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Engineering Classification of Soil in Shri Muktsar Sahib District of Punjab State (India)

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Abstract- Realistic data of soil classification after geotechnical investigations play vital role in design and execution of an engineering project. Due to the increasing rates of site investigation, geotechnical data contributes substantially to the cost of engineering projects. The Geographic Information System (GIS) has versatile applications in different fields. In this paper, important parameter – Indian standard classification based on Standard Penetration Test (SPT) results, were analyzed at ten different levels varying from 1.5 m to 15.0 m depth from natural surface level. The varying complexity of SPT data was converted into useful information by integrating the subsurface conditions of Shri Muktsar Sahib District of Punjab (India). The Spatial analysis has been done using ArcGIS software to prepare zonation maps and histograms for different depths of the area under study. Each depth level has been interpolated as a surface to create zonation maps for the classification of soil as per Indian Standards. The aim of this research is to; collate, correlate, analyze different type of soils encountered at various levels, which are required for the suitability of a foundation for the design of a new structure. Finally, zonation map and histogram for water table are presented and problems encountered due to high water table are discussed.
Keywords: classification of soil, histograms; spatial analysis; zonation maps, water table.

I. INTRODUCTION

India has to create huge infrastructure in area of Highways, housing and water resource management to become a develop nation. This requires careful planning to prevent failure of these facilities in case of disaster. The geotechnical engineers can play a very important role in site characterization and minimizing risk of natural disaster. High quality geotechnical investigations are essential for preventing geo-hazard. Detailed guidelines and specifications for geotechnical investigations are provided by Bureau of Indian standards (IS: 1892, IS: 2720). However, the range of practices varies widely in India both in terms of field investigation and soil profile. As a result of the variation of these practices, substantial differences exist between actual soil profile and the profiles available at the time of design, as a part of the tender specifications in a large number of projects. If, the soil strata during execution of the project are found to be deviating from, given in the tender document, a dispute may arises between contractor and owner. Considering the variation of soil type, if a guide map representing the engineering properties of soil is prepared, it can help the builder/contractor to estimate the realistic soil properties before bidding. Thus, the dispute can be avoided. However to take care of natural variations in the soil profiles at a given site, one can work out some norms for permissible deviation. The important engineering behavior of any soil deposit may be predicted by studying the 'Soil Classification' based on index properties of soil and water table of that location.

Due to the high cost of soil investigation sometimes sufficient funds are not available in small projects, hence soil investigation part is overlooked. The Geographic Information System (GIS) can be used as an important tool in the field of geotechnical engineering for a variety of applications. Haider et al. 2014, used this method for geotechnical zonation maps in Surfers Paradise in Australia. Statistical models have been developed in ArcGIS to evaluate landslide hazards by Carrara et al. 1991; Xie and Esaki 2006. Orhan and Tosun 2010, used Standard Penetration Test (SPT) N value data for preparing maps by using Inverse Distance Weighting (IDW) method based in GIS Spatial Analysis. These days, geotechnical engineers are finding the zonation maps useful to predict suitability for type of foundation for a structure. Hellawell et al. 2001 has done work related to small-scale geotechnical projects by utilization of ArcGIS in geotechnical engineering at the United Kingdom.

Some reports regarding the site-specific engineering properties of soil have been reported time to time in different Indian Geotechnical Conferences, but any detailed, area specific engineering properties has not been tried till date in India. However, attempt has been taken by some author to report the region specific engineering properties of soil (Ajayi 1983, Ola 1983, 1988). Around 85 to 90 percent of conventional foundations are designed using Standard Penetration Test data in North and South America (J. Bowles 1996). As mentioned above site specific information about engineering properties of soil are available with different sources like government agencies, Consultants, Construction Companies and Contractors etc. in the different forms as per their own Project requirements. There is a need to compile the data available in different forms and present them in a logical/suitable manner, so that it may be useful reference/ guide in different fields of Geotechnical Engineering. This paper is an area specific paper in which soil classification is discussed.

II. STUDY AREA

Sri Muktsar Sahib district, formerly known as Mukstar; is one of the twenty-two districts of Punjab state in India. It lies between Latitudes 29.300 to 32.700 and Longitudes 74.700 to 75.320, on the southern side of Punjab state of India. The figures 1 to 3 represent the area under study.

Figure 1. India map, highlighting Punjab state.

Figure 2. Punjab state map.

Figure 3. District Sri Muktsar Sahib.

III. METHODOLOGY

Sri Muktsar Sahib is a historical district in Punjab, India (Fig. 3) and this district is taken as study area in the present Paper. SPT Data of the soils properties was collected from various government/private agencies. This data is mostly in the form of Bore logs as shown below (Fig. 4).

