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# A STUDY ON GEOTECHNICAL CHARACTERIZATION OF RED SOIL OF DHAKA CITY OF BANGLADESH

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## Abstract

Generally red soils characters are different from other soils. In Bangladesh, a very few red soils are characterized in geotechnical point of view. However, it is necessary to massive study on it. From this point of view, a study has been undertaken to characterize the red soils from their properties which assist the engineer for design of structure of foundation on red soil and same strata of red soil in other area. From this study the iron concentration have been found about 27.8% for red soils with 38% clay whereas soils with 4% clay contain iron concentration of about 12.9%. That is soils containing high percentage of clay have more iron and manganese concentration in compare with soils containing low percentage of clay. The pH values have been varied from 5.6 to7.026. It indicates the soils are strongly acidic and sometime it is neutral. The natural moisture content varies from (8.90-28.99)% whereas plasticity ranges from (28-32)% and shrinkage limit varies from 7% to 22%.The consistency ranges from stiff to very stiff and the red soils have contained particles sand (12-25)%, silt (39-49)% and clay (26-39)%. The dry density of these soils varies from (14-16) kN/m$^3$ and the specific gravity of the cohesive soil varies from (2.675-2.684) and of the non-cohesive soil varies from (2.642-2.653). The study finds that the natural moisture content is not adequate to fulfill engineering needs. Plasticity as well as stiffness of red soil should also be considered to draw engineering attention for construction works.

**Keywords:** Dhaka city**,** Red soils, geotechnical characterization, iron content, alkali content.

## Introduction

*Geological Formation of Bangladesh*

Brammer (1996) classified Bangladesh as three main geological formations of area. Tertiary sediments in the northern and eastern hills; the Madhupur clay of the Madhupur and Barind tracts in the center and west; and recent alluvium underlying the floodplain and estuarine areas which occupy the remainder of the country. The Madhupur and Barind tracts which together occupy about 8 percent of the country are underlain by the Madhupur Clay. The same formation may occur also on the so-called Akhaura Terrace and on the summit of the Lalmai hills. Unweathered Madhupur Clay is remarkably homogeneous in appearance throughout its extent, both vertically and laterally. It comprises a layer of unconsolidated clay about 10m thick near Dhaka, but it apparently becomes thin towards the east and is much thicker in the west of the Barind tract.

*Nature of Red Soil*

Siyanbola Samuel Malomo, (1977) expressed that red soils are tropically weathered soils with a high concentration of sesquixides of iron and/or alumina. They have correspondingly low content of alkalis and alkaline earths. They exist in wide ranges of chemical composition. Silica content varies from low to medium and exists usually as kaolinite, whenever it is found in substantial amounts.

Mishra & Suresh (2017) explained that red soils are formed due to weathering of igneous rocks. They are deficient in nutrient sand humus and have low water holding capacity. Red soils form the second largest soil group in India. The red color is mainly due to the presence of iron oxides.

These soils are found with low rainfall and they are not capable of retaining moisture. Red soil possesses lower strength compared to other soils due to its porous and friable structure.
They also worked to improve the engineering and strength properties of these soils by adding some additives to these soils. They use plastic products such as polythene bags, bottles, chairs, toys etc. which creates much environmental problems and increases day by day. They observed that the effect of addition of various percentages of waste plastic bag strips enhance the properties of red soil. Hence the use of waste plastics is a means of soil stabilizer and an economical utilization since there is scarcity of good soil for different engineering application.

*pH*

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Soils throughout the world exhibit different pH values. Because of the variations in climatic conditions, geology, land use, fluctuations in groundwater tables, etc. pH is an important factor for the chemical properties of the soil and can impact cation-and anion-exchange capacity by altering the charge on the soil colloids. Although some soils may exhibit electropositive charge, electronegative charge predominates in most soils. (https://www.sciencedirect.com)

Saroja & Visakhapatnamp (2017) studied on the investigation in the red soils of Visakhapatnam region as the region is significant with red soil deposits. They have been verified red soils collapsibility and effective utilization in geotechnical applications based on these values. They conclude that soil compacted at low dry densities and low water content exhibited high degree of collapsibility. They also conclude that saturation destroys the bond between sand particles by dissolved clay particles and salts of oxides leads to increases the collapsible behavior. They recommend that structures located on this soil deposit need a special attention to understand the behaviour of the soil to avoid distress.

