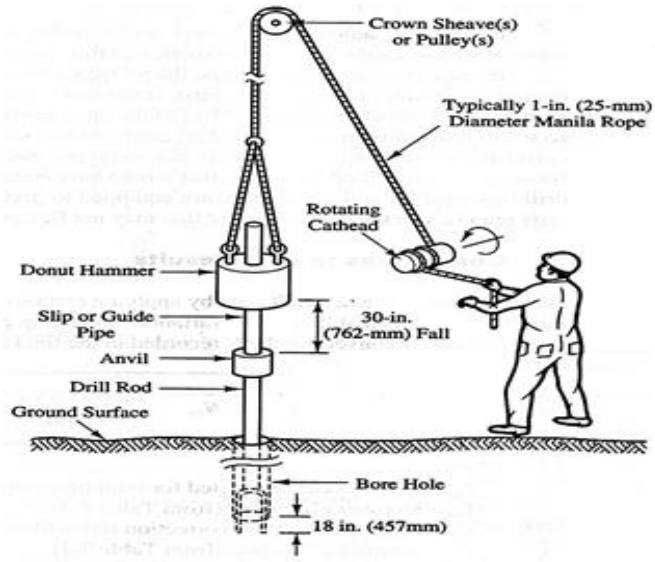
REPORT ON SUB-SOIL INVESTIGATION WORK
FOR
HIGH MAST TOWER
AT
IIT GUWAHATI, KAMRUP DISTRICT OF ASSAM

Name of work:

Sub-Soil Investigation works for the Installation of Proposed high Mast National Flag At IIT Guwahati, Kamrup(M) District of Assam



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GEOTECHNICAL INVESTIGATION REPORT

FOR
PROPOSED CONSTRUCTION OF HIGH MAST TOWER
AT
IIT GUWAHATI, KAMRUP DISTRICT OF ASSAM

CONTENTS

September **2022**

INTRODUCTION:

Sub-soil investigation was carried out at the site of investigation for the Installation of Proposed high Mast National Flag At IIT Guwahati, Kamrup (M) District of Assam.

Altogether two (02) numbers of boreholes was drilled at the site of investigation up-to the depth 20.00m from existing ground level for boreholes BH-01 & BH-02 respectively. Sub-soil investigation was carried out at the site of construction to ascertain the physical and engineering properties for the purpose of construction.

OBJECTIVE:

This report describe the finding of sub-soil investigation and laboratory tests conducted on these soil sample and the data required for design of foundation together with recommended allowable bearing capacity for the structure and assessment of soil strata for construction ,design and estimation.

TIME OF FIELD WORK:

The field investigation work was carried out on 6^{th} & 8^{th} September, 2022. It comprised of both field and laboratory tests in accordance with BIS & IRC code of practice.

INVESTIGATION INFORMATION:

In an attempt for optimization in the design of foundation for the proposed structure to be constructed at this site, Geo-technical Investigation was done. The entire investigation work had been divided mainly into two parts (i) Field works & (ii) Laboratory tests.

- **FIELD INVESTIGATION**: Field works determine the types of sub-soil deposit and their characteristics. including making 150mm diameter borehole at designated location up to depth 20m from existing ground level for boreholes BH-01, Bh-02 respectively, Preparation of borehole chart mentioning the depositional features along with other characteristics of the sub-soil strata, carrying out standard penetration test (S.P.T) at an interval of 1.5M in each borehole and recording in the borehole chart

- **LABORATORY INVESTIGATION**: Laboratory tests help in determining the relevant geo-technical properties of the sub-surface deposits leading to finalization of foundation depth of the structure basing on Bearing Capacities of the foundation strata as well as the influence zone. Final depths of boring and observation of water table for each borehole are given below.

- **BORING PROCESS:** The borehole was drilled by using post holes type augur boring technique up to a depth of 2.00m from EGL and remaining depth of the borehole was drilled by wash boring technique operated manually up to the depth of depth 20m from existing ground level for boreholes BH-01, Bh-02 respectively.

- **SAMPLING:** Representative soil samples collected from boreholes were confirming to IS: 1892-1979 code in categories Disturb Sample & undisturbed sample along with proper leveling.

- **DISTURBED SOIL SAMPLES:** Disturbed soil samples were reasonably collected from cutting shoe of undisturbed soil samples and recovered were logged, labeled depth wise and placed in polythene bags for conducting necessary laboratory tests.

- **UNDISTURB SOIL SAMPLES:** Undisturbed soil samples were recovered by using thin walled metal sampling tubes as per IS 1932-1963 specification. The Sampling tubes were lubricated before use so as to minimize the wall friction. The samples so recovered were sealed with molten paraffin at the both ends so that the in situ properties were retained.

- **GROUND WATER TABLE:** The information about the fluctuation of underground water table is essential for correct assessment of soil parameters. If the water table is much below the depth of boring, this information should be collected from nearby bores, bore well or tube well etc. Ground water table has furnished in the table in this report.

- **LOGS OF BORING:** A boring log is a written record of information about the soil removed from a hole drilled in the earth which contains the sob-soil stratification, N-values and details of samples. Logs of Boring, which represent the field data

- **BRIEF DETAILS OF PROPOSED CONSTRUCTION SITE:** The site is a plane land and the boreholes were drilled up to depth 20m from existing ground level for boreholes BH-01, Bh-02 respectively. Field identification such as colour, change of strata etc. were made visually during the time of field investigation and recorded in the borehole chart.
  In this proposed construction site N-values are graphically represented in borehole log enclosed with this report

LABORATORY INVESTIGATION:

For proper identification & classification of the sub-soil strata and for deriving adequate information regarding its relevant Geo-technical properties of the site under investigation, the following laboratory tests were conducted on the soil samples collected from boreholes-

1.1 GRAIN SIZE ANALYSIS AS PER IS: 2720, part-IV

- **SIEVE ANALYSIS**
  The complete sieve analysis can be divided into two parts, i.e, the coarse analysis and fine analysis. An oven dried samples of soil is separated into two fractions by sieving it through a 4.75 mm IS sieve. The portion retained of it (+4.75mm size) is termed as the gravel fraction and is kept for the coarse analysis, while the portion passing through it (-4.75mm size) is subjected to fine sieve analysis. For this purpose an oven dry pulverized soil sample is sieved through the set of sieves 20mm, 10mm, 4.75mm, 2.0mm, 1.0mm, 600micron, 300micron, 150micron and 75micron. The amounts of soil retained on each sieve are noted down. The % retained, cumulative % retained and % passing are computed by these retained weights.

