A Research on Access of Load Carrying Capacity of Large Diameter 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 behavior 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 site of project name Four Laning Project 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.

Sufficient number of borings taken in accordance with IS: 1892. Study is done by using all these geotechnical engineering properties at all bore holes locations, varying length and diameters of piles for evaluation of load carrying capacities as per IS:2911 (Part 2) and IRC:78. 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 increases up to 170%, whereas contribution of frictional resistance increases up to 40%.

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.

Index Terms -- Deep foundation, Piles, End bearing resistance, Frictional resistance.

I. INTRODUCTION

The Large Diameter Pile Foundations are also known as Drilled Well Foundations. This is another type of pile or an alternate for pile foundations. Strictly speaking these large sized bored/drilled piles having a minimum diameter of up to 1.2 m for river bridges (1 m in the case of bridges located on land such as flyovers, road bridge over railway track etc.) are almost analogous to well foundations. These large sized piles combine the methodology and load transfer mechanism of well foundation. Frictional forces are mostly neglected while calculating their load carrying capacity thus deriving their load carrying capacity from the transfer of load to the hard stratum on which it is resting.

In geotechnical engineering the evaluation of settlements of deep foundations is an important design aspect to obtain safe and economical structures. Excessive settlements could lead to a loss in serviceability or even failure of the superstructure. Therefore, pile design may be governed by movement and not capacity. Fellenius (2009) points out that pile analysis is often thought limited to estimating only the ultimate capacity, sometimes separating the components of shaft and end base resistance. However, the load transfer relationship can provide further information about the soil structure interaction. How the load is transferred to the soil depends on factors such as soil type, pile material, installation method and the presence or absence of residual loads (Mosher & Dawkins, 2000).

The following were the objectives studied in the research:-

- The effect of diameter on the load carrying capacity of pile.
- The effect of length on the load carrying capacity of pile.
- The settlement of the piles due to the change in length/diameter of piles.

II. FIELD AND LABORATORY INVESTIGATIONS

Investigation was made to find 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 to the depth of 30 m below ground level. Bore holes are drilled at spacing of about 50 m.

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.

The soil samples collected from bores were tested in laboratory for soil classification as per IS codes. The classification and stratification of soil of bore holes are done as per SPT value is given in Table 1. A sample bore log is given in the Figure 1.

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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. The depth of fixity is not given in results which are to be confirmed by structural consultants for calculations of moments.

Table: 1 Classification and Stratification of soil with respect to Standard Penetration Test Results (N)

Type of Stratum	Location & Depth Of Stratum in Meter							
	BH1	BH2	BH3	BH4	BH5	BH6	BH7	BH8
Blackish clayey soil	Gl-3.0	Gl-3.5	Gl-2.0	Gl-2.0	Gl-2.0	Gl-2.0	Gl-1.5	Gl-3.0
Yellowish clayey Soil	3.0-7.5	3.5-4.5	2.0-5.0	2.0-15.0	2.0-13.5	2.0-4.0	1.5-10.0	3.0-3.5
Clayey Sand	7.5-17.0	4.5-16.5	5.0-9.0	15.0-15.5	13.5-15.0	4.0-15.0	-	3.5-10.5
Highly Weathered Sandstone	-	16.5-30.0	9.0-30.0	-	-	15.0-30.0	-	10.5-30.0
Radish Clay Shale	17.0-30.0	-	-	15.5-17.0	15.0-18.0	-	-	-
Highly Weathered Sandstone	-	-	-	17.0-22.5	18.0-24.0	-	-	-
Shale Grey	-	-	-	22.5-30.0	24.0-30.0	-	-	-

