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Engineering Properties of Soil in Sri Muktsar Sahib District of Punjab (India) - Statistical Analysis

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Abstract

Soil geotechnical properties include soil type, bulk density, SPT-N-value, shear strength parameters and consistency limits etc. These properties have influence on the soil characteristics as well as management of civil engineering construction projects. The current methods for their determination are expensive and time consuming. There is a need for rapid and fairly accurate methods that can guarantee speed and allow comparison of point measurements.

This paper attempts to provide an overview of the main domains of application of statistical based techniques to geotechnical data. The study was carried out in Sri Muktsar Sahib District of Punjab state (India) in order to meet out some soil characteristics and assess their variability within the study area. Soil data was collected from various government and private agencies. After arranging the data in proper format, statistical methods were used to describe the soil properties, such as soil type, N value, bulk density, shear/strength parameters and water table depth, and geo-statistical analysis was used to illustrate the spatial variability of the soil properties. The graphs and tables presented can be effectively utilized by the geotechnical/civil engineers, designers and planers.

Keywords: *Geotechnical Assessment, Engineering Properties, Standard Deviation, Skewness, Statistical analysis.*

1. Introduction

Deterministic strategies lie at the basis of virtually each technological science, and geotechnical engineering is not an exception. However, the importance of explicitly modeling and assessing the variability of geotechnical parameters is increasingly diagnosed in geotechnical layout and characterization. Site examination and estimation of soil properties are fundamental parts of a geotechnical investigation process. Geotechnical engineers must determine the fluctuation of soil properties while planning and designing any project. The statistical methods are advantageous because natural variability is taken into consideration. The geological recognition can then be correlated to numerical values, so that it becomes easier to manipulate and make it more consistent (Ryder, 2002). Statistical techniques are not a purely theoretical perspective. A number of textbooks are available for a more comprehensive insight into the formal aspects of statistical science in the context of geotechnical engineering (Ang & Tang, 1975; Ayyub & McCuen, 2003; Baecher & Christian, 2003).

Many procedures have been developed by geotechnical researchers and practitioners for analysis of geotechnical data using

statistics (Holtz, R.D. and Krizek, R.J., 1972; Jiang J, 2011).

1.1. Site Description and Choice of Study Area

Sri Muktsar Sahib is one of the twenty two districts of Punjab in India. The district occupies the total area of 2,615 km^2. It is situated in the south western part of the state and lies between North Latitude 29^0 54' and 30^0 40' and East Longitude 74^0 15' and 74^0 19'.

Almost the entire district is facing the problem of water logging. Southern and north western parts are severely affected by the water logging problem. The severeness of water logging problem is due to the network of canals passing through this district. The water table varies rapidly before and after the monsoon season. The geotechnical properties are tremendously affected due to variation in water table. Therefore, it is interesting and important to analyze the geotechnical properties of soil. The boundary map and data points (boreholes) location of study area is shown in Figure 1.

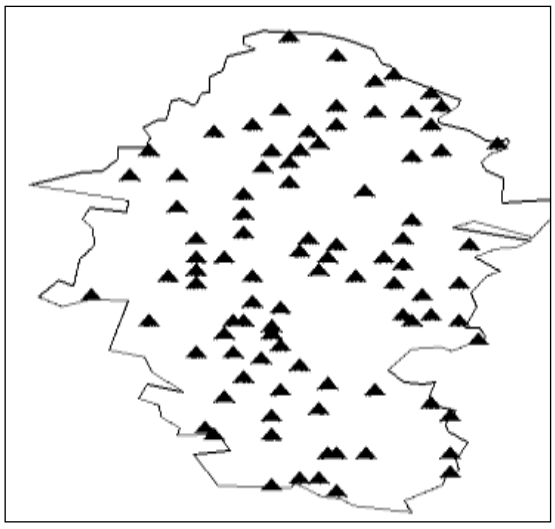

Fig.1 Study Area Map showing data point (Bore Hole) locations.

2. Methodology of Study

The scope of work in this study included reviewing previous geotechnical studies of the area and conducting additional SPT tests in areas not previously explored. Geotechnical investigation program included studying physical and engineering properties of soil. In the present study, a geotechnical assessment is carried out as below:

2.1 Data Collection and Soil Investigation

Geotechnical studies are based on the data from different sources like some government and private agencies and the data explored by the author. In the present study, the total numbers of locations under study are 99. The data is in the form of borehole logs and each borehole is geo-referenced in terms of its latitude and longitude. A typical borehole log chart is shown in Figure 2.

