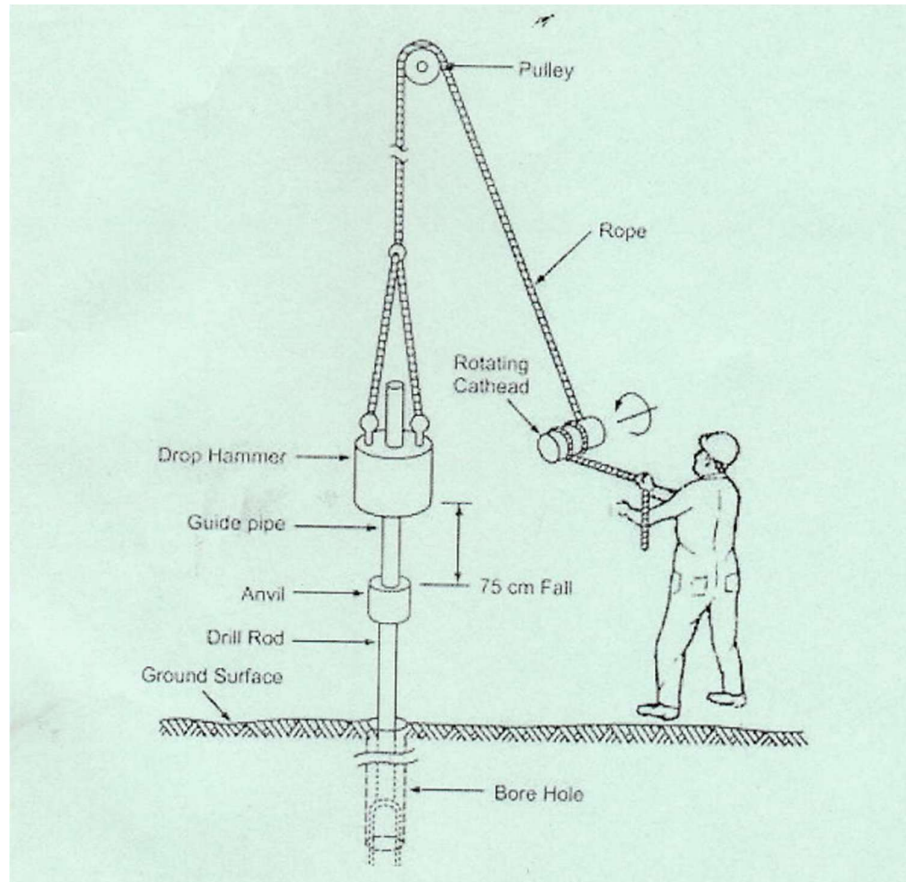


GEO TECHNICAL INVESTIGATION REPORT



NAME OF THE WORK: CONSTRUCTION OF BHARAT RATNA DR. BHUPEN
HAZARIKA MUSEUM

AT

SRIMANTA SANKARDEVA KALASHETRA SOCEITYPANJABARI, GUWAHATI-

PREPARED BY :

NORTH EAST ENGINEERS

G.M.C. Market Complex, Chandmari, Guwahati-3, Room No.50

Phone: 0361-2970624, Email: ckbnee@gmail.com

CONTENTS

1. Introduction
2. Objective
3. Field investigation information
4. Boring Process
5. Seismic activity
6. Laboratory Investigation
7. Standard Penetration Test
8. Observed & Corrected N-Value
9. Grain Size distribution Summary
10. Soil Stratum with classification summary
11. Index properties of soil with depth summary
12. Shear strength parameters
13. Calculation of Allowable bearing Capacity of shallow footing
14. Safe load on RCC bored pile
15. Results
16. Conclusion
17. Borehole log
18. Grain Size distribution graph

The report herein deals with field and laboratory investigations carried out to assess the nature of sub-soil strata and to evaluate soil parameters required for design of foundations for the proposed structure. Two (02) numbers of boreholes were drilled at the site of investigation from existing ground level for BH-1, BH-2

2. OBJECTIVE:

The objective of the report is to find the load carrying capacity of shallow and pile foundation required for the proposed structure so that the structural designer may suitably select a foundation. This report describe the finding of sub-soil investigation, laboratory tests conducted on collected soil sample and the data required for design of foundation in tabular form.

3. FIELD INVESTIGATION INFORMATION:

- a) Preparation of borehole chart mentioning the depositional features along with other characteristics of the sub-soil strata.
- b) Carrying out standard penetration test (S.P.T) at an interval of 1.5 m in each borehole and recording in the borehole chart for determining the relative densities and bearing capacity of the various strata.
- c) Recording of the sub-soil water level during the time of exploration work in the borehole chart.
- d) Collection of disturbed and undisturbed soil samples at the time of sub-soil exploration at regular interval as per IS 2132 specification.

4. BORING PROCESS:

Boring was done by wash boring technique conforming to IS 1892-1962. All the boreholes were drilled manually upto the depth of 22.5 m from existing ground level for BH-1, BH-2 respectively having a borehole diameter 100 mm.

Time of field work:-Sub-soil exploration work was carried out at the site of investigation on 21/08/2021

4.1 SAMPLING:

Representative soil samples collected from boreholes were confirming to IS 2132 in categories of Disturbed Sample & undisturbed sample.

4.1.A) DISTURBED SOIL SAMPLE:

Disturbed soil samples were reasonably collected from cutting shoe of undisturbed soil samples and recovered were logged, labelled depth wise and placed in polythene bags for conducting necessary laboratory tests.

4.1.B) UNDISTURBED 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.

4.2 FIELD INVESTIGATION:

The site is basically plain in terrain and located in most seismically active region of the country. 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 in between 2 to 48 which are also graphically represented in borehole log enclosed with this report.

5. SEISMIC ACTIVITY:

The proposed construction site is located in an earthquake zone and falls in seismic zone V with seismic co-efficient of 0.36 as per IS: 1893-2002.

6. LABORATORY INVESTIGATIONS:

The following laboratory test are conducted to assess the various soil parameters :

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

6.1.A) 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.

6.1.B) 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.

6.2 ATTERBERG'S LIMIT TEST AS PER IS: 2720, part-V

Liquid limit and plastic limits are determined since it has a great role in soil classification and finding settlement parameters. Liquid limits determined with the help of Standard cone penetrometer. Plastic limit is the water content at which the soil begins to crumble when rolled out into a thin thread of 3 mm.

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

It is the ratio of the weight of water to the dry weight of soil determined by oven drying.

6.4 DRY DENSITY AND BULK DENSITY AS PER IS: 2720, part-IX :

These were determined by measuring the weights and dimensions of tri-axial shear and unconfined compressive strength test samples before testing and after oven drying. The bulk density & dry density values of the samples have been given in the enclosed laboratory sheet.

6.5 SPECIFIC GRAVITY AS PER IS: 2720, part-II :

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.

