A Study on Comparative Analysis of Vertical & Lateral Load Capacity of Pile Foundation at Various Locations

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Abstract. **When structures are constructed at a situation where stratum of required bearing capacity is at greater depth or steep slopes are encountered or if the underneath soil are compressible soil or water logged type or soil of made of type and also in where load coming from the structure is heavy and non uniform then all these above conditions demands heavy compressive load. These structure needs foundation which can take these heavy compressive load, uplift load and lateral load without failure. Piles of different materials are extensively used in such cases depending on the in situ condition. In the present study soil exploration has been executed and undisturbed soil samples has been collected upto depth of 30 m below ground level from three locations of West Bengal namely, Beleghata (Site - 1), Girish Park (Site - 2), Kajipara (Barasat) (Site - 3) respectively. Engineering Properties of soil samples has been determined by routine tests from three above mentioned sites and furthur evaluation has been prococuted for the types of foundation required for minimum reruirement for construction of G+4 building (assumed) at that respective sites from which the soils are collected for the study and after that determination of the vertical load, uplift load (if any) and lateral load capacity of the pile foundation has been done and ultimately a compartive study has been executed between that capacities (vertical, lateral and uplift) for three different locations used in the present study.**

Keywords — Vertical Pile Load Capacity, Comparative Analysis, Lateral Pile Load Capacity, Pile Foundation, Uplift Pile load Capacity.

I. INTRODUCTION

When structures are constructed at a situation where stratum of required bearing capacity is at greater depth or steep slopes are encountered or if the underneath soil are compressible soil or water logged type or soil of made of type and also in where load coming from the structure is heavy and non uniform then all these above conditions demands heavy compressive load. These structure needs foundation which can take these heavy compressive load without failure. Piles of different materials are extensively used in such cases depending on the in situ condition. In the early nineteen century, there are number of pile driving formulae to estimate the bearing capacity of piles: the static approach, which basically used in normal soil mechanics techniques to calculate the load carrying capacity of piles from measured soil properties and the dynamic approach which estimates the load capacity of the driven piles from analysis of pile driven data. In static formula the ultimate load capacity of the single pile is expressed by the sum of ultimate shaft and base resistance less the weight of the pile. Boussinesq and Wester Guard [5] developed a method based on elastic analysis for estimating soil pressures at various points in semi infinite, isotropic, homogeneous and elastic mass of soil stratum. Here loading is vertical load at the surface. Mindlin [18] produced a set of equations giving the stresses due to vertical point load applied below the surface of a semi-infinite medium. Whitaker and Cooke [23] presented a simplified method of constructing load settlement curve taking account of pile soil slip along the shaft. In the present ongoing investigation therefore the ultimate compressive load capacity of pile and pile groups in homogeneous cohesionless soil has been studied. The various parameters such as length of the pile, embedment length, pile materials have been changed to bring out the effect of the parameters.

In this paper soil exploration has been executed and undisturbed soil samples has been collected upto depth of 30 m below ground level from three locations of West Bengal namely, Beleghata (Site - 1), Girish Park (Site - 2), Kajipara (Barasat) (Site - 3) respectively. Engineering

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Properties of soil samples has been determined by routine tests from three above mentioned sites and furthur evaluation has been procecuted for the types of foundation required for minimum reruirement for construction of G+4 building (assumed) at that respective sites from which the soils are collected for the study and after that determination of the vertical load, uplift load (if any) and lateral load capacity of the pile foundation has been done and ultimately a compartive study has been executed between that capacities (vertical, lateral and uplift) for three different locations used in the present study.

II. METHODOLOGY AND SOIL EXPLORATION PROCESS

A. *Soil Investigation Process*

Field Exploration

The boring was advanced by a combination of Auger and Mud circulation method as per IS 1892-1981 and standard penetration test (SPT) was conducted at suitable intervals, within the borehole, as per IS 2131-1981. Flush Joined casings were used to prevent the caving of the sub-soil during boring work.

The undisturbed and disturbed soil samples were collected from suitable depths and were brought to the laboratory for testing purpose. The water level was found to be at 3.00m to 7.50m below the existing ground level (E.G.L.).

Field Investigations

The programmed of field work at the present site was consisted of the following:-

(i) Sinking of boreholes (2 No).

(ii) Collection of undisturbed soil sample from suitable depth below G.L.

(iii) Conduction of standard penetration test at suitable depths below G.L.

(iv) Collection of disturbed soil samples.

(v) Observed water level and Standing water level after 24 hours.

Method of Boring

In this method different types of tools have to be adopted for boring. In case of soft to stiff clay, cylindrical auger consisting of a hollow tube of *75* to 200mm in diameter with a cutting edge at its bottom is used. In case of various stiff and hard clay, shells with cutting edge or teeth at lower end are to be adopted while in case of sandy soil, shells or sand, pumps are used for boring. By this method it is possible to make vertical boring up to 200 mm in diameter and 25 m in depth by use of a hand rig. By use of mechanical rig it is possible to extend the depth of the bore hole up to 50m. The samples of the soil are recovered at regular intervals (or whenever there is a change in strata) for conducting tests in laboratory for identification of soils and establishing properties of the sub-soil strata at various depths.