  If the % passing 75micron sieve is appreciable, Hydrometer method is used to find the % fraction of particle sizes from 75micron to 2micron

- **HYDROMETER ANALYSIS**
  In the wet method of mechanical analysis or sedimentation analysis, the soil fraction, finer than 75 micron size is kept in suspension in a liquid

(usually water) medium. The analysis is based on stoke's law, according to which the velocity at which grains settle out of suspension, all other factor being equal, is depended upon the shape, weight and size of the particles/grains

1.2 SOIL CONSISTENCY AS PER IS: 2720, part-V

These are arbitrary moisture contents to determine the instant at which the soil is on the verge of being viscous liquid (Liquid limit) or non–plastic /Plastic limit. Liquid limits determined with the help of a liquid limit apparatus. Plastic limit is the water content at which the soil begins to crumble when rolled out into a thin thread of 3mm

1.3 MOISTURE CONTENT AS PER IS: 2720, part-IX

For this test the soil sample of known quantity (Wm) is taken in a container. The container with this soil sample is placed in an oven for drying at 105-110^{o}c for 16-24 hours. After drying the dry sample is again weighed to determine the dry weight of sample (W_d)

The moisture content is computed by the following equation:

$$Wn=(Wm-W_d)/W_d$$

1.4 DRY DENSITY AND BULK DENSITYAS PER IS: 2720, part-IX

For determination of bulk density, a sample of known volume 'V' is extracted from the undisturbed sample. Its bulk weight 'W' and moisture content 'Wn' is determined by oven drying method.
The bulk density is determined by following equation;

$$\gamma_b=W/V$$

And
Dry density $\gamma_d=\gamma_b/(1+Wn)$.

The Bulk density & Dry density values of the samples have been given in the enclosed laboratory sheet.

1.5 SPECIFIC GRAVITY AS PER IS: 2720, part-III

The Specific Gravity of the soil samples was determined by adopting standard procedure. The soil sample was dried in oven dried for 24 hours and pulverized. The sample was then poured into a specific gravity bottle and topped up with distilled water. The specific gravity bottle was stirred and heated to eliminate air bubbles. The weight of the specific gravity bottle was recorded along with the temperature of the sample.

For this test 5-10g (W_2) sample of oven dry, cool soil is taken in 50ml capacity density bottle and its weight is noted down. The soil is covered with distilled water and left for sufficient period for suitable soaking. The entrapped air is removed by vacuum. The soil in bottle is filled full with water and its is noted down as w_3. The mass of empty bottle (w_1) and bottle with full distilled water also noted (w_4).
The specific gravity is found by the following equation.

$$G=w_2-w_1/[(w_2-w_1)-(w_3-w_4)]$$

1.6 DIRECT SHEAR TEST AS PER IS: 2720, part-XIII

Direct Shear Test is a strength test which is performed on the soil sample to determine the value of angle of internal friction. The direct shear test is generally conducted on cohesion less soil as consolidated drained (CD) test. In the present case, the soil samples were prepared for various depths and were tested in the Direct Shear Apparatus under CD-condition.

1.7 TRI-AXIAL SHEAR TEST AS PER IS: 2720, part-XII

The shear strength properties of soil play an important role in the determination of the bearing of soil. The values of "C" and "ϕ" are obtained from Mohr's circle drawn as required in IS: 2720 (part-XII) for the soil samples tested in unconsolidated un-drained triaxial compression without measurement of pore pressure**.**

1.8 CONSOLIDATION TEST AS PER IS: 2720, part-XV

To obtain specimens for consolidation test, the odometer ring was placed on the trimmed horizontal faces of the soil within the 10 cm diameter 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 a piano wire saw. Consolidation tests were run in floating ring type odometers, in single & four unit consolidation frames under standard load increment ratio starting from 0.25 kg/sq.cm and going up to 16 kg/sq.cm in general. The pressure vs void ratio curves are given in this report**.**

1.9 UNCONFINED COMPRESSIVE STRENGTH TEST AS PER IS : 2720, part-XI

The UCC test was carried out on the saturated undisturbed soil samples. Which is gives the tentative idea of safe bearing pressure of soil at different depth**.**

1.10 CHEMICAL TEST OF SOIL AND WATER SAMPLES

As per specifications, soil samples at depths of 2.0m from the borehole and water sample also have been analyzed to determine the presence and percentage to determine pH, Cloride (Cl) and Sulphate (S04) ions**.**

ANALYSIS OF FIELD DATA:

From proper geotechnical investigation all parameter of the soil profile collected from during field investigation-

❖ STANDARD PENETRATION RESISTANCE

As per IS: 2131:1981, Standard Penetration Test requires one drop hammer of 63.5Kg weight, a string of drill rods (A-type rods of 41.27mm OD and 28.57mm ID) of suitable length, casing, one split spoon sampler, one guide to transfer the impulse load from drop hammer to the drill rods and a mechanism to elevate the load and to release the same on the drill rods.

First the sampler is driven into the borehole with the drill rods to the required depth, at which we are going to take the S.P.T. value. The sampler is first driven in to the soil by light blows of hammer to a seating penetration of 15cm. Then the sampler is driven under full blows of the 63.5Kg hammer falling from a height of 75cm, to an additional penetration of 30cm and the no. of blows are recorded as the 'Standard Penetration Resistance' N -value.

The observed value of N has to be corrected for (i) submergence correction and ii) Overburden pressure correction.

(i) **Submergence correction** :-In very fine or silty sand, situated bellow the water table, an apparent increase in penetration resistance occurs. Tarzaghi and Peck have recommended the use and equivalent penetration resistance Ne in place of actually observed N, when N is greater than 15. Ne is given by the following relation:

$Ne=15+0.5(N-15)$ ……(i)

(ii**) Overburden pressure correction** :-For a constant density index the N-value increase with increasing effective overburden pressure for which correction have been proposed by Gibbs and Holtz, peck, Thornburn, Whitman and others.

Peck (1974) proposed that N-values be reported at a reference overburden pressure of100KN/m2, and the normalized value of N (corrected for overburden as pressure) be expressed as follows :

$N0=cn \cdot N$
Where, No = Corrected value for overburden effect,
N = Actual values (observed),
cn= Normalizing factor ,
$= 0.77x\log_{10}(2000/\sigma/)$,
Where $\sigma/$ = Effective overburden pressure (KN/m2)

❖ GROUND WATER TABLE:

The information about the fluctuation of underground water table is essential for correct assessment of soil parameters. If the water table is much below the depth of boring, this information should be collected from nearby bores, bore well or tube well etc. Ground water table has furnished in the table in this report.