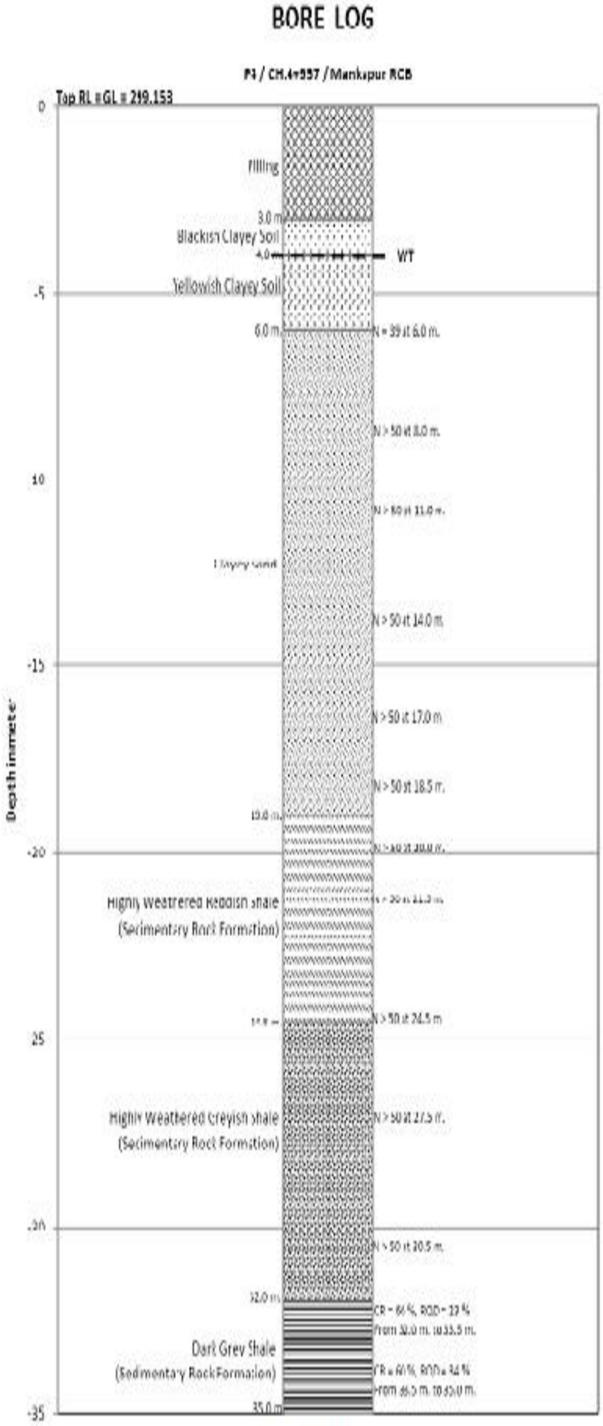

Figure 1

III. FRICTIONAL, END BEARING RESISTANCE CALCULATIONS

The determination of the ultimate point bearing capacity, q_b, of a deep foundation on the basis of theory is a very complex one, since there are many factors which cannot be accounted for in the theory. The theory assumes that the soil is homogeneous and isotropic which is normally not the case. All the theoretical equations are obtained based on plane strain conditions. Only shape factors are applied to take care of the three-dimensional nature of the problem.

Compressibility characteristics of the soil complicate the problem further. Experience and judgment are therefore very essential in applying any theory to a specific problem. The skin load $Q_{f,}$ depends on the nature of the surface of the pile, the method of installation of the pile and the type of soil. An exact evaluation of Q_b is a difficult job even if the soil is homogeneous over the whole length of the pile. The problem becomes more complicated if the pile passes through soils of variable characteristics.

The restrictions for the type of pile, method of construction & installations, availability of machineries with required diameter of piles, soil profile, location of piling work has the great effect on the selection of piling equipment diameter of auger. It is possible to provide available diameter of pile by increasing the length of the pile provided the soil strata can be drilled with that equipment. Also it is possible to minimise the settlement with lesser diameter of pile provided that the section of pile must satisfy the structural stability of piles with the surrounding soils.As the design of piles to be handy to all the structural and geotechnical engineers a MS Excel was designed where in all the inputs are to be incorporated to get the frictional resistance, end bearing resistance and total resistance of the pile. Screen shot of sample excel sheet is shown in the Table 2.

Table 2. Sample Calculation of Frictional resistance and End Base resistance

BORE HOLE NO. 8-(1 M)

For accuracy ,Whole 25 m layer is sub-divided in to layer of 1m each and frictional resistance is calculated for each layer