Bore Hole Designation: BH 01 of 01 Date of Testing: 25.11.2018 Depth of water table: 1.80 m w.r.t. NSL

Depth from BHL (m)	IS Classification	Grain Size Analysis (%)			Consistency Characteristic		Bulk Unit Weight	Strenght Properties		SPT Value (Oveserved)		Symbolic Representation	Remarks
		Gravel	Sand	Silt & Clay	L.L.	P.L.	γ (t/m³)	C (t/m²)	Φ˚	N	Graphical		
1.00	ML	0	19	81	NP	NP	1.59	0.0	25.0	2			Silt of Low Compressibility
1.50	SM	0.0	71.0	29.0	NP	NP	1.62	0.0	26.0	5			Silty Sand
3.00	SM	0.0	90.0	10.0	NP	NP	1.65	0.0	27.0	7			
4.50	SP	0.0	94.0	6.0	NP	NP	1.68	0.0	29.0	11			Poorly Graded Sand
6.00	SP	0.0	94.0	6.0	NP	NP	1.71	0.0	30.0	12			
7.50	SP	0.0	94.0	6.0	NP	NP	1.74	0.0	30.5	14			
9.00	SP	0.0	94.0	6.0	NP	NP	1.76	0.0	30.5	14			
10.50	SW	0.0	96.0	4.0	NP	NP	1.77	0.0	31.0	16			Well Graded Sand
12.00	SW	0.0	96.0	4.0	NP	NP	1.78	0.0	31.0	17			
13.50	SW	0.0	96.0	4.0	NP	NP	1.80	0.0	31.0	18			
15	SW	0.0	96.0	4.0	NP	NP	1.80	0.0	31.0	19			

Figure 4 A typical bore log chart showing engineering properties of soil.

This data is arranged in tabular form as per location and engineering properties of that location. Data for about 105 locations was analyzed for the area under research. These locations are geo-referenced by locating its latitude and longitude.

3.1 Classification of Soil for Geotechnical Engineering Purposes

Soil is the most essential component in geotechnical engineering, which is identified with a lot of cases on the plane. The real assortment of soils for the most part found in India are silts, clays, sandy loam and gravel etc. The conduct of each type of soil is diverse in view of its geotechnical engineering characteristics. Therefore, the purpose of soil investigation is really important to know the soil types before the start of a project. In this section, the discussion on results obtained from the field and laboratory tests regarding soil classification, have been presented as per Indian Standard Code IS 1498:1970.

The soils found in the study area are broadly divided on the basis of particle size into two types. They are fine grained and coarse grained soil.

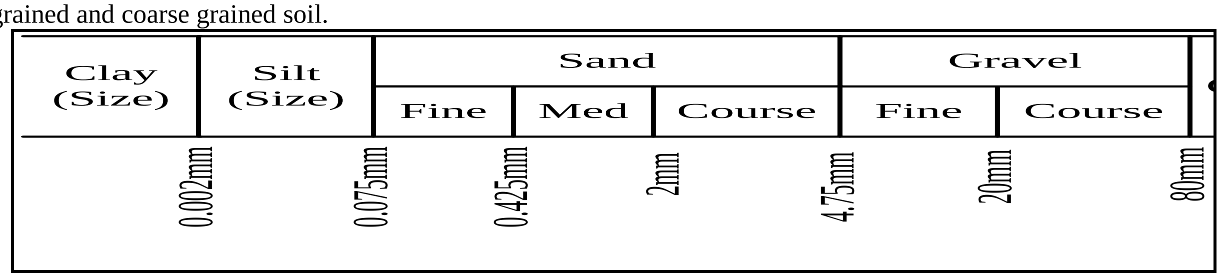

Figure 5: Nomenclature of soil as per particle size.

Coarse grained and fine grained soils are further divided into sub groups as per size and index properties of soil. The major soil found in the study area with their symbolic representation are given below:

Inorganic silts of low compressibility – ML
Inorganic clays of low compressibility – CL
Inorganic silts/clay of low compressibility – ML/CL
Silty sands – SM
Well graded sands with little or no fines – SW
Poorly graded sands with little or no fines – SP

Table.1. Classification of soil as per IS: 1498-1970.