STANDARD PENETRATION RESISTANCE TEST VS DEPTH

(As per IS: 2131)

BH NO.	Depth (M)	N	N_O	N_E
1	1.50	3	3	3
	3.00	2	2	2
	4.50	9	9	9
	6.00	12	12	12
	7.50	14	14	14
	9.00	15	15	15
	10.50	21	21	18
	12.00	17	17	16
	13.50	19	19	17
	15.00	19	19	17
	16.50	15	15	15
	18.00	15	15	15
	19.50	16	16	16
2	1.50	5	5	5
	3.00	3	3	3
	4.50	4	4	4
	6.00	14	14	14
	7.50	15	15	15
	9.00	15	15	15
	10.50	22	22	19
	12.00	17	17	16
	13.50	18	18	17
	15.00	21	21	18
	16.50	17	17	16
	18.00	16	16	16
	19.50	18	18	17

Depth (M) = Depth in meter below the existing Ground surface level.
N = Standard penetration Resistance, N-Value recorded in field
N_E = Corrected N-value for N exceeding 15.
N_O = Adjusted N-Value in respect of existing over burden
R = Refusal N-value

Note: Standard Penetration test value correction only for sandy soil using IS: 2131 & IS: 1893

SUB-SOIL WATER TABLE:

The ground water level was recorded in each borehole during exploration and is furnished below.

Borehole No	Depth Above the EGL in meter
1	2.00m
2	2.00m

LABORATORY TEST DATA

From proper geotechnical investigation all parameter of the soil tested in laboratory has furnished in the table for respective boreholes in details as follows-

GRAIN SIZE DISTRIBUTION, SOIL CONSISTENCY PARAMETER, MOISTURE CONTENT, DENSITIES, SPECIFIC GRAVITY VOID RATIO, SHEAR & CONSOLIDATION PARAMETERS

(As per IS: 2720, Part-IV &Part-V, Part-III & Part-IX, Part-XI, Part-XII, Part-XIII & Part-XV)

BH. No.	Disturbed Soil Samples parameter									Undisturbed Soil Samples parameter									
	Depth below EGL in meter	Particle Size Distribution					Atterberg's Limit			Shrinkage Limit	Depth Below the EGL in meter	In-Situ Properties of Soil					Shear parameter		Consolidation parameter C_C	UCC in t/m^2
		Clay	Silt	Sand	Gravels	IS Classification	Liquid limit (%)	Plastic limit (%)	Plastic Index (%)			Moisture Content in %	Bulk Density in t/m^3	Dry Density in t/m^3	Specific Gravity	Void Ratio	Cohesion in t/m^2	ϕ in degree		
1	**3.00**	23.00	71.00	6.00	0.00	**CI**	47.44	29.09	18.35	---	**2.50**	28.063	1.902	1.485	2.621	0.765	2.73	3	0.1973	---
	6.00	19.00	69.00	12.00	0.00	**CI**	40.08	25.04	15.03	---	**5.50**	26.235	1.915	1.517	2.622	0.728	2.98	6	---	---
	9.00	17.00	67.00	16.00	0.00	**CL**	---	---	---	---	**8.00**	22.015	1.920	1.574	2.629	0.671	2.69	15	---	---
	12.00	15.00	62.00	23.00	0.00	**CL**	---	---	---	---	**11.00**	21.526	1.924	1.583	2.628	0.660	2.64	16	---	---
	15.00	14.00	59.00	27.00	0.00	**CL**	34.38	22.91	11.47	---	**14.00**	21.032	1.922	1.588	2.630	0.656	2.53	16	---	---
	18.00	15.00	58.00	27.00	0.00	**CI**	32.75	22.01	10.74	---	**18.50**	20.989	1.926	1.592	2.630	0.652	2.70	16.5	---	---
2	**3.00**	21.00	69.00	10.00	0.00	**CI**	42.52	26.38	16.13	---	**2.50**	27.989	1.902	1.486	2.619	0.762	2.83	3	0.1969	---
	6.00	20.00	72.00	8.00	0.00	**CI**	41.86	26.02	15.84	---	**5.50**	27.330	1.905	1.496	2.622	0.753	2.78	3	---	---
	9.00	15.00	63.00	22.00	0.00	**CL**	32.76	22.02	10.74	---	**8.00**	22.635	1.919	1.565	2.630	0.681	2.56	15.5	---	---
	12.00	14.00	62.00	24.00	0.00	**CL**	---	---	---	---	**11.00**	20.845	1.926	1.594	2.629	0.650	2.69	16	---	---
	15.00	16.00	65.00	19.00	0.00	**CL**	32.57	21.91	10.66	---	**14.00**	20.326	1.924	1.599	2.627	0.643	2.57	16.5	---	---
	18.00	12.00	69.00	19.00	0.00	**CL**	---	---	---	---	**18.50**	20.156	1.925	1.602	2.630	0.642	2.64	16.5	---	---

BRIEF DESCRIPTION AND CLASSIFICATION OF THE SUB-SOIL PROFILE:

The borehole log and particle size distribution curves reveal the following underlying sub-soil strata as per IS: 1498 specification below the investigation area-

BH No	**CI:** Brownish to Greyish/light ash coloured silty clay, impervious, low compressibility, sticky, medium plasticity, low compressibility, impervious layer, fair to moderate in consistency, traces of non-plastic silt in some layer, saturated, inorganic, cohesive soil in	**CL:** Light Brownish to Greyish/Greyish/Ash colour silty clay, fairly Sticky, impervious layer, low compressibility, impervious layer, low to medium plasticity, fairly saturated, inorganic soil in-
1	From EGL to 6.50m,	From 6.50m to 19.50m
3	From EGL to 6.00m	From 6.00m to 19.50m

Note:

- Relative stiffness of clayey horizons and compactness of Sandy Strata's at different depths of each Bore hole may be pursued from the record of N-Values shown in the Bore hole log profiles

FOUNDATION ANALYSIS:

Foundation of a structure is to be designed from considerations of superstructure loading as well as subsoil condition at the site. Suitable foundations for a structure should satisfy the following basic design criteria. For ultimate bearing capacity, groundwater table calculation is not needed for clayey soil as per IS: 6403. However, parameters have been considered for saturated condition with water table at ground surface. There must be adequate factor of safety of the foundations against any possible bearing capacity failure and the settlement of the foundations must be within permissible limits. On the basis of requirement, both shallow and deep foundation may be adopted at the site for different types of structures. Hence both shallow and deep foundation has been studied as follows:

- **SHALLOW FOUNDATION**: **As per IS 6403: 1981,**the Net safe bearing capacity from C-Φ values has been calculated by applying the following formula for various footing is as follows :-

For General shear failure,

$$q_a=\frac{1}{F}\left[C\times N_c\times S_c\times i_c+\gamma\times D\times\left(N_q-1\right)\times S_q\times d_q\times i_q+0.50\times B\times\gamma\times N_\gamma\times S_q\times d_\gamma\times i_\gamma\times w'\right]$$

For Local shear failure,

$$q_a=\frac{1}{F}\left[\frac{2}{3}\times C\times N_c{}'\times S_c\times i_c+\gamma\times D\times\left(N_q'-1\right)\times S_q\times d_q\times i_q+0.50\times B\times\gamma\times N_\gamma{}'\times S_q\times d_\gamma\times i_\gamma\times w'\right]$$

Where,

F=Factor of safety
C=Cohesion
γ=Submerged density
D=Depth of footing.
B= Width of footing
W/=Water table correction
Φ/ =Tan-1(0.667×tanΦ) (Which is consider for Local shear failure)

$Nc, Nq, N\gamma$ & $Nc', Nq', N\gamma'$ are the bearing capacity factors depending upon the Φ & Φ/ values respectively.

S_c, S_q, S_γ are the shape factors

Shape of footing	S_c,	S_q	S_γ
Square footing	1.3	1.2	0.80
Circular footing	1.3	1.2	0.60
Rectangular footing	1+0.2(B/L)	1+0.2(B/L)	1-0.4(B/L)
Continuous footing	1.0	1.0	1.0

d_c, d_q, d_γ are the depth factors

$$d_{c,}=1+0.2\frac{D}{B}\tan\left(45^\circ+\frac{\phi}{2}\right),\qquad d_q=d_\gamma=1 \text{ when } \Phi<10$$

$d_q = d_\gamma$ =1+.1 ($\frac{D}{B}$) tan ($45^\circ + \frac{\phi}{2}$) when Φ >10°

i_c, i_q, i_γ are the inclination factors of inclined loads.

- **DEEP FOUNDATION:** Deep foundation in the form of RCC bored cast-in-situ piles has been investigated. Pile toe may be kept at various depths below the Existing Ground Level. Cut-off level may be considered as per investigation area soil profile below the EGL. The ultimate load carrying capacity (Qu) of bored cast in-situ RCC pile foundation of different pile dimension were evaluated using as per **IS code: 2911(part 1/Sec 2): 2010**

The ultimate load capacity of the piles in tones

$$Q_u = A_P N_c C_P + \sum_{I=1}^{n} K_i . P_{Di} . \tan\delta_i . A_{S\,i} + \sum_{i=1}^{n} \alpha_i C_i A_{Si}$$

Or,
The ultimate load capacity of the piles in tones

$$Q_u = A_P (\frac{1}{2} D\gamma N_\gamma + P_D N_q) + \sum_{I=1}^{n} K_i . P_{Di} . \tan\delta_i . A_{S\,i} + \sum_{i=1}^{n} \alpha_i C_i A_{Si}$$

Where

A_p = Cross-sectional area of pile tip in m^2

Nc = Bearing capacity factor = 9

Nq = Bearing Capacity factor

Ny = Bearing capacity factor depending upon internal friction angle

Cp = Average cohesion at pile tip in t/m^2

Ki = Coefficient of earth pressure ith layer

P_{Di} = Effective overburden pressure for ith layer.

P_D = Effective overburden pressure at the pile tip.

δ_i = Angle of wall friction between pile and soil for ith layer.

A_{si} = Surface area of pile shaft in the ith layer in m^2

α_i = Adhesion factor for the ith layer depending on the consistency of soil.

D = Diameter of the pile shaft

ALLOWABLE BEARING CAPACITY OF SOIL FROM SHEAR PARAMETER OF SOIL: SAMPLE CALCULATION

As per soil horizon of borehole No-01, consider the parameter for the significant depth as follows-

Basic data:

Depth of the foundation (d_f) : 2.50m

Type of foundation : ISOLATED FOOTING

Width of the foundation (B) : 1.50m

Length of foundation (L) : 1.50m

Y_{sub} (Submerged density) : 0.90t/m^3

q (Affective surcharge) : 2.26t/m^2

C_{av} (Cohesion) : 2.73t/m^2

Φav (I.F. angle) : 3^0

W$^/$ (Water table correction factor) : 0.50

Since

$\Phi < 29^0$ and Void (e_0) >0.55, As per criteria of IS: 6403: 1981, For local shear failure

$\Phi^/m = Tan^{-1}(0.667 \times tan\Phi) = 2^0$

Different factors of SBC					
General Shear Failure			Local Shear failure		
Nc	**Nq**	**Nγ**	**Nc$^/$**	**Nq$^/$**	**Nγ$^/$**
5.87	**1.31**	0.24	5.60	1.20	0.15
Sc	**Sq**	**Sγ**	**Sc**	**Sq**	**Sγ**
1.30	**1.20**	0.80	1.30	1.20	0.80
dc	**dq**	**dy**	**dc**	**dq**	**dy**
1.21	**1.00**	1.00	1.20	1.00	1.00
i_c	**i_q**	**i_y**	**i_c**	**i_q**	**i_y**
1.00	**1.00**	1.00	1.00	1.00	1.00

Therefore,
For General Shear Failure,

q_d = C×Nc ×Sc ×dc×ic + γ ×Df×(Nq-1)×Sq×dq×iq + 0.5×Y×B×Nγ×Sy×dy×iγ×W/

= 29.08t/m^2 …… (i)

For Local Shear Failure,

$q_{d/}$ = (2/3)×C×Nc$^/$ ×Sc ×dc×ic + γ$^/$ ×Df×(Nq$^/$-1)×Sq×dq×iq + 0.5×Y$^/$×B×Nγ$^/$×Sy×dy×iγ×W/

$= 18.46 t/m^2$ …… (ii)

As per IS 6403: 1981, Interpolate between (i) and (ii) with respect to void ratio

$q_d = 19.95 t/m^2$

. : $q_{ns} = q_d / FoS = 6.65 t/m^2$ (where FoS=3)

Hence, Net safe bearing capacity (q_{ns})= $6.65 t/m^2$ for square footing 1.5m x 1.5m at 2.50m depth below the EGL**.**

SETTLEMENT ANALYSIS OF SHALLOW FOUNDATION: The Net safe bearing capacity of soil from shear parameter of soil has check for settlement failure as per IS: 8009 (part-I) & IS: 1904

Basic data for Settlement Analysis:

With of the foundation (B) : 1.50M

Z = significant depth below base of the foundation = 3.00m

qs= Net safe Bearing capacity = 6.65Tone/M^2

Compression index (Cc) = 0.199

Void ratio (e_o) = 0.75;

Thickness of compressed Stratum (H) = Z = 3000 mm

Po =3.61MT/SM, at the middle of the compressed stratum;

ΔP = 0.74MT/SM

Therefore,

$Sc = HC_C/ (1+e_0) \times \log[(P_0 + \Delta P)/ P_0] = 27.70mm$

Since, no sandy layer exist within significant depth so, consider Si = 0.00mm
Total Settlement (St) = Si + Sc = 27.70mm,

Also St<50mm,(i.e., maximum permissible settlement under isolated RCC footing as per IS:1904)

Hence, Net safe bearing pressure (q_{ns}) = $6.65 t/m^2$ for square footing 1.5m x 1.5m at 1.50m depth below the EGL.