	Length of pile (m)	Dia. of pile (m)	Length/ Diameter ratio	Depth (m)	Pdl (t/sq.m)	Asl (sq.m)	Tanφ	K	K.Pdi.Tanφ	K.Pdi.Tanφ x Asi
Frictional Resistance	25	1	25.00	2.25	0	0	0.4	1.5	0.0	0
	(From 2.25m to 27.25) Sandy Soil with Clay			3.25	1.0	3.14			0.6	1.79
				4.25	1.9	3.14			1.1	3.58
				5.25	2.9	3.14			1.7	5.37
				6.25	3.8	3.14			2.3	7.16
				7.25	4.8	3.14			2.9	8.95
				8.25	5.7	3.14			3.4	10.74
				9.25	6.7	3.14			4.0	12.53
				10.25	7.6	3.14			4.6	14.32
				11.25	8.6	3.14			5.1	16.11
				12.25	9.5	3.14			5.7	17.90
				13.25	10.5	3.14			6.3	19.69
				14.25	11.4	3.14			6.8	21.48
				15.25	12.4	3.14			7.4	23.27
				16.25	13.3	3.14			8.0	25.06
				17.25	14.3	3.14			8.6	26.85
				18.25	15.2	3.14			9.1	28.64
				19.25	16.2	3.14			9.7	30.43
				20.25	17.1	3.14			10.3	32.22
				21.25	18.1	3.14			10.8	34.01
				22.25	19.0	3.14			11.4	35.80
				23.25	20.0	3.14			12.0	37.59
				24.25	20.9	3.14			12.5	39.38
				25.25	21.9	3.14			13.1	41.17
				26.25	22.8	3.14			13.7	42.96
				27.25	23.8	3.14			14.3	44.75
	Capacity of pile (t)									581.69
	Capacity of pile (t) FOS=2.5 (clause 709.3.2 of IRC 78)									232.67
Base Resistance	Highly Weathered sandstone	Nq and Nγ are based on Angle of internal friction which in turn depends on N value SPT at 10.5 m . Onwards indicated refusal . Considering N=refusal , φ= 45° also pile may plough in the soil stratum below .local shear is considered and φ is reduced to 2/3 tanφ=33°								
		for this angle we have, Nγ=35.2 and Nq=40								
		pd=17.5x(1.95-1)=16.62 Ap.(1/2.Dγ.Nγ + Pd.Nq)= A_p*(0.5*1.0*(1.95-1)*35.2+16.62*40								534.99
Capacity of pile (t) FOS=2.5 (clause 709.3.2 of IRC 78)										214.00
TOTAL CAPACITY =										446.67

Table 3. Design Summary For Length Of Pile 25 M

Bore Hole No.	Design Parameters (For Length 2.25 TO 27.25),L=25 M			Shaft Resistance (t)	Base Resistance(t)	Total Resistance(t)
	N' Value	Bulk Density	Pile Dia. (m)			
8	>50	1.95	1.0	232.6	214	446.67
8	>50	1.95	1.1	255.9	284.8	540.74
8	>50	1.95	1.2	279.2	369.9	649.11
8	>50	1.95	1.3	302.4	470.8	773.35
8	>50	1.95	1.4	325.7	587.2	913.00
7	>50	1.929	1.0	227.5	209.2	436.76
7	>50	1.929	1.1	250.2	278.5	528.85
7	>50	1.929	1.2	273.0	361.5	634.6
7	>50	1.929	1.3	295.7	459.7	755.58
7	>50	1.929	1.4	318.5	574.3	892.92
6	>50	1.942	1.0	230.7	208.2	438.91
6	>50	1.942	1.1	253.7	277.0	530.80
6	>50	1.942	1.2	276.8	359.7	636.56
6	>50	1.942	1.3	299.9	457.4	757.35
6	>50	1.942	1.4	323	571.3	894.31
5	>50	1.911	1.0	223.8	205.9	429.81
5	>50	1.911	1.1	246.2	274.2	520.44
5	>50	1.911	1.2	268.6	355.8	624.44
5	>50	1.911	1.3	291.0	452.6	743.62
5	>50	1.911	1.4	313.4	565.2	878.69
4	>50	1.921	1.0	225.5	207.3	432.88
4	>50	1.921	1.1	248.1	276.0	524.21
4	>50	1.921	1.2	270.6	358.5	629.28
4	>50	1.921	1.3	293.2	455.8	749.12
4	>50	1.921	1.4	315.8	569.3	885.14
3	>50	1.95	1.0	232.6	214	446.67
3	>50	1.95	1.1	255.9	284.8	540.74
3	>50	1.95	1.2	279.2	369.9	649.11
3	>50	1.95	1.3	302.4	470.2	772.72
3	>50	1.95	1.4	325.7	587.2	913
2	>50	1.956	1.0	234.1	215.4	449.55
2	>50	1.956	1.1	257.5	246.7	504.26
2	>50	1.956	1.2	280.9	341.9	622.89
2	>50	1.956	1.3	304.3	473.0	777.46
2	>50	1.956	1.4	327.8	590.5	918.35
1	>50	1.958	1.0	234.6	215.8	450.43
1	>50	1.958	1.1	258.1	287.2	545.39
1	>50	1.958	1.2	281.5	372.8	654.43
1	>50	1.958	1.3	305.0	474.3	779.39
1	>50	1.958	1.4	328.4	592.3	920.79

