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COMPARATIVE STUDY ON LOAD CARRYING CAPACITY OF PILES WITH VARYING LENGTH /DIAMETER RATIO OF PILES

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Abstract:-The evaluation of load carrying capacity of piles needs the geotechnical properties, **penetration tests**, the nature of the subsoil both around and beneath the proposed pile, adequate description of rock to convey its physical behaviour on borings, dead loads, live loads dimensions of the piles (length and diameter of pile).To compare the length and diameter response of bored cast in situ piles, the data required is obtained from the ongoing work in Nagpur city. The site is located at Mankapur ROB, Nagpur–Saoner road under the project name of Four Laning of **Nagpur-Saoner-Betul Section of NH-69.** The subsoil profile of site shows the **clayey and silty clayey soils** at the top to the considerable depth underlying highly weathered sandstone. The water table is observed from 4.5 m below the ground level. Here it is not possible to provide shallow, raft foundation as the soil strata mostly clayey and silty clayey soils which have very less safe load bearing capacity. Hence deep foundation proposed for the work. Theoretical settlement for different diameters of piles for 25m length of pile has been computed. It has been observed that the theoretical settlement for 1.2 m diameter pile for 25 m length of pile is found to be more than actual settlement obtained from pile test for the same dimensions of the pile. Since theoretical settlement prediction is within in permissible limit and greater than the settlement obtained from the actual pile load test data, the load – settlement designed using excel can be used by the geotechnical engineers for prediction of the load and settlement calculations.

The load carrying capacity for different diameter of piles and for different length of piles goes on increasing with the increase in diameter. The contribution of end bearing resistance is up to 170%, whereas contribution of frictional resistance is up to 40%.

I. INTRODUCTION

The National High-Way Authority of India has proposed to construct the four laning of Nagpur-Saoner-Betul Section of NH-69.The geotechnical investigation is carried out for the proposed construction of Railway over Bridge (ROB) at CH. 5+165 for M/s Oriental structural Engineers Pvt. Ltd.The Geotechnical Investigation is done by Geotech Services, Soil & Material Testing Laboratory Nagpur. Investigation was intended to evaluate the geotechnical parameters for the design of safe bearing capacity of the available soil/rock stratum and other physical parameters necessary for the design of suitable foundation. In geotechnical investigation eight bore holes drilled the Depth of 30 m below ground level. Bore holes are drilled at spacing of about 50 m and about 25 m near the railway track. Disturbed and undisturbed soil samples are collected during drilling from various depths. Standard Penetration Tests (SPT) as per IS: 2131:1981 are also conducted in bores at different depths. Water table was observed from 4.5 m to 10 m. below GL .in bores. In laboratory ,soil samples collected from bores are tested for soil classification (IS: 1498) i.e. sieve analysis (IS:2720 Part 2).liquid and plastic limits (IS:2720 Part 5),free swell index (IS:2720 Part 40),natural moisture content and density (IS:2720 Part 27),specific gravity (IS:2720 Part 3),direct shear test (IS:2720 Part 13),consolidation test (IS:2720Part15) ,design of piles (IS 2911 Part 1) & (IRC 78 SEC-7) Laboratory testing carried out by M/s Geotech Services, Nagpur on 31.01.2011 Laboratory test results on soil samples are presented. Because of presence of soft soil strata up to considerable depth, pile foundation is preferred for all piers of ROB at 5+165 location. The design of piles is prepared from the results of laboratory tests i.e. cohesion from shear test and from data of 'N' Value of SPT.

II. FORMULAS

2.1 GEOTECHNICAL DESIGN OF PILE:-

As per IRC 78 (2000) clause :-709.3.1

Axial load carrying capacity is initially determined by calculating resistance from End bearing at the toe/tip or wall friction /skin friction along pile surface or both. Based on the soil data, the ultimate load carrying capacity (Qu) is given by

Qu= Ru+Rf

Ru= ultimate base resistance

Rf= ultimate frictional resistance

$$R_u = Ap(½D.\gamma.N_\gamma + P_d N_q) + A_p N_c C_p \quad \text{Equ.2.1.1}$$

Ap =cross-sectional area of base of pile

D =Diameter of pile in cm.

γ=effective unit weight of soil at the pile tip in kg/cm3

Nq & Nγ = Bearing capacity factors at the tip of pile based on angle on angle of internal friction

Nc=bearing capacity factor usually taken as 9

Cp=average cohesion at the tip (calculate from the unconsolidated undrained test)

Pd=effective overburden pressure at the pile tip limited to 20 times the diameter of pile for piles

where,

K=Coefficient of earth pressure

P_{di}=effective overburden pressure in kg/cm2 along the embedment of pile for the ith layer where i varies from 1 to n δ=angle of intern $R_f = \sum_{i=1}^{n} KP_{di} \tan\delta \, A_{si} + \alpha \bar{C} A_s$ taken as equal Equ.2.1.2

internal friction

Asi=surface area of pile shaft in cm^2 ,I varies from 1 to n

2.2. Calculation for ultimate bearing capacity of piles in cohesive soils:-

The ultimate bearing capacity of piles is dependent on the properties of the soil in which it is embedded. Axial load from a pile is normally transmitted to the soil through skin friction along the shaft and end bearing at its tip. By using the static formulae, the estimated value of ultimate load capacity of a typical pile is obtained; the accuracy depends on the reliability of the formulae and the reliability of the available soil properties for various strata. Two separate formulae for cohesive and non-cohesive soils are indicated in IS: 2911 (SEC2).

