SOIL INVESTIGATION

FOR

PROPOSED G+IV STORIED BUILDING.

AT

DAG NO- 2018, L.R. KHATIAN NO- 2940, MOUZA- CHAKPACHURIYA, J.L. NO- 33, P.S.- RAJARHAT, DIST- 24 PGS(N).

NEW ECONOMIC SOIL

Branch office
40, Arunachal West, Sodepur,
Kolkata-700110
Phone No.- 9903435800
E-mail Id: neweconomicsoil@gmail,com

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ANNEXURE

1. INTRODUCTION

A project build on **Construction of Proposed G+IV Storied Building**. The soil investigation was necessary for the purpose of the foundation design and construction of the said **Proposed G+IV Storied Building at Dag No- 2018, L.R. Khatian No- 2940, Mouza- Chakpachuriya, J.L. No- 33, P.S.- Rajarhat, Dist- 24 Pgs(N).** Accordingly the subsoil exploration work with **02 boreholes (25.00m+15.00m depth)** was carried out as proposed by the project authority.

During borehole exploration, disturbed and undisturbed samples were collected. The present report deals with the geotechnical investigation findings at the location and the recommendation of type of the most suitable foundation depending on the field and laboratory test results.

2. SOIL EXPLORATION

Two boreholes were sunk within the premises of the proposed project, the depths of boreholes were measured from the existing ground level and hence the depth of borehole indicates depth below ground level (BGL). The execution of the subsoil exploration job at site was **commenced on July 02nd 2021 and completed on July 03rd 2021.**

Our site in-charge has maintained the log sheets of the boreholes. Visually classified soils encountered according to the standard soil classification system. We have also obtained relatively undisturbed and bulk samples for the sub-surface materials from each borehole advanced at different locations. The soil exploration methodology followed at site, has been explained below.

3. FIELD INVESTIGATION

Geotechnical Investigation was conducted in an attempt for optimization in the design of foundation for the proposed structures to be constructed at this site. The entire Investigation program had been divided mainly into two parts, I) Field works & II) Laboratory tests.

I) Field works unfold the sub-surface deposit types and their characteristics

II) Laboratory tests part would help determining the relevant physical and geotechnical properties of the sub-surface deposits leading to analysis etc.

Schedule of boreholes in tabulated form is given below:

Bore Hole No.	Terminating Depth (m)	Standing Water Table below EGL (m)	Date of Commencement	Date of Completion
BH-1	25.00	0.50	02.07.21	03.07.21
BH-2	15.00	0.60	03.07.21	03.07.21

4. EXPLORATORY BORING

The provision laid down in BIS 1892: 1979 was followed in sinking the exploratory boreholes. Boreholes were advanced into the soil by Auger to sink 150 mm diameter bore holes by using manually operated equipment. The Auger boring continued upto maximum depth of 4.5m and thereafter wash boring technique was adopted. Stabilization of the boreholes was achieved by circulating Bentonite slurry. Suitable casings were used upto about 3.0 m below ground level (BGL) to prevent cave-in of soil inside the boreholes. Log sheet of each borehole has been presented in Annexure.

FIELD AND LABORATORY WORKS

FIELD WORK	Relevant I.S. Codes
Collections of soil samples	IS: 1892-1979 IS: 2131-1981 IS: 2132-1986
Labeling and Packing	IS: 1892-1979 IS: 2131-1981 IS: 2132-1986
Standard Penetration Test (SPT)	IS: 9640-1980 IS: 2131-1981

Laboratory Tests	Relevant I.S. Codes
Water Content	IS: 2720(Part-2)-1973
Liquid Limit (LL) and Plastic Limit (PL)	IS: 2720(Part-5)-1985
Grain-Size Analysis	IS: 2720(Part-4)-1985
Specific Gravity	IS: 2720(Part-3)-1980
Consolidation Test	IS: 2720(Part-15)-1986
Unconfined Compressive Strength	IS: 2720(Part-10)-1991
Tri-axial Test	IS: 2720(Part-11)-1993
Direct Shear Test	IS: 2720(Part-13)-1986

5. SAMPLING

Disturbed samples were collected from split spoon sampler of Standard Penetration Test (SPT) at different depths of each borehole; the disturbed samples were also collected near the ground level. The undisturbed samples were collected at average 3m interval, while the SPT field test was conducted at average 1.5m interval. Groundwater table was observed and recorded in the field bore log sheet. Undisturbed sample were obtained as per the specification by forcing a thin wall sample of internal diameter 100 mm and 450 mm length open drive sampling assembly having area ratio of about 10% (as per IS: 2132-1986). Before insertion of sampling tube in the borehole the disturbed soils were removed properly form the same. The sampling assembly was driven to the required depth manually with the help of jarring link. The undisturbed samples retained in the lowest tube were brought to the surface and both the ends of

the tube were sealed by a thin layer of molten wax. Further the end of the tube was closed by screwed caps or tight fittings lids. The depth of the samples and other particulars were marked on the tube along with the label. Representative disturbed soil samples were collected from Auger, cutting shoe of the undisturbed sampling assembly and split spoon of standard penetrometer, as per the specification, at close intervals to maintain a continuous record of subsurface strata. The collected samples were kept in airtight polythene packets and labeled properly about project name, date of sampling, borehole number, and depth of sampling.