∴ From the Shear criteria & Settlement Criteria of soil, it is concluded that the allowable bearing capacity (q_a) = 6.65tons/m^2 for Square footing 1.50M × 1.50M Size at 2.50M depth.

ALLOWABLE BEARING CAPACITY OF SOIL FROM SHEAR CRITERIA AND SETTLEMENT CRITERIA IN t/m^2

D(M) Below EGSL	BH NO	FOOTING SIZE OF 1.5M × 1.5M	FOOTING SIZE OF 2.00M × 2.00M	FOOTING SIZE OF 2.5M × 2.5M	FOOTING SIZE OF 3.00M × 3.00M
2.50		6.65	6.25	6.01	5.85
3.00		7.38	6.54	6.25	6.06
3.50		7.78	6.81	6.47	6.24
4.00		9.52	8.05	7.60	7.31
4.50	BH-01	10.09	8.41	7.90	7.57
2.50		6.92	6.50	6.25	6.09
3.00		7.66	6.80	6.50	6.31
3.50		8.08	7.09	6.73	6.49
4.00		8.47	7.33	6.92	6.65
4.50	BH-02	8.94	7.64	7.17	6.87

Note: SBC of the fill-up soil layer has not furnished in the above table

SAMPLE CALCULATION OF BORED CAST IN-SITU RCC PILE

Basic Data: In pile calculation minimum data has been consider from respective borehole area of BH-01 in respective depth.

Length of the Pile from EGL	10.00m
Length of the pile (Embedded)	8.00m
Cutoff length from EGL	2.00m
Diameter of the pile	450mm
Depth of the pile top from EGL	1.00m
Max. overburden pressure acts upto the effective length	6.75m
Factor of Safety for safe load Capacity of pile	2.5
Factor of Safety for safe Uplift Capacity of pile	3.0

In pile calculation, shear parameter & effective unit weight has considered as per layer of the construction area, which are furnished in table.

Parameter for the pile friction calculation as follows-

Pile depth from cut off (M)	Thickness of layer (m)	C **(t/m^2)**	Φ In Degree	Effective unit weight γ/ **(t/m^2)**	P_{Di} **γ/D (t/m^2)**	Co-efficient of earth pressure (Ki)	Adhesion factor (α)
2m-4m	**2.00**	2.73	3.00	0.902	1.80	**1.00**	1.00
4m-7m	**3.00**	2.98	6.00	0.915	4.55	**1.00**	1.00
7m-9m	**2.00**	2.69	15.00	0.920	6.42	**1.00**	1.00
9m-10m	**1.00**	2.64	16.00	0.924	7.36	**1.00**	1.00

Parameter for the pile end bearing calculation as follows-

Cross sectional of pile toe	0.19625m^2
Value of Φ at toe	16.5^0
Cohesion at the Tip (C)	2.70t/m^2
Nc (Bearing capacity factor)	9.00
N_q (Bearing capacity factor)	4.54
N_Y (Bearing capacity factor)	3.28
Effective overburden pressure at toe of the pile (P_D)	6.24t/m^2

As per IS: 2911(part-I, Sec-2), Skin friction and End bearing has furnished in table-

Pile depth from cut off (M)	Thickness of layer (m)	Friction Contribution in		End Bearing in	
		Clay	Sand	Clay	Sand
2m-4m	**2.00**	7.71	0.27	**---**	---
4m-7m	**3.00**	12.63	2.03	**---**	---
7m-9m	**2.00**	7.60	4.86	**---**	---
9m-10m	**1.00**	3.73	2.98	**3.86**	3.41

Total Skin friction of the pile = 41.81tone/m^2
& the End bearing of the pile = 7.27tone/m^2

From the above data,

Ultimate load capacity of the piles = **49.08**tone/pile
Safe load Capacity of the Piles = **19.63**tone/pile
Uplift Capacity of the Pile = **14.57**tone/pile

Also, As per IS 1893(Part-I)-2016,

Seismic Safe working Load of the Piles = 24.54tone/pile

Horizontal capacity of the pile:

Basic Data:
Young's modulus of pile (E) = 2738612Mpa (for M30 grade of concrete)

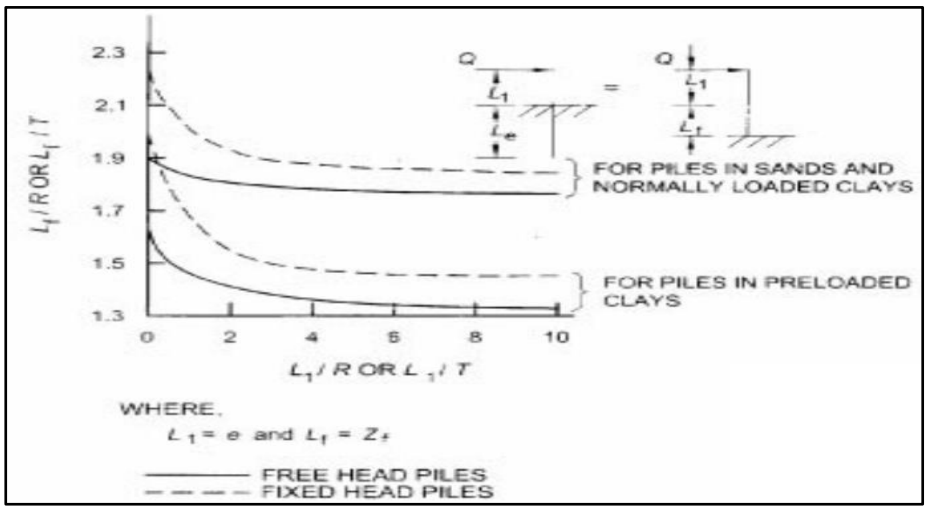
Average N-value = 13

Moment of inertia of the pile cross Section (I) = 0.002m^4

From the table 3 of IS 2911 part-I (sec-2),
Interpolating for N-value η_h = 1.88mn/m3