Gravel	Sand %	Silt & Clay %	PI	Code
			NP or < 4	ML
	1-49	51-99	4-7	ML/CL
			>7	CL
	50-88			SM
	89-95			SP
	96-100			SW
> 50	Sand > Silt & Clay			GP
> 50	Sand < Silt & Clay		NP or < 4	GM
> 50	Sand < Silt & Clay		4-7	GM/GC
> 50	Sand < Silt & Clay		>7	GC

3.2 Spatial Data Analysis Using ArcGIS

The data for soil classification is tabulated as per software requirements. One basic engineering characteristic i.e. classification of soil, is taken under study at a depth of 1.50 m to 15.0 m with respect to Natural Surface Level (NSL) at an interval of 1.5 m. The tabulated data have been used as an input to the ArcGIS. In ArcGIS Map, the Spatial and Geostatistical analysis interpolation techniques have been examined in terms of their suitability to represent the data. The water table depth for various locations has also been analyzed. The utilized interpolation technique was ‘Spatial Analyst tool’, which includes Inverse Distance Weighing (IDW) method. Histograms and zonation maps were developed using the ArcGIS software using the geotechnical data as input (figure 6).

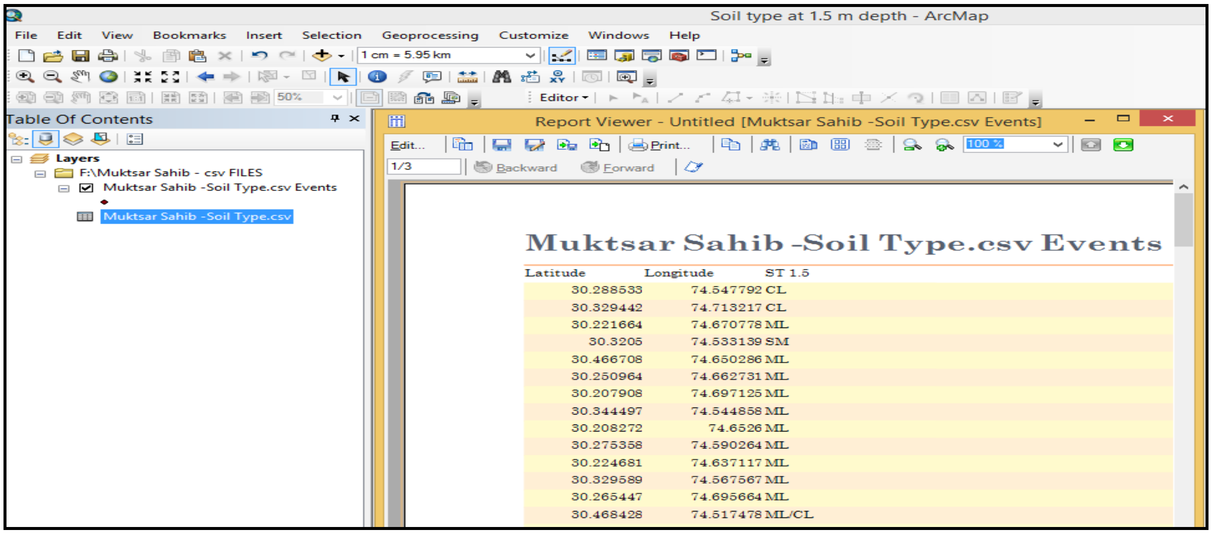

Figure 6: Screen shot of tabulation of data used as an input in ArcGIS Software.

IV. RESULTS AND DISCUSSION

There are a number of factors on which bearing capacity of soil depends. These are shape, size, depth, width of foundation and location of water table etc. However type of soil has a great significance while calculating the bearing capacity of a foundation. Hence, identifying the soils, the results are presented in the form of zonation maps and histograms.