Mohanalakshmi et al (2016) has studied on the effect of wollastonite ($Casio_3$) on geotechnical properties of soil. They observed that addition of wollastonite improves the properties of the red soil. It increases of maximum dry density (MDD) by the addition of wollastonite enhances the strength of the red soil. It also improves unconfined compressive strength results in the reduction of difficulties in foundation work. They also found that the addition of wollastonite to the red soil lead to the reduction of optimum moisture content (OMC) and increases of MDD (maximum dry density).

John et al (2017) studied the soil properties in presence of iron as iron is one among the oldest heavy metals existing on earth and the presence of iron in soil can also result in the alteration of soil properties. Their study deals with the presence of iron and how iron can alter the liquid limit, plastic limit and hydraulic conductivities of two soils; one of low plasticity (CL) and another of high plasticity (CH). They observed that an increase in liquid limit of 41% was observed for CL clay and a decrease by 50% for CH clay. The plastic limit decreased by 35% for CH clay and increased by almost 85% for CL clay. They also observed that permeability decreased by two orders, i.e., from $10^{-7}$ to $10^{-9}$ cm/sec on the addition of the contaminant, then as the concentration of contaminant increased, a slight increase in permeability was observed, but still lower than that of virgin soil.

Bangladesh is occupied by red soils of about 8% of the country. Red soil is formed due to weathering of igneous rocks with a high concentration of iron. They have correspondingly low content of alkalis and alkaline earths. Red soils possess lower strength and different properties compare to other soils due to its porous and friable structure. Their character is different from other soil. That's why an attempt has been made to undertake the study. In order to characterize the red soils of Dhaka city of Bangladesh, data have been collected from soil testing report of River Research Institute (RRI).

Though Bangladesh is occupied by red soil of small area of the country but their characters are different from any other soils in engineering practice however, research and defining character of red soils in engineering aspect is limited. Under such circumstances, an attempt has been made to characterize the red soils of Dhaka city of Bangladesh from their properties which assist the design engineer for other structure of construction on red soil and same soil strata in the other area.

## Objectives

The specific objectives of the study have been described below-

- to determine geotechnical properties of red soil in the study area
- to determine iron and some other chemical properties of red soils in the study area.
- to characterize the red soil as geotechnical point of view.
- to draw engineering attention on geotechnical properties of red soils for construction works.

## Methodology

The soil testing parameters are collected from the soil testing report of geotechnical research directorate (GRD) of River Research Institute (RRI).The sample was sent by SDS Engineering and Construction through boring and field investigation from the site Kurmitola, Dhaka Cantonment, Dhaka which has been shown in Fig-1. The sub-soil has been explored up to 15m and the samples were collected at an interval of 1.5m depth. The boring log of the hole has been presented here recording ground water table, reduced level, SPT value, colour as per depth which provide field investigation synopsis.

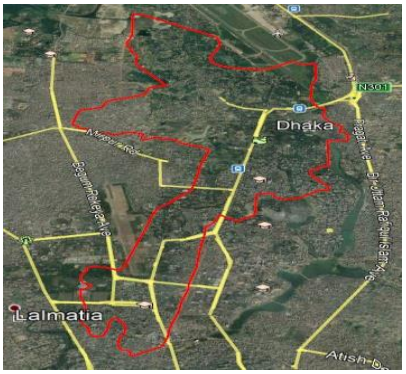


**Fig. 1:** Dhaka Cantonment area (red line).

**Table 1.** Showing soil profile of field investigation and ground water level in accordance with depth and its reduced level

| Sample ID | Depth (m) | Ground Water Table (m) | Soil Description | Colour | Reduced Level (m) |
|---|---|---|---|---|---|
| D-1 | 1.5 | 2.2-6.90 | Medium to stiff cohesive soil | Red | 10.006-10.298 |
| D-2 | 3.0 | | | | |
| D-3 | 4.5 | | | | |
| D-4 | 6.0 | | | | |
| D-5 | 7.5 | | | | |
| D-6 | 9.0 | | | | |
| D-7 | 10.5 | | Medium Dense Non-cohesive soil | Red | |
| D-8 | 12.0 | | | | |
| D-9 | 13.5 | | | | |
| D-10 | 15.0 | | | | |

