the additional data for foundation analysis.

• Testing selected soil and groundwater sample in the laboratory to determine pertinent index and engineering properties of the soils.

• analyzing all field and laboratory data in order to develop engineering recommendations for foundation design and construction. This reports presents our engineering analysis and recommendations for the entire plant site, including detailed liquefaction susceptibility analysism Cohesiveness, soil angle of friction, Density water levels SPT N Values *Static Cone Penetration Test:* The static cone penetration is a specialized penetration test to obtain a profile of soil resistance with depth. The test was conducted using our skid mounted 10 tones capacity, hydraulically operated. The cone penetrometer used is a mechanical cone with friction jacket type that measures the total resistance to penetration, cone tip resistance and cone plus friction resistance. The test was conducted in general accordance with IS 4968 Part III

Plate Load Test: Plate load test was performed at the site at specified depth using a 30 x 30 cm size test plate. The test procedure was in general accordance with IS:1888-1982 Test results are presented as a graphical plot of bearing pressure on plate are measured

Laboratory Tests: The laboratory testing has been carried out in CENGRES laboratory. The quality procedure in our laboratory confirms to IS 2911. Soil Classification showing RL and Depth

Soil Data

Layer	Depth	Layer Thickness	Density	Submerged density	N	Cohesion	Angle of friction
No.	below	(m)	(kN/m3)	(kN/m3)	value	(kN/m2)	(deg)
1	6.53	6.53	18	7.75	38	150	
2	15.53	9	18	7.75	26	80	0
3	23.03	7.5	18	7.75	18	160	0
4	26.03	3	18	7.75	50	0	35
5	29.15	3.12	18	7.75	80	0	35
6	31.15	2	20	7.75	80	300	0

Pile Load Test

Static pile load test is the most reliable means of determining the load capacity of a pile. The test procedure consists of applying static load to the pile in increments up to a designated level of load and recording the vertical deflection of the pile. The load is usually transmitted by means of a hydraulic jack placed between the top of the pile and a beam supported by tow or more reaction piles. The vertical deflection of the top of the pile is usually measured by mechanical gauges attached to a beam, which span over the test pile

Load Applied to Pile

- Combinations of vertical, horizontal and moment loading may be applied at the soil surface from the overlying structure for the majority of foundations the loads applied to the piles are primarily vertical
- For piles in jetties, foundations for bridge piers, tall chimneys, and offshore piled foundations the lateral resistance is an important consideration
- The analysis of piles subjected to lateral and moment loading is more complex than simple vertical loading because of the soil-structure interaction. Pile installation will always cause change of adjacent soil properties, sometimes good, sometimes bad
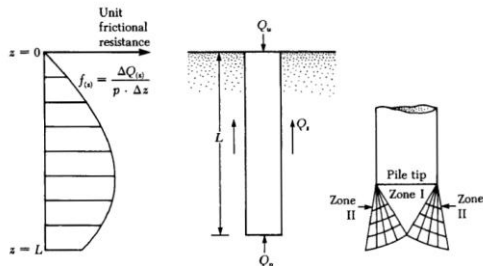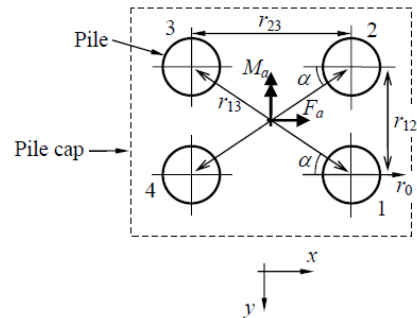

Design of Pile Foundations

The general criteria for the design of pile groups is that:

- The load-carrying capacity of a single pile should not be exceeded due to loads and moments coming from the superstructure.
- The load-carrying capacity of the group should not be exceeded by the total superposed loads.
- The settlements, both total and differential, should be within permissible limits.