6.6 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.

6.7 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.

6.8 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.

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

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

7. STANDARD PENETRATION TEST :

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

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

7.1 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 of 100 kN/m² and the normalized value of N (corrected for overburden as pressure) be expressed as follows :

$$N_0 = C_n \cdot N$$

Where, N_0 = Corrected value for overburden effect,

N = Observed N-Value

C_n = Normalizing factor = $0.77 \times \log_{10} (2000/\sigma')$

Where, σ' = Effective overburden pressure (kN/m²)

7.2 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 N_e in place of actually observed N, when N is greater than 15. N_e is given by the following relation.

$$N_e = 15 + 0.5 (N - 15) \dots\dots\dots(i)$$

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

TABLE NO 1 : GROUND WATER TABLE

BH No	DEPTH BELOW G.L. (m)
1	2.00
2	2.00

8. OBSERVED AND CORRECTED N VALUE :

Observed and Corrected N value details are shown in the table given below -

TABLE NO 2 : OBSERVED AND CORRECTED N VALUE

BH No	DEPTH (m)	OBSERVED N VALUE	CORRECTED N VALUE
1	1.50	2	3
	3.00	7	9
	4.50	11	13
	6.00	12	13
	7.50	14	14
	9.00	16	15
	10.50	18	16
	12.00	19	16
	13.50	22	17
	15.00	27	19
	16.50	29	19
	18.00	36	21
	19.50	37	21
	21.00	42	23
	22.50	48	24
2	1.50	3	4
	3.00	6	7
	4.50	9	10
	6.00	11	12
	7.50	13	13
	9.00	17	16
	10.50	19	16
	12.00	21	17
	13.50	23	17
	15.00	26	18
	16.50	28	19
	18.00	31	19
	19.50	34	20
	21.00	37	21
	22.50	41	22

9. GRAIN SIZE DISTRIBUTION SUMMARY

Grain Size Distribution Summary are shown in the table given below -

TABLE 3 : GRAIN SIZE DISTRIBUTION SUMMARY

BH No	DEPTH (m) Below EGSL	CLAY (%) < 0.002 mm	SILT (%) 0.002 - 0.075 mm	SAND (%) 0.075 - 4.75 mm	GRAVEL (%) > 4.75 mm
1	1.50	33.00	42.00	25.00	0.00
	3.00	42.00	32.00	26.00	0.00
	4.50	15.00	30.00	55.00	0.00
	6.00	14.00	29.60	56.40	0.00
	7.50	13.20	29.40	57.40	0.00
	9.00	10.00	29.00	61.00	0.00
	10.50	9.40	28.40	52.20	10.00
	12.00	9.00	28.00	63.00	0.00
	13.50	8.00	27.60	64.40	0.00
	15.00	8.00	27.40	64.60	0.00
	16.50	5.00	26.00	69.00	0.00
	18.00	0.00	26.00	74.00	0.00
	19.50	0.00	25.40	74.60	0.00
	21.00	0.00	24.90	75.10	0.00
	22.50	0.00	23.00	77.00	0.00
2	1.50	36.00	42.00	22.00	0.00
	3.00	55.00	35.00	10.00	0.00
	4.50	54.00	34.90	11.10	0.00
	6.00	50.00	33.00	17.00	0.00
	7.50	10.00	33.00	57.00	0.00
	9.00	10.00	32.40	57.60	0.00
	10.50	9.60	31.00	59.40	0.00
	12.00	9.10	31.00	59.90	0.00
	13.50	9.00	30.80	60.20	0.00
	15.00	8.40	30.50	61.10	0.00
	16.50	8.10	30.10	61.80	0.00
	18.00	8.00	29.00	63.00	0.00
	19.50	6.90	29.00	64.10	0.00
	21.00	6.40	28.40	65.20	0.00
	22.50	5.00	28.00	67.00	0.00
	24.00	0.00	28.00	72.00	0.00

10. SOIL STRATA WITH CLASSIFICATION SUMMARY

Soil Strata with Classification Summary is shown in the table given below -

Table No 4 : SOIL STRATA WITH CLASSIFICATION SUMMARY

BH NO	DESCRIPTION OF LAYERS	DEPTH OF SAMPLE (m)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)	GROUP SYMBOL
1	Filledup Soil (GL - 2.0 m)	1.50	35.97	28.86	7.11	MI
	Silt mixed with Clay (2.0 m - 4.0 m)	3.00	39.77	24.19	15.58	CI
		4.50	35.78	NP	-	SM
	Silt mixed with Sand (4.0 m - 22.5 m)	6.00	35.74	NP	-	SM
		7.50	35.72	NP	-	SM
		9.00	35.69	NP	-	SM
		10.50	35.65	NP	-	SM
		12.00	35.63	NP	-	SM
		13.50	35.59	NP	-	SP
		15.00	35.56	NP	-	SP
		16.50	35.54	NP	-	SP
		18.00	35.50	NP	-	SP
		19.50	35.48	NP	-	SP
		21.00	35.44	NP	-	SP
		22.50	35.41	NP	-	SP
2	Filledup Soil (GL - 2.0 m)	1.50	35.93	28.86	7.07	MI
	Silt mixed with Clay (2.0 m - 7.0 m)	3.00	39.77	24.10	15.67	CI
		4.50	39.74	24.07	15.67	CI
		6.00	39.72	24.06	15.66	CI
		7.50	35.76	NP	-	SM
	Silt mixed with Sand (7.0 m - 22.5 m)	9.00	35.72	NP	-	SM
		10.50	35.68	NP	-	SM
		12.00	35.66	NP	-	SM
		13.50	35.62	NP	-	SP
		15.00	35.59	NP	-	SP
		16.50	35.57	NP	-	SP
		18.00	35.53	NP	-	SP
		19.50	35.50	NP	-	SP
		21.00	35.46	NP	-	SP
		22.50	35.42	NP	-	SP
		24.00	35.38	NP	-	SP