BH-#8	Date of Testing: 23.05.2016.				Depth of Water Table : 3.40 m					
Name of Work: Construction of Building at Sri Muktsar Sahib										
Depth from	IS		Grain Size Analysis		Consistency Char.		Bulk Unit Wt.	Strength Properties		SPT Value
NSL (m)	Classification	Gravel	Sand	Silt/Clay	LL	PI	γ(t/m^3)	C(t/m^2)	Q	N
1.00	ML	0	31	69	NP	NP	1.66	0.00	24.00	2.00
1.50	ML	0	24	76	NP	NP	1.68	0.00	25.00	3.00
2.00	ML	0	26	74	NP	NP	1.69	0.00	27.00	7.00
3.00	ML	0	11	89	NP	NP	1.72	0.00	26.00	6.00
4.50	SM	0	27	73	NP	NP	1.73	0.00	28.00	9.00
6.00	SM	0	90	10	NP	NP	1.76	0.00	30.50	16.00
7.50	SM	0	92	8	NP	NP	1.78	0.00	31.75	18.00
9.00	SM	0	92	8	NP	NP	1.78	0.00	31.75	18.00
10.50	SM	0	93	7	NP	NP	1.79	0.00	31.50	15.00
12.00	SM	0	93	7	NP	NP	1.79	0.00	31.00	17.00
13.50	SM	0	94	6	NP	NP	1.79	0.00	31.75	18.00
15.00	ML	0	94	6	NP	NP	1.80	0.00	31.75	18.00

Fig.2 Typical Bore log showing engineering properties of soil

The soil investigation is done as per the code of practice for site investigation according to IS: 2131-1997, which are utilized for taking the samples. Laboratory tests are performed on samples collected from each borehole. The tests are carried out in accordance with Indian Standard.

2.2 Statistical Analysis of the Data

To make the better assessment of geotechnical data of the study area using statistical methods, statistical terms associated with it are explained below.

2.3 Statistical Terms

2.3.1 Minimum

The smallest value of a quantity in a data set is known as minimum.

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2.3.2 Maximum

The greatest quantity or value in different quantities in a data set is termed as maximum.

2.3.3 Mean or Average

A number communicating the central value in a set of data, which is computed by dividing the sum of all values in the set by the total number of data points.

2.3.4 Standard Deviation

Standard deviation is the measure of scattering of an arrangement of data from its mean. Standard deviation (σ) is characterized as the square root of the variance. It measures the variability about the mean of a data set: the closer to the mean, the lower the standard deviation.

2.3.5 Coefficient of variance

The coefficient of variation represents the ratio of the standard deviation to the mean, and it is a useful statistic for comparing the degree of variation from one data series to another, even if the means are drastically different from one another. The coefficient of variance (CV) is equal to standard deviation divided by the mean. Higher the coefficient of variance, more prominent is the level of scattering around the mean.

2.3.6 Skewness

Skewness is asymmetry in a statistical distribution, in which the curve appears distorted or skewed either to the left or to the right. Skewness can be quantified to define the extent to which a distribution differs from a normal distribution. The skewness value can be positive or negative, or undefined.

3. Results and Discussion

The parameters analyzed and taken under consideration for discussion are soil type, bulk density, SPT N-value, angle of internal friction, cohesion and water table.