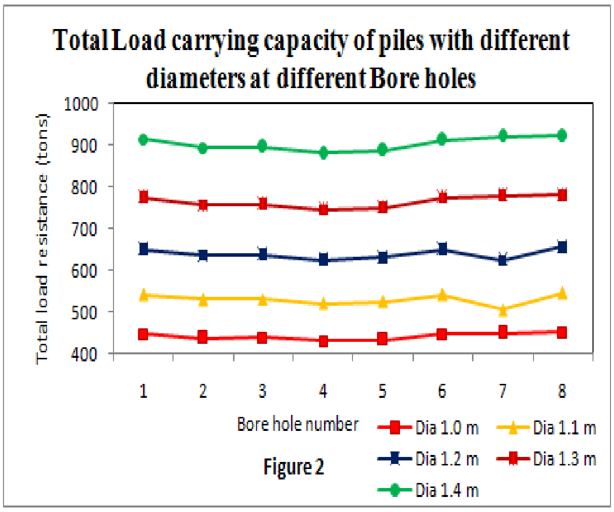

Figure 2

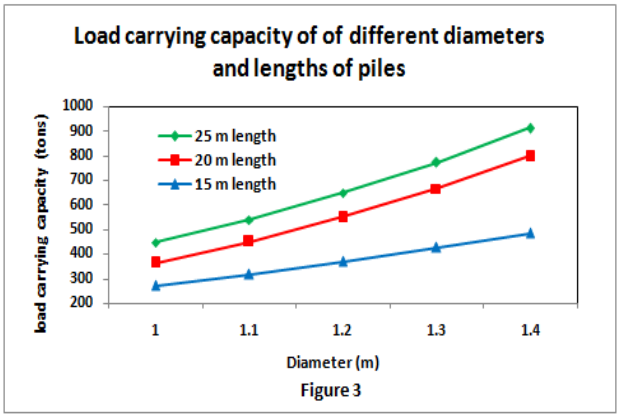

Figure 3

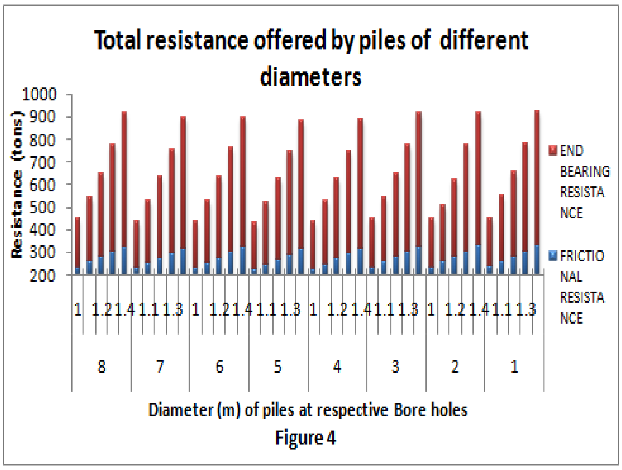

Figure 4

IV. SETTLEMENT ANALYSIS& RESULTS

The settlement was calculated for the 25 m length of pile for each bore hole with varying diameters of piles. The settlement of piles through compressible strata into sand depends upon the ratio between point resistance and total load. It will be the sum of the settlement of the compressible strata and the sand stratum. After separating the skin friction and the point resistance, the settlement of the upper strata (layer 1) due to skin friction and the settlement of the sand stratum (layer II) are added to obtain the total settlement.

A) Test Procedure for initial pile load test in compression

The test shall run in general as per procedures laid down in IS: 2911-IV.

i. The pressure gauge of jack and dial gauges shall be set zero before application of any load.

ii. The load shall be applied in increment of about 1/5th safe load and shall be maintained as given in the table 2.

iii. After maintaining the load at each stage as stated above, load shall be reduced to 0 and displacement of the pile top shall be recorded after 15 minutes of release of load to zero.

iv. Further next increment shall be applied, starting from zero, and shall be maintained and released as stated above. Increment shall be given till the final test load (i.e. 800 MT) is achieved and same shall be maintained for 24 hours.

v. Final test load shall be unloaded in the same decrement and rebound shall be recorded.