The design of pile foundation may be carried out in the following steps:

- Calculate the loads. The total load acting on the piles includes the weight of the pile cap and the soil above it. If the ground is newly filled or will be filled in the future, the additional load on piles due to negative skin friction should be included.
- Get the soil profile of the site and, superimpose the outline of the proposed foundation and substructure on this. Mark the ground water level.
- Determine type and length of piles.
- Determine pile capacity.
- Establish pile spacing
- Check stresses in lower strata

Pile Analysis, Design and Detailing

For this pile foundation design, piles will be fixed-head, 0.2m diameter, cast-in-place piles arranged in pile groups with piles spaced at 0.4m inches center-to-center. The computer program STAAD PRO is used to analyze piles for both soil conditions (cohesive, cohesiveless) length of pile 12m, 28m. The response to lateral loads is affected to some degree by the coincident axial load
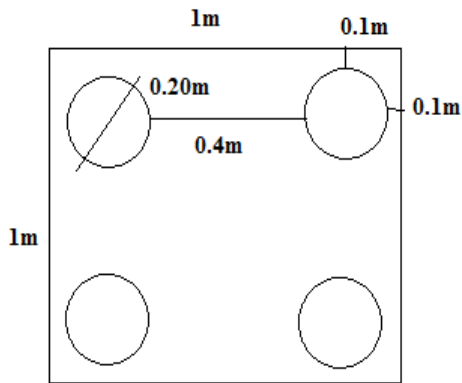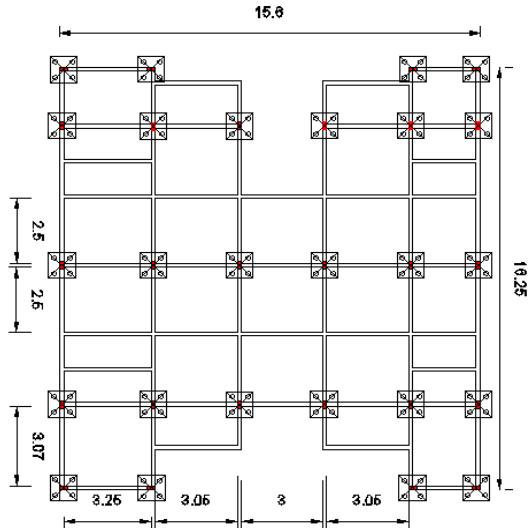
Piles Arrangement

Vertical Load Analysis Of Piles By P-Y Curves
The bearing capacity of groups of piles subjected to vertical or vertical and lateral loads depends upon the behavior of a single pile. The bearing capacity of a single pile depends upon size and length pile parameters. type of soil and the method of pile installation. The bearing capacity of a single pile increases with an increase in the size and length

Load Transfer Mechanism
The load transfer mechanism from a pile to the soil is complicated. consider pile of length L main factor. The load on the pile is gradually increased from Zero point to Q (z=o) at the ground surface, part of this load will be resisted by the side friction developed along the shaft Q_1. and part by the soil below the tip the pile Q_2. A static vertical load is applied on the top. It is required to determine the ultimate bearing capacity Q_u of the pile. When the ultimate load applied on the top of the pile is Q_u

Equations for determine Pile Capacity
The ultimate load carrying capacity Qu of a pile is given by the equatin $Q_u = Q_p + Q_s$
where Q_p= load carrying capacity of the pile point, Q_s = frictional resistance (skin friction) derived from the soil pile inter face.
Point bearing capacity Q_p: The Ultimate bearing capacity of shallow foundation according to terzaghi's equations $Qu = 1.3 \, C \, N_c + q \, N_q + 0.4 \, y \, B \, N_y$
The general bearing capacity equation for shallow foundations for vertical loading $q_u \, C \, N_c + q \, N_q + y \, B \, N_y$ where N_c, n_q and N_y are the bearing capacity factors the include the necessary shape and depth factors
$Q_p = C \, N_c + q \, N_q$ now that the term q has been replace by q' to signify effective vertical stress. thus the point bearing of piles is $Q_p = A_p \, q_p = A_p \, (\, c' \, N_c + q' \, N_q)$ where Ap= Area of pile tip c= cohesion of the soil supporting the pile tip, qp = unit point resistance q- effective vertical stress at the level of the pile
The total ultimate load Qu is expressed as the sum of these two, that is, $Q_u = Q_b + Q_f = q_b \, A_b + f_s \, A_s$