Stiffness factor (T) = 1.96m

As per IS: 2911 (part 1/Sec-2)
Minimum embedded length of the pile required = 4T= 7.86**m** <8.0m. It is O.K



From the above IS : 2911(part-1/sec-2) figure we get
Lf/T=2.20(Fixed headed)
Lf/T=1.90(Free headed)

Depth of fixity to be adopted (Zf) = 4.32**m** for Fixed headed
Depth of fixity to be adopted (Zf) = 3.73**m** for Free headed
Deflection(y)=4.5mm (In IRC:78 (2014):Fixed head pile max allowable deflection of the pile head(y)=1% of the diameter)

As per IS: 2911(Part-1/Sec-2)

Deflection (y) = $\frac{H(e+Z_f)^3}{3EI} \times 10^3$ for **free headed pile**

&

Deflection (y) = $\frac{H(e+Z_f)^3}{12EI} \times 10^3$ for **fixed headed pile**

Where,

H = Lateral Load in KN
y = Deflection of pile head in mm
E = Young's Modulus of pile material in KN/m^2
Z_f = depth of point of fixity in m
E = Cantilever length above the ground/bed ti the point of Load application in m

∴ **Horizontal load capacity of the pile = 3.68tons for Fixed headed pile**

&

Horizontal load capacity of the pile = 1.43tons for Free headed pile

SAFE LOAD ON BORED CAST IN-SITU RRC PILE

(Area covered by BH-01, BH-02)

Pile Length from EGL	Pile Length from cutoff level (cutoff=1.00m)	Diameter of the pile in mm	Safe working Load (non-Seismic) **t/Pile**	Safe working Load (Seismic) **t/Pile**	Safe uplift working Load **t/Pile**	Horizontal load capacity of the pile (Fixed headed)	Horizontal load capacity of the pile (Free headed)
10.00	8.00		17.04	21.31	12.89	2.71	1.05
12.00	10.00		22.30	27.87	17.40	2.71	1.05
14.00	12.00	**400**	28.30	35.37	22.52	2.71	1.05
10.00	8.00		19.63	24.54	14.57	3.68	1.43
12.00	10.00		25.54	31.93	19.66	3.68	1.43
14.00	12.00	**450**	32.29	40.37	25.44	3.68	1.43
10.00	8.00		22.36	27.95	16.27	4.84	1.88
12.00	10.00		28.93	36.16	21.94	4.84	1.88
14.00	12.00	**500**	36.43	45.54	28.39	4.84	1.88
10.00	8.00		25.24	31.55	17.98	6.20	2.41
12.00	10.00		32.46	40.58	24.24	6.20	2.41
14.00	12.00	**550**	40.71	50.89	31.36	6.20	2.41

Note: Pile diameter 400mm has been taken off from IS: 2911(part-II/ sec-2): 2010. The data of 400mm diameter has been furnished in the above table only for designer information.

Recommendation & conclusion:

From the careful study it is concluded that the sub soil horizons in investigated detailed in soil investigation area was undertaken to assess the quality of the existing subsoil and to suggest suitable foundation systems for the proposed structures. Based on field and laboratory tests and analysis of the results the following recommendations may be made.

I. In proposed construction area, top soil consists of fill-up soil upto 2.50m below the EGL and then homogeneous soft silt clay layer up to 6.50below the EGL followed by sand clay layer encountered upto terminal level of the boreholes. **Shallow foundation is not suitable for the proposed construction area without proper soil improvement.**

II. Looking to the soil profile and soil strength along with proposed construction, a pile section shall be used for the proposed construction and the recommended design data as follows-

Total length of the pile	= 10.00m below the EGL
Cut off of the pile	= 2.00m
Diameter of the pile	= 450mm
Embedded length of the pile	= 8.00m
Safe working load (non-seismic condition)	= 19.63ton/Pile
Safe working load (seismic condition)	= 24.54ton/pile
Uplift working load	= 14.57ton/pile
Safe horizontal load (fixed headed)	= 3.68ton/pile
Safe horizontal load (fixed headed)	= 1.43ton/pile

- An initial load test as per IS: 1888 (both single and in group) shall be conducted for authentication of theoretical values. Two nos. minimum random routine load test shall preferably be carried out to ascertain the actual soil-pile behavior under vertical and horizontal loadings.

- Appropriate reduction of safe loads shall be required to be made using suitable group efficiency factor inconsonance with pile group geometry

- Construction area is included in the zone V of earthquake with high seismic intensity of Z=0.36.Hence due precautions may be taken to design the foundations of building as per IS: 4326 and IS:1893

- Adequate grade of concrete considering zero lateral support upto a depth of 3.0M below the existing ground surface level

- If required, ground improvement techniques, appropriate to the site condition may be adopted and proper scheme has to be designed for that purpose based on the soil data presented in this report

However, the type of foundation and depth may be decided by the design engineer based on various data furnished in the report for safety and economy.

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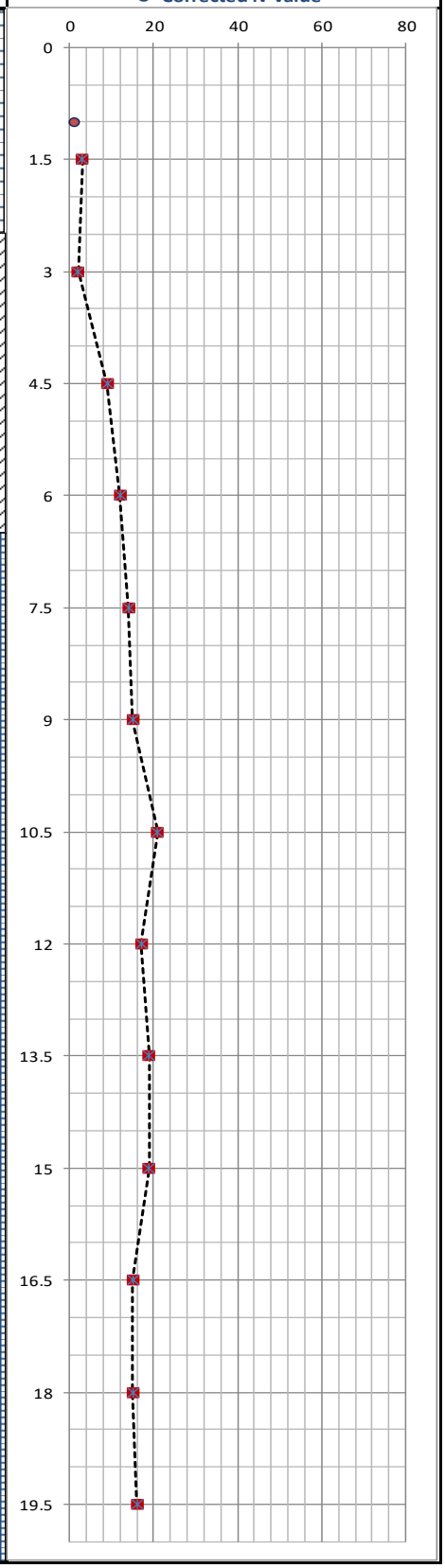
DRAWINGS & CURVES