3.1 Grain Size Analysis

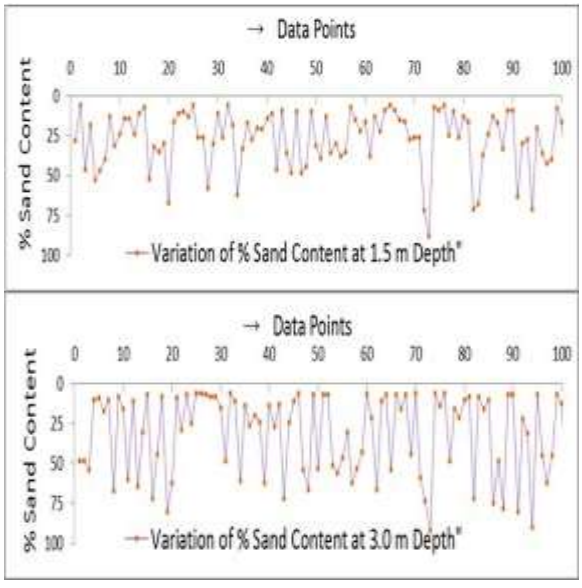
The soil classification is based on the grain size distribution and nomenclature of soil. In 1959, Bureau of Indian Standards adopted the Unified classification system as a standard, which was revised in 1970. Soil particles mainly consist of following four size fractions; Gravel: 80 – 4.75 mm, Sand: 4.75mm – 0.075mm (75 micron), Silt: 75 – 2 micron and Clay: less than 2 micron.

On the basis of soil classification the graphs are developed at depths of 1.5 m to 9.0 m at an interval of 1.5 m. In the present study, the graphs are being shown at depths of 1.5 m, 3.0 m and 6.0 m only.
Results indicate that there is no noticeable gravel content in soil profile up to 9.0 m depth; this can be neglected on taking the effect of gravel content on soil profile of the study area. Hence, the graphs for gravel content have not been shown in this paper.

3.1.1 Sand Content

As per the results drawn from graphs and tables, the majority of soil profile consists of silt to silty sands and sand with a trace of clay at some points especially for shallow depths. Then, after 6 m depth below natural ground surface, the amount of sand content increases and becomes more effective at most of the places of Study area.

The graphs by percentage weight of sand at a depth of 1.5 m, 3.0 m and 6.0 m at different locations in study area are presented in Figure 3.



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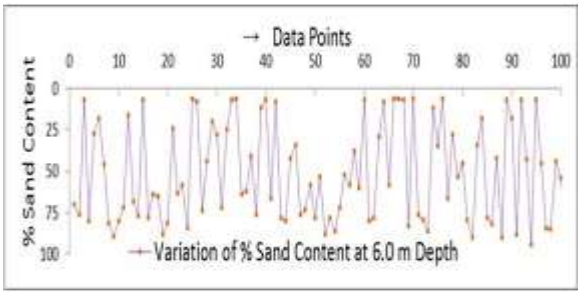


Fig.3 Variation of %age sand content at different data points at a depth of 1.5 m, 3.0 m and 6.0 m

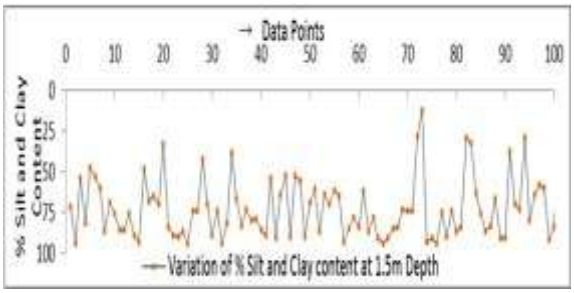
The variation of different statistical parameters for sand content from 1.5 m to 9.0 m depth at an interval of 1.5 m are presented in Table 1.

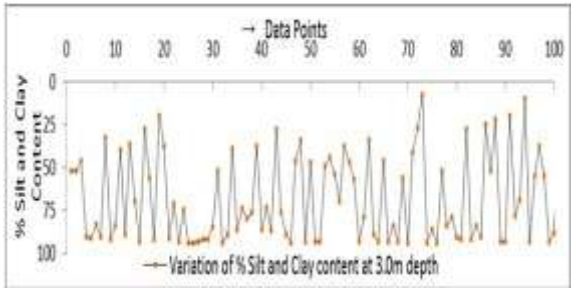
Table.1 Variation of Statistical Parameters wrt % of sand content with Depth (1.5m to 9.0 m at 1.5 m interval)

Statistical Parameter / Depth	1.5 m	3.0 m	4.5 m	6.0 m	7.5 m	9.0 m
Minimum	6	6	6	6	6	7
Maximum	88	92	94	94	96	96
Mean	27.43	31.89	37.95	51.31	62.72	68.93
Range	6.00 - 88.00	6.00 - 92.00	3.00 - 94.00	6.00 - 94.00	6.00 - 96.00	7.00 - 96.00
Standard Deviation	18.56	25.72	29.26	29.53	27.26	24.54
Co-variance	0.68	0.81	0.77	0.58	0.43	0.36
Skewness	1.09	0.63	0.35	-0.33	-0.89	-1.20

3.1.2 Silt and Clay Content

The major proportion of soil type is sand and silt, however very fey locations indicate presence of small amount of clay. Silt and clay content together at a depth of 1.5 m, 3.0 m and 6.0 m in are shown in Figure 4.