*Laboratory Investigation*

Laboratory investigation is performed in RRI Soil Mechanics Laboratory and the tests are conducted in the same. In order to investigate geotechnical properties of the soils all the samples are visually examined and the representative soil samples are tested. One of the laboratory tests has been shown in the Fig-2. The respective results are shown in Table- 5. In this study, iron content is especially determined as red soil is responsible for its colour in accordance with depth and noticeable physical and index properties. The photograph of the selected four soils is shown in Fig-3. The chemical test has been conducted for selected red soils in the Chemical Laboratory and their respective results are shown in the Table-6 with their respective particle size.

**Fig. 2.** Plasticity (Liquid limit and Shrinkage limit) measurement test

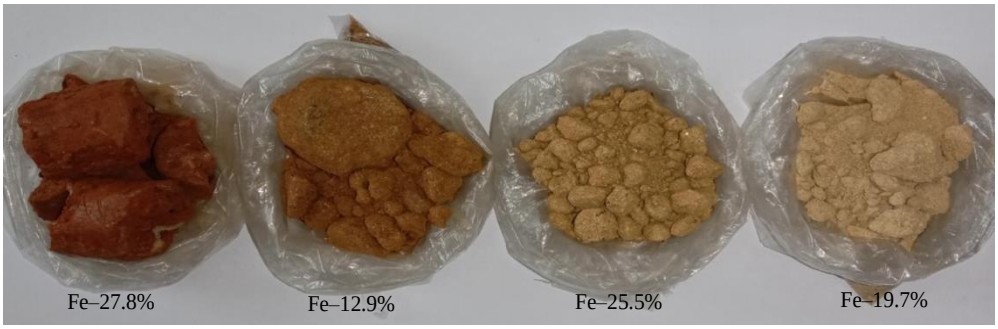


**Fig. 3.** A view of the selected typical red soils are shown up in accordance with iron content

**Table 2.** Relation of Consistency of Clay,Number of Blows N on Sampling spoon and Unconfined Compressive Strength,$q_u$ in tons per sq ft

| Consistency | Very soft | Soft | Medium Stiff | Stiff | Very stiff | Hard |
|---|---|---|---|---|---|---|
| Unconfined Compressive Strength,$q_u$ (TSF) | 0-0.25 | 0.25-0.50 | 0.50-1.00 | 1.00-2.00 | 2.00-4.00 | >4.00 |
| Compressive Strength($kN/m^2$) | 0-23.94 | 23.94-47.88 | 47.88-95.76 | 95.76-191.52 | 191.52-383.04 | >383.04 |
| Standard Penetration Resistance-'N' | 0-2 | 2-4 | 4-8 | 8-16 | 16-32 | >32 |

**Table 3.** Density Index ($I_D$) of Sand

| Number of blows | Density Index(ID) |
|---|---|
| 0-4 | Very loose |
| 4-10 | Loose |
| 10-30 | Medium Dense |
| 30-50 | Dense |
| Over 50 | Very dense |

(**Source:** Terzaghi & Peck, 1948)

**Table 4.** Soil reaction is measured by laboratory or field tests and expressed on a logarithmic scale referred to as pH. Degrees of acidity and alkalinity corresponding with particular pH levels are given below-

| | | | |
|---|---|---|---|
| Extremely acid | Below pH 4.5 | Neutral | pH 6.6-7.6 |
| Very strongly acid | pH 4.5-5.0 | Mildly alkaline | pH 7.4-7.8 |
| Strongly acid | pH 5.1-5.5 | Moderately alkaline | pH 7.9-8.4 |
| Medium acid | pH 5.6-6.0 | Strongly alkaline | pH 8.5-9.0 |
| Slightly acid | pH 6.1-6.5 | Very Strongly alkaline | pH>9.0 |

**(Source:** Brammer, 1996)

## Results and Discussion

*Field Investigation Result*

The data have been collected from the field investigation record. The graph is plotted as depth versus SPT-value. In graph depth is plotted as abscissa and SPT-value as ordinate.