Collection of Undistrubed Samples

These were taken by methods, which preserves the structure and properties of the materials. Undisturbed samples were collected at suitable intervals of depth from the borings by dividing two-tier thin-walled open drive sampler of 100mm internal diameter (ID). The area ratio of each tube was kept within 15 % to minimize possible disturbance during sampling. The tubes were sealed with paraffin wax at both ends, labeled depth wise and dispatched to the laboratory for testing. A properly designed sampling tool in the form of open tube sampler made up seamless steel tube was used for the same. These samples were collected in strict compliance with the specification stipulated in IS 1892 and IS 2131.Such samples were only recovered from cohesive deposits as because undisturbed samples cannot be recovered from cohesion less soil.

Standard Penetration Tests

Standard penetration test were conducted at each borehole at suitable intervals of depth in between levels from which undisturbed samples were taken in the cohesive strata. S.P.T. was also conducted with the sandy strata. The test was done with standard split spoon sampler as per IS: 2131. The N-Values were obtained by counting the number of blows required to drive the spoon from 15 cm. to 45 cm.

Collection of Disturbed Samples

Disturbed samples are collected manually from the Auger and from split spoon sampler. These samples are taken in polythene bags, sealed properly to make it water tight and sent to laboratory. These samples are used for grain size analysis, Atterberg tests etc. These are also done to enable to locate the change of layers.

Ground Water Table

Ground water observations generally made during boring and the depth at which it was encountered and the standing water level as observed may be recorded in the respective bore log sheet for all the boreholes sunk at the present site. Moreover the standing water level generally measured in the boreholes after 24 hours of removal of casings. However, in the existing condition these levels of ground water are likely to change with the seasonal variation. For design purpose it is advisable to consider the worst possible condition of standing water level to merge with existing ground level, which has been done is present case. The results of bearing capacity of any foundation will not be affected by the fluctuation of water table, since the same

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was estimated under worst condition.

Laboratory Tests

The programmed of the laboratory testing was consisted of the following:

(i) Determination of Natural Moisture Contents (N.M.C.) IS:2720 (Part 2).

(ii) Determination of Bulk & Dry Unit Weight IS:2720 (Part 2).

(iii) Mechanical Analysis (Hydrometer & Sieve Analysis) IS:2720 (Part 4).

(iv) Determination of Atterberg Limits (Liquid Limit and Plastic Limit) IS:2720 (Part 5).

(v) Tri-axial Tests (UU & CU) IS:2720 (Part 11, 12).

(vi) Unconfined Compression Test (UC) IS:2720 (Part 10).

(vii) Permeability Test IS:2720 (Part 17).

(viii) Consolidation Tests IS:2720 (Part 15).

(ix) Direct Shear Test IS:2720 (Part 13).

(x) Specific Gravity IS:2720 (Part 3).

(xi) Chemical Tests on Soil and Water Samples IS: 2720 (Part 26,27) & IS: 3250 (Part 11,24,32).

All these tests are conducted as per relevant IS codes were such exists and the test results are tabulated in tables. In this section, the result of all laboratory tests from three locations of West Bengal namely, Beleghata, Girish Park and Kajipara (Barasat) have been reflected in a form in Bore log and test result and is prescribed in figures (1-3) and tables (1-3) respectively.

B. Analysis of Vertical, Lateral and Uplift Pile Load Capacity of Three Sites

Vertical Pile Load Capacity for site 1 (Beleghata)

Cut off level = 2.00 m

Top Soil : Brownish grey silty clay with kankars and brick bats (0.00 m - 1.00 m below G.L)

Average Thickness = 1.00 m

$\gamma_b = 1.8$ t/m^3

$\gamma_{sub} = (1.8 – 1.0) = 0.8$ t/ m^3

$\Phi = 0^\circ$

[For $\Phi = 0^\circ$, $\delta = 0^\circ$, $N_\gamma = 0$, $P_D = 0$, $N_q = 0$ and K = 0]

c = 0 t/ m^2

$\alpha = 0.00$

[As the layer is filled with fill material we will not consider any c value]

Stratum – I (Soft to medium grey to brownish grey silty clay/clayey silt (1.00 m - 5.00 m below G.L))

Average Thickness = 4.00 m

$\gamma_b = 1.83$ t/m^3

$\gamma_{sub} = (1.83 – 1.0) = 0.83$ t/ m^3

$\Phi = 0^\circ$

[For $\Phi = 0^\circ$, $\delta = 0^\circ$, $N_\gamma = 0$, $P_D = 0$, $N_q = 0$ and K = 0]

c = 2.60 t/ m^2

$\alpha = 1.00$ [From table IS 2911 Part 1]

[γ_b = Bulk Density of soil, γ_{sub} = Submerged Density of soil, Φ = Angle of shearing resistance, K = Co-efficient of earth pressure, δ = Angle of internal friction, N_γ, Nq = Bearing Capacity Factor, c = Cohesion, α = Adhesion Factor]

Stratum – II (Very soft to soft grey silty clay with organic materials and decomposed wood (5.00 m - 13.50 m below GL))

Average Thickness = 8.50 m

$\gamma_b = 1.70$ t/m^3

$\gamma_{sub} = (1.70 – 1.0) = 0.70$ t/ m^3

$\Phi = 0^\circ$

[For $\Phi = 0^\circ$, $\delta = 0^\circ$, $N_\gamma = 0$, $P_D = 0$, $N_q = 0$ and K = 0]

c = 2.10 t/ m^2

$\alpha = 1.00$

Stratum – III (Medium stiff light bluish grey silty clay with kankars (13.50 m - 16.50 m below GL))

