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Chapter 35

SOIL INVESTIGATION USING STANDARD PROCTOR TEST IN TRIPURA

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Abstract. Geological investigations are of paramount importance in assessments of physical properties, index characteristics, shear strength, and settlement parameters. The work emphasizes on borehole data interpretation of Pratapgarh-Agartala which lies in the North-Eastern region of India adopting standard proctored test (SPT) for soft black soil. The experiment conducted encompasses the collection of both undisturbed and disturbed samples at regular intervals for on-site visual and physical soil identification. The excavation was carried out to a maximum depth of 22.50 meters below the current ground level. It was observed that upto 8.5 m blackish soft and silty clay with traces of organic matter and upto 20.5 m dark greyish medium sandy clayey silt was found through augur and wash boring. As soft clay is poor in nature therefore shallow foundation is not suitable, hence deep foundations were recommended. Black soil has high shrinkage and swelling potential. Therefore, the ground water-level inter phase were thoroughly investigated. Deep foundations in the form of bored cast in-situ piles were recommended and adopted based on the outcomes of the investigations conducted on soft soil. Angle of internal friction for tip was correlated with N value and bearing capacity factors Nq and Nγ were taken as 108.00 and 109.41. Minimum piled meter taken for the foundation were maintained as 0.45m. The maximum test loads for the initial pile load test were two and a half times than the safe load. While for routine pile load tests; it was taken as one and a half times than the safe load. Subsoil profiling was conducted at suitable intervals and at strata transitions, with samples obtained in both disturbed and undisturbed states using samplers compliant with relevant IS standards.

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I. INTRODUCTION

Laboratory testing plays a crucial role in geotechnical engineering research and practice. Ameticulously planned and meticulously executed laboratory testing program yields essential soil properties required for effective geotechnical analysis and decision-making. The current project scope involves the sinking of one borehole, which is 150 mm in diameter, to facilitate in-situ investigations through thestandard penetration test (SPT)(1). The borehole advancement was carried out using shell and auger equipment. To maintain brevity, this work omits specific details regarding the SPT but can be referenced in IS: 2131-1981 (R.A. 2002). In addition to the SPT, this scope encompasses the collection of both undisturbed and disturbed samples at regular intervals for on-site visual and physical soil identification (2). Subsoil profiling was conducted at suitable intervals or at strata transitions, with samples obtained in both disturbed and undisturbed states using samplers compliant with relevant IS standards (3). The collected samples underwent comprehensive laboratory investigations, including assessments of physical properties, index characteristics, shear strength, and settlement parameters. Based on the data from field and laboratory tests, an analysis was conducted to determine the soil's load-bearing capacity at the proposed site. This work has been meticulously carried out after a thorough examination of all data collected during field and laboratory testing. This investigation encompasses both in-situ and laboratory assessments. In-situ tests are instrumental in understanding the subsoil characteristics, while laboratory investigations provide insights into the describing the physical and engineering properties of soil, there are several characteristics that are typically considered (4). The rapid urbanization and increasing population density have spurred the demand for tall structures and vital infrastructure. Therefore, the design of foundations for such constructions necessitates a comprehensive geotechnical investigation prior to any construction activity (5).

II. STUDY AREA

The study area is located at Pratapgarh, Agartala-India between 23°48’26.3’’N latitude and 91°17’16.0’’ E longitude located in the northeastern region (NER) of India, Tripura stands out due to its geographical positioning and rich biodiversity, supported by complementary climatic conditions, particularly high rainfall conducive to abundant photo-biomass in the form of forests and associated vegetation. Despite being classified as a non-traditional black soil area, studies reveal that approximately 18.20% of Tripura's area comprises black soils. This study aims to uncover the key factors contributing to the formation of black soils in this non traditional region and particularly in Tripura state. The black soils found in Tripura are typically deep to very deep and predominantly characterized by smectitic clays. The study reveals that within the 0-30 cm soil depth, black soils in Tripura have the capacity to store 0.01Pg of soil organic carbon stock, which accounts for approximately 20% of the SOC stock of the entire state and 0.01% of the SOC stock of India. These soils are highly fertile, retaining ample nutrients and moisture, and are still in the weathering stage, exhibiting the presence of HIS and HIV in their mineral composition. Consequently, this information can

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aid in the development of appropriate land use and conservation plans to preserve the natural ecosystems in northeastern India, particularly in Tripura state.