II. INDEX PROPERTIES OF SOIL WITH DEPTH SUMMARY .

Index Properties of Soil Summary is shown in the table given below -

Table No 5 : INDEX PROPERTIES OF SOIL SUMMARY

BE NO	DESCRIPTION OF LAYERS	DEPTH OF SAMPLE (m)	WATER CONTENT (%)	BULK DENSITY (kN/m^3)	DRY DENSITY (kN/m^3)	SPECIFIC GRAVITY	VOID RATIO
11	Filledup Soil (GL - 2.0 m)	1.50	26.89	19.05	15.01	2.67	0.72
	Silt mixed with Clay (2.0 m - 4.0 m)	3.00	32.89	19.01	14.31	2.70	0.89
		4.50	24.52	18.93	15.20	2.66	0.65
	Silt mixed with Sand (4.0 m - 22.5 m)	6.00	24.45	18.93	15.21	2.66	0.65
		7.50	24.35	18.93	15.22	2.66	0.65
		9.00	24.28	18.93	15.23	2.66	0.65
		10.50	24.22	18.93	15.24	2.66	0.64
		12.00	24.16	18.93	15.25	2.66	0.64
		13.50	24.09	18.93	15.26	2.66	0.64
		15.00	24.01	18.93	15.26	2.66	0.64
		16.50	23.93	18.93	15.27	2.66	0.64
		18.00	23.83	18.93	15.29	2.66	0.63
		19.50	23.74	18.93	15.30	2.66	0.63
		21.00	23.62	18.93	15.31	2.66	0.63
		22.50	23.50	18.93	15.33	2.66	0.63
12	Filledup Soil (GL - 2.0 m)	1.50	26.84	18.80	14.82	2.68	0.72
	Silt mixed with Clay (2.0 m - 7.0 m)	3.00	32.81	19.54	14.71	2.70	0.89
		4.50	32.73	19.54	14.72	2.70	0.88
		6.00	32.67	19.54	14.73	2.70	0.88
		7.50	24.85	18.95	15.18	2.65	0.66
	Silt mixed with Sand (7.0 m - 22.5 m)	9.00	24.75	18.95	15.19	2.65	0.66
		10.50	24.69	18.95	15.20	2.65	0.65
		12.00	24.63	18.95	15.21	2.65	0.65
		13.50	24.54	18.95	15.22	2.65	0.65
		15.00	24.46	18.95	15.23	2.65	0.65
		16.50	24.40	18.95	15.23	2.65	0.65
		18.00	24.32	18.95	15.24	2.65	0.64
		19.50	24.25	18.95	15.25	2.65	0.64
		21.00	24.14	18.95	15.27	2.65	0.64
		22.50	24.04	18.95	15.28	2.65	0.64
		24.00	23.93	18.95	15.29	2.65	0.63

12. SHEAR STRENGTH PARAMETERS :

For the purpose of design based on weakest subsoil profile

TABLE 6 : SHEAR STRENGTH PARAMETERS

DEPTH (m)	GROUP SYMBOL	C_u (kN/m ²)	ϕ (Degree)	REMARKS
1.50	MI	19.00	0.00	Total stress analysis
3.00	CI	25.20	0.00	Total stress analysis
4.50	CI	29.00	0.00	Total stress analysis
6.00	CI	32.00	0.00	Total stress analysis
7.50	SM	0.00	31.00	Effective stress analysis
9.00	SM	0.00	32.20	Effective stress analysis
10.50	SM	0.00	33.40	Effective stress analysis
12.00	SM	0.00	34.90	Effective stress analysis
13.50	SP	0.00	35.60	Effective stress analysis
15.00	SP	0.00	36.00	Effective stress analysis

13. CALCULATION OF ALLOWABLE BEARING CAPACITY OF SHALLOW FOOTING :

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 $C-\phi$ values has been calculated from two criteria

a) SHEAR CRITERIA: As per IS 6403: 1981, the safe bearing capacity from $C-\phi$ values has been calculated by applying the following formula for circular well is as follows :

For General shear failure,

$$q_a = \frac{1}{F} [c N_c s_c d_c i_c + \gamma D (N_q - 1) s_q d_q i_q + 0.5 \gamma B N_\gamma s_\gamma d_\gamma i_\gamma + w'] + \gamma D$$

For Local shear failure,

$$Q_s = \frac{1}{F} [\frac{2}{3} c N_c s_c d_c i_c + \gamma D (N_q - 1) s_q d_q i_q + 0.5 \gamma B N_\gamma s_\gamma d_\gamma i_\gamma + w'] + \gamma D$$

Where,

F = factor of safety

C = Cohesion

γ = Submerged density

D = Depth of footing

B = Width of footing

L = Length of the footing

w' = Water table correction

N_c, N_q, N_γ & N_c', N_q', N_γ' are the bearing capacity factors depending upon the ϕ & ϕ' values respectively

s_c ; s_q ; s_γ are the shape factors :

Shape of the footing	s_c	s_q	s_γ
Square	1.3	1.2	0.8
Circular	1.3	1.2	0.6
Rectangular	$1 + 0.2 (B/L)$	$1 + 0.2 (B/L)$	$1 + 0.4 (B/L)$

d_c ; d_q ; d_γ are the depth factors :

$$d_c = 1 + 0.2 \frac{D}{B} \tan(45^\circ + \frac{\phi}{2})$$

$$d_q = d_\gamma = 1 \text{ when } \phi < 10^\circ$$

$$d_q = d_\gamma = 1 + 0.1 \frac{D}{B} \tan(45^\circ + \frac{\phi}{2}) \text{ when } \phi > 10^\circ$$

i_c ; i_q ; i_γ are the inclination factors for inclined loads

SETTLEMENT CRITERIA: The settlement of footing below structures consists of mainly two parts namely- immediate settlement which is predominant in Coarse grain soil and Consolidation settlement which occurs mainly in fine grained soil. The settlement of shallow footings on Coarse grained and fine grained soil is determined using the procedure given in IS 8009-Part I-2009.

The allowable bearing capacity is the smaller of Safe bearing capacity obtained from shear criteria and Safe bearing pressure as obtained from settlement analysis.

The following expression is used to compute the consolidation settlement of fine grained soil

$$S = \frac{C_c H}{1 + e_0} \log_{10} \frac{p_0 + dp}{p_0}$$

Here,

C_c = Compression Index

H = Height of Consolidating layer

e_0 = In-situ void ratio

p_0 = Effective overburden pressure at middle of consolidating layer

dp = Increase in vertical stress due to applied loading at center of layer

The settlement obtained from above expression is corrected for rigidity and 3 Dimensional consolidation effect as per IS 8009- Part I: 2009. The settlement in coarse grained soil is obtained from corrected N-value using Standard Chart of IS 8009-Part I:2009. The permissible settlement for fine grained and coarse grained soil is adopted 75 mm and 50 mm as per Codal provision.

The Allowable bearing Capacity values of square and rectangular isolated footings with different sizes and depths are worked out and shown in tabular form.

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 (Q_u) of bored cast insitu RCC pile foundation of different pile dimension were evaluated using as per IS code: 2911(part 1/Sec 2): 2010 Safe Load carrying capacity of bored cast in-situ RCC pile of different pile dimension are evaluated using as per IS code: 2911(part 1/Sec 2): 2010.