Average Thickness = 3.00 m

$\gamma_b = 1.87$ t/m^3

$\gamma_{sub} = (1.87 – 1.0) = 0.87$ t/ m^3

$\Phi = 0^\circ$

[For $\Phi = 0^\circ$, $\delta = 0^\circ$, $N_\gamma = 0$, $P_D = 0$, $N_q = 0$ and K = 0]

c = 5.00 t/ m^2

$\alpha = 0.865$

Stratum – IV (Stiff to very stiff light yellowish grey silty clay/clayey silt (16.50 m - 21.50 m below GL))

Average Thickness = 5.00 m

$\gamma_b = 1.90$ t/m^3

$\gamma_{sub} = (1.90 – 1.0) = 0.90$ t/ m^3

$\Phi = 0^\circ$

[For $\Phi = 0^\circ$, $\delta = 0^\circ$, $N_\gamma = 0$, $P_D = 0$, $N_q = 0$ and K = 0]

c = 7.60 t/ m^2

$\alpha = 0.585$

Stratum – V (Medium to dense light yellowish grey silty fine sand with mica (21.50 m -28.00 m below GL))

Average Thickness = 3.50 m [As R.C.C. Cast- in- situ bored pile of length 25.00 m below cut off level off (2m below ground level) is suggested.]

$\gamma_b = 1.92$ t/m^3

$\gamma_{sub} = (1.92 – 1.0) = 0.92$ t/ m^3

$\Phi = 32^\circ$

[For $\Phi = 32^\circ$, $\delta = (\Phi-3^\circ) = (32^\circ-3^\circ) = 29^\circ$, $N_\gamma = 20.10$ $P_D = 15.00$, $N_q = 18.00$ and K = 1.10]

c = 0 t/ m^2

$\alpha = 0$

Ultimate Skin Friction Resistance (Q_{ults})

$Q_{ults} = [(\alpha * c * A_s) + (\sum K * P_{Di} * \tan\delta * A_s)]$

[(A_s = Surface Area = π* D*h), D = Diameter of Pile, h = Thickness of that layer.]

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From Depth 0.00 m to 1.00 m i.e average thickness = 1.00 m Top Soil

Q_{ults0} = (α * c * л* D*h) [Q_{ults0} = Ultimate Skin Friction Resistance for Top soil]

Q_{ults1} = (0.00*0.00 *3.14*D *4.00) = 0.00 D

From Depth 1.00 m to 5.00 m i.e average thickness = 3.00 m Stratum – I

Q_{ults1} = (α * c * л* D*h) [Q_{ults1} = Ultimate Skin Friction Resistance for Stratum I]

Q_{ults1} = (1.00*2.60 *3.14*D *3.00) = 32.656 D

From Depth 5.00 m to 13.50 m i.e average thickness = 8.50 m Stratum – II

Q_{ults2} = (α * c * л* D*h) [Q_{ults2} = Ultimate Skin Friction Resistance for Stratum II]

Q_{ults2} = (1.00*2.10 *3.14*D *8.50) = 56.049 D

From Depth 13.50 m to 16.50 m i.e average thickness = 3.00 m Stratum – III

Q_{ults3} = (α * c * л* D*h) [Q_{ults3} = Ultimate Skin Friction Resistance for Stratum III]

Q_{ults3} = (0.865*5.00*3.14*D *3.00) = 40.74 D

From Depth 16.50 m to 21.50 m i.e average thickness = 5.00 m Stratum – IV

Q_{ults4} = (α * c * л* D*h) [Q_{ults4} = Ultimate Skin Friction Resistance for Stratum IV]

Q_{ults4} = (0.585*7.60*3.14*D *5.00) = 69.8022 D

From Depth 21.50 m to 25.00m i.e average thickness = 3.50 m Stratum – V

Q_{ults5} = (K * P_{Di} * tanδ* л* D*h) [Q_{ults5} = Ultimate Skin Friction Resistance for Stratum V]

[P_{Di} = [{∑ γ_{sub} * (Depth upto last Stratum)} + {γ_{sub} * (Depth of the last Stratum/2)}]

P_{Di} = [(0.80*1.00) + (0.83*4.00) + (0.70*8.50) + (0.87*3.00) + (0.90*5.00) + (0.92 * 3.50/2)]

P_{Di} = 18.79

Q_{ults5} = (1.10*18.79*tan(29°)*3.14*D*3.50) = 125.71 D

Total Ultimate Skin Friction Resistance (Q_{ults}) = (Q_{ults0} +Q_{ults1} + Q_{ults2} + Q_{ults3} + Q_{ults4} + Q_{ults5})

Q_{ults} = (0.00 D +32.656 D +56.049 D + 40.74 D+ 69.8022 D +125.71 D) = 324.9572 D

Ultimate End Bearing Resistance (Q_{ultb})

Q_{ultb} = [A_p * {(0.5*D* γ_{sub}* N_γ) + (P_D*0.80*D* N_q)}]

[A_p = Section Area of the pile at it's base = (лD^2/4)]

Q_{ultb} = [(лD^2/4)] * {(0.5*D* γ_{sub}* N_γ) + (P_D*0.80*D* N_q)}]