SUB-SOIL INVESTIGATION FOR THE INSTALLATION OF PROPOSED HIGH MAST NATIONAL FLAG AT IIT GUWAGHATI CAMPUS, KAMRUP DISDRICT OF ASSAM

Date commenced:	06.09.2022	BOREHOLE NO-01	TYPE OF BORING: AUGUR & WASH BORING
Date of completed:	06.09.2022		GROUND WATER TABLE: 2.00m below the EGL

Depth Below EGSL	TYPE OF SAMPLE	N-Value	VISUAL DESCRIPTION OF SOIL PROFILE	BH LOG
1.50-1.95	SPT	3	Fill-up soil upto 2.50m below EGL	FILL-UP SOIL
2.00	UDS	---		
3.00-3.45	SPT	2		
3.50	UDS	---	Greyish to Browniah coloured silty clay mixed with non-plastic silt,low medium plasticity, soft to fairly sticky cohesive soil upto 6.50m below the EGL (CI)	
4.50-4.95	SPT	9		
5.00	UDS	---		
6.00-6.45	SPT	12		
7.50-7.95	SPT	14		
8.00	UDS	---		
9.00-9.45	SPT	15		
10.00	UDS	---		
10.50-10.95	SPT	21		
11.00	UDS	---		
12.00-12.45	SPT	17		
13.50-1395	SPT	19		
14.00	UDS	---		
15.00-15.45	SPT	19		
16.50-16.95	UDS	15		
18.00-18.45	SPT	15		
18.50	UDS	---		
19.50-19.95	SPT	16	Greyish to Browniah coloured sandy clay mixed with non-plastic silt,low plasticity, inorganic, cohesive soil up to 19.50m below the EGL (CL)	

GRAPHICAL REPRESENTATION OF N-VALUE
-o- Observed N-value
-o- Corrected N-value



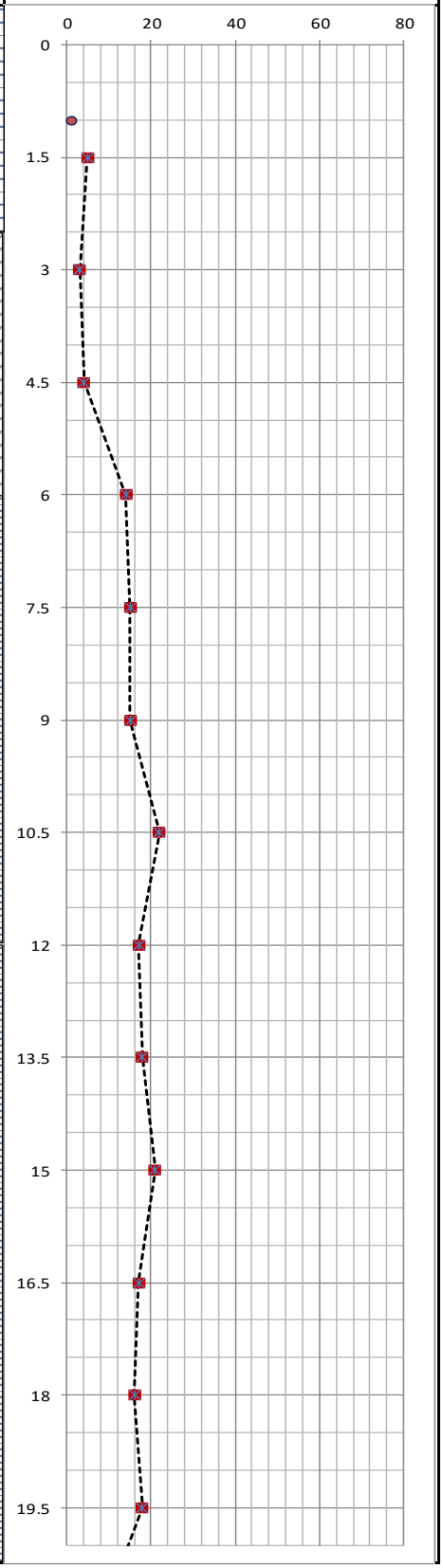
*** SPT=Standard Penetration test, UDS= Undisturbed Soil Sample, RM= Remoulded Soil Sample

SUB-SOIL INVESTIGATION FOR THE INSTALLATION OF PROPOSED HIGH MAST NATIONAL FLAG AT IIT GUWAGHATI CAMPUS, KAMRUP DISDRICT OF ASSAM

Date commenced:	08.09.2022	BOREHOLE NO-02	TYPE OF BORING: AUGUR & WASH BORING
Date of completed:	08.09.2022		GROUND WATER TABLE: 2.00m below the EGL