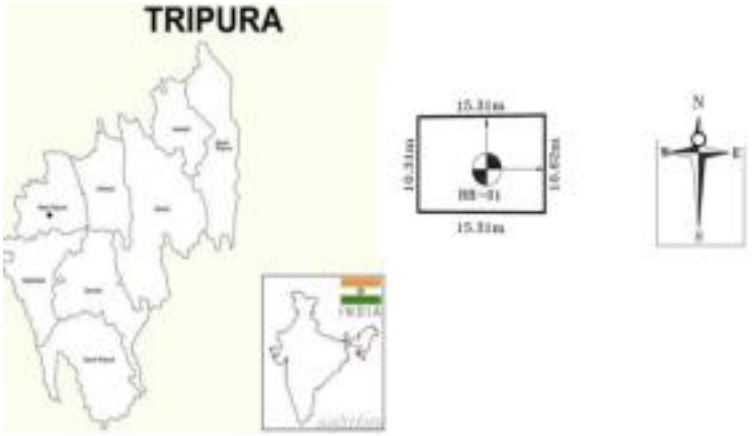

Figure 1: Location Map of study area: Tripura

III. METHODOLOGY

The drilling activities were carried out to a depth of 22.50 meters beneath the current ground level. Boring through the soil was carried out by Auger and Wash. Suitable casings have been used upto 5.0 m below the existing ground level to prevent cavity inside the borehole. The cation exchange capacity (CEC) of these soils indicates the prevalence of low-activity clays (LAC). However, their clay CEC exceeds 30 and extends up to 60, indicating a mixed mineralogy with a dominance of smectites or hydroxy interlayer smectites in the clay fraction (5). This composition allows these soils to retain more nutrients and moisture, transforming the region into the granary of the State. In addition to the significant influence of the humid climate with cooler winter months and abundant vegetation, the quality and quantity of expanding clay minerals in the soil substrate play a fundamental role in organic carbon (OC) sequestration (6, 7). The following laboratory tests were conducted on soil samples collected from boreholes: grain size analysis (sieve as well as hydrometer), liquid limit, plastic limit, shrinkage, and unconsolidated undrained test (UU) Unconfined compression test on "UDS"(unconfd.), Performing an unconfined compression test on remoldedsamples and conducting a one-dimensional consolidation test are essential procedures for evaluating settlement potentiality (8). The rapid urbanization and increasing population density have spurred the demand for tall structures and vital infrastructure. Therefore, the design of foundations for such constructions necessitates a comprehensive geotechnical investigation prior to any construction activity.

IV. SAMPLE PREPARATION AND INVESTIGATION

Soil sample obtained from split spoon sampler of standard penetrometer and cutting shoe of undisturbed sampling assembly. The collected samples were carefully placed in appropriately sized polyethylene bags, ensuring proper sealing, labeling, and recording before being transported to the laboratory for testing physical and index parameters. Nominal 100 mm diameter was adopted to recover undisturbed samples. The sampling equipment employed featured a two-tier assembly comprising a sample tube with a length of 450 mm,

fitted at its lower end. The sampling process involved driving the assembly to its full length or to the maximum depth feasible using a jarring link mechanism. Subsequently, the ends of the tubes were meticulously sealed with wax and capped to ensure sample integrity during transportation to the laboratory (8). During the process of boring, both undisturbed and disturbed soil samples were gathered using the open drive sampling method, either at appropriate intervals or at the transition of strata, whichever occurrence was encountered first S.P.T test were also conducted at suitable intervals and the number of blows encountered at 1.5minterval was recorded (9). The test was carried out by following the guidelines as specified in IS:2131-1981(R.A.2002) parameters. Collected undisturbed samples were adopted to determine shear strength and settlement. Although these soils share similarities with vertisols identified elsewhere in the country in terms of texture, periodic cracking, and subsurface coloration, they differ in terms of slickenside development, wedge-shaped structure, and surface coloration (10 - 14).

V. RESULTS

Conversely, when soft or loose soil is found near the surface, deep foundations are recommended. Settlement analysis is another crucial factor influencing the choice of foundation type and size. To ascertain the bearing capacity of the soil and estimate settlement levels, engineers can refer to the relevant BIScodes, which provide guidancevarious foundation sizes.