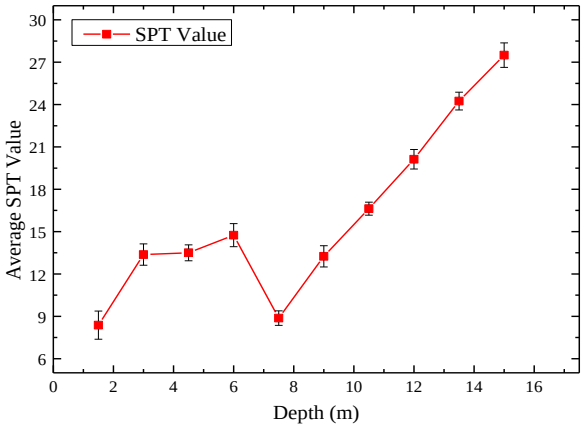


**Fig 4.** Graph showing the SPT value in accordance of depth

From the graphical presentation of field investigation result it has been observed that the SPT-value has been increased with the increases of depth. However, SPT-value decreases suddenly with the increases of depth at certain layer of soils. After that SPT value smoothly increases with the increases of depth.

*Laboratory Investigation Result*

**Table 5.** Showing the laboratory test results of physical and index parameters of cohesive and non-cohesive soils

| Name of the parameter | Location | |
|---|---|---|
| | Kurmitola, Dhaka Cantonment, Dhaka | |
| | Cohesive Soil | Non-cohesive Soil |
| Depth, in m | 0-7.50 | 9-15 |
| Colour | Red | Red |
| SPT value | 4-19 | 11-29 |
| Natural Moisture Content, NMC in (%) | 8.90-28.99 | |
| Liquid Limit, LL in (%) | 56-62 | |
| Plastic Limit,PL in(%) | 28-30 | |
| Plasticity Index,PI in (%) | 28-32 | |
| Shrinkage Limit, SL in (%) | 7.049-21.56 | |
| Organic Content in (%) | 5.77 | |
| Wet Unit Weight,$\gamma_w$ in kN/m$^3$ | 18.51 | |
| Dry Unit Weight $\gamma_d$ in kN/m$^3$ | 15.13 | |
| Specific Gravity, Gs | 2.675-2.684 | 2.642-2.653 |
| Compression index, Cc | 0.147 | |
| Hydraulic Conductivity, k in cms$^{-1}$ | 7.65×10$^{-4}$ | 9×10$^{-2}$ |
| Unconfined compressive Strength, $q_u$ (kN/m$^2$) | 198.70 at 8% strain | |
| Cohesion, c (kN/m$^2$) | 90.4 | |
| Angle of internal friction $\phi$ (degree) | 19 | |
| Sand (%) | 12-25 | 56-64 |
| Silt (%) | 39-49 | 28-30 |
| Clay (%) | 26-39 | 7-16 |

**(Source:** Report No. Soil- 11 (2018-19)

**Table 6.** Showing the results of laboratory test of iron, manganese, chloride, sulphate content and pH value in accordance of particle size

| Location | Depth (m) | Colour | Fe (%) | Mn (%) | pH | $Cl^-$ (mgkg$^{-1}$) | $SO_4^{2-}$ (mgkg$^{-1}$) | Percentage of soil | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Clay (%) | Silt (%) | Sand (%) |
| Kurmitola, Dhaka | 4.5 | Red Cohesive | 27.8 | 0.564 | 5.66-7.08 | 110 | 115 | 38 | 44 | 18 |
| | 7.5 | | 25.4 | 0.421 | | | | 26 | 40 | 34 |
| | 9 | Red Non-Cohesive | 12.9 | 0.276 | | | | 4 | 26 | 70 |
| | 13.5 | | 19.7 | 0.378 | | | | 8 | 30 | 62 |

**(Source:** Report No. Soil-11 (2018-19)

In graphical presentation, a plot of clay percentage versus NMC has been shown in Fig. 5(a).The graphs have been plotted altogether with clay percentage versus iron and manganese concentration in Fig.5 (b). Similar graphs have been plotted separately for manganese and iron which have been shown in Fig. 5(c) and Fig.5 (d) respectively.