B) Safe load and maximum settlement criteria as per IS: 2911:1979

i. Two-thirds of the final load at which the total displacement attains a value of 12 mm unless otherwise required in a given case on the basis of nature and type of structure in which case the safe load should be corresponding to the stated total displacement permissible.

ii. 50 percent of the final load at which the total displacement equal to 10 percent of the pile diameter in case of uniform diameter piles and 75 percent of bulb diameter in case of under reamed piles.

C) In pile load test :-

The test is continued until the deformation reaches 0.1 D or a single where further deformation does not increases load significantly.

i) After reaching the ultimate load, the load is released in decrements of 1/6th of the total load and recovery is measured until full rebound is established.

ii) After final unloading, the settlement is measured for 24 hours to estimate full elastic recovery.

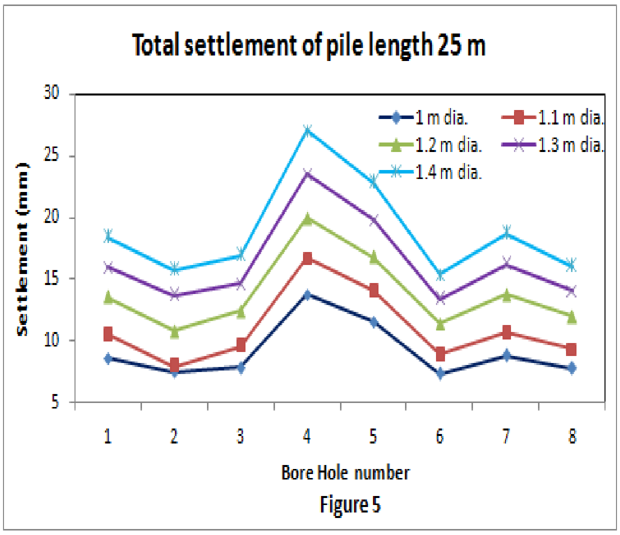

Figure 5

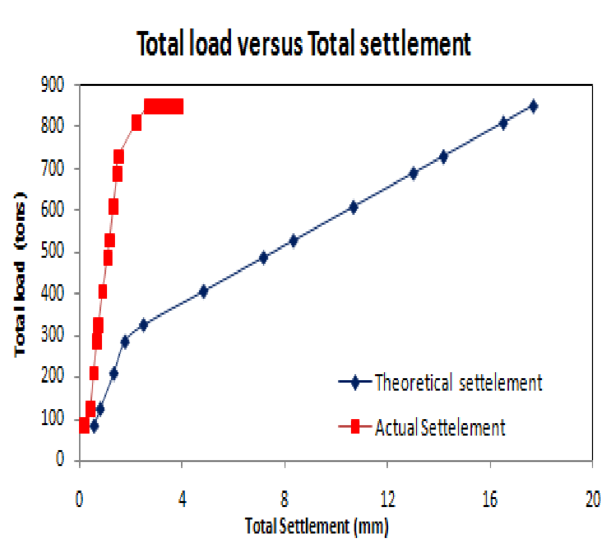

Figure 6

V. CONCLUSION

By varying the diameter from 1.0 m to 1.4 m the following conclusions are drawn in respect of ultimate/safe carrying capacity and settlement of single pile foundation.

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 pile diameter of 1.4 m and pile length of 25 m, the frictional resistance carrying capacity is found to increase by 40%, whereas end bearing resistance is found to increase by 174% .

2. As the diameter of pile increased 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 gets almost doubled for piles length more than 20 m .

3. As the diameter of pile increased from 1.0m to 1.4m, the total Settlement of the pile increases to 109 %. For 25 m length of pile, the settlement due to frictional load is found to approximately25%, due to end bearing resistance it is found to be approximately 106 %.

4. The theoretical Settlement for the pile diameter of 1.2 m and length 25 m is found to be approximately18.0 mm and from the initial pile load test it is found to be approximately 4.0mm.

5. An Excel sheet is designed for practice engineers to find the theoretical frictional resistance and end bearing resistance and total resistance (i.e., total load carrying capacity of the pile). The sample of the same shown in the table 2.

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