These tests adhere to Standards (BIS), to the standards set by the Bureau of Indian Standards ensuring reliable and effective design effective soil identification, leading to improved outcomes. Beyond field and laboratory investigations, site reconnaissance also plays a pivotal role in determining the nature of the required field investigation, whether it should be invasive. Ground water table was observed after dewatering the boreholes b. After dewatering the boreholes using an appropriate method, a waiting period of 24 hours was observed to allow for the recuperation of groundwater. Subsequently, groundwater samples were collected for chemical analysis, as per IS:3025 (Part–24 and 32), to determine parameters such as pH, sulphate, and chloride content, where applicable,

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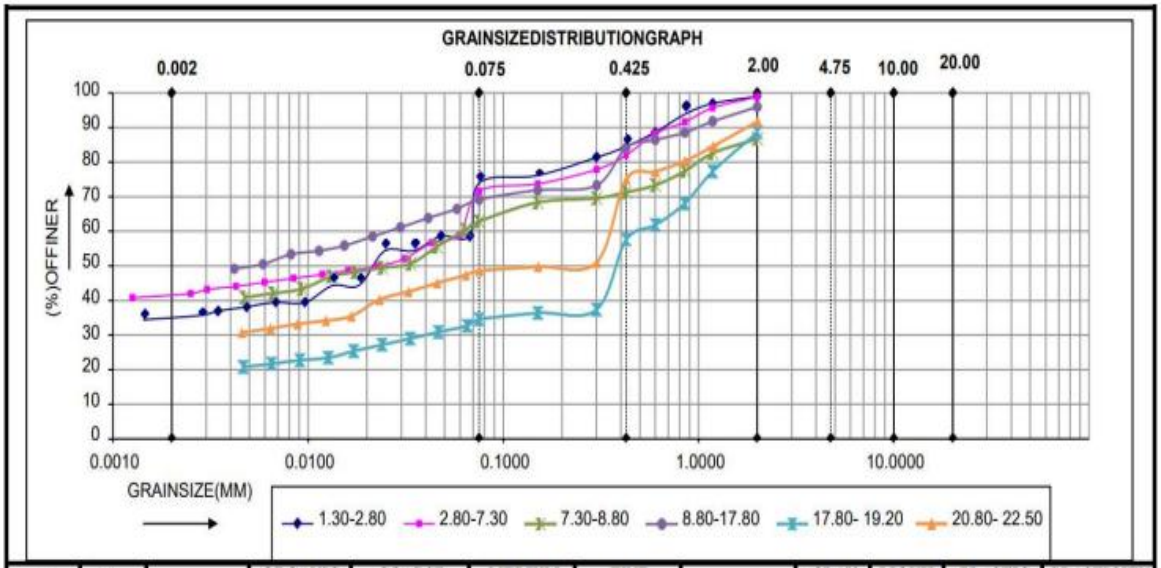
Table 1: Grain size and Sedimentation Analysis



Location	Bore Hole No.	DEPTH (m)	ORGANIC % > 4.75 (mm)	COARSE SAND% 4.75-2.00 (mm)	MEDIUM SAND% 2.00-0.425 (mm)	FINE SAND% 0.425-0.075 (mm)	SILT%0.075-0.002 (mm)	CLAY % < 0.002 (mm)	LIQUID LIMIT (W_L) %	PLASTIC LIMIT (W_P) %	PLASTICITY INDEX (I_P) %
	01	1.30-2.80	6	0	9	11	40	34	55	_	_
		2.80-7.30	0	0	18	10	31	41	43	24	19
		7.30-8.80	8	0	9	12	31	40	_	_	_
		8.80-17.80	0	0	8	8	35	49	47	26	21
		17.80-19.20	0	0	26	20	33	21	_	_	_
		19.20-20.80	0	0	18	9	42	31	39	22	17
		20.80-22.50	0	0	44	32	17	7	_	_	_

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Table 2: Experimental Result BH-01