Qu (cohesive soil)=Ap.Nc.Cp + α.C.As Equ2.2.1

The part one gives the ultimate load carrying capacity at the tip of pile in case of cohesive soils. The part two gives the ultimate load carrying capacity surrounding the pile in case of the cohesive soils. Symbol notations are as per the equations 2.1.1 & 2.1.2.

2.3. Calculation for ultimate bearing capacity of piles in cohesion-less soils:

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

Qu=Ap*(1/2 *D*γ*Nγ + Pd*Nq) + ∑DK*Pdi*Tanδ*Asi Equ.2.3.1

The part one gives the ultimate load carrying capacity at the tip of pile in case of cohesion- less soils. The part two gives the ultimate load carrying capacity surrounding the pile in case of the cohesion- less soils. Symbol notations are as per the equations 2.1.1 & 2.1.2. (Table No.7.1.2 Bearing Capacity Factors as IS: 6403: 5.1.1)

III. CALCULATIONS

3.1. Calculation of settlement due to compressible strata.

The settlement due to compressible strata (**as per the clause 9.3.3**) is given by-

$$S_I = C_c \frac{H_c}{1 + e_0} \log_{10} \frac{p_0 + \Delta_p}{p_0}$$ Equ.3.1.1

Cc=compression index
Hc=Thickness of compressible strata undergoing settlement, cm
e_0=Initial void ration at the mid height of the layer.
P_0=Initial effective pressure at the mid height of the layer, kg/cm2
Δp=pressure increment, kg/cm2
Note-1.The thickness of the compressible strata will be 1/3 of the thickness of the upper strata for the approximate stress distribution method.
Note-2. P_0 and Δp are to be taken for the point at the middle of the thickness. (H1)

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3.2. Calculation of settlement due to sand (incompressible strata.)

The settlement due to incompressible strata for the equivalent raft loading (**as per the clause 9.3.4 IS 8009:1980**) is given by-

$$S_{II} = \frac{\mu_1 \mu_0 pB}{E_v} \quad \text{Equ. 3.2.1}$$

μ_1, μ_0= Factors related to depth of the equivalent raft foundation thickness of compressible soil layer and length/width ratio of equivalent raft foundation.
P=foundation pressure on an equivalent raft, kg/cm^2
B= width of pile (D=B)
Ev=Modulus of elasticity in vertical direction, kg/cm^2
Note-1.The constants μ_1 and μ_0 are read from the following As per IS CODE 8009 (Part 2). (here Hc=Hii)
Note- 2.The deformation modulus Ev can be obtained from the standard Penetration test. The curves relating to the deformation modulus to the standard Penetration resistance (N Value) is shown in IS CODE 6403 .for μ =1.5
Note-3.The possibility of development of negative skin friction should not overlook in this case.
Note-4.In this case settlement is to be calculated for the loading at end and for the Frictional loadings separately, and the two added to get the relevant value.
Note-5.The computations are done as per equations 3.1.1 & 3.1.2 (IS 8009:1980 Clause 9.3.3 &9.3.4) the settlement may computed for the equivalent raft, as if the footing is at shallow depths and therefore the computed values are corrected for depth as per **IS** CODE 8009 (Part 2)

IV. CONCLUSIONS

1. As the diameter is increased from 1.0m to 1.4m, the C/S area of pile increases up to 96 %, the total load carrying capacity of the pile increases up to 104 %. For the diameter of 1.4 m the frictional load carrying capacity is found to increase by 40%, whereas end bearing resistance is found to increase by 174% for pile length of 25 m.
2. As the diameter of pile increases from 1.0m to 1.4m, the total load carrying capacity of the pile increases to 79 % for pile length of 15 m..I.e. Total load carrying capacity of pile almost get doubled for piles length more than 20 m.
3. As the diameter of pile increases from 1.0 m to 1.4 m, the total Settlement of the pile increases to 109 %. Separating, for 96% C/S Area increment the Settlement due to frictional load is found to 25%.whereas Settlement due to end bearing resistance is found to be 106 %.for pile 25 m long.
4. The theoretical Settlement for the pile diameter of 1.2 m and length 25 m is found to be 18.0 mm and that for the practical load application (initial pile load test) is found to be 4.0 mm.

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