1. INTRODUCTION

The subsoil investigations reported herein were taken up (vide W.O. No. BSEIDC/Tech/1960/2018-1369 Dated – 02.03.2021 [Serial No. 12] ('Peaveshika' in W.O. has been corrected to 'Praveshika.') to find out the nature of subsoil at the site of the proposed construction and to recommend the capacity and type of its foundation. After certain tests on the soil, as detailed below, the desired recommendations have been made on **page 3-4** of this Report.

2. FIELD WORK

The fieldwork consisted of sinking bore holes, collecting soil samples and conducting the necessary field tests.

2.1. Boring

Taking guidance from IS: 1892, 150 mm diameter bore holes were sunk at locations shown in the bore hole location map.

2.2 Sampling

2.2.1 Undisturbed Soil Samples

Open drive samplers of 100-mm diameter and about 450-mm length were used for obtaining undisturbed samples of cohesive soils. The collection, sealing, labeling and transportation of the samples to the laboratory were done as per the IS guide-lines.

2.2.2 Disturbed Soil Samples

Disturbed soil samples were collected at suitable intervals of depth (not more than 2.5 m) and at all depths of change in the nature of the subsoil. These samples were sealed in polythene bags with proper identification labels.

2.3 Field Tests

2.3.1 Standard Penetration Tests (SPT)

These tests were conducted as per IS: 2131 – 1963. The depth interval between two consecutive tests was 1 to 1.5 m. The tests were located in between the levels at which undisturbed soil samples were collected.

3. LABORATORY TESTS

Some or all of the following laboratory tests, as necessary, were done on the collected soil samples. Representative soil samples were selected for this from the different soil strata encountered during boring. The tests were performed as per the relevant Indian Standard Codes of Practice.

(a) Natural moisture content

(b) Bulk density

(c) Grain size analysis (using sieves and / or hydrometer)

(d) Specific gravity of soil solids

(e) Atterberg's limit tests (liquid, plastic and shrinkage limits)

(f) Shear Tests :

- [I] Triaxial compression test (unconsolidated – undrained), generally for fine- grained soils
- [II] Unconfined compression tests, only on cohesive soils
- [III] Direct shear tests, generally for coarse-grained soils

(g) Other tests as and when required.

4. PRESENTATION OF TEST RESULTS

The field and laboratory test are given in the **Appendix B.**

5. SOIL STRATIFICATION

The results of field tests in three bore hole sunk at the site [vide Location Sketch in App. A] and the results of laboratory tests conducted on the collected soil samples indicate that the soil stratification at the site is as describe below.

The sub soil in all 3 BH's is silty clay [type CI/CL/CH] in various sequences and different depths up to the investigated depth of 10.5 m bgl.

Ground water table was struck at about 5.70 m to 5.80 m depth below GL in April, 2021. It is subject to seasonal variations.

6. FOUNDATION ANALYSIS

The safe capacity of foundation of any type and size may be determined on the basis of the soil data given in this Report by using the standard methods of foundation design and following the relevant Indian Standard Codes.

7. RECOMMENDATIONS

The design of the foundation for the proposed structure depends on the nature of both [a] the subsoil and [b] the structure.

The sub soil in all 3 BH's is silty clay [type CI/CL/CH] in various sequences and different depths up to the investigated depth of 10.5 m bgl.

Ground water table was struck at about 5.70 m to 5.80 m depth below GL in April, 2021. It is subject to seasonal variations.

Hence,

1. The proposed structure may be provided with shallow foundation at a depth of 1.5 m or more.
2. Alternatively, U/R piles of lengths 4.0 m to 8.0 m may be used with stem diameters of 0.25 m, 0.30 m and 0.40 m and bulb diameters equal to 2 times the stem diameter.

   By way of example, the values of safe capacities of

   (1) Shallow foundations and (2) Single or double bulbed u/r piles of the above mentioned sizes and depths have been calculated (vide Samples of Calculations in Appendix F) and are tabulated below.

Table 1: Allowable Net Bearing Pressures [q_{na}] and Settlements Expected [s]

Depth (m)	Width (m)	Net allowable bearing pressure (t/m²) for			Maximum expected settlement (mm)
		Strip footing	Square footing	Raft footing	
1.5	2.0	6.0	7.1	…	75
	3.0	4.9	6.8	…	75
	10.0	…	…	6.5	100
2.0	2.0	7.7	9.2	…	75
	3.0	5.6	8.7	…	75
	10.0	…	…	7.3	100
2.5	2.0	9.7	11.5	…	75
	3.0	6.5	10.8	…	75
	10.0	…	…	8.0	100
3.0	2.0	11.2	14.2	…	75
	3.0	7.4	12.9	…	75
	10.0	…	…	8.5	100
3.5	2.0	12.6	17.7	…	75
	3.0	8.2	14.3	…	75
	10.0	…	…	9.0	100
4.0	2.0	14.1	20.0*	…	75
	3.0	9.0	15.8	…	75
	10.0	…	…	9.6	100
4.5	2.0	15.5	20.0*	…	75
	3.0	9.8	17.2	…	75
	10.0	…	…	10.1	100

*****The calculated values are 20.0 (t/m²) or more, but for the sake of safety they have been limited to 20.0 (t/m²).

Table 2. Safe Capacities of U/R Piles [Factor of safety = 2.5]

[Bulb diameter = 2.0 times the shaft diameter]

Pile length below pile Cap (m)	**Safe Pile Capacity [tonnes]** *(subject to checking for slenderness ratio)*					
	Stem diameter (m)					
	0.25		**0.30**		**0.40**	
	One bulb	Two bulbs	One bulb	Two bulbs	One bulb	Two bulbs
4.0	5.3	6.2	7.3	8.6	12.1	14.6
6.0	7.9	9.3	10.6	12.6	17.2	20.7
8.0	11.0	12.9	14.5	17.2	22.6	27.4

*For a preliminary checking of the slenderness ratio, the modulus of subgrade reaction (k) may be estimated from the following empirical relation given in IS: 2950-1981 (Second Revision) Table 1.
$k\ (kN/m^3) = 240\ c$, where $c\ (kN/m^2)$ is the value of cohesion of the soil at the concerned depth.

Notes :

1. If a subsoil condition much different from those reported herein is met with during foundation trenching or piling, suitable steps should be taken.
2. If concreting of piles is to be done below water table, DMC and tremie method should be adopted.
3. If u/r piles are provided, care should be taken to ensure proper formation of bulbs.
4. Shallow foundations or pile caps should be isolated from the surrounding expansive soil by layers of compacted local sand.
5. As per the provisions of the IS Code, **an appropriate number of piles must be subjected to routine load tests to check the veracity of the above recommended values of the safe capacities of piles.**

For Bihar Foundation Consultants

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