Pakistan Journal of Science (Vol. 64 No. 3 September, 2012)

ENGINEERING GEOLOGICAL CHARACTERIZATION OF LAHORE SOIL, BASED ON GEOTECHNICAL TESTING AND MINERALOGICAL COMPOSITION USING X-RAY DIFFRACTION

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ABSTRACT: Engineering geological investigation was carried out to characterize the soil in the Lahore area. Eleven samples were collected from various locations from 25-50 cm depth. Mostly these samples are from green belt and parks where original alluvial deposits exist. Field and laboratory tests were performed to determine the geotechnical properties by adopting standard test procedures. The mineralogical composition of the soil has been verified with XRD for all the samples. The results indicate that geotechnical properties of the soil are as, density 18.30 KN/m^3, moisture content by oven dried method 11.90%, moisture content by speedy moisture meter 19.25%, specific gravity 2.78, liquid limit 32.46%, plastic limit 21.57%, friction angle 23.07^o, optimum moisture content 8.55% and dry density 3.97g/cm^3. The XRD results clearly shows that the soil in Lahore area is predominately composed of Quartz, Muscovite and Clinoclore as major minerals and can be classified as silty clay.

Key words: Engineering geology, X-Ray diffraction, soil, alluvial deposits, characterization.

INTRODUCTION

Engineering geological soil characterization has unique importance with respect to construction of embankments and other engineering structures. The durability and stability of all the engineering structures are directly dependant on soil type and its response under loading condition. Characterizations of the various soils with respect to mineral composition have been investigated by using X-Ray diffraction and performing soil tests by a number of researchers (Righi and Elsass, 1996., Ghosh and Datta, 2005., Shafique et al., 2009)., Manhaes et al., (2002) described, “The quaternary sedimentary basin of Campos Dos Goytacazes, RJ, Brazil, is a low altitude plain which extends 50 km away from the Atlantic Ocean. Soil from this region has high content of clay minerals. The sediments of this basin were deposited by the Paraiba Do Sul River meandering over its flood plain.” Keeling et al., (2000) made geological characterization by using XRD technique by taking samples as, “The entire samples for each interval was ground in a Tungston Carbide ring mill and sample taken for quantitative XRD.”

According to Barroso et al. (2001), “X-ray spectrometry is a non destructive and multi-elemental technique widely used for elemental analysis. This technique has inherent complexities for quantitative analysis because of matrix effects. Matrix absorption is the most important determining factor when accurate measurements are required for thick samples. Gonzalez et al. (2003) have analyzed the geological materials using X-Ray diffraction to quantify the mineralogy of the volcanic rocks.

Harris and White (2007) stressed x-ray diffraction technique for soil minerals identification and explained its importance as “X-ray diffraction (XRD) is the technique most heavily relied in soil mineralogical analysis. X-ray diffraction is a technique that provides detailed information about the atomic structure of crystalline substances. It is a powerful tool in the identification of minerals in rocks and soils. The bulk of the clay fraction of many soils is crystalline, but clay particles are too small for optical crystallographic methods to be applied. Therefore, XRD has long been a mainstay in the identification of clay-sized minerals in soils”.

Since long researchers are investigating the geotechnical properties of soils to establish and support the engineering structures. Farooq et al., (2010) made geotechnical zoning of Lahore for shallow foundation design based on SPT data and evaluated allowable bearing capacity for each zone. Kibria, et al., (2010) made a comparative study of pile anchor support system for deep excavation in alluvial deposits of Lahore. The mineralogical composition of soil is responsible for all the engineering properties such as specific gravity, shear strength, atterburg limits, petro-physical properties and soil classification. Therefore it is noteworthy for planning point view that the soil be engineering geologically characterized.

Lahore is one of important urban center of the Pakistan with high rate of population growth, where a number of flyovers, multi-story buildings, embankments for ring roads and levee works for protection against floods in Ravi River are under progress. The focus of this paper is to determine the geotechnical engineering properties of the soil of Lahore through a number of tests and also to establish mineralogical composition of surface geology through X-Ray diffraction which greatly influences geotechnical properties.