The following expression is used to determine the capacity of single pile in Compression :

$$Q_u = A_p N_c C_p + \sum_{i=1}^n K_i \rho_{Di} \tan \delta_i A_{si} + \sum_{i=1}^n \alpha_i C_i A_{si}$$

Here,

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

N_c = Bearing capacity factor = 9

N_q = Bearing Capacity factor

N_γ = Bearing capacity factor depending upon internal friction angle

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

K_i = Coefficient of earth pressure in i th layer

ρ_{Di} = Effective overburden pressure for i th layer

ρ_D = Effective overburden pressure at the pile tip

δ_i = Angle of wall friction between pile and soil for i th layer

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

α_i = Adhesion factor for the i th layer depending on the consistency of soil

D = Diameter of the pile shaft

For Accurate Analysis the full length of pile which is responsible for developing skin friction is divided into several segments based on type and nature of soil stratum encountered. For fine grained strata total stress analysis and for coarse grained strata effective stress analysis is used. A factor of safety 2.5 is used to obtain safe load carrying capacity over ultimate load carrying capacity of piles.

ALLOWABLE BEARING CAPACITY OF SOIL FROM SHEAR PARAMETER OF SOIL:**SAMPLE CALCULATION****Basic Data :**

Type of Foundation	Isolated Footing
Length of footing L (m)	1.5
Width of footing B (m)	1.5
Depth of footing D (m)	2.0
Cohesion C or C_u (KN/m ²)	17
Angle of internal friction ϕ	0
bulk unit weight above water table (KN/m ³)	19
saturated unit wt. below water table (KN/m ³)	20
Factor of safety (FOS)	2.5

Different Factors of SBC :

The mode of failure is	Local Shear Failure
Bearing Capacity factor N_c or N'_c	5.14
Bearing Capacity factor N_q or N'_q	1
Bearing Capacity factor N_γ or N'_γ	0
Effective overburden pressure at depth of footing (KN/m ²)	20.38
Shape factor S_c	1.3
Shape factor S_q	1.2
Shape factor S_γ	0.8
Depth factor D_c	1.27
Depth factor D_q and D_γ	1.00
Water Table correction factor W'	0.50

Therefore,

$$Q_u = \frac{1}{F} \left[\frac{2}{3} c N'_c s_c d_c i_c + \gamma D (N'_q - 1) s_q d_q i_q + 0.5 \gamma B N'_\gamma s_\gamma d_\gamma i_\gamma + w' \right] + \gamma D$$

$$= 77.93 \text{ kN/m}^2$$

SAFE BEARING PRESSURE OF SOIL FROM SETTLEMENT CALCULATION AS PER IS 8009 (PART I)**Basic Data :**

Length of footing, L (m)	1.5
Width of footing, B (m)	1.5
Depth of footing, D (m)	2.0

Soil Parameters :

Specific Gravity of soil, G	2.67
Average value of Natural moisture content of soil (%)	28.6
Average value of liquid limit, LL (%)	37.6
Compression Index of the soil, Cc	0.167
In-Situ void ratio of the soil	0.764

Calculations:

Net SBC to be imposed at base of footing (kN/m ²)	57.55
The Thickness of Consolidating Layer (m)	3
Effective overburden pressure at the middle of layer (kN/m ²)	30.57
Increase in stress due to Load at middle of consolidating layer (kN/m ²)	14.388
Correction factor for rigidity of footing	0.8
Corrected settlement of the layer (mm)	33
The settlement of the footing is within permissible limit of 75 mm. Hence safe	

Therefore,

$$S = \frac{C_c H}{1 + e_0} \log_{10} \frac{p_0 + dp}{p_0}$$

$$= 162.38 \text{ K/m}^2$$

Shear Criteria Governs the design of the footing

ALLOWABLE BEARING CAPACITY FROM SHEAR CRITERIA AND SETTLEMENT CRITERIA

Depth (m)	Footing size (m)	S.B.C. (Shear criteria) (kN/m ²)	S.B.P. (Settlement criteria) (kN/m ²)	Allowable Bearing Capacity (kN/m ²)
2.0	1.5 × 1.5	77.93	162.38	77.93
	1.8 × 1.8	75.91	136.87	75.91
	2.0 × 2.0	74.91	125.24	74.91
2.5	1.5 × 1.5	93.19	185.55	93.19
	1.8 × 1.8	90.37	154.90	90.37
	2.0 × 2.0	88.96	140.91	88.96
3.0	1.5 × 1.5	101.67	208.76	101.67
	1.8 × 1.8	98.28	172.89	98.28
	2.0 × 2.0	96.59	156.54	96.59
3.5	1.5 × 1.5	117.99	231.94	117.99
	1.8 × 1.8	113.63	190.92	113.63
	2.0 × 2.0	111.44	172.21	111.44

SAMPLE CALCULATION OF BORED CAST IN-SITU RCC PILE

Basic Data

Length of pile from EGL, m	19
Length of pile embedded, m	18
Cutoff length, m	1
Diameter of pile, mm	400

Parameter for pile friction calculation as follows

Pile depth from cut off (m)	Layer Thickness m	C_u KN/m ²	ϕ	Effective unit wt. (KN/m ³)	P_{Di} KN/m ²	A_{si} m ²	Co-efficient of earth pressure (K _i)	Adhesion
1.00-7.00	6	29		9.19		7.5		0.7
7.00-19.00	12		33.00	9.19	86.28	15.1	1	

Parameter for the pile end bearing calculation as follows:

Cross sectional of pile toe	125600
Value of ϕ	35
Cohesion at tip, KN/m ²	

As per IS 2911 (part-I, sec-2) Skin friction and end bearing has furnished in

Pile depth from cut off (m)	Skin Friction KN	End bearing KN
1.00-7.00	527.86	
7.00-19.00	641.70	365.35

From the above data

$$\text{Ultimate load capacity of piles, } Q_u = A_p N_c C_p + \sum_{i=1}^n K_i \rho_{Di} \tan \delta_i A_{si} + \sum_{i=1}^n \alpha_i C_i A_{si}$$

Ultimate load capacity of piles= 1534.91 KN

Safe load capacity of piles= 613.96 KN

TABLE 8: LOAD CARRYING CAPACITY OF PILES AT DIFFERENT DIAMETER

Diameter (mm)	Pile Length from cutoff level 1.00 m	safe load carrying capacity (KN)
400	18.00	613.96
	20.00	728.10
450	18.00	701.20
	20.00	799.10
500	18.00	784.20
	20.00	890.10

Conclusion:

From the careful study it is concluded that sub-soil horizon is investigated area may be suitable for design and construction. The bearing capacity estimation and settlement calculation of the foundation soil is carried out using standard penetration resistance values and undisturbed soil samples collected from the site. The safe bearing capacity and safe bearing pressure based on shear and settlement behavior of the soil along with the Allowable bearing pressure values are shown in tabular form. It has been seen that the allowable bearing pressure values ranges between 74.91 KN/m² to 117.99 KN/m² at depths 2.00 m, 2.50 m, 3.00 m and 3.50 m. Further for the higher load on foundation bearing pile shall be used. Further safe load capacity of pile is calculated based on field and laboratory test result and shown in tabular form above. The safe load carrying capacity of single pile falls in the range of 613.96 KN to 7890.10 KN with 400 to 500 mm diameter pile with length 18.00 m & 20.00m below cut off level.