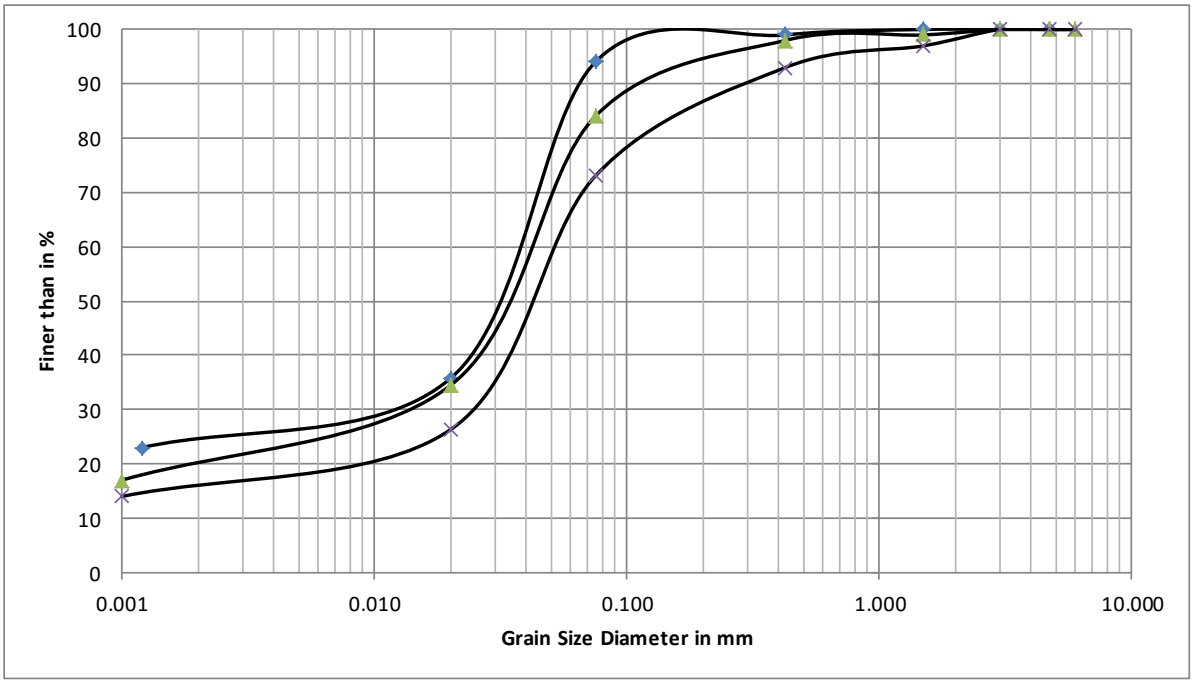
Depth Below EGSL	TYPE OF SAMPLE	N-Value	VISUAL DESCRIPTION OF SOIL PROFILE	BH LOG
1.50-1.95	SPT	5	Fill-up soil upto 2.50m below EGL	FILL-UP SOIL
2.00	UDS	---		
3.00-3.45	SPT	3		
3.50	UDS	---	Greyish to Browniah coloured silty clay mixed with non-plastic silt,low medium plasticity, soft to fairly sticky cohesive soil upto 6.00m below the EGL (CI)	
4.50-4.95	SPT	4		
5.00	UDS	---		
6.00-6.45	SPT	14		
7.50-7.95	SPT	15		
8.00	UDS	---		
9.00-9.45	SPT	15		
10.00	UDS	---		
10.50-10.95	SPT	22		
11.00	UDS	---		
12.00-12.45	SPT	17		
13.50-1395	SPT	18		
14.00	UDS	---		
15.00-15.45	SPT	21		
16.50-16.95	UDS	17		
18.00-18.45	SPT	16		
18.50	UDS	---		
19.50-19.95	SPT	18	Greyish to Browniah coloured sandy clay mixed with non-plastic silt,low plasticity, inorganic, cohesive soil up to 19.50m below the EGL (CL)	

GRAPHICAL REPRESENTATION OF N-VALUE
-o- Observed N-value
-o- Corrected N-value

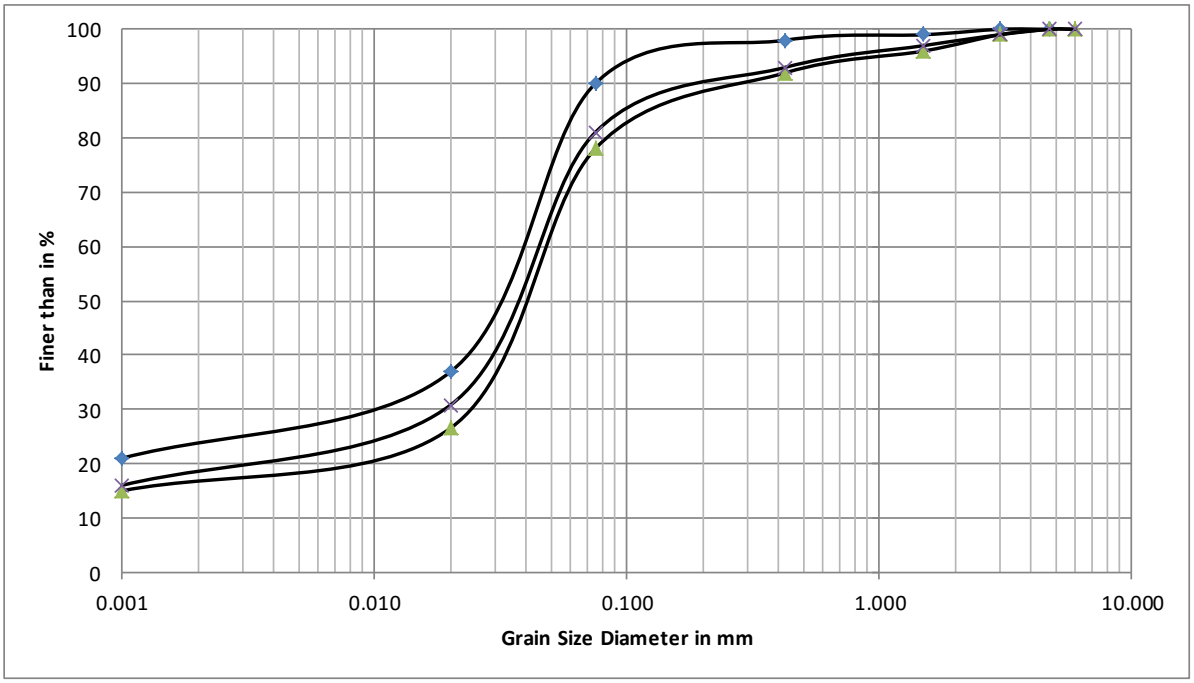


*** SPT=Standard Penetration test, UDS= Undisturbed Soil Sample, RM= Remoulded Soil Sample

GRAIN SIZE ANALYSIS CURVE OF BOREHOLE NO-01						
Depth (M)	Index	Clay %	Silt %	Sand %	Gravel %	Remarks
3.00	□	23.00	71.00	6.00	0.00	
9.00	Δ	17.00	67.00	16.00	0.00	
15.00	*	14.00	59.00	27.00	0.00	



GRAIN SIZE ANALYSIS CURVE OF BOREHOLE NO-02						
Depth (M)	Index	Clay %	Silt %	Sand %	Gravel %	Remarks
1.50	□	21.00	69.00	10.00	0.00	
9.00	Δ	15.00	63.00	22.00	0.00	
16.50	*	16.00	65.00	19.00	0.00	



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