MATERIALS AND METHODS

Multi disciplinary approach has been adopted to characterize the soil of Lahore, which comprised, field testing, soil sampling, laboratory testing for geotechnical properties and XRD for the determination of mineralogical composition. Globe Soil Characterization Field Protocol, NASA (2005) was used for the physical characterization in the field to estimate structure, color, consistency, texture and carbonate content of the soil. Soil sampling was carried out by removing the grass roots and vegetation from the depth of 25 cm to 50 cm to obtain the intact samples from the alluvial deposits.

Geotechnical properties were determined for all the soil samples by following standard procedures recommended by ASTM. The major geotechnical tests performed are density, moisture content, specific gravity, permeability, liquid limit, plastic limit, standard compaction test, direct shear test and grain size analysis. On the basis of these tests, soil type is determined.

X-Ray diffractometer model, "Panalytic X-ray Diffractometer with X'Pert Software" was used for identification of crystalline solids based on their atomic structure. The samples were prepared according to the requirement of instrument manufacturer. Oven dried samples were grinded and sieved to obtain -400 mesh size powder which was placed in dish before positioned in detector chamber. The system uses Cu K radiation with a wavelength of 1.54 A^0. Every mineral has its own diffraction peaks which are used to identify it.

Fig. 1. Location map of study area indicating the soil sampling points.

RESULTS AND DISSCUSSION

On the basis of Field Protocol NASA (2005), the soil was physically characterized by performing field testing; the results are given in Table 1. Samples collected from various locations, show different properties. The soil structure is mostly composed of granular type, however, at few places it is platy type. The consistency of the surface soil is graded as friable. The presence of carbonate contents is reflected by most of the samples. The soil can be classified as silty clay.

On the basis of lab testing to establish geotechnical properties a number of tests were performed on all the samples, the results are presented in Table 2. The average values of geotechnical properties for density

18.30 KN/m^3, moisture content by oven dried method 11.90%, moisture content by speedy moisture meter 19.25%, specific gravity 2.78, liquid limit 32.46%, plastic limit 21.57%, friction angle 23.07^o, optimum moisture content 8.55% and dry density 3.97g/cm^3. These results have been compared with the reported result for geotechnical properties. Farooq et. Al., (2010) described their conclusion as, “The subsurface soils of the study area basically consists of 1 to 7 meter thick top stiff to very stiff, cohesive clayey Silt/Silty Clay”. This classification presented for soil of Lahore area is in good agreement with our findings.

Table 1. Physical characterization of soil samples from Lahore based on Field Protocol NASA (2005).

Sample No	Location	Structure	Color	Consistency	Texture	Carbonates
R-1	New Lecture Theaters (UET)	Granular	Dark Reddish Brown	Friable	Clay	Strong
R-2	Stadium (UET)	Granular	Dark Reddish Brown	Friable	Sandy Loam	Strong
L-1	American National School	Granular	Reddish Brown	Friable	Sandy Loam	Strong
L-2	The Lahore Lyceum	Platy	Dark Brown	Friable	Loam	Slight
L-3	Jail Road	Granular	Dark Brown	Friable	Silty Clay	Slight
L-4	F.C College	Granular with Quartz	Dark Brown	Friable	Loam	Strong
L-5	Preston University	Platy	Strong Brown	Friable	Silty Clay	Strong
L-6	Punjab College	Granular	Strong Brown	Friable	Clay Loam	Strong
L-7	PU Jamiah Masjid	Single Grain	Brown	Friable	Loam	None
L-8	Wafaqi Colony	Granular	Dark Reddish Brown	Friable	Silty Clay	Slight
L-9	Expo Center	Granular	Dark Reddish Brown	Friable	Silty Clay	Slight

Table 2. Geotechnical properties of the soil in Lahore based on lab tests.