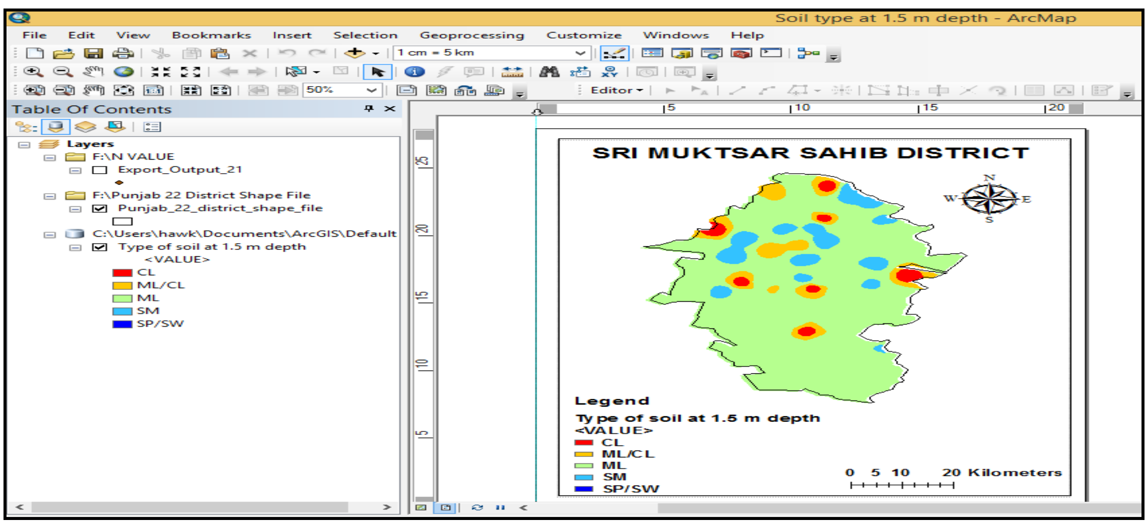

Figure 7: Screenshot taken during development of zonation map for soil type in Sri Muktsar Sahib District at 1.5 m depth.

4.1 Zonation Maps Showing Soil Classification in Study Area.

Thematic maps showing variation in the soil type and Water Table values of soil along the depth of soil at different locations of Shri Muktsar Sahib District of Punjab in India are presented. Zonation maps have been developed for different depths from the available data of the area, as done by Orhan and Tosun 2010. In all the cases depth has been taken from natural surface level NSL. The IDW interpolation technique provides better and reasonable representation for any data among the various interpolation techniques. As per Al-Ani et al. 2014, only the IDW technique provides a zonation maps with a resulted values very close to the original input data. It has been also used for predicting and mapping of potassium soil by Bekele, et al. 2003. The zonation maps for soil classification at different levels are presented from figure 8 to figure 17.

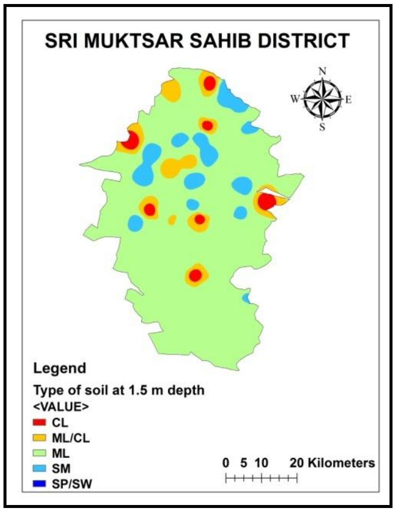

Figure 8: Zonation map for soil type at 1.5 m depth.

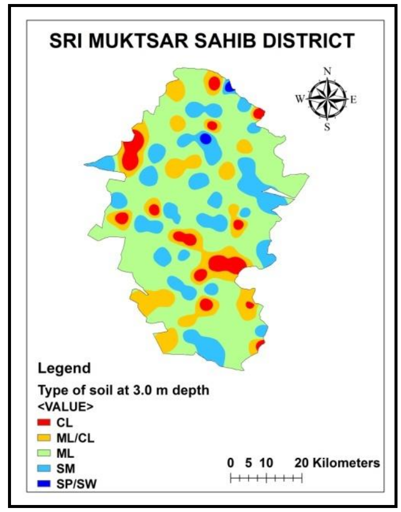

Figure: 9 Zonation map for soil type at 3.0 m depth.

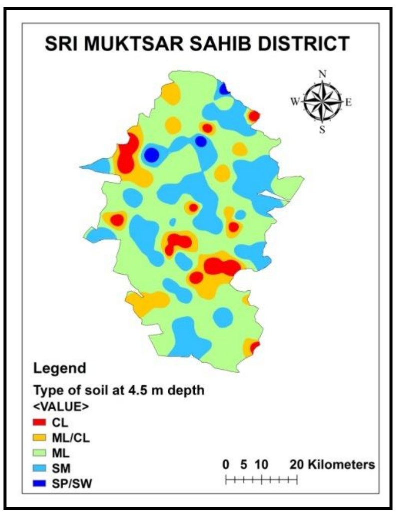

Figure 10: Zonation map for soil type at 4.5 m depth.

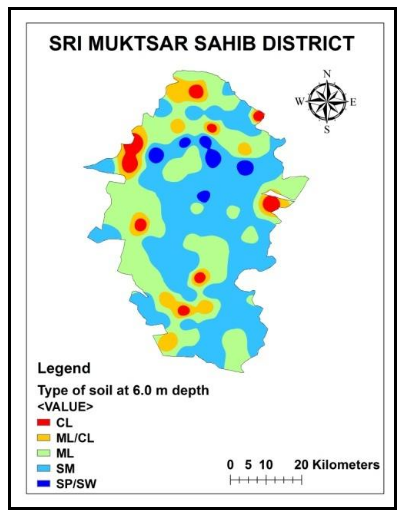

Figure 11: Zonation map for soil type at 6.0 m depth.