Q_{ultb} = [(3.14*D^2/4)]* {(0.5*D*0.92*20.10) + (15.00*0.80*D*18.00)}]

Q_{ultb} = [7.25811D^3 + 169.56 D^3] = 176.818 D^3

Ultimate Load Bearing Capacity (Q_{ult}) = [Ultimate Skin Friction Resistance (Q_{ults}) + Ultimate End Bearing Resistance (Q_{ultb})]

Ultimate Load Bearing Capacity (Q_{ult}) = 324.9572 D + 176.818 D^3

Safe Load Carrying Capacity in Compression (By taking Diameter of the Pile 0.5 m and Factor of Safety = 2.5) = [{(324.9572 * 0.5) + (176.818 * 0.5^3)}/(2.5)] = (184.58/2.5) = 73.83 MT

Safe Load Carrying Capacity in Tension (By taking Diameter of the Pile 0.5 m and Factor of Safety = 3.0) = Ultimate Skin Friction Resistance = (324.9572 D)/FOS) = {(324.9572 *0.5)/3} = 54.159 MT

For other pile diameters safe load capacity of pile in compression and tension are tabulated in table 4

Table 4 - Safe Load Capacity of Pile in Compression and Tension for different Pile Diameters of Site – 1 (Beleghata)

Diameter of Pile (mm)	450	500	550	600	700	800	900	1000
Safe Load Carrying Capacity in Compression (MT)	65	74	83	93	115	140	169	201
Safe Load Carrying Capacity in Tension (MT)	49	54	59	65	76	87	98	108

Lateral Pile Load Capacity for site 1 (Beleghata)

Let, Pile Diameter = 0.5 m and

Grade of the Concrete = M 25

UCS Value = 2 * [{∑(Thickness of Individual Clay Layer * Cohesion)}/{(Total Depth of Clay Layer)}]

UCS Value = 2* [{(2.60*3.00)+(2.10*8.50)+(5.00*3.00)+(7.60*5.00)}/{(3.00+8.50+3.00+5.00)}]

UCS Value = 2 * 4.033 = 8.066 t/m^2 = 80.667 KN/m^2

Depth of Fixity Calculation

Terzaghi's Modulus of Horizontal of Subgrade Reaction (K1) = 14.5206 MN/m^2

(From Table of IS 2911-Part 1-Sec-2 : 2010)

[1MN = 1000 KN]

Modulus of Horizontal of Subgrade Reaction (K) = K1/5B = [(14.5206)/(5*0.5)] = 5.80824 MN/m^2

Here, E = 5000$\sqrt{f_{ck}}$ = 5000$\sqrt{25}$ = 25000 MN/m^2

I = [(л*D^4)/64] [I = Section Modulus, B = D = Diameter of Pile] [As pile is a circular section so for finding sectional modulus we are using this above formula.]

I = [(л*0.5^4)/64] = 0.003067962 m^4

Hence Relative Stiffness Factor (R) = $^4\sqrt{}${(E*I)/(K*B)} = $^4\sqrt{}${(25000 * 0.003067962)/(5.80824 * 0.5)} = $^4\sqrt{}$(26.411) = 2.269 m = 2.27 m

Unsupported Length of The Pile (L_1) = 0.00 m [As the superstructure is not a bridge so no water pressure will come so no scour depth will come]

Therefore, L_1/R = (0.00/2.7) = 0.00 m

From graph i.e. (figure 4) (L_f/R -Vs- L_1/R) for normally loaded clays and fixed head pile, L_f /R = 2.17

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(From IS 2911-Part 1-Section 2 : 2010) [[L_f = Depth of Fixity]

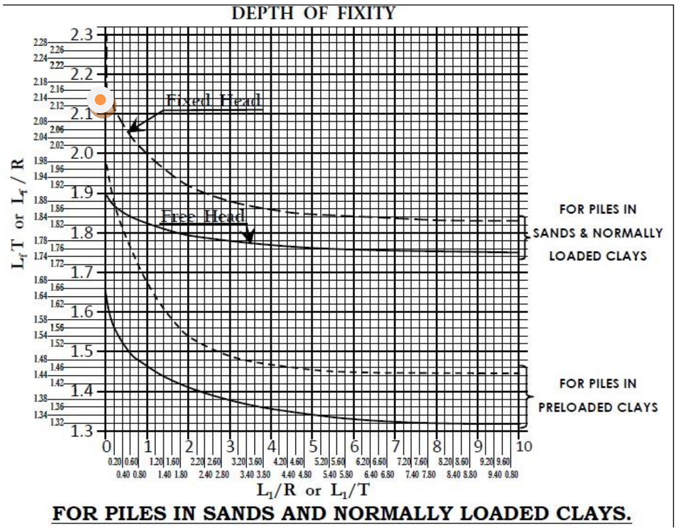

Figure 4 – (L_f/R -Vs- L_1/R) for normally loaded and preloaded clays and fixed head pile of site at Beleghata (site – 1)

$L_f/R = 2.17$

$L_f = 2.17 * R = 2.17 * 2.27 = 4.9259$ m

Effective depth of fixity (L_{eff}) = L_f+L_1 = 4.92 m + 0.00 m = 4.92 m

Calculation of Lateral Load Capacity

[Allowable Deflection (δ) = 5 mm = 0.005 m when the pile diameter is less than 1 m or 10% of pile diameter if the pile diameter is more than 1 m.]