6. STANDARD PENETRATION TEST (SPT)

These tests were conducted in the boreholes at regular intervals or the change of strata; it was carried out by standard sampler (a split-spoon sampler) of standard design and dimension (50 mm OD and 35 mm ID, with minimum length of 450 mm). The sampler was driven by a 63.5 kg drive weight (monkey) as per guidelines laid in IS: 2131. As per the IS code of practice for this test, the monkey was allowed to fall on the top of the drill rod from a height of 750 mm several times until the sample penetrates about 150 mm into the soil as a seating drive. The numbers of blows required to drive the spoon from 150 mm to 450 mm i.e., beyond the seating drive, were recorded and this number of blows is called 'N' value or Standard Penetration Test (SPT) value of the sub-soil at that particular depth.Where the test has been carried out on completion of a test, the split spoon sampler was brought out of the borehole and opened the same. The collected soil sample from the split spoon sampler was preserved in air tight polythene packets for classification purpose. The samples were labeled properly with the project name, borehole and the depth of sampling.

7. GROUND WATER TABLE (GWT)

Ground water observations were made during boring and the depth at which it was encountered and the standing water level was recorded in the respective bore log sheet.

8. LABORATORY TEST

The soil samples from the 100 mm diameter sampling tubes were extracted in the laboratory by pushing out the soil cone by employing and extractor frame. The cone was jacked out in the direction that corresponds with the soil movement within the tube during sampling. The extracted samples using 100 mm diameter were made to the actual size of the samples to be used for the testing. Relevant laboratory tests were conducted on selected disturbed and undisturbed soil samples collected during the field investigation for proper identification, classification and for determining the various engineering properties including the shear strength parameters of these sub-soils deposits. Some of the routine tests were also carried out using the soil samples. In general, the following tests were carried out on representative soil samples collected from exploratory boreholes at different depth/ strata:

1. Natural Moisture content (NMC)
2. Atterberg limits (Liquid limit, Plastic limit and Shrinkage limit)
3. Bulk density/ Dry density
4. Triaxial test
5. Unconfined compressive strength test
6. Grain size analysis (Sieve and Hydrometer).
7. Consolidation tests.

The above mentioned laboratory tests were conducted as per the relevant Indian Standard Codes of practice and the results of these tests are furnished in the Annexure of this report. Results have been presented in the form of tables and graphs.

8.1 NATURAL MOISTURE CONTENT (NMC) AND ATTERBERG LIMITS

Natural moisture content (NMC), Liquid limit (LL), Plastic limit (PL), and Shrinkage limit (SL) of silty clay/ clayey silt samples were determined to (a) classify the soil by the unified soil classification system, (b) qualitatively assess their consistency and compressibility, and (c) obtain swelling characteristics of the soil. Soil has been

considered both from disturbed and undisturbed samples collected from the exploratory boreholes.

8.2 BULK DENSITY AND DRY DENSITY

These were determined by measuring the weight and dimension of triaxial/ unconfined compression test samples. The dry density has been calculated from the estimated bulk density and the NMC. The bulk density and dry density values have been given in the laboratory test results sheets.

8.3 GRAIN SIZE ANALYSIS (SIEVE AND HYDROMETER)

The grain size distribution of some representative samples were determined from sieve analysis and hydrometer analysis depending upon the average grain diameter of the soil samples. The higher grained samples like sand were analyzed through sieve and the lower grain samples like fine silt and clay were analyzed through hydrometer. The results have been presented in the tables and graphs.

8.4 TRIAXIAL TEST AND UNCONFINED COMPRESSIVE STRENGTH TEST

For triaxial test, 38 mm diameter and 76 mm long specimens were obtained by jacking out the soil core into three thin-walled brass tubes, each having a wall thickness of 1/800 mm. The inside of the tubes was coated with a thin layer of silicon oil. To obtain the specimens for consolidation test the Oedometer ring was placed on the trimmed horizontal face of the soil within the 100 mm sampling tube and the soil around the cutting edge was gradually removed with a spatula as the ring was gently pushed into the soil. The ring with the soil was then removed by cutting across the soil core with the help of piano wire saw. The triaxial test was conducted on the clay / silty clay/ clayey silt samples to determine the shear strength parameters of the collected soil samples. The cell pressures employed for the test were 1.0 kg/ cm^2, 1.5 kg/ cm^2, and 2.0 kg/ cm^2. The strain rate for the triaxial test under quick condition has been taken 1.25 mm/min. The samples both for triaxial test and unconfined compressive strength test were loaded maximum upto 20% of axial strain, if not failed before the said strain.