Sample No	Location	Density (KN/m^3)	Moisture Content		Specific Gravity (G_s)	Permeability (cm/sec)	Atterberg’s limit		Standard Compaction Test		Soil Type
			Oven Dry (%)	Speedy Moisture meter (%)			Liquid Limit (%)	Plastic Limit (%)	Optimum moisture content (%)	Dry density (g/cm^3)	
R-1	New Lecture Theaters (UET)	20.27	16.55	25	3.1	----	29.70	21.04	3.2	4.94	----
R-2	Stadium (UET)	16.15	2.7	9.65	2.3	$1.30 x 10^{-6}$	35.5	25.17	----	----	Silty Clay
L-1	American National School	19.55	9.2	16.82	2.7	$5.40 x 10^{-5}$	31.83	21.61	----	----	Uniform Silt
L-2	The Lahore Lyceum	17.93	9.4	4.60	2.6	$1.67 x 10^{-7}$	33.93	20.74	----	----	Clay
L-3	Jail Road	19.34	18.6	28.87	2.7	$3.61 x 10^{-6}$	38.43	13.90	15	3.76	Silty Clay
L-4	F.C College	17.88	14.6	21.95	2.7	$2.56 x 10^{-7}$	26.08	22.63	----	----	Clay
L-5	Preston University	18.25	13.7	9.17	2.8	$4.67 x 10^{-6}$	30.91	20.25	----	----	Silty Clay
L-6	Punjab College	14.88	5.2	8.70	3	$3.65 x 10^{-6}$	31.98	24.56	----	----	Silty Clay
L-7	PU Jamiah Masjid	15.66	5.5	9.17	2.9	$2.39 x 10^{-7}$	34.09	21.09	16	3.72	Clay
L-8	Wafaqi Colony	21.63	16.7	25.63	2.9	----	29.10	20.22	----	----	----
L-9	Expo Center	19.85	18.8	34.41	2.9	----	35.56	26.11	15	3.47	----
Average Values		18.31	11.90	17.63	2.78	$1.67 x 10^{-7}$ --- $5.40 x 10^{-5}$	32.46	21.57	12.3	3.97	

Mineralogical composition of the soil is very important. It has great bearing on the engineering properties. The XRD method is one of the very useful methods, which is applied to find out the mineralogical composition of soil. All the samples were analyzed with X-Ray diffraction to determine the mineralogical composition of the soil, the results indicate that the major mineralogical composition for all the samples remain similar. The results from three selected locations are given in Table 3. Our results for mineralogical composition determined by XRD are comparable with the internationally reported values (Smyth et al., 1997) for the similar crystal structures. The intensity curves and stick pattern for all the three major minerals, Quartz, Muscovite and Clinochlore is given in Figure 2 and 3 respectively.

Table 3. Mineral composition of soil samples for three selected locations from study area.

Location	Ref. Code	Compound Name	Chemical Formula	Score	Scale Factor
New Lecture Theater UET	00-003-0849	Muscovite	$H_4K_2 (Al,Fe)_6Si_6O_{24}$	52	0.087
	01-079-1270	Clinochlore	$(Mg_{2.96}Fe_{1.55} Fe_{.136} Al_{1.275}) (Si_{2.622}Al_{1.376}O_{10}) (OH)_8$	50	0.105
	01-085-0504	Quartz	SiO_2	75	0.615
Sabzazar	00-046-1045	Quartz, syn	SiO_2	73	0.999
	01-079-1270	Clinochlore	$(Mg_{2.96}Fe_{1.55}Fe_{.136}Al_{1.275}) (Si_{2.622}Al_{1.376}O_{10}) (OH)_8$	38	0.229
	00-003-0849	Muscovite	$H_4K_2(Al,Fe)_6Si_6O_{24}$	38	0.058
Bagh-e-Jinnah	00-046-1045	Quartz, syn	SiO_2	71	1.012
	00-003-0849	Muscovite	$H_4K_2(Al,Fe)_6Si_6O_{24}$	44	0.061
	01-079-1270	Clinochlore	$(Mg_{2.96}Fe_{1.55}Fe_{.136}Al_{1.275}) (Si_{2.622}Al_{1.376}O_{10}) (OH)_8$	35	0.165