TYPE OF SAMPLE	DEPTH(m)	OBSERVED N VALUE IS-2131	CORRECTED N VALUE IS-2131	AVERAGE N VALUE	NMC (%) IS-2720 PART-2	NATURAL DENSITY γ_b gm/cc	NATURAL DENSITY γ_d gm/cc	G IS-2720 PART-3	GRAIN SIZE ANALYSISIS-2720 PART-4 ORGANIC (%)	GRAVEL (%)	SAND (%)	SILT (%)	CLAY (%)	ATTERBERG LIMITS IS-2720PART-5 &6 W_L (%)	W_P (%)	I_P (%)	SHEAR PARAMETER IS-2720PART-11 /13 C_u T/m²	ϕ_u Deg.	CONSOLIDATION IS-2720PART-15 e_0	Cc	SOIL CLASSIFICATION IS-1498	DESCRIPTION	LAYER STRATIFICATION
DS	0.50	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	Plant vegetation	I(EGL-1.30)
DS	1.00	_	_																				
SPT	1.50	0	0	0	42.83	1.55	0.55	2.48	6	_	20	40	34	55	_	_	1.30	2	1.28	_	MH	Blackish soft sandy Clayey silt with traces of organic matter	II(1.30-2.80)
UDS	2.50	_	_																				
SPT	3.00	4	3	2	37.48	1.68	0.68	2.68	_	_	28	31	41	43	24	19	2.20	3	1.19	_	CI-MI	Greyish soft sandy silty clay	III(2.80-7.30)
SPT	4.50	0	0																				
SPT	6.00	1	1																				
SPT	7.50	2	2	2	49.11	1.47	0.47	2.42	8	_	21	31	40	_	_	_	1.80	4	1.45	_	CI-MI	Blackish soft sandy silty clay with traces of organic matter	IV(7.30-8.80)
SPT	9.00	0	0	2	32.21	1.66	0.66	2.69	_	_	16	35	49	47	26	21	2.30	6	1.14	_	CI-MI	Dark greyish medium sandy silty clay	V(8.80 - 17.80)
SPT	10.50	1	1																				
SPT	12.00	1	1																				
SPT	13.50	0	0																				
SPT	15.00	1	1																				
SPT	16.50	2	2																				
SPT	18.00	83+	50+	50+	22.81	1.94	0.94	2.67	_	_	46	33	21	_	_	_	_	31	0.69	_	SP	Yellowish medium clayey silty sand	VI(17.80-19.20)
SPT	19.50	4	3	3	26.90	1.77	0.77	2.68	_	_	27	42	31	39	22	17	2.00	4	0.92	_	MI	Dark greyish medium Sandy clayey silt	VII(19.20-20.80)
SPT	21.00	87+	50+	50+	18.12	1.99	0.99	2.64	_	_	76	17	7	_	_	_	_	34	0.57	_	SP	Wheatish dense silty sand	VIII (20.80-22.50)
SPT	22.50	100+	50+																				

γ_b:	BULK DENSITY	G:	SPECIFIC GRAVITY	W_P:	PLASTICLIMIT	W_L:	LIQUID LIMIT	ϕ_u:	ANGLE OF INTRENAL FRICTION		DS/UDS	DISTURBED/ UNDISTURBED SAMPLE
γ_d:	DRY DENSITY	C_u:	COHESION	I_P:	PLASTICITY INDEX	e_o:	INITIAL VOID RATIO	C_c:	COMPRESSION INDEX		SPT	STANDARD PENETRATION TEST

This analysis is crucial for predicting the corrosive effects of groundwater on structures.Assessing the soil's load-bearing capacity holds paramount importance, particularly when it comes to designing foundations, especially for high-rise buildings,critical infrastructure, residential complexesand commercial apartments.

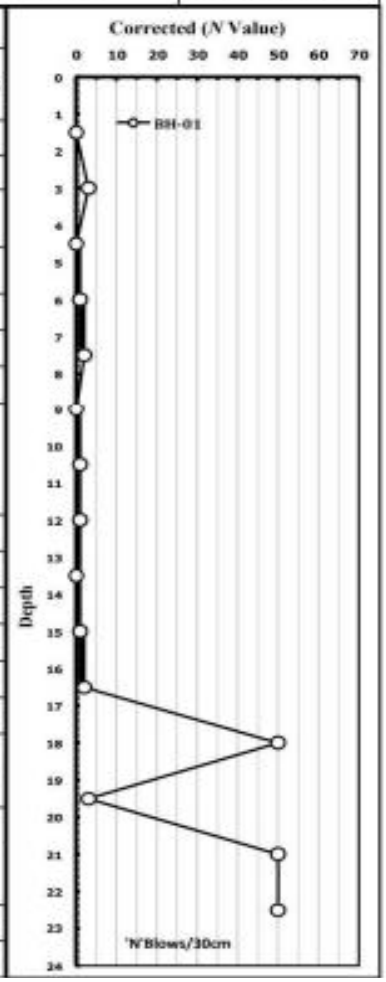
Table 4: Vertical uplift and lateral load capacity of Piles

BH	Pile length (Cutoff-1.50m)	Diameter of Pile(mm)	Vertical capacity (Ton)	Recommended vertical Capacity(Ton)	Uplift capacity(Ton)	Lateral capacity (Ton)
01	21.00	450	136.95	136.00	30.62	1.85
		500	164.19	164.00	33.56	2.05
		550	194.78	194.00	37.15	2.26