8.5 CONSOLIDATION TEST

Consolidation test was conducted in floating ring type oedometers in single and four units consolidation frame under standard load increment ratio starting from ¼ kg/cm^2 and upto 8 kg/cm^2 in general. The soil was kept saturated during the consolidation test, as specified the relevant IS code of practice. The void ratio (e) vs. Log (p) curves has been presented in the report as Annexure. The values of $c_c/(1+e_o)$, which represents the volume compressibility of soil at different depths are given in the report as results in the form of data sheet. During consolidation no swelling pressure was observed during the incremental loading in the tests.

8.6 DIRECT SHEAR TEST

In this test a cubical size soil sample of 6 cm x 6 cm x 2 cm in size, is confined in a direct shear box which has two detachable halves of the same size. The soil sample in this shear mould is loaded vertically under different vertical loads and then sheared of exactly half way in between the sample, such that soil shearing horizontally, shear resistance goes on developing and at failure reaches a maximum value which is recorded. The test is repeated 2 or 3 times on the same type of specimen under different vertical loading conditions, obtaining each time the maximum shear strength developed at failure. A graph of shear strength vs. normal load is drawn and the points on the graph are joined with the average straight line that will cut the Y axis to give the value of cohesion while the inclination of the straight line with the X axis gives the Φ angle, known as the angle of internal friction.

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Project: Proposed [illegible] Building at [illegible]

9. SOIL PROFILE AND PROPERTIES

Based on visual classification and results of field and laboratory tests on the samples recovered the proposed site may be divided into the following major soil strata as described below:

Stratum No	Layer Details: Description	Depth below EGL (m): From	Depth below EGL (m): To	Average Field N Value	Bulk Density (t/m³)	Liquid Limit (%)	Plasticity Index (%)	Shear strength Parameters
I	Filled up with soil and grave roots etc.	0.00	1.00/1.10	-	-	-		
II	Medium Stiff to stiff brownish grey silty clay - clayey silt.	1.00/1.10	4.10/4.20	4 to 10	1.92	40	23	C= 2.5 t/m², φ =0 deg
III	Very soft to soft greyish silty clay with decomposed wood.	4.10/4.20	13.10/13.30	2 to 3	1.72	65	37	C= 1.5 t/m², φ =0 deg
IV	Medium stiff to stiff yellowish brown silty clay with brown spot.	13.10/13.30	18.60	5 to 13	1.85*	45	22	C= 4.9* t/m², φ =0 deg
V	Medium dense brownish silty fine to medium sand with mica	18.60	25.45	2? to 25	1.9?	Non-Plastic		C= 0.0 t/m², φ =25 deg

Suggested

A profile through the boreholes and the distribution of Field N-value with depth are shown in Figure 5 respectively

10. CALCULATION OF BEARING CAPACITY
SHALLOW FOUNDATION

Sample Calculation of Bearing capacity against shear failure on the basis of laboratory test result:

Below a sample calculations have been made:

As per IS code clause 5.12 of (IS: 6403- 1981) the formula for bearing capacity is as follows: -

$$q \text{ net ultimate} = CNcScdcic + \gamma D\,(Nq - 1)Sqdqiq + 0.5B\gamma N\gamma S\gamma d\gamma i\gamma W$$

The net safe bearing capacity is calculated as

$$q \text{ net safe} = q \text{ net ultimate} / F.O.S$$

Where, C = undrained cohesion of the soil

Nc, Nq, Nγ = bearing capacity factors

Sc, Sq, Sγ = shape factor

dc, dq, dγ = depth factor

ic, iq, iγ = inclination factor

q = effective surcharge at the base level of the foundation

W = correction factor for water table location

B = least width of the foundation

γ = bulk unit weight of foundation soil

FOS = factor of safety

So, the property of this layer is used for determination the bearing capacity of shallow foundation.
Isolated Foundation of width 2.00 X 2.00m at a depth 1.50m below the existing ground level:

D = 1.50m, B= 2.00m, C = 2.8 t/m^2, ϕ = 0°, γ = 0.82 t/m^3
Sc = 1.30, Sq = 1.20, Sγ = 0.80,
dc = 1.15, dq = dγ = 1.0, ic = iq = 1.0, iγ = 1.0,
Nc = 5.14, Nq=1, Nγ = 0,
F.O.S = 2.5

Ultimate Bearing Capacity:

$$q \text{ net ultimate} = CNcScdcic + \gamma D\,(Nq - 1)Sqdqiq + 0.5B\gamma N\gamma S\gamma d\gamma i\gamma W$$

$$= 21.52 \text{ t/m}^2$$

Allowable Bearing Capacity:

$$q \text{ net safe} = 1 / 2.50 \text{ X } 21.52 = 8.6 \text{ t/m}^2$$

SETTLEMENT CALCULATION:

The foundation settlement occurs for cohesive layers of soil which are stressed due to the superstructure loads. The settlements may be computed using the following relations following IS: 8009(Part-I)-1976.