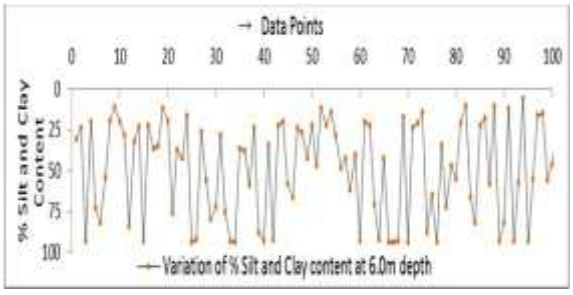


Fig.4. Variation of %age Silt and Clay content at different data points at a depth of 1.5 m, 3.0 m, 6.0 m.

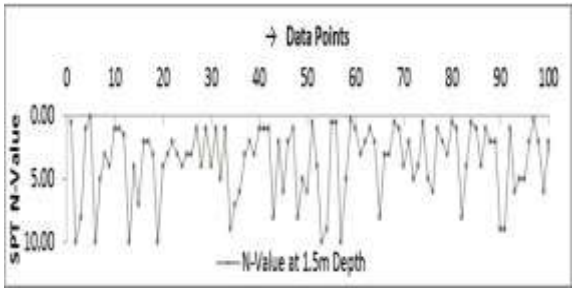
Clay content goes on decreasing as we go deeper into the soil strata. Size of particles also goes on decreasing with depth. The variation of various statistical parameters with regards to silt and clay content are shown in Table 2.

Table.2 Variation of Statistical Parameters wrt % of silt and Clay content with Depth (1.5m to 9.0 m at 1.5 m interval)

Statistical Parameter / Depth	1.5 m	3.0 m	4.5 m	6.0 m	7.5 m	9.0 m
Minimum	12	8	6	6	4	4
Maximum	94	94	94	94	94	93
Mean	72.57	68.11	62.05	48.69	37.28	31.07
Range	12.00 - 94.00	8.00 - 94.00	6.00 - 94.00	6.00 - 94.00	4.00 - 94.00	4.00 - 93.00
Standard Deviation	18.56	25.72	29.26	29.53	27.26	24.54
Co-variance	0.26	0.38	0.47	0.61	0.73	0.79
Skewness	-1.09	-0.63	-0.35	0.33	0.89	1.20

3.2 N-Value

The number of blows required for 300 mm penetration (during SPT) are designated as "N-Value" . In the present study the results of N-Values recorded at 1.5 m, 3.0 m and 6.0 m depth are displayed graphically in different locations of Sri Muktsar Sahib District in Figure 5.



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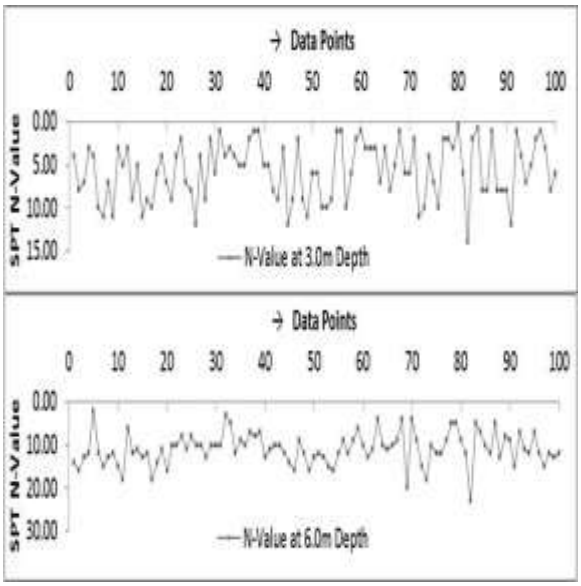

Fig.5. Variation of N-Value at location points at various depths

The variations of SPT N-value for different statistical parameters at different locations for depth 1.5 m to 9.0 m at 1.5 m interval are presented in Table 3.