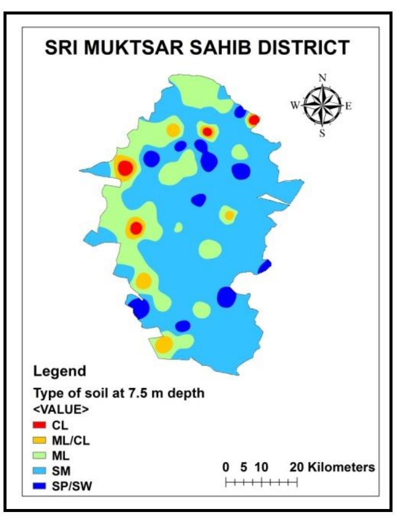

Figure 12: Zonation map for soil type at 7.5 m depth.

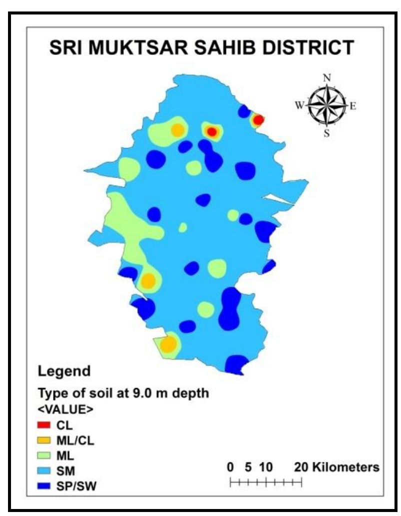

Figure 13: Zonation map for soil type at 9.0 m depth.

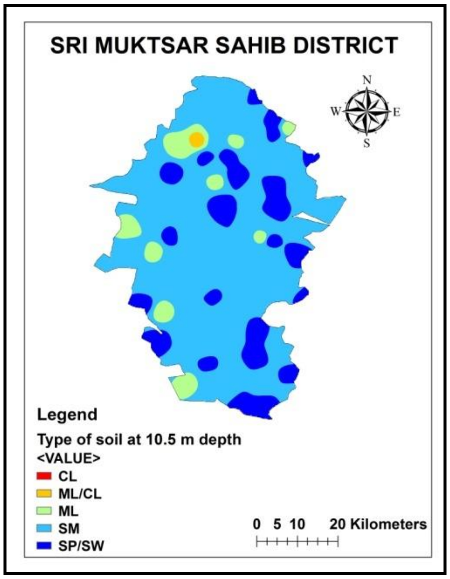

Figure 14: Zonation map for soil type at 10.5 m depth.

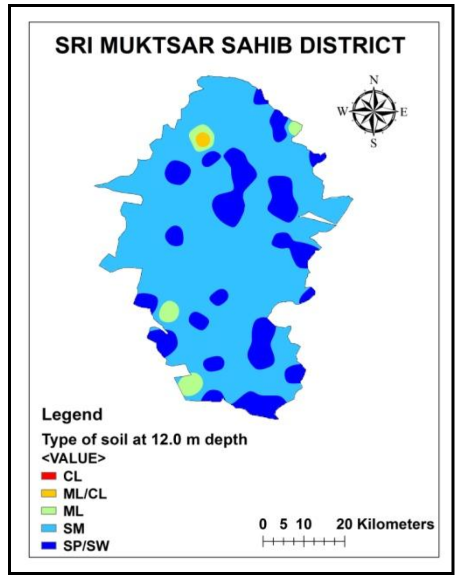

Figure 15: Zonation map for soil type at 12.0 m depth.

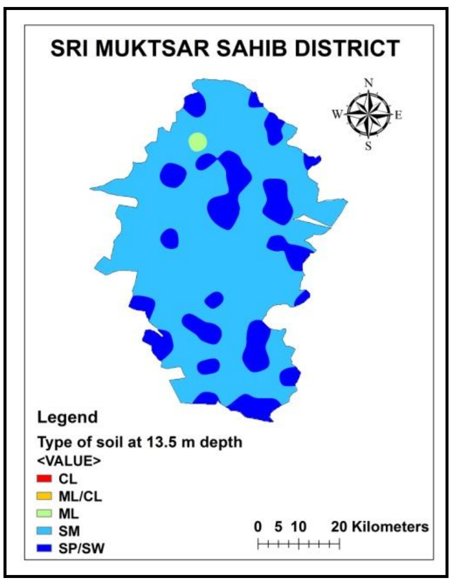

Figure 16: Zonation map for soil type at 13.5 m depth.