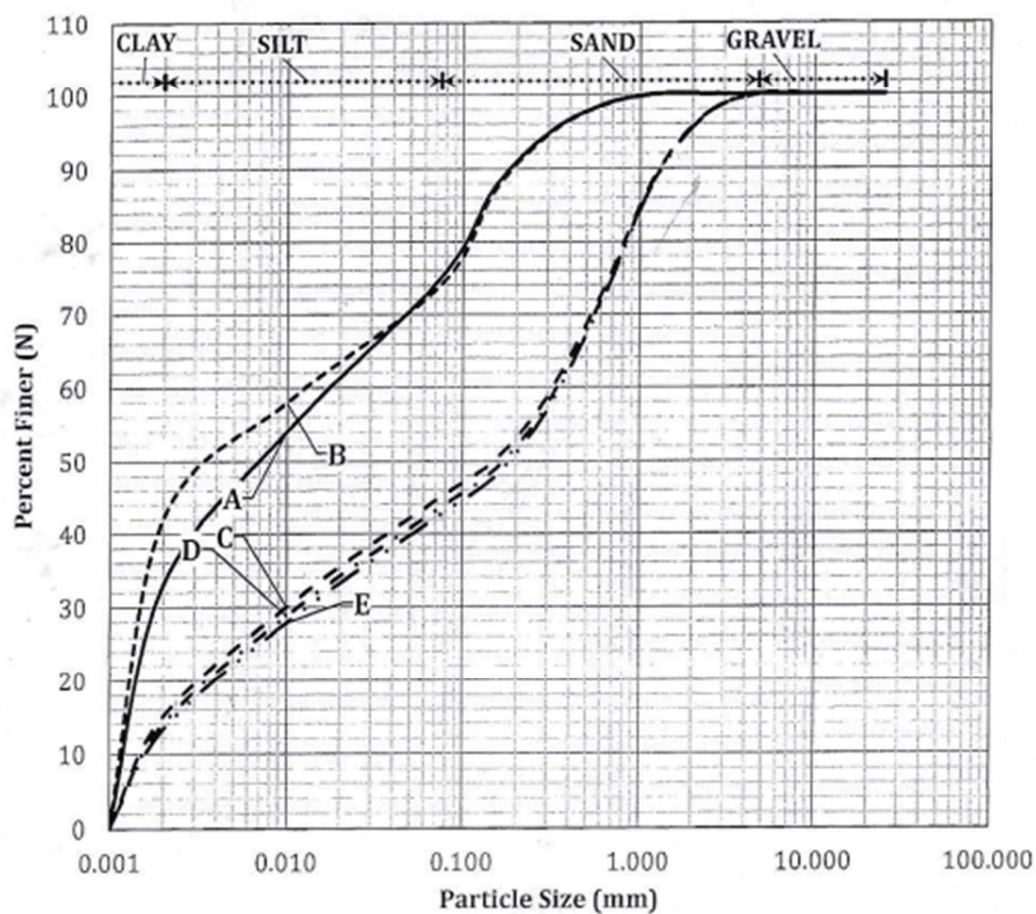
An initial load test as per IS: 1888 shall be conducted for authentication of theoretical values. Two nos. minimum random routine load test shall preferably be carried out to ascertain the actual soil-pile behavior under vertical and horizontal loadings.

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

18. GRAIN SIZE DISTRIBUTION GRAPH

TABLE 3 : GRAIN SIZE DISTRIBUTION SUMMARY

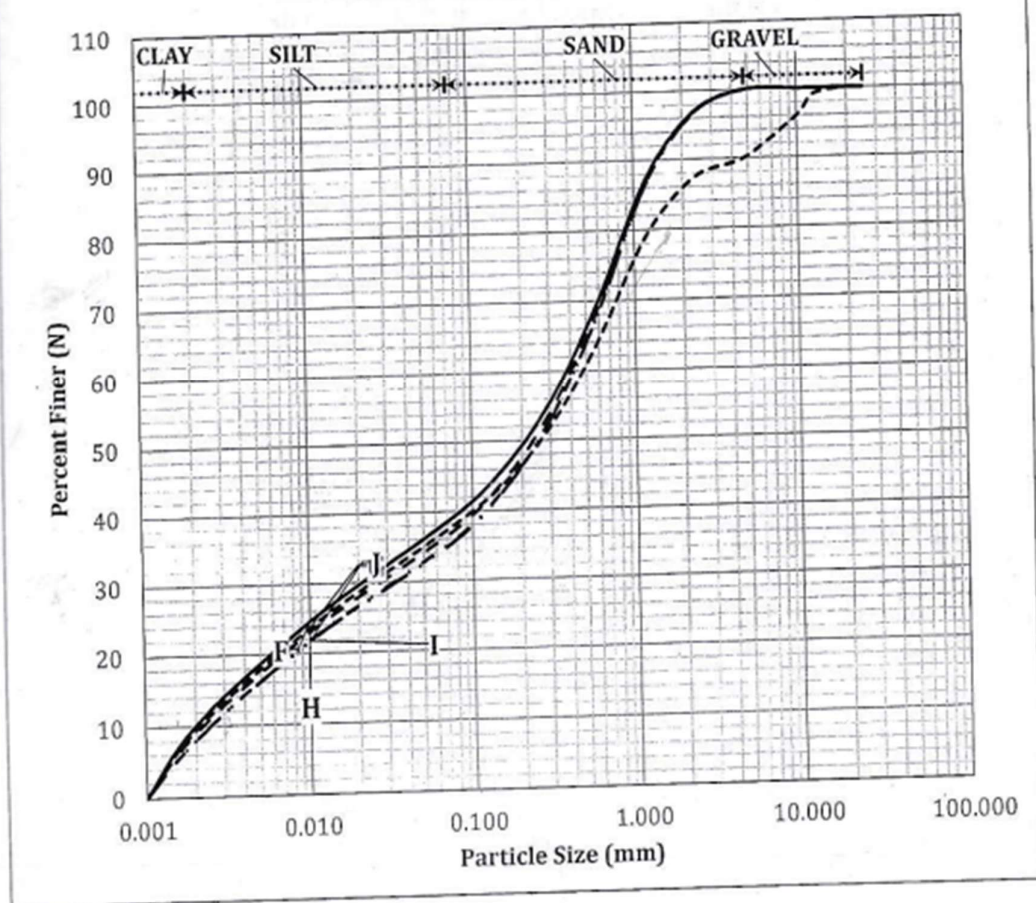
BH No	DEPTH (m) Below EGSL	INDEX	CLAY (%) < 0.002 mm	SILT (%) 0.002-0.075 mm	SAND (%) 0.075-4.75 mm	GRAVEL (%) > 4.75 mm
1	1.50	A	33.00	42.00	25.00	0.00
	3.00	B	42.00	32.00	26.00	0.00
	4.50	C	15.00	30.00	55.00	0.00
	6.00	D	14.00	29.60	56.40	0.00
	7.50	E	13.20	29.40	57.40	0.00