Table.3 Variation of Statistical Parameters wrt N-Value with Depth (1.5m to 9.0 m at 1.5 m interval)

Statistical Parameter / Depth	1.5m	3.0m	4.5m	6.0m	7.5m	9.0m
Minimum	0.10	0.50	2.00	2.00	4.00	8.00
Maximum	10.00	14.00	19.00	23.00	28.00	28.00
Mean	3.65	5.74	8.57	10.97	13.71	15.69
Range	0.00 - 10.00	0.50 - 14.00	2.00 - 19.00	2.00 - 23.00	4.00 - 28.00	8.00 - 28.00
Standard Deviation	2.90	3.38	3.22	3.70	4.33	4.05
Co-variance	0.79	0.59	0.38	0.34	0.32	0.26
Skewness	0.84	0.24	0.03	0.14	0.62	0.51

3.3 Bulk Density of Soil

Bulk density is the mass of the particles of the soil divided by the total volume. The unit of bulk density is ton/m^3. The Variation of Bulk Density Values at 1.5m, 3.0 m and 6.0 m depth along location points is shown in Figure 6.

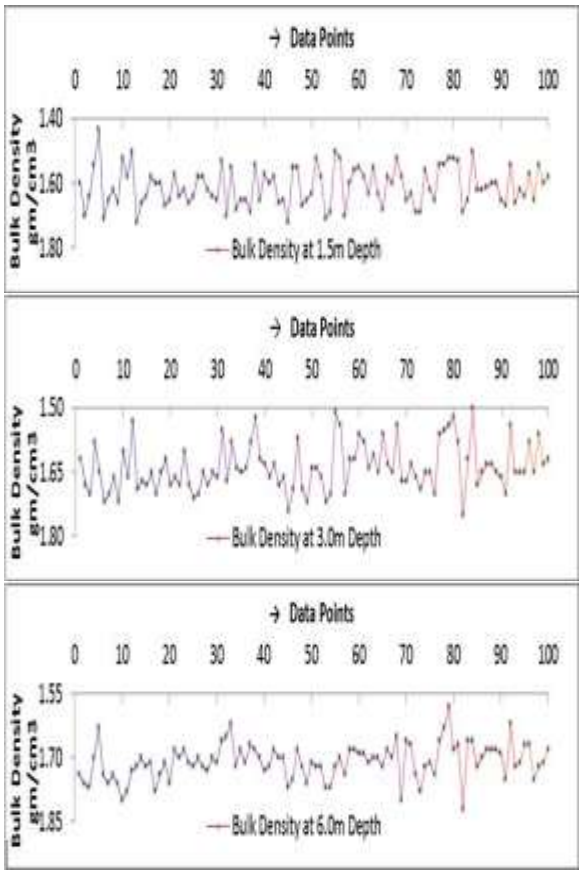

Fig.6 Variation of Bulk Density Values at location points at various depths

The statistical parameter for variation of bulk density at different depths is given in Table 4.

Table.4 Variation of Statistical Parameters w.r.t. Bulk Density value with Depth (1.5m to 9.0 m at 1.5 m interval)

Statistical Parameter / Depth	1.5m	3.0m	4.5m	6.0m	7.5m	9.0m
Minimum	1.43	1.50	1.55	1.58	1.65	1.68
Maximum	1.72	1.75	1.79	1.82	1.83	1.85
Mean	1.61	1.64	1.68	1.71	1.74	1.76
Range	0.90 - 1.72	1.50 - 1.75	1.55 - 1.79	1.58 - 1.82	1.65 - 1.83	1.68 - 1.85
Standard Deviation	0.06	0.06	0.04	0.04	0.04	0.04
Co-variance	0.04	0.03	0.03	0.02	0.02	0.02
Skewness	-0.32	-0.59	-0.58	-0.02	0.29	0.16

3.4 Shear Strength of Soil

The shear strength is the maximum shearing stress that soil derives from friction or from force of attraction among particles. It can be expressed as the angle of internal friction, φ or cohesion, c between particles, or both. The unit of 'c' is force/unit area.