Here our pile diameter is 0.5 m, So, δ = 0.005 m

Lateral Load Capcity of Pile $[Q]_D = \{(12EI*\delta)/(L_f+L_1)^3\}$ $=\{(12*25000*0.003067962*0.005)/(4.92)^3\}$ = 0.03864 MN = 3.864 Ton

For other pile diameters lateral safe load capacity and depth of fixities of piles are tabulated in table 5

Table 5 - Lateral Safe Load Capacity and Depth of Fixities for different Pile Diameters of Site – 1 (Beleghata)

Diameter of Pile (mm)	450	500	550	600	700	800	900	1000
Lateral Safe Load Carrying Capacity (T)	3.48	3.87	4.25	4.64	5.41	6.18	6.96	7.73
Depth of Fixity (m)	4.43	4.92	5.41	5.90	6.89	7.87	8.85	9.84

By the above said method the vertical and lateral pile load capacity of other 2 sites i.e. Girishpark and Kajipara (Barasat) has been analysed and the values are tabulated in tables 6 – 9 respectively.

Table 6 - Safe Load Capacity of Pile in Compression and Tension for different Pile Diameters of Site – 2 (Girishpark)

Diameter of Pile (mm)	450	500	550	600	700	800	900	1000
Safe Load Carrying Capacity in Compression (MT)	39	44	50	57	72	88	108	130
Safe Load Carrying Capacity in Tension (MT)	28	31	34	38	44	50	56	62

Table 7 - Lateral Safe Load Capacity and Depth of Fixities for different Pile Diameters of Site – 2 (Girishpark)

Diameter of Pile (mm)	450	500	550	600	700	800	900	1000
Lateral Safe Load Carrying Capacity (T)	3.17	3.514	3.88	4.23	4.94	5.64	6.35	7.05
Depth of Fixity (m)	4.57	5.07	5.58	6.09	7.10	8.12	9.13	10.15

Table 8 - Safe Load Capacity of Pile in Compression and Tension for different Pile Diameters of Site – 3 (Kajipara (Barasat))

Diameter of Pile (mm)	450	500	550	600	700	800	900	1000
Safe Load Carrying Capacity in Compression (MT)	46	53	61	69	87	107	132	160
Safe Load Carrying Capacity in Tension (MT)	33	37	41	44	52	59	67	74

Table 9 - Lateral Safe Load Capacity and Depth of Fixities for different Pile Diameters of Site – 3 (Kajipara (Barasat))

Diameter of Pile (mm)	450	500	550	600	700	800	900	1000
Lateral Safe Load Carrying Capacity (T)	2.37	2.64	2.90	3.16	3.69	4.22	4.75	5.27
Depth of Fixity (m)	5.03	5.59	6.15	6.71	7.92	8.94	10.06	11.18

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III. Comparative Analyses

A. *Comparative Analysis of Vertical Load Capacity of Three Sites*

In this section a comaparative analysis of vertical load capacity (compression (fig 5) and tension (fig 6)) has been studied with different pile diameters for three sites namely Beleghata (site-1), Girishpark (site-2) and Kajipara(Barasat) (site-3).

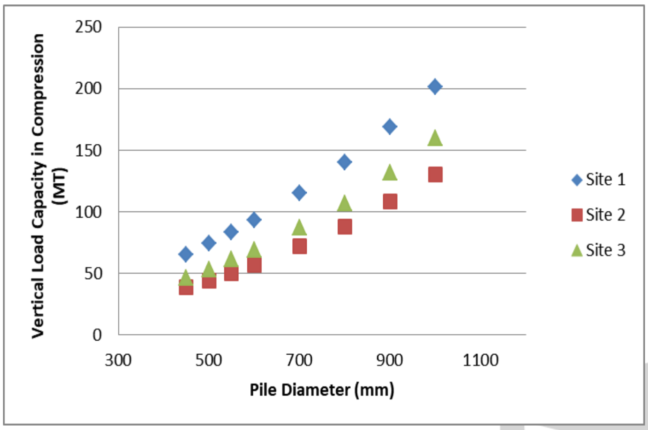

Figure 5 – Variation of vertical pile load capacity in compression with different diameters of pile for three locations.

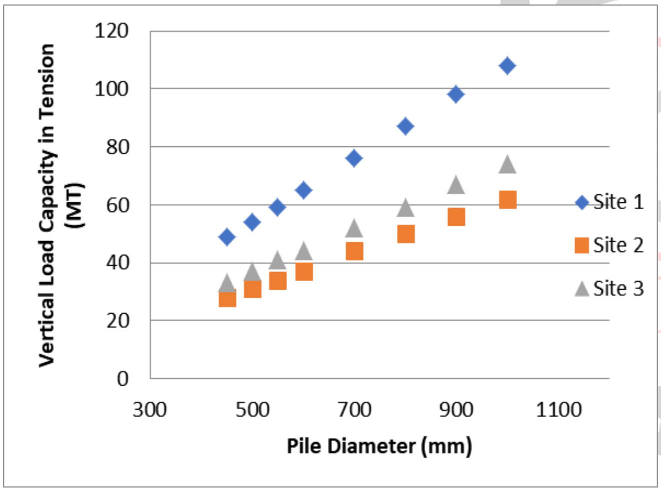

Figure 6 – Variation of vertical pile load capacity in tension with different diameters of pile for three locations.

