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GEOTECHNICAL SITE CHARACTERIZATION AND STABILIZATION OF WEAK DEPOSITS – A CASE STUDY

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ABSTRACT

Detailed soil investigation of proposed construction area in Rohtak City was carried out. Five bore holes (one at centre and four at corners) for an area of 0.4 hectares were dredged and bore hole with minimum SPT value 'N' was selected for further investigations. The index properties as well as engineering properties of soil were investigated and soil was found to be unsuitable for construction of heavy structures without stabilization. Hence, compacted soil samples stabilized with cement were prepared at maximum dry density (MDD) by adding optimum moisture content (OMC) and optimum percentage of stabilizer was chosen on the basis of maximum compaction offered by the samples. The sample with maximum value of MDD was then tested for shear strength parameters and found to be suitable for the construction of heavy structures. Liquefaction potential of proposed construction site was also evaluated and site was found to be safe against liquefaction.

KEYWORDS: SPT, Index Properties, Stabilization, MDD, OMC, Shear Strength, Consolidation, Liquefaction

INTRODUCTION

The safe and efficient design of foundations of any structure requires an adequate knowledge of the sub-soil characteristics. The field and laboratory investigations required for obtaining necessary information are usually termed as 'sub-soil exploration'. Basic aim of subsoil exploration is to obtain the stratigraphy and physical properties of soil underlying the site including ground water table. These may be supplemented by geological studies and geological survey. The purpose of a sub-surface exploration before the construction of a new structure is to:

- Select the type and depth of foundation.
- Determine bearing capacity of the selected foundation.
- Predict settlement of selected foundation.
- Establish ground water table.
- Evaluate the earth pressure against retaining wall and abutments.
- Adopt provisions against constructional difficulties.
- Determine stability of soil and degree of compaction required.
- Evaluate the liquefaction potential during an earthquake.

The complete process of subsurface exploration can be divided in two stages, preliminary work and site reconnaissance. In preliminary work, examination of already existed data about soil and geological conditions of site is done. Valuable information for many sites may be obtained if geological reports and maps or other previous relevant soil survey and investigation records are available like SPT data. In site reconnaissance, the purpose is to establish by actual inspection of site and surrounding area, the nature of the soil, bedrock and ground water location. The information obtained during site reconnaissance may sometime be sufficient for judging the general suitability of the site or for making a comparison of alternate site.

It also helps in deciding about the exploration techniques which may be necessary for further investigation. A study of the topographical features of a site may give an indication of the geological processes by which soils have been formed and deposited and hence the general characteristics of the sub-surface soil can be guessed. It should include an inspection of the following : Local topography, excavations, quarries, evidence of landslides, behavior of the existing structure at or near the site, water level in streams, water bodies and wells, flood marks, nature of the vegetation, drainage pattern etc. Special enquiries should be made if the site has been used earlier for underground works.

Exploration of sub-soil can be done either by boring methods or sounding methods or both. In boring method, a borehole is sunk at a predetermined location to a required depth by methods suitable for the site and to obtain fairly intact samples of soil. On the other hand, sounding methods includes geophysical and sounding techniques. In sounding methods, the variation in penetration resistance of sampler or metal cone is utilized to interpret some of the physical properties of strata. Some of the methods are SPT (Standard penetration test), DCPT (Dynamic cone penetration test) and SCPT (Static cone penetration test) [12][13].

In the present study, several standard penetration tests (SPT) were conducted in order to carry out geotechnical site characterization along with the evaluation of liquefaction susceptibility of proposed construction site in Rohtak City. Further investigations were carried out on the soil samples retrieved from the weakest borehole in order to determine index properties and engineering properties of soil.

INDEX PROPERTIES OF SOIL

Index properties of soil were determined. These index properties were utilized in determining the type of soil. The soil was classified as sandy silt (ML), as per the specifications of IS: 1498 (1970) [2]. The other index properties of soil were investigated in soil laboratory and are reported in Table 1 below.

Table 1: Index Properties of Soil

Index Properties		Soil
Grain Size Distribution Data	Gravel (%)	0
	Sand (%)	20
	Clay + Silt (%)	79
Natural Moisture Content (%)		18.11
Specific Gravity		2.28
Liquid Limit		22
Plastic Limit		NP
Shrinkage Limit		29.98
In-Place Density		18%
Is Classification		ML
OMC (%)		14.73%
MDD (g/cc)		1.66

The particle size distribution curves and compaction curves are shown in Figure 1 and Figure 2.