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3.4.1 Angle of Internal Friction (ϕ)

Angle of internal friction or shear angle is a measure of the ability of a soil to withstand a shear stress. Angle of Internal Friction (ϕ) can be determined in the laboratory by the Direct Shear Test or the Triaxial Stress Test. It is the angle (φ), measured between the normal force (N) and resultant force (R), that is attained when failure just occurs in response to a shearing stress (S). Values for angle of internal friction (in degree) at depth of 1.5 m, 3.0 m and 6.0 m are shown in the Figure 7.

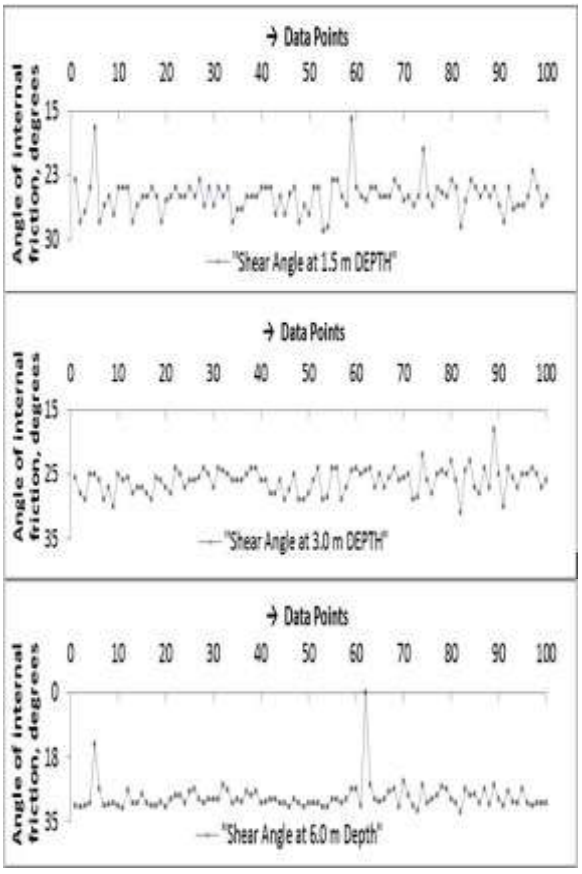

Fig.7 Variation of Angle of Internal friction (ϕ) Values at location points at various depths

The variation in angle of internal friction for different parameters at depths varying from 1.5 m to 9.0 m at 1.5 m interval is shown in Table 5.

Table.5 Variation of Statistical Parameters wrt Angle of Internal Friction (ϕ) values with Depth (1.5m to 9.0 m at 1.5 m interval)

Statistical Parameter / Depth	1.5m	3.0m	4.5m	6.0m	7.5m	9.0m
Minimum	16.00	18.00	18.00	14.00	25.00	26.00
Maximum	29	31	32	32.5	32.5	32.5
Mean	24.96	26.06	27.45	28.77	29.94	30.62
Range	16.00 - 29.00	18.00 - 31.00	18.00 - 32.00	14.00 - 32.50	25.00 - 32.50	26.00 - 32.50
Standard Deviation	1.98	1.99	2.29	2.36	1.55	1.11
Co-variance	0.08	0.08	0.08	0.08	0.05	0.04
Skewness	-1.38	-0.27	-1.36	-2.75	-1.12	-0.89

3.4.2 Cohesion (c)

Cohesion is the force of attraction which holds together the particles within a soil. The cohesion is a term used in describing the shear strength of soils. Cohesion (c) is usually determined in the laboratory from the Direct Shear Test or the Triaxial Shear Test. Its units here are ton/m^2. The variation of cohesion for different locations of bore holes is shown in the form of graphs at a depth of 1.5 m, 3.0 m and 6.0 m in the Figure 8 below.