Utimate friction load
The load transmitted to the soil along the length of the pile is called the Ultimate Friction load or Skin load Q_f. load transmitted to the base is calld the base or point load Q_b. The Total Ultimate Load is expressed as the Sum of Base load and Ultimate friction load

Q_u = Ultimate Friction load (Q_f) + Base Point load (Q_b)

Factor of Safety
The working load for all pile types in all types of soil may be taken as equal to the sum of the base resistance and shaft friction divided by a suitable factor of safety. A safety factor of 2.5 is normally used
$Q_a = Q_b + Q_f$ / 2.5 (Factor of Safety as per IS 2911)

General Theory For Ultimate Bearing Capacity
The total failure load Q_u may be written as follows:
$Q_u = Q_u + W_p = Q_b + Q_f + W_p$ The general equation for the base resistance may be written as $Q_b = C \, N_c + q'_o \, N_q + 0.5 \, yd \, N_y \, A_b$ For cohesionless soils, c = 0 and the term cohesive friction becomes insignificant in comparison with the term $q_o N_q$ for deep foundations $Q_b = Q_u + W_p = q \sim N_q A_b + W_p + Q_f$

The net ultimate load in excess of the overburden pressure load $q_o A_b$ is

$$Q_u + W_p - q_o A_b = q'_o N_q A_b + W_p - q'_o A_b + Q_f$$

If we assume, for all practical purposes, W_p and $q'_o A_b$ are roughly equal for straight side or moderately tapered piles

$$Q_u = q'_o N_q A_b + Q_f$$

$$Q_u = q'_o N_q A_b + A_s \bar{q}'_o \overline{K}_s \tan \delta$$

Cohesive Soils

For cohesive soils such as saturated clays (normally consolidated), we have for $</> = 0$, N - 1 and N= 0. The ultimate base load from Eq. (5) is

$$\overline{Q}_b = (c_b N_c + q'_o) A_b$$

The net ultimate base load is

$$(\overline{Q}_b - q'_o A_b) = Q_b = c_b N_c A_b$$

Therefore, the net ultimate load capacity of the pile, Q_u, is

$$Q_u = c_b N_c A_b + Q_f$$

$$Q_u = c_b N_c A_b + A_s \, \alpha \, \overline{c}_u$$

Pile Spacing: The minimum centre-to-centre spacing of piles is considered from three aspects, namely, practical aspects of installing the piles, diameter of the pile, and nature of the load transfer to the soil and

possible reduction in the load capacity of piles group. In case of piles resting on rock, the spacing of two times the said diameter may be adopted. The spacing of piles in a group depends upon many factors such as overlapping of stresses of adjacent piles, cost of foundation and efficiency of the pile group.

Pile Groups In Cohesive Soils:

The effect of driving piles into cohesive soils (clays and silts) is very different from that of cohesionless soils. When piles are spaced at closer intervals, the soil contained between the piles move downward with the piles and at failure The load-carrying capacity of a pile groupmay be equal to or less than the load-carrying capacity of individual piles multiplied by the number of piles in the group

$$Q_u = q'_o N_q A_b + \bar{q}'_o \overline{K}_s \tan \delta \, A_s \quad \text{-->Eqn 11}$$

$$Q_u = q_b A_b + f_s A_s \quad \text{-->Eqn 12}$$

Ultimate bearing capacity Load Carrying Capacity of Piles The Ultimate Bearing Capacity Q_u of Piles

$$Q_u = A_s \, (\, 0.5 \, D \, y \, N_{y+} P_D \, N_q) + K_i \, P_{Di} \tan \delta_i \, A_{si}$$

III. LATERAL LOAD ANALYSIS

Laterally Loaded Analysis by Using Subgrade Reaction Using Vesics method : A horizontal load on a vertical pile is transmitted to the subsoil primarily by horizontal subgrade reaction generated in the upper part of the shaft. A single pile is normally designed to carry load along its axis. Transverse load bearing capacity of a single pile depends on the soil reaction developed and the structural capacity of the shaft under bending.

As per Vesic (1961), modulus of subgrade reaction There are various methods available for

analysis of laterally loaded piles such as Equivalent Fixity Depth Approach As per IS: 2911-1979

Vesic has suggested the following for approximating ks from the allowable bearing capacity qa based on geotechnical data:

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Range of modulus of subgrade reaction ks.