Immediate settlement (Si) = q B (1-μ2) I/E

Consolidation Settlement Sc = ∑mv .Δp. H

Where, q = net pressure on soil

B = least width of the foundation

E = modulus of elasticity of soil

ν = Poisson's ratio

I = Influence factor

mv = co-efficient of volume compressibility

H = Thickness of compressible layer

Δp = effective overburden pressure at the center of the corresponding layer

Immediate settlement (Si) = q B (1-μ^2) I/E

q	=	8.6 t/m^2	B	=	2.00 m
D	=	1.50 m	μ	=	0.5
I	=	1.12	E	=	1540 t/m^2
Si	=	9.0mm			

Consolidation Settlement Sc = mv x Δp x H
= 57.00 mm

Total Settlement = 66.00 mm < 75 mm which is safe.

11. DISCUSSIONS ON FOUNDATION

The structure for which the subsoil exploration was conducted is a G+IV storied building. The load coming on the foundation is moderate. Considering the above factor it is suggested that shallow foundation in the form of isolated and strip footings are the best option for the building in discussion.

The bearing capacities for such isolated and strip foundation along with allowable settlement are tabulated below.

Foundation Type	Foundation size	Depth of foundation	Safe bearing capacity (t/m2)	Estimated settlement (mm)
Isolated footing	2.0mx2.0m	1.50m below E.G.L.	8.6	66
	2.5mx2.5m		8.4	75
	3.0mx3.0m		8.2	75
Strip footing	1.5m wide		6.9	58
	2.0m wide		6.9	75
	2.5m wide		6.4	75

12. PILE CAPACITY CALCULATION

Determining the Pile Capacity Calculation as per IS: 2911(Part-I/Sec-2)

Layers	From	To	Depth	Φ	c	Bulk density(γ)	Eff. Over-burden Pressure (q) (t/m2)
I	0.00 m	1.00 m	1.00 m	0	0.0 t/m²	0.000 t/m³	0.00 t/m³
II	1.00 m	4.20 m	3.20 m	0	2.8 t/m²	0.820 t/m³	2.21 t/m³
III	4.20 m	13.10 m	8.90 m	0	1.5 t/m²	0.720 t/m³	6.75 t/m³
IV	13.10 m	18.60 m	5.50 m	0	4.9 t/m²	0.850 t/m³	6.75 t/m³
V	18.60 m	25.45 m	6.85 m	25	0.0 t/m²	0.870 t/m³	6.75 t/m³

Ground level = 000.00m

Pile cut off level = (-1.50m)

Termination depth of pile = 18.00m

Length of pile = 16.50m

Pile diameter = 450 mm

Coefficient of earth pressure K = 1.25

Frictional resistance of pile shaft, **Psu =(S (Ks.Pdi.Tan).Asi + a.c.As)**

Layer mkd.	Asi (m2)	(Ks.Pdi.tan)	(Ks.Pdi.tan). Asi	Eff. Over-burden Pressure at c.g of the layer 'Pdi' (t/m2)	(a)	a.c.As	Psu (t)
I	0.00	0.00	0.00	0.00	0.00	0.00	0.00
II	3.82	0.00	0.00	1.11	1.00	10.69	10.69
III	12.58	0.00	0.00	3.67	1.00	18.87	29.56
IV	6.93	0.00	0.00	5.13	0.84	28.61	58.17
V	0.00	2.99	0.00	5.13	0.00	0.00	0.00

Total Ultimate Skin Frictional Resistance= 58.2 (t)

End bearing of Base Resistance, **Ppu = Ap *(C.Nc + q.Nq + 0.5.g.D.Ng)**

Layer mkd.	Nc	Nq	Ng	C.Nc	q.Nq	0.5.g'.D.Ng	Ppu (t)
I	9.00	0.00	0.00	0.00	0.00	0.00	0.00
II	9.00	0.00	0.00	25.20	0.00	0.00	4.01
III	9.00	0.00	0.00	13.50	0.00	0.00	2.15
IV	9.00	0.00	0.00	44.10	0.00	0.00	7.01
V	9.00	10.00	10.88	0.00	51.30	2.13	8.50

Total Ultimate Base Resistance= 7.01 (t)

Total Ultimate Capacity of Pile = 65.2 (t), Factor of safety = 2.50

Allowable safe load Capacity of Pile = **26.1 (t)**