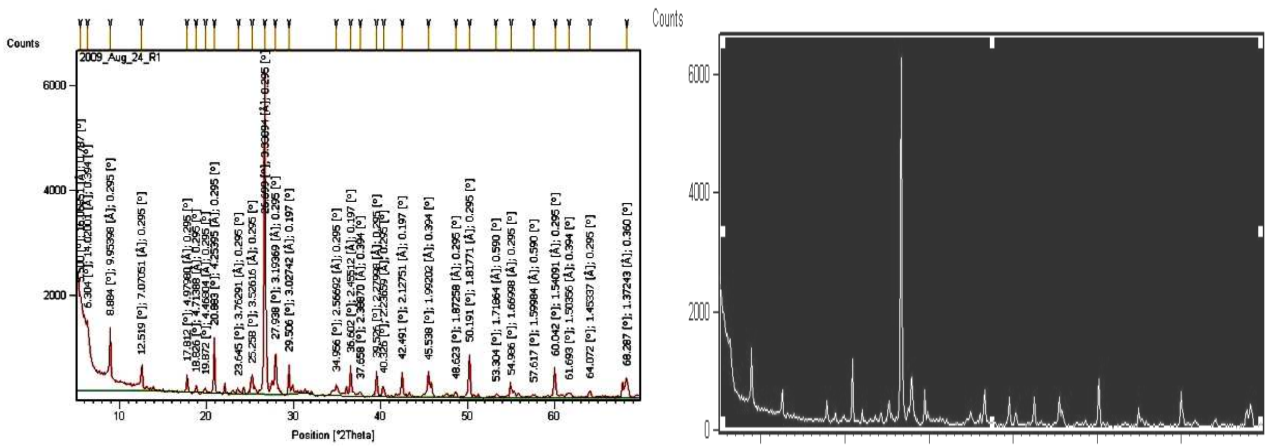
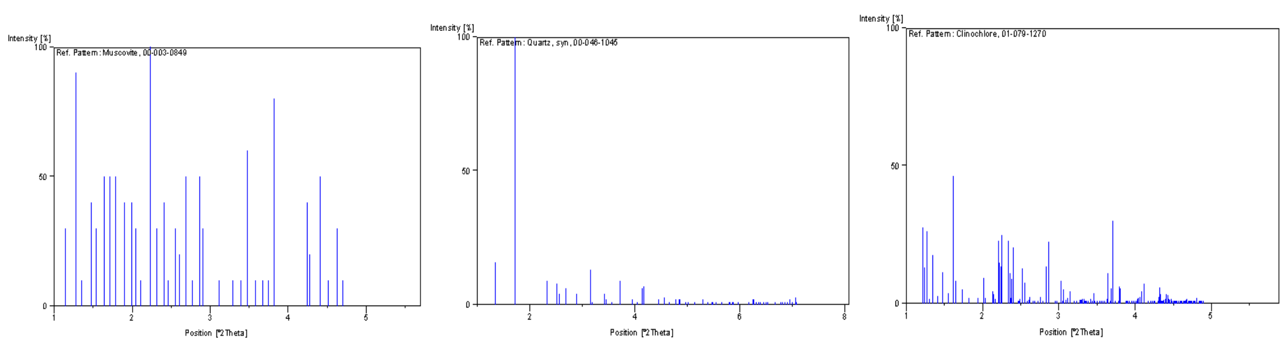


Fig. 2. Intensity Curves for soil sample from one selected site, New Lecture Theaters UET



Stick pattern (Muscovite) Stick pattern (Quartz, syn) Stick pattern (Clinochlore)

Fig. 3. Stick pattern developed by XRD for major minerals for Lahore soil.

Conclusions: The geotechnical properties and mineralogical composition of the soil, determined by field & laboratory testing and XRD, confirms that the Lahore soil is composed of silty clay. The X-Ray diffraction provides an easy and fast methodology for mineral identification in soil and its geological origin and depositional environment history can be depicted. The major mineral composition for Lahore soil is Quartz, Muscovite and Clinochlore, which shows that the alluvial deposit received sediments from metamorphic origin.

Acknowledgement: The authors are grateful to the University of Engineering and Technology Lahore for providing the research facilities. Special thanks are to Dr. Anwar Latif, Department of Physics for his support in XRD testing of the samples

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