18. GRAIN SIZE DISTRIBUTION GRAPH

TABLE 3 : GRAIN SIZE DISTRIBUTION SUMMARY

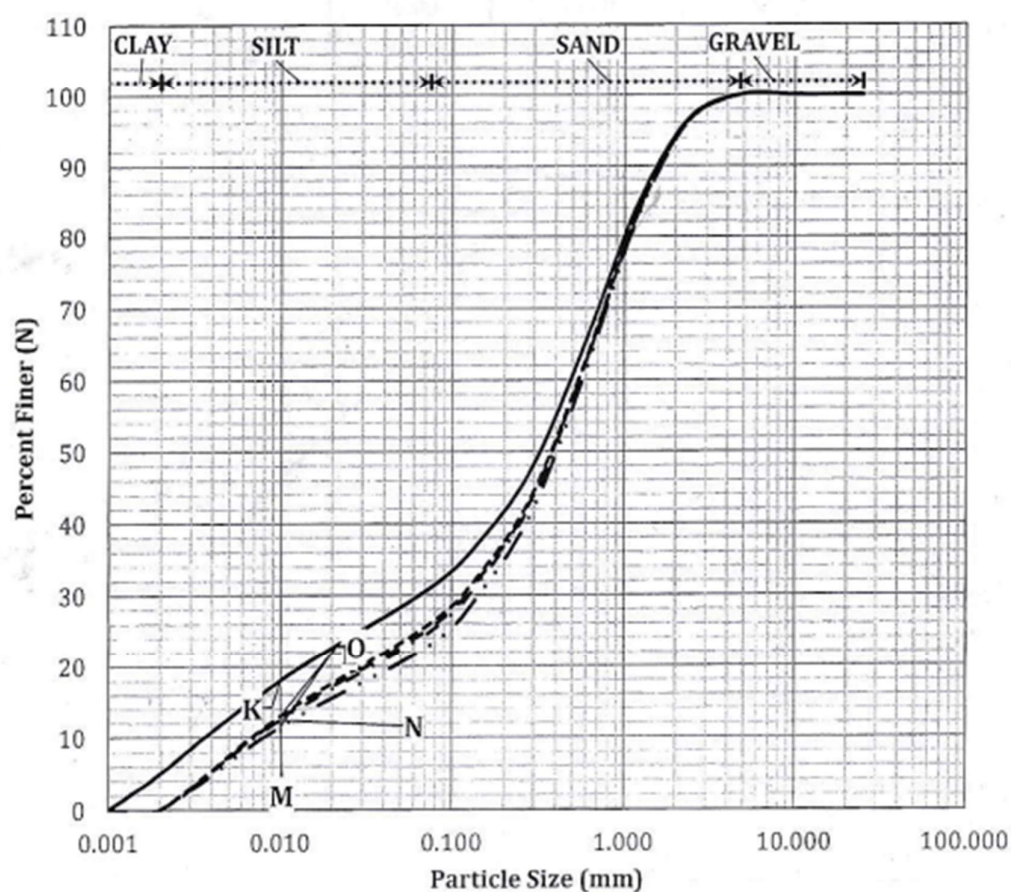
BH No	DEPTH (m) Below EGSL	INDEX	CLAY (%) < 0.002 mm	SILT (%) 0.002-0.075 mm	SAND (%) 0.075-4.75 mm	GRAVEL (%) > 4.75 mm
1	9.00	F	10.00	29.00	61.00	0.00
	10.50	G	9.40	28.40	52.20	10.00
	12.00	H	9.00	28.00	63.00	0.00
	13.50	I	8.00	27.60	64.40	0.00
	15.00	J	8.00	27.40	64.60	0.00



18. GRAIN SIZE DISTRIBUTION GRAPH

TABLE 3 : GRAIN SIZE DISTRIBUTION SUMMARY

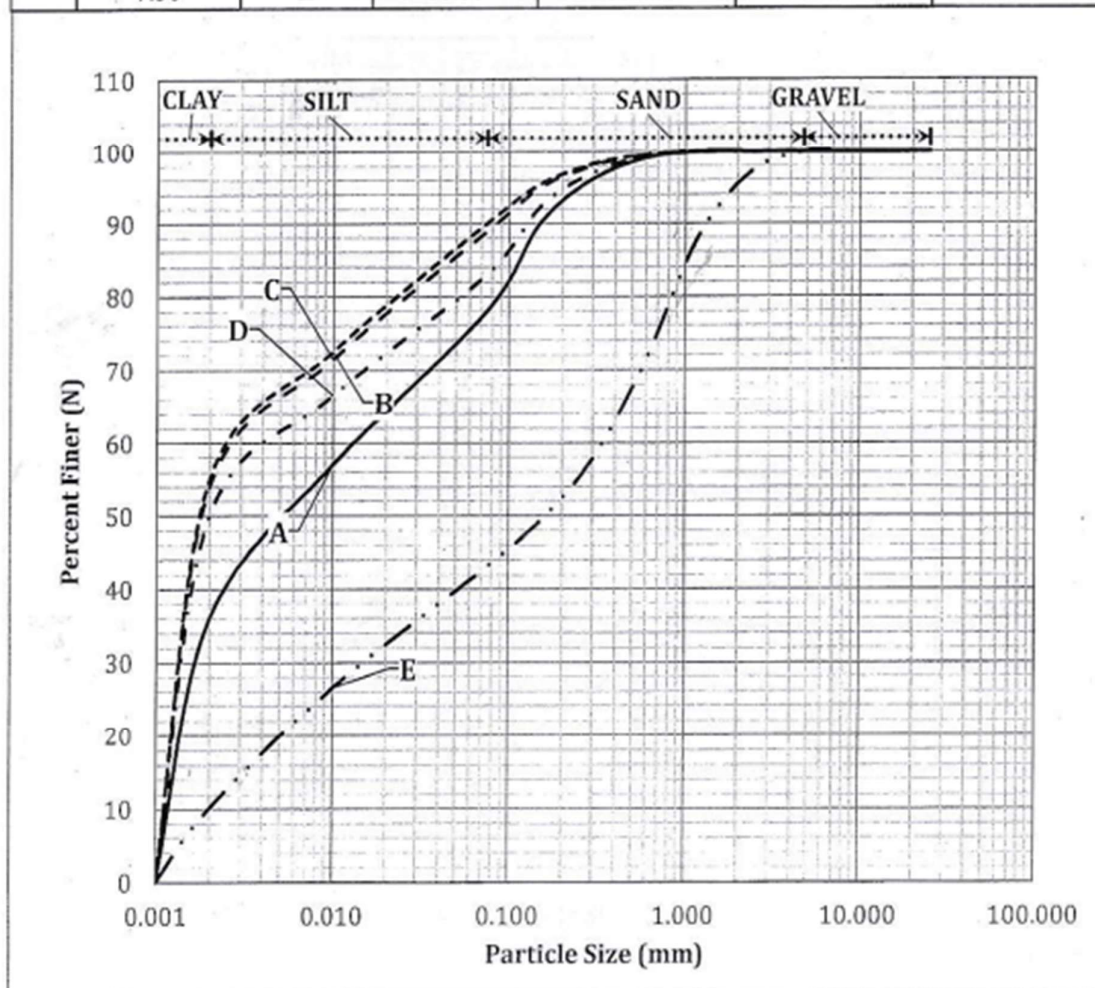
BH No	DEPTH (m) Below EGSL	INDEX	CLAY (%) < 0.002 mm	SILT (%) 0.002-0.075 mm	SAND (%) 0.075-4.75 mm	GRAVEL (%) > 4.75 mm
1	16.50	K	5.00	26.00	69.00	0.00
	18.00	L	0.00	26.00	74.00	0.00
	19.50	M	0.00	25.40	74.60	0.00
	21.00	N	0.00	24.90	75.10	0.00
	22.50	O	0.00	23.00	77.00	0.00