From figure 5 and 6 it can be observed that as pile diameter increases vertical load capacity in compression and tension both increases, this rate of increase can be upto 209.23 %, 233.33% and 247 % when pile diameter increases from 450 mm to 1000 mm for compression of site 1, site 2 and site 3 respectively and this rate of increase can be upto 120.46 %, 121 % and 124 % when pile diameter increases from 450 mm to 1000 mm for tension of site 1, site 2 and site 3 respectively. Furthur the variation of vertical load capacity has been observed for three different sites, this is due to the variation of soil parameters in three different locations.

B. : *Comparative Analysis of Lateral Load Capacity and Depth of Fixity of Three Sites*

In this section a comaparative analysis of lateral load capacity (compression (fig 7) and depth of fixity (fig 8)) has been studied with different pile diameters for three sites namely Beleghata (site-1), Girishpark (site-2) and Kajipara(Barasat) (site-3).

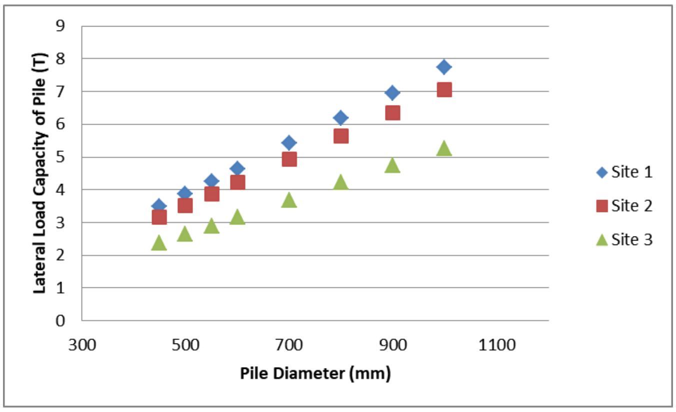

Figure 7 – Variation of lateral pile load capacity with different diameters of pile for three locations.

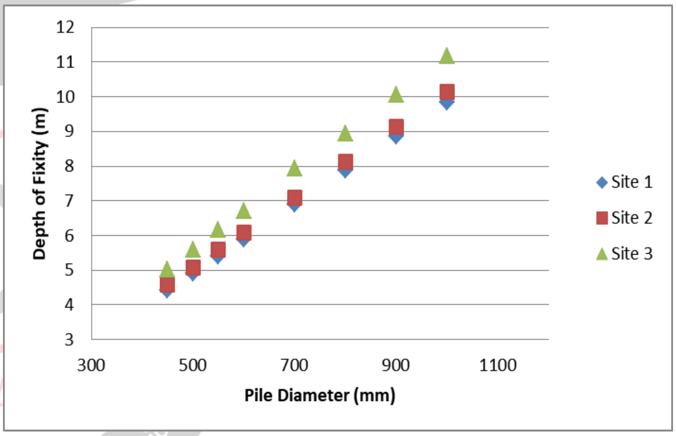

Figure 8 – Variation of depth of fixity with different diameters of pile for three locations.

From figure 7 and 8 it can be observed that as pile diameter increases lateral load capacity of pile increases, this rate of increase can be upto 122.12 %, 122.33% and 122.36 % when pile diameter increases from 450 mm to 1000 mm for compression of site 1, site 2 and site 3 respectively and this rate of increase can be upto 122.12 %, 122.10 % and 122.26 % when pile diameter increases from 450 mm to 1000 mm for tension of site 1, site 2 and site 3 respectively. Furthur it has been noticed that as cohesion value of soil decreases the lateral load capacity of soil decreases and depth of fixity value increases.

IV. CONCLUSION

In the present study soil exploration has been executed and undisturbed soil samples has been collected upto depth of 30 m below ground level from three locations of West Bengal namely, Beleghata (Site - 1), Girish Park (Site - 2),

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Kajipara (Barasat) (Site - 3) respectively. Engineering Properties of soil samples has been determined by routine tests from three above mentioned sites and furthur evaluation has been procecuted for the types of foundation required for minimum reruirement for construction of G+4 building (assumed) at that respective sites from which the soils are collected for the study and after that determination of the vertical load, uplift load (if any) and lateral load capacity of the pile foundation has been done and ultimately a compartive study has been executed between that capacities (vertical, lateral and uplift) for three different locations used in the present study.

The following conclusion can be concluded -

As pile diameter increases vertical load capacity in compression and tension both increases, this rate of increase can be upto 209.23 %, 233.33% and 247 % when pile diameter increases from 450 mm to 1000 mm for compression of site 1, site 2 and site 3 respectively and this rate of increase can be upto 120.46 %, 121 % and 124 % when pile diameter increases from 450 mm to 1000 mm for tension of site 1, site 2 and site 3 respectively. The variation of vertical load capacity has been observed for three different sites, this may be due to the variation of soil parameters in three different locations.