	Ks (kN/m3)
Loose sand	4800-6000
Medium dense sand	9600-80000
Dense sand	64000-128000
Clayey medium dense sand	32000-80000
Slity medium dense sand	24000-48000
Clayey soil	
qa $\leq$ 200 kPa	12000-24000
200 < qa $\leq$ 800 kPa	24000-48000
qa > 800 kPa	>48000

Soil Spring Constants
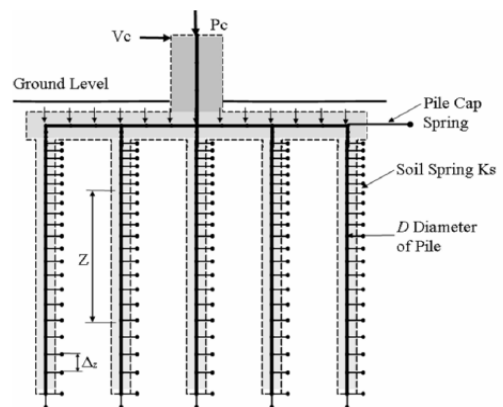
Lateral Load Analysis Using Broms Method

Analysis of piles using Brom's methods by IS 2911: Analysis of a single pile according to Brom's is described in Brom's, 1964. This method exclusively assumes a pile in the homogeneous soil. Thus the analysis method does not allow for layered subsoil. The lateral soil resistance for granular soils and normally consolidated clays which have varying soil modulus is modelled according to the equation

Modulus of Subgrade Reaction for Granular Soils, ϕh, in kN/m3

Sl No.	Soil Type	N (Blows/30 cm)	Range of η_h kN/m^3 × 10^3	
			Dry	Submerged
(1)	(2)	(3)	(4)	(5)
i)	Very loose sand	0-4	< 0.4	< 0.2
ii)	Loose sand	4-10	0.4-2.5	0.2-1.4
iii)	Medium sand	10-35	2.5-7.5	1.4-5.0
iv)	Dense sand	> 35	7.5-20.0	5.0-12.0

NOTE — The η_h values may be interpolated for intermediate standard penetration values, N.

The lateral soil resistance for preloaded clays with constant soil modulus is modelled according to the Brom's equation with help of K_1 Terzaghi's modulus of subgrade reaction.

From analysis of structure, it is found that maximum axial load in working condition is 2932 kN. Pile capacity is checked for above value of axial load required to be transmitted. Bearing capacity of piles is calculated as per procedure given in Appendix B IS: 2911-1979 part 1/sec 2

Ultimate Skin Resistance $Qs = (\alpha*C + K*Pdi*\tan\delta)*Asi$

Ultimate End Bearing Capacity $Qb = (Cp*Nc + Pd*Nq + 0.5*\gamma*B*N\gamma)*Ap$

Ultimate Bearing Capacity Of Soil $Qu = Qs + Qb-W$

IV COMPARISION & CONCLUSION

The analytical methods like Broms presented almost half a century back still holds good in estimating the pile head deflections under the lateral loads. Even though these methods overestimate the deflection, they can still be adopted considering the soil as a complex and nonlinear material which is influenced by many variables, including its history, nature of loading, changes in the environment, method of pile installation etc. Broms methods which gave fairly accurate results can be adopted for small scale projects and when softwares are not available for the analysis. The STAAD Pro analysis, though applicable for structural analysis and design, can be effectively used to evaluate pile head deflections with some multiplication factor due to its consistently lower deflection values. Its dependence on soil spring constants and ultimately on the accuracy in the estimation of soil elastic modulus based on soil properties and field data shall be well understood before its use. Comparision between Cohesive Soils, Cohesiveless Soils Behaviour of piles Single pile lateral and verticial load bearing capacity and group of piles. Obtain Various Pile Parameters (Length) Ground Level soil behavior. Calculating efficiency of the pile Subjected to lateral loads. Calculating Bending moment, shear forces, deflection and response of Piles. Conclude with effeciency Pile length soil spring constant suitable for site. While comparing Pile length on cohesivess less soils pile. showing results with suitable pile length and diameter for buidling.

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