18. GRAIN SIZE DISTRIBUTION GRAPH

TABLE 3 : GRAIN SIZE DISTRIBUTION SUMMARY

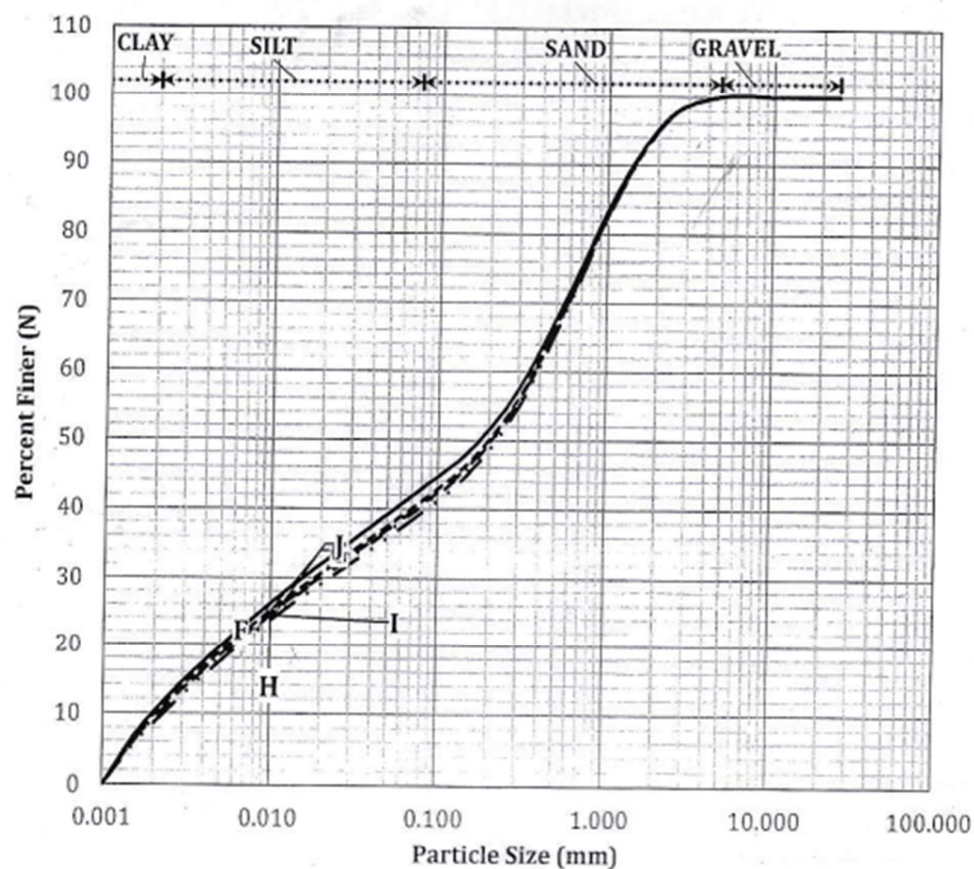
BH No	DEPTH (m) Below EGSL	INDEX	CLAY (%) < 0.002 mm	SILT (%) 0.002-0.075 mm	SAND (%) 0.075-4.75 mm	GRAVEL (%) > 4.75 mm
2	1.50	A	36.00	42.00	22.00	0.00
	3.00	B	55.00	35.00	10.00	0.00
	4.50	C	54.00	34.90	11.10	0.00
	6.00	D	50.00	33.00	17.00	0.00
	7.50	E	10.00	33.00	57.00	0.00