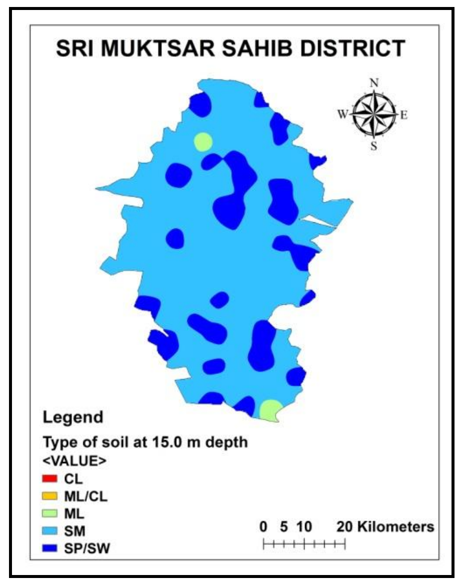

Figure .17: Zonation map for soil type at 15.0 m depth.

All the maps are divided into five zones. Each zone is represented by a unique color. Red color represents (Clayey soil) CL, the yellow colour represents (silty clay) ML/CL and light green colour represents (silty soil) ML. Similarly light blue colour represents (silty sand) SM and finally dark blue colour represents (poorly and well graded sands) SP/SW. Legend given in each zonation map represents the colour and soil type as per IS classification of soil. Fig. 8 represents a GIS based zonation map for the classification of soil at a depth of 1.5 m in Sri Muktsar Sahib District of Punjab in India. We can view the red colored zone occupying small portion at different parts, representing clayey soils in that area. Similar pattern is seen up to 7.5 m however the area goes on decreasing. After that depth the clayey soil do not occur in the study area.

The silty clays are encountered at some locations but their occurrence is small that too up to a depth of 9.0 m, beyond this depth silty clays are rarely found. Silty sands are predominant up to the depth of 4.5 m, after that depth major soil type that occurs is sandy silt. Poorly graded and well graded sands occupy the most of area up to a depth of 15.0 m. This can be well understood from the zonation maps given above. The north direction and scale is also marked on the maps. Hence from the analysis of soil classification study, we conclude that the soil strata of Sri Muktsar Sahib District vary horizontally as well as vertically.

4.2 Histograms For Soil Classification

The second section shows the histogram plot and normal distribution for soil type at various locations. A histogram is a plot that shows the hidden recurrence dispersion (shape) of an arrangement of constant information. This permits the review of the information for its fundamental appropriation (e.g., ordinary dispersion), skewness. A histogram is a speedy method to get data about a data group without point by point measuring, charting or investigating. To construct a histogram from a continuous variable, the data is split into intervals, called bins. Each bin contains a particular soil type occurrences in the data set and signify the height of bin. The bin size (width) has been kept uniform throughout. A symmetric distribution of data is often described as bell-shaped. Histograms (Fig. 19 to figure 28) have been drawn at different levels at starting from 1.5 m depth to 15.0 m depth at an interval of 1.5 m. Fig 19 shows histogram at 1.5 m depth. It is very much clear that 7 locations have clayey soil, 4 locations have silty clayey type however, 79 locations have silty soils and 15 locations have silty sand. The occurrence of different soils at different locations can be seen in histograms presented for different depths (from figure 18 to figure 27. The skewness can be judged, but, since the data is not numeric, the statistical analysis is not possible.

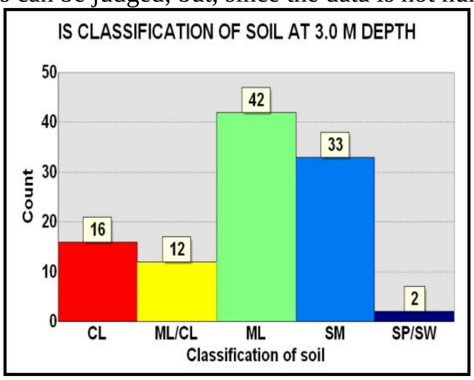

Figure 18: Histogram for soil type at 1.5 m depth.

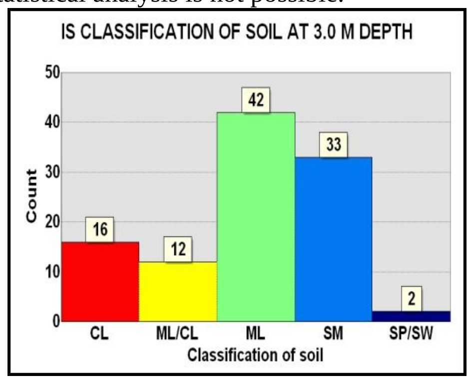

Figure 19: Histogram for soil type at 3.0 m depth.