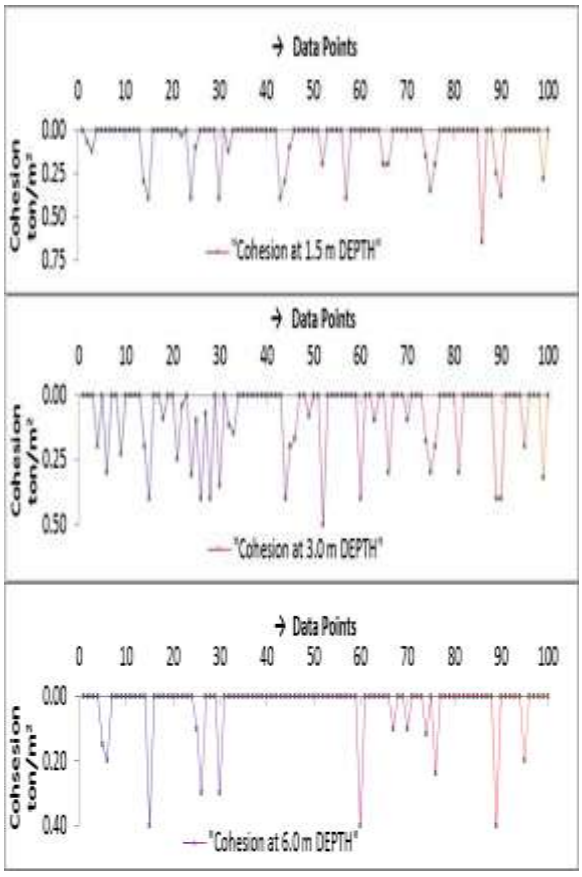

Fig.8 Variation of Cohesion (c) Values at location points at various depths

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The variation of statistical parameter at different depths for cohesion is shown in Table 6.

Table.6 Variation of Statistical Parameters wrt Cohesion (C) values with Depth (1.5m to 9.0 m at 1.5 m interval)

Statistical Parameter / Depth	1.5m	3.0m	4.5m	6.0m	7.5m	9.0m
Minimum	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	0.65	0.5	0.4	0.4	0.4	0.4
Mean	0.06	0.08	0.06	0.03	0.01	0.01
Range	0.00 - 0.65	0.00 - 0.50	0.00 - 0.40	0.00 - 0.40	0.00 - 0.40	0.00 - 0.40
Standard Deviation	0.13	0.14	0.12	0.09	0.06	0.05
Co-variance	2.20	1.68	2.05	2.93	4.21	6.25
Skewness	2.33	1.50	2.02	3.17	4.73	6.47

3.5 Ground Water Table Observation

The underground water level was measured at end of boring at the time of sub-soil investigation from the natural ground surface. From analysis of the results of this study, the values of water table below natural ground surface in different location in study area are presented in Figure 9.

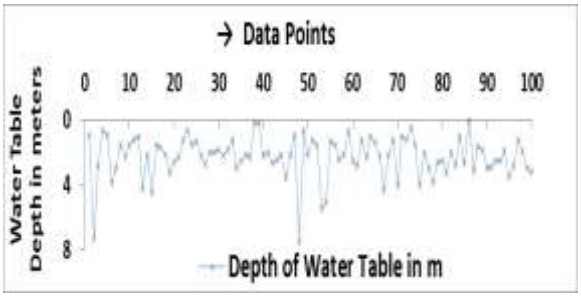

Fig.9. Variation of water table values at location points

There are some locations where water table is at a depth of less than 1.00 m under natural ground level. It can be seen from graph that water table is at a shallow depth of less than 3.0 m at most of the locations.

4. Conclusions

The conclusions drawn are:

1. The soil is almost free from gravel. The soil at shallow depths is silty, containg small quantity of clay at some locations only. As we go deeper the average silt content goes on decreasing and sand content goes on increasing.
2. The average N-Value at 1.5 m depth is 3.65 only, however some improvement is seen in its value, but it is not sufficient.
3. The average bulk density at 1.5 m depth is 1.61 gm/cm^2 showing that soil is loose at shallow depths. The soil is not sufficiently dense as we go deeper .
4. The soil being silty or sandy, gains its strength from shearing resistance. The mean shear angle varies from 24.96^0 to 30.62^0 along the depth.
5. The cohesive soil is noticed at some locations only.
6. The water table is very high at most of the locations.

Hence, it is concluded that the soil strata is weak with respect to all parameters, studied. Water table creates construction problems and it is difficult to provide normal shallow foundations. Deep foundation is comparatively a costly alternate. This paper may guide geotechnical experts for design and management of various development activities in this area.

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