18. GRAIN SIZE DISTRIBUTION GRAPH

TABLE 3 : GRAIN SIZE DISTRIBUTION SUMMARY

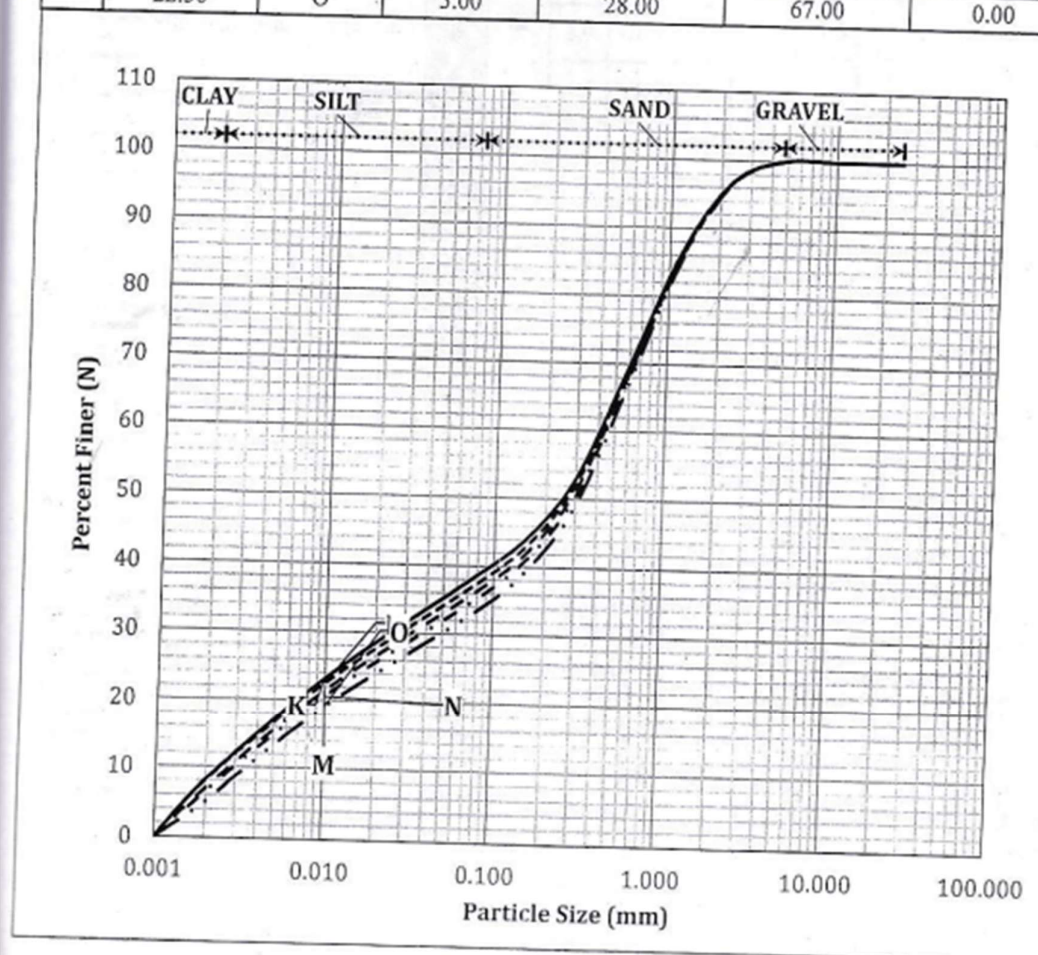
BH No	DEPTH (m) Below EGSL	INDEX	CLAY (%) < 0.002 mm	SILT (%) 0.002-0.075 mm	SAND (%) 0.075-4.75 mm	GRAVEL (%) > 4.75 mm
2	9.00	F	10.00	32.40	57.60	0.00
	10.50	G	9.60	31.00	59.40	0.00
	12.00	H	9.10	31.00	59.90	0.00
	13.50	I	9.00	30.80	60.20	0.00
	15.00	J	8.40	30.50	61.10	0.00



18. GRAIN SIZE DISTRIBUTION GRAPH

TABLE 3 : GRAIN SIZE DISTRIBUTION SUMMARY

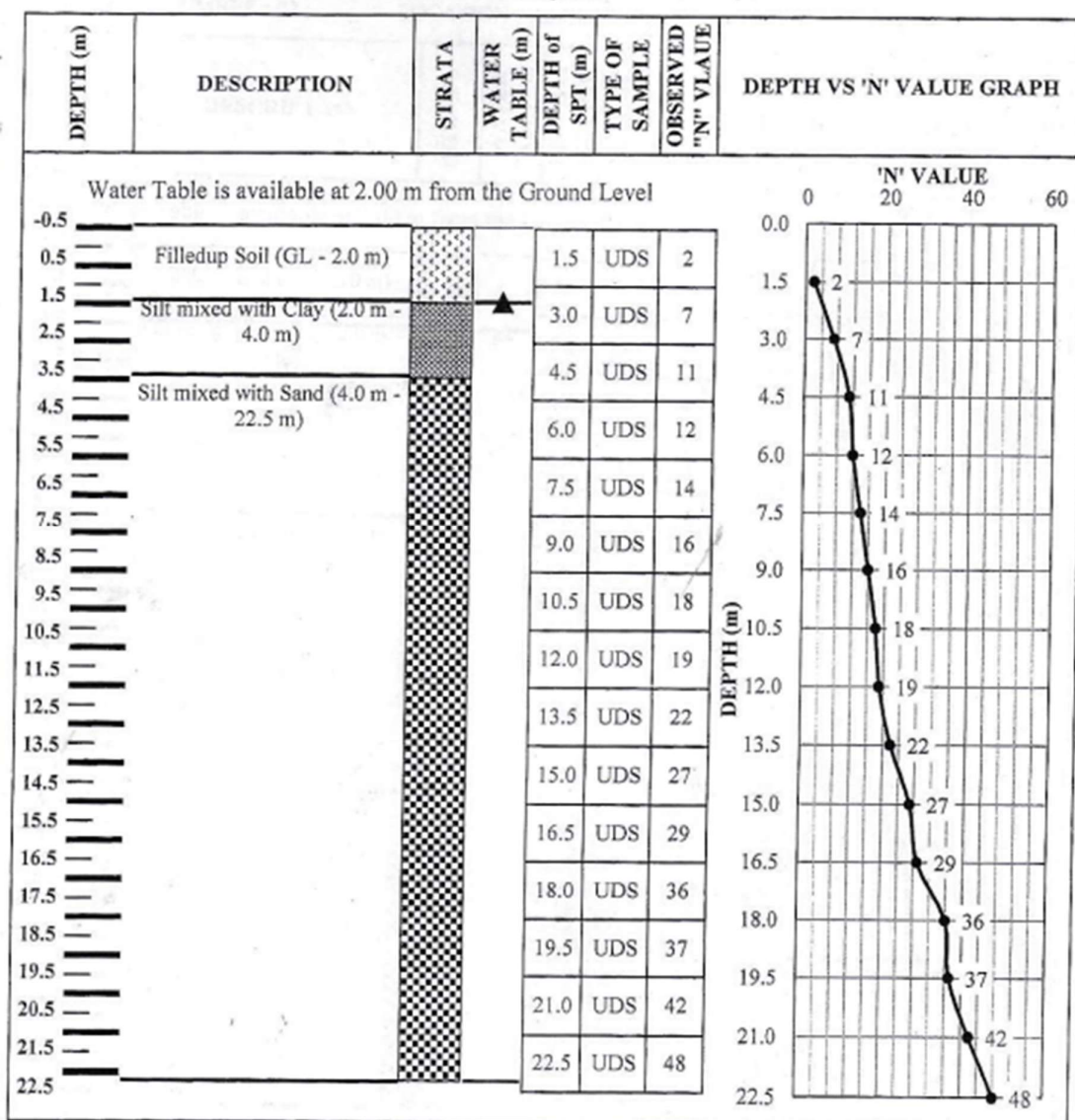
BH No	DEPTH (m) Below EGSL	INDEX	CLAY (%) < 0.002 mm	SILT (%) 0.002-0.075 mm	SAND (%) 0.075-4.75 mm	GRAVEL (%) > 4.75 mm
2	16.50	K	8.10	30.10	61.80	0.00
	18.00	L	8.00	29.00	63.00	0.00
	19.50	M	6.90	29.00	64.10	0.00
	21.00	N	6.40	28.40	65.20	0.00
	22.50	O	5.00	28.00	67.00	0.00



17. BOREHOLE LOG GRAPH

BOREHOLE NUMBER : 01 ;

LOCATION : Panjabari



17. BOREHOLE LOG GRAPH

BOREHOLE NUMBER : 02 ;

LOCATION : Panjabari