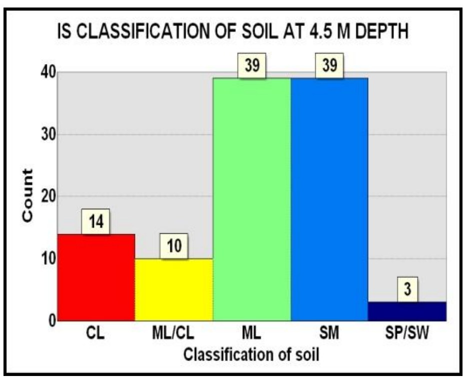

Figure 20: Histogram for soil type at 4.5 m depth.

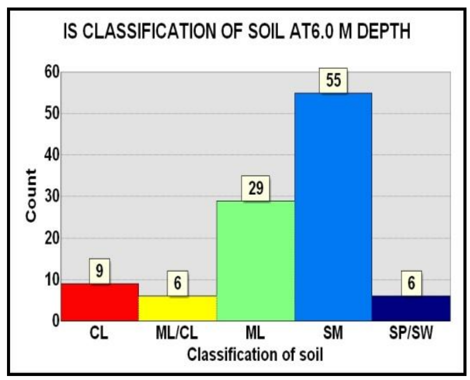

Figure 21: Histogram for soil type at6.0 m depth.

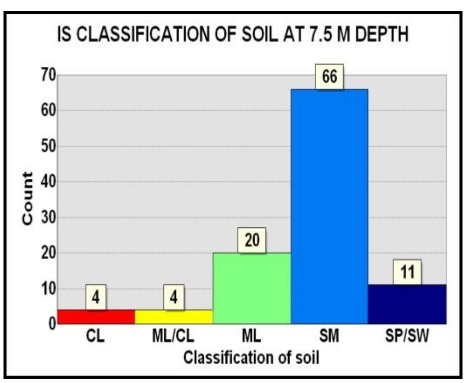

Figure 22: Histogram for soil type at 7.5 m depth.

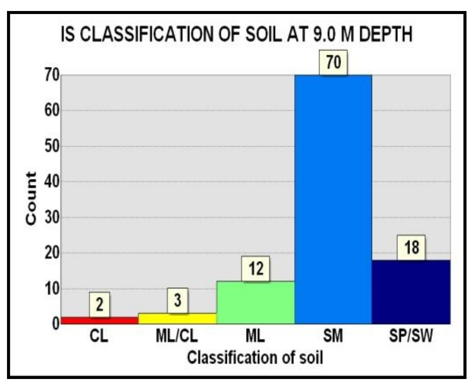

Figure 23: Histogram for soil type at 9.0 m depth.

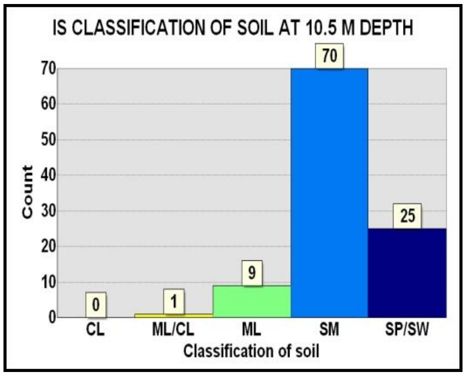

Figure 24: Histogram for soil type at 10.5 m depth.

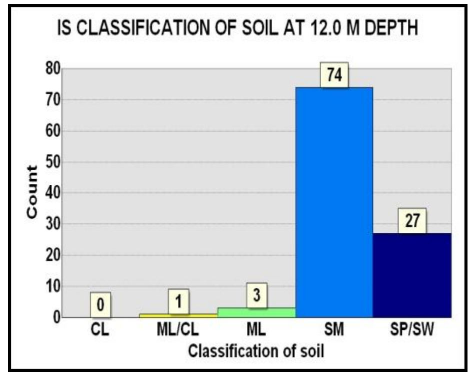

Figure 25: Histogram for soil type at 12.0 m depth.

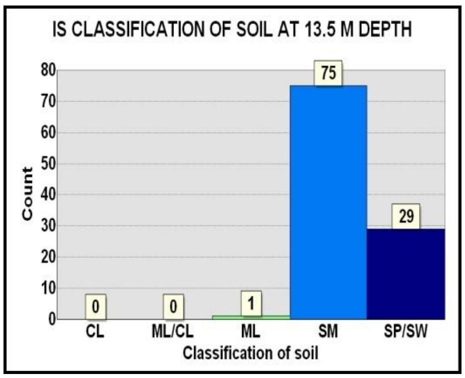

Figure 26: Histogram for soil type at 13.5 m depth.