Further it has been observed that as pile diameter increases lateral load capacity of pile increases, this rate of increase can be upto 122.12 %, 122.33% and 122.36 % when pile diameter increases from 450 mm to 1000 mm for lateral load capacity of site 1, site 2 and site 3 respectively and this rate of increase can be upto 122.12 %, 122.10 % and 122.26 % when pile diameter increases from 450 mm to 1000 mm for depth of fixity of site 1, site 2 and site 3 respectively. It has also been noticed that as cohesion value of soil decreases the lateral load capacity of soil decreases and depth of fixity value increases.

DESCRIPTION		Depth (m) From	Depth (m) To	Thickness (M)	N-Value	Type & marked	Samples Depth (M)
Top Soil : Brownish grey silty clay with kankars and brick bats		0.00	1.00	1.00	-	DS	0.50
					-	DS	1.00
Soft to medium grey to brownish grey silty clay/clayey silt		1.00	5.00	4.00	3	SPT	1.50
					-	UDS	3.00
					4	SPT	4.50
Very soft to soft grey silty clay with organic materials and decomposed wood		5.00	13.50	8.50	2	SPT	6.00
					3	SPT	7.50
					3	SPT	9.00
					2	SPT	10.50
					4	SPT	12.00
					7	SPT	13.50
Medium stiff light bluish grey silty clay with kankars		13.50	16.50	3.00	-	UDS	15.00
					15	SPT	16.50
Stiff to very stiff light yellowish grey silty clay/clayey silt		16.50	21.50	5.00	-	UDS	18.00
					18	SPT	20.00
Medium to dense light yellowish grey silty fine sand with mica		21.50	28.00	6.50	24	SPT	22.00
					38	SPT	24.00
					42	SPT	26.00
					50	SPT	28.00
Very dense brownish grey silty medium to fine sand with mica		28.00		7.50	52	SPT	30.00
					58	SPT	32.00
					62	SPT	34.00

Figure 1 - Borehole data of site at Beleghata (site – 1)

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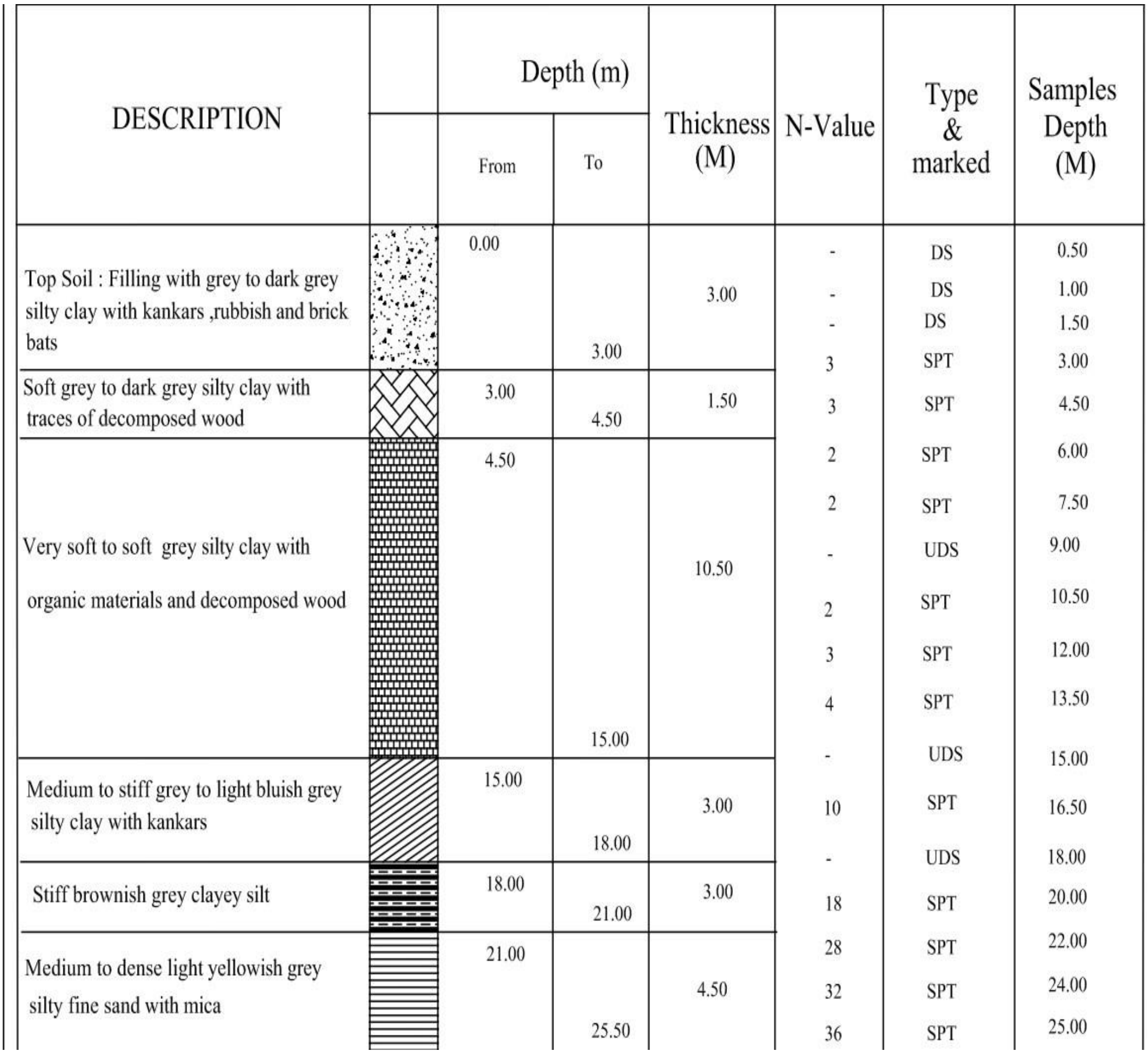
Table 1- Laboratory Test Results of site at Beleghata (site – 1)