Table 3: Borelog datasheet

Location	Pratapgarh, Agartala-India 23°48'26.3"N 91°17'16.0"E			No. of SP Test (SPT)	14
Borehole No.	1	Commencement Date	07.01.2024	No. of Undisturbed Sample (UDS)	1
Ground Elevation (G.L.)	0.000	Completion Date	29.01.2024	No. of Disturbed Sample (DS)	2
Boring Method & Boring Equipment	Auger/Wash	Standing Water Level	1.20M BELOW G.L.	Termination Depth	22.50MBELOWG.L.

Description of Soil Stratum	Hatching Pattern	Sample/Event Type	Depth(m)	Standard Penetration Test IS-2131 15cm	30cm	45cm	N Value	Corrected "N"
Plant vegetation 0.00mto1.30m		DS	0.50 - 1.00	–	–	–	–	–
		DS	1.00 - 1.50	–	–	–	–	–
Blackish soft and Clayey silt with traces of organic matter 1.30mto2.80m		SPT	1.50 - 2.20	1	1	1	2	2
		UDS	2.20 - 3.00	–	–	–	–	–
Greyish soft and silty clay 2.80mto7.30m		SPT	3.00 - 4.50	0	0	0	0	0
		SPT	4.50 - 6.00	0	0	0	0	0
		SPT	6.00 - 7.50	0	0	0	0	0
Blackish soft and silty clay with traces of organic matter 7.30mto8.80m		SPT	7.50 - 9.00	0	0	0	0	0
Dark grayish medium sandy silty clay 8.80mto17.80m		SPT	9.00 - 10.50	0	3	7	10	9
		SPT	10.50 - 12.00	5	8	13	21	17
		SPT	12.00 - 13.50	12	18	24	42	25
		SPT	13.50 - 15.00	14	21	26	47	26
		SPT	15.00 - 16.50	0	1	1	2	2
		SPT	16.50 - 18.00	24	35	45	80	37
Yellowish medium clayey silty sand 17.80mto19.20m		SPT	18.00 - 19.50	50+	50+	50+	100+	50+
Dark greyish medium sandy clayey silt 19.20mto20.80m		SPT	19.50 - 21.00	50+	50+	50+	100+	50+
Wheatish dense silty sand 20.80mto22.50m		SPT	21.00 - 22.50	50+	50+	50+	100+	50+
		SPT	22.50 - 23.10	50+	50+	50+	100+	50+



Following the dewatering of boreholes using an appropriate method, a 24-hour waiting period was observed to allow for groundwater recuperation. Subsequently, groundwater samples were collected from residential complexes and commercial apartments for chemical analysis according to IS:3025 (Part–24 and 32). Parameters such as pH, sulphate, and chloride content were determined where applicable. This analysis is crucial for predicting the corrosive effects of groundwater on structures. The diameter and configuration of bored cast-in-situ piles should be determined by the designer based on the required load transfer, taking into account the cut-off level and tip level mentioned in Table 4.There commended pile capacity values are presented below:

VI. CONCLUSION

It provides and, based on provides bore logs, laboratory and field test results, and, these findings and their analysis, foundations at analysis, offers recommendations for suitable foundations the proposed construction following are construction site. Based on the above discussion, the following summarized below:

- It is observed that upto traces of organic upto 8.5 m blackish soft and silty clay with traces matter and upto 20.5 m dark greyish medium sandy clayey silt was found through augur and wash boring.
- Soft clay is poor in nature therefore shallow foundation is not suitable, hence deep foundations were recommended. Black soil has high shrinkage and swelling potential, hence, the ground water-level interphase has to be checked.
- Deep foundations on the form of bored cast insitu piles are most widely adopted in this kind of a soft/loose soil-{2911(Part1/Sec2)- 2010}soft soil is available at shallow depth which extends upto a depth of 20.80 below existing ground level(EGL),which is highly unsuitable for shallow foundation.
- Angle of internal friction for tip is correlated with N value and bearing capacity factors Nq and Nγ are taken as 108.00 and109.41[referIS:2911(Part1/Sec2)–2010andIS:6403 -1980]
- Minimum piled meter is taken0.45m as perIS:2911(Part1/Sec2). The maximum test load for the initial pile load test should be two and a half times the safe load, while for routine pile load tests; it should be one and a half times the safe load.

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