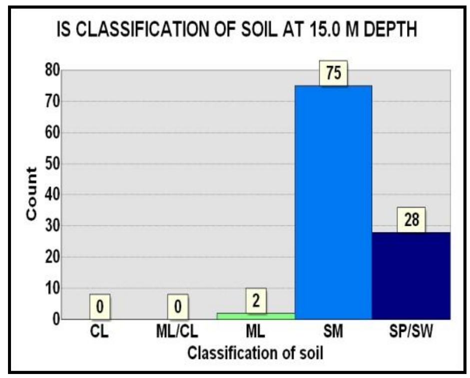

Figure 27: Histogram for soil type at 15.0 m depth.

4.3 Effect of Water Table

Water table plays an important role in soil investigation of a site. The bearing capacity of soil and liquefaction largely depends on water table.

4.4 Zonation Map and Histogram for Sub Soil Water Table in Study Area.

In the present study most of the locations has sub soil water table at less than 1.5 m depth.

Zonation Map for water table depth is shown in Fig. 28. The high water table shown by red colour in the map represents high water table between 0.00 to 3.00 m depth. Eighty six locations have water table between 0.00 m and 3.00 m. Water table lies at depths of 3.01 m to 6.00 m depth, only for seventeen locations, represented by yellow colour in map (Figure. 28 and figure 29). Only two locations have water table (shown in light green colour in map) in the range of 6.01 m to 9.00 m.

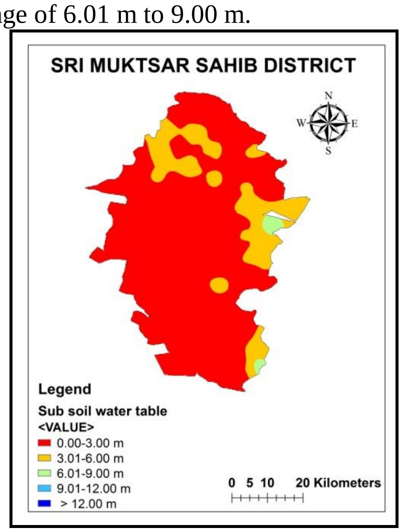

Figure 28: Zonation Map for Water Table depth.

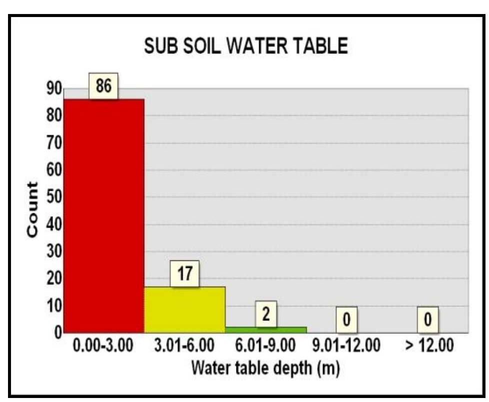

Figure 29: Histogram for Water Table Depth.

The average water table in this area is 2.27 m. Thus the overall water table of the area under study is high enough to create problems. It creates a problem of subsidence of soil during excavation of foundation. The dewatering during construction is not only difficult, but a costly affair also. Moreover, high water Table exaggerates the construction problem in this area. So, it is not possible to provide normal shallow foundations. The alternate available is deep foundation which is not always an easy and economical choice. This increases the overall cost of project and sometime leads to quarrel between contractor and owner.

V. CONCLUSIONS

The following are the major conclusions drawn from the study:

The soil strata varies horizontally as well as vertically in the area under study.

The most of the soil encountered in the study area are clayey, silty clays, silty sands, sandy silts and poorly/well graded sands.

The fine grained cohesive soils are encountered at shallow depths up to 6.0 m depth, after that depth the coarse grained soils are predominant.

The particle size of soil increases with depth.

The average water table is 2.26 m. The water table at a shallow depth, creates a lot of problems, during and after construction of a project. The bearing capacity of soil gets reduced due to high water table in this area.

The analysis of soil classification study, it is concluded that the soil strata of Sri Muktsar Sahib District is weak. Moreover high water table exaggerates the construction problem in this area.

It is not possible to lay the foundations at shallow depth. The alternate for this is deep foundation, which is not easy. Moreover, it increases the project cost. The increase in the cost of project may lead to dispute between contractor and owner.

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