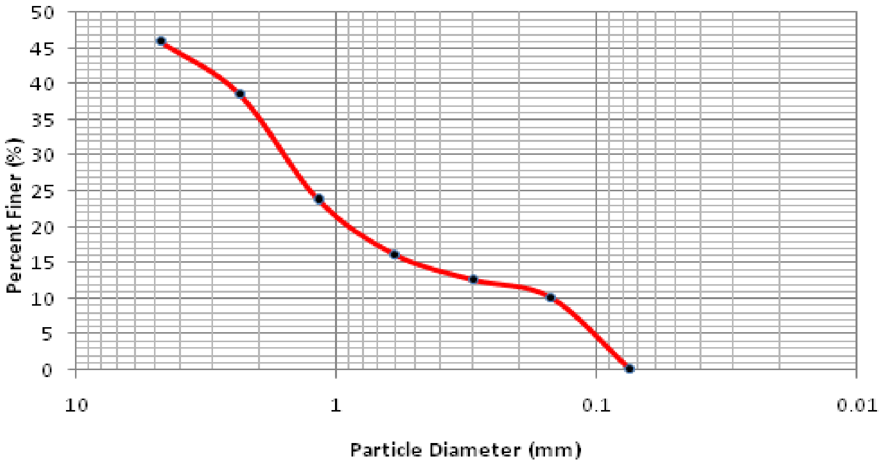

Figure 1: Grain Size Distribution of Soil

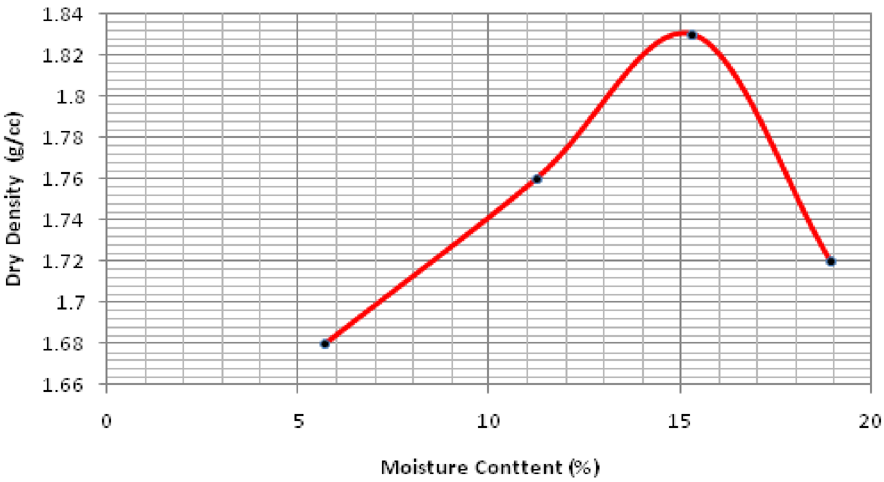

Figure 2: Compaction Curve for Parent Soil

SAMPLE PREPARATION

The method of sample preparation can be divided into three parts, 1) Composition of samples, 2) Mechanical Mixing and 3) Static compaction [13].

Composition of Specimens

Specimens of parent soil and parent soil treated with 1, 2, 3, 4 and 5% cement by weight were prepared at maximum dry density and optimum moisture content as per specifications of IS: 2720 (Part 7) (1974) [3].

Cement stabilization becomes un-economical beyond 5%. Hence extent of stabilization was limited to 5% [15].

Mechanical Mixing

Oven dry soil was dry mixed with various percentages of oven dried cement. Sufficient quantity of water was then added to bring the moisture content to the optimum level. The mixture was then manually mixed thoroughly with a spatula.

Static Compaction

Cylindrical specimens were statically compacted in 39 mm diameter split mould to the required height of 85 mm. The inner surface of the split mould was tarnished with oil to reduce friction during the withdrawal of sample. The wet homogenous mixture was placed inside the split mould using spoon with continuous tapping with spatula and leveled. The complete assembly was then statically compacted in a loading frame to the desired density. The sample was kept under static load for at least 20 minutes in order to prevent any increase in height of sample due to swelling. Due to presence of fine grained soil (silt), the samples were kept in polythene bags for a week to get matured. Figure 3 shows prepared samples kept for maturing.