Borehole	Depth (m)	Type of Sample	Bulk Density (t/m^3)	NMC (%)	Sp Grav	Atterberg's Limit		Shear Strength Parameters				Consolidation (m_v (cm^2/kg)
						LL (%)	PL (%)	Type of Test	C = (kg/cm^2)(UCS test)	C = (kg/cm^2)(UU test)	Φ (˚)	
1	3. 00	UDS	1.83	32.45	2.67	49	20	UCS/UU	0.26	0.23	7	0.055
	15.00	UDS	1.88	30.86	2.67	59	24	UCS	0.55	-	-	0.028
	18.00	UDS	1.90	28.63	2.68	47	25	UCS	0.76	-	-	0.018
	32.00	SPT	1.95	-	2.65	NA	NA	DS	-	0	33	-



DESCRIPTION	Depth (m) From	Depth (m) To	Thickness (M)	N-Value	Type & marked	Samples Depth (M)
Top Soil : Filling with grey to dark grey silty clay with kankars ,rubbish and brick bats	0.00	3.00	3.00	-	DS	0.50
				-	DS	1.00
				-	DS	1.50
				3	SPT	3.00
Soft grey to dark grey silty clay with traces of decomposed wood	3.00	4.50	1.50	3	SPT	4.50
Very soft to soft grey silty clay with organic materials and decomposed wood	4.50	15.00	10.50	2	SPT	6.00
				2	SPT	7.50
				-	UDS	9.00
				2	SPT	10.50
				3	SPT	12.00
				4	SPT	13.50
				-	UDS	15.00
Medium to stiff grey to light bluish grey silty clay with kankars	15.00	18.00	3.00	10	SPT	16.50
				-	UDS	18.00
Stiff brownish grey clayey silt	18.00	21.00	3.00	18	SPT	20.00
Medium to dense light yellowish grey silty fine sand with mica	21.00	25.50	4.50	28	SPT	22.00
				32	SPT	24.00
				36	SPT	25.00

Figure 2 - Borehole data of site at Girishpark (site – 2)

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Table 2- Laboratory Test Results of site at Girishpark (site – 2)

Borehole	Depth (m)	Type of Sample	Bulk Density (t/m^3)	NMC (%)	Sp Grav	Atterberg's Limit		Shear Strength Parameters				Consolidation (m_v (cm^2/kg)
						LL (%)	PL (%)	Type of Test	C = (kg/cm^2)(UCS test)	C = (kg/cm^2)(UU test)	Φ (˚)	
	9. 00	UDS	1.70	40.93	2.57	62	28	UCS/UU	0.20	0.21	7	-
	15.00	UDS	1.86	30.86	2.67	58	23	UCS	0.48	-	-	0.031
	18.00	UDS	1.90	28.76	2.67	44	24	UCS	0.86	-	-	0.017
1	24.00	SPT	1.91	-	2.65	NA	NA	DS	-	0	31	-

DESCRIPTION	Depth (m) From	Depth (m) To	Thickness (M)	N-Value	Type & marked	Samples Depth (M)
Top Soil : Dark grey silty clay with kankars consil and organic materials	0.00	1.50	1.50	-	DS	0.50
				-	DS	1.00
Very soft to soft dark grey silty clay with organic materials	1.50	6.00	4.50	2	SPT	1.50
				2	SPT	3.00
				-	UDS	4.50
				9	SPT	6.00
Medium to stiff grey clayey silt	6.00	10.50	4.50	11	SPT	7.50
				-	UDS	9.00
				20	SPT	10.50
Medium dense grey to brownish grey sandy silt / silty fine sand with mica	10.50	15.00	4.50	22	SPT	12.00
				29	SPT	13.50
				46	SPT	15.00
Dense to very dende brownish grey silty medium to fine sand with mica	15.00	25.50	10.50	38	SPT	17.00
				43	SPT	19.00
				48	SPT	21.00
				53	SPT	23.00
				78	SPT	25.00

Figure 3 - Borehole data of site at Kajipara (Barasat) (site – 3)

Table 3- Laboratory Test Results of site at Kajipara (Barasat) (site – 3)

Borehole	Depth (m)	Type of Sample	Bulk Density (t/m^3)	NMC (%)	Sp Grav	Atterberg's Limit		Shear Strength Parameters				Consolidation (m_v (cm^2/kg)
						LL (%)	PL (%)	Type of Test	C = (kg/cm^2)(UCS test)	C = (kg/cm^2)(UU test)	Φ (˚)	
	4. 50	UDS	1.70	37.64	2.57	61	27	UCS	0.20	-	-	-
1	9. 00	UDS	1.86	30.75	2.66	38	24	UCS/UU	0.36	0.30	8	0.033
	12.00	SPT	1.88	-	2.66	NA	NA	DS	-	0	31	-
	23.00	SPT	1.93	-	2.64	NA	NA	DS	-	0	33	-

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