Figure 3: Soil Samples Kept for Maturing

EXPERIMENTAL INVESTIGATIONS

In order to evaluate the soil-parameters required for designing the foundation system, it is essential to determine the physical and engineering characteristics of sub-soil strata down to the zone of influence of the foundations. For this, the scope has been framed of sinking 5 boreholes (for an area of 0.4 hectares) down to 20 m depth or refusal with all necessary and required field and laboratory tests, all as per the relevant I.S codes. The experimental investigations are explained below:

Standard Penetration Test (SPT)

Several standard penetration tests were performed and borehole log prepared for the weakest borehole is reported in APPENDIX A.

Proctor Compaction Test

On the basis of SPT value 'N' offered by soil it has been observed that soil is not suitable for construction without stabilization. The soil was then stabilized by adding 1, 2, 3, 4 and 5% of cement by weight of soil. Moisture-density relationships for these samples were determined by performing proctor compaction test. It has been observed that MDD and OMC increased with increase in percentage of cement as stabilizer. MDD varies from 1.66 to 1.99 g/cc and OMC varies from 14.73 to 18%. Values for various soil-cement mixtures are reported in Table 2.

Table 2: MDD and OMC Values for Stabilized Soil Samples

Description of Sample	MDD (g/cc)	OMC (%)
Soil+ 1% Cement	1.87	16.5
Soil+ 2% Cement	1.91	17.5
Soil+ 3% Cement	1.95	17.5
Soil+ 4% Cement	1.97	17.6
Soil+ 5% Cement	1.99	18

Variation of MDD and OMC with percentage of cement is shown in Figure 4 and Figure 5 respectively.

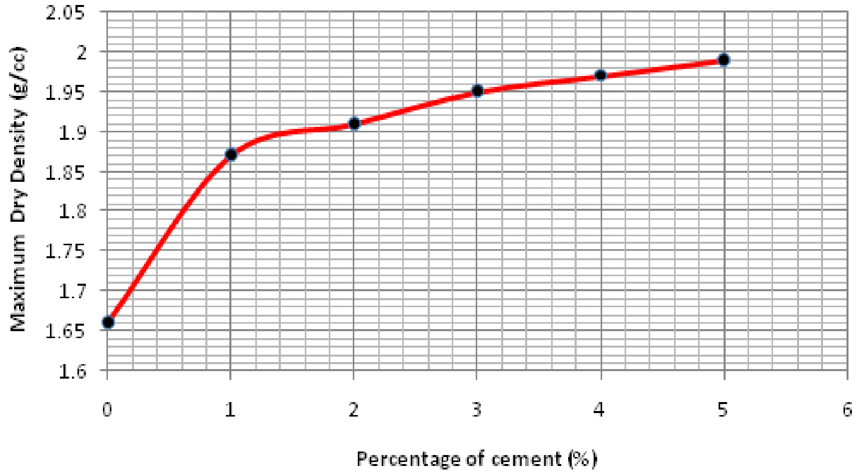

Figure 4: MDD vs. Percentage of Cement

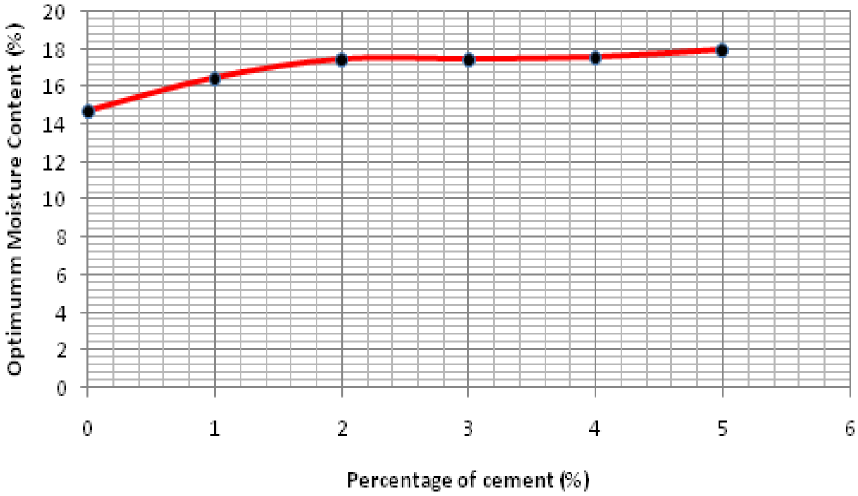

Figure 5: OMC vs. Percentage of Cement

Shear Strength Parameters

Unconsolidated un-drained (UU) triaxial tests were performed on parent soil and soil-cement mixtures. It has been observed that with increase in percentage of cement as admixture shear strength of soil increases. Value of angle of shearing resistance (φ^O) varies from 24 to 38 degrees and value of shear strength (τ) ranges from 0.85 to 2.78 kg/cm^2 for the range of percentage of cement as stabilizer. Good strength was observed from soil-cement mixtures and on the basis of that authors suggest to use soil-cement columns of varying diameter as foundations for single storey buildings. Similar results were reported by other investigators [15].

Liquefaction Susceptibility

Liquefaction potential of the proposed site was calculated by using simplified procedure suggested by Professors T.L Youd and I.M Idriss [17] in 2001. Cyclic stress ratio (CSR) and cyclic resistance ratios (CRR) were calculated for an earthquake of 7.5 magnitude as per the specifications. The values of factor of safety (F.O.S) against liquefaction for different soil layers were found to be satisfactory. A value of F.O.S greater than 1.25 ensures that liquefaction will not occur during the earthquake of 7.5 magnitude. All the values are reported in Table 3.

Table 3: Liquefaction Susceptibility of Different Soil Layers of Construction Site

Depth (in m)	CSR	CRR	F.O.S	Liquefaction
3	0.0735	0.1396	1.9	No
4.5	0.067	0.1924	2.87	No
7.5	0.058	0.1924	3.31	No
15	0.069	0.096	1.39	No

CONCLUSIONS

The following conclusions have been drawn based on the laboratory and field investigations carried out in this study:

- Very small SPT ‘N’ values were observed during the study. It was observed that soil profile was weak and need to be stabilized.
- Moisture—Density relationships of soil-cement mixtures were determined in order to prepare samples for various tests. It was observed that with increase in percentage of cement as admixture values of MDD and OMC increases.
- It was observed that shear strength of stabilized soil specimens was well enough to sustain heavy loads.
- Ground water table was encountered below 30 feet and hence will not adversely affect the stability of structures built over the construction area.
- A thick layer of silty sand below 15 feet was encountered. Author suggests providing effective drainage facilities to prevent liquefaction during earthquakes [16].
- The soil profile encountered here is best suitable for deep foundations.
- Stabilization of weak deposits before construction is beneficial practice. Similar results were also reported by other investigators. Author also suggests the use of flyash, cement kiln dust, stone dust, rubber chips etc instead of cement (if locally available) to make the project more economical [6][7][8][9][10][11][14].
- The proposed construction site is not susceptible to liquefaction during earthquakes.

APPENDIX A BORE HOLE LOG

Table 4: Weakest Borehole

Depth below Ground Level in Feet	Soil Type	Description	SPT 'N' Value	Triaxial Test Results φ Deg.	Triaxial Test Results c kg/cm²	GWT	LL & PL %	BD & DBD g/cc	SIEVE ANALYSIS PERCENT: Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt and Clay
									-	-	-	45	55
5.0	ML	SANDY SILT	05	24	0.00	▽	NP	1.74 1.66	06	01	-	42	51
									01	02	-	37	60
10.0			11	20	0.14		P	1.80 1.72	-	01	-	20	79
									-	-	-	13	87
15.0	ML-CL	Sandy SILT WITH CLAY OF LOW PLASTICITY	18	22	0.16		P	1.82 1.74	01	01	-	19	79
									-	01	-	49	50
20.0	SM	SILTY SAND	19	32	0.00		NP	1.85 1.76	-	02	-	75	23
25.0									-	-	-	78	22
30.0	ML	SANDY SILT WITH GRAVEL (KANKAR) AS SHOWN	24	30	0.00	▽	NP	1.82 1.74	-	-	-	33	67
35.0									-	01	-	29	70
40.0			13	28	0.00		NP	1.80 1.72	14	06	-	12	68
45.0									15	05	-	09	71
50.0			09	30	0.00		NP	1.82 1.74	01	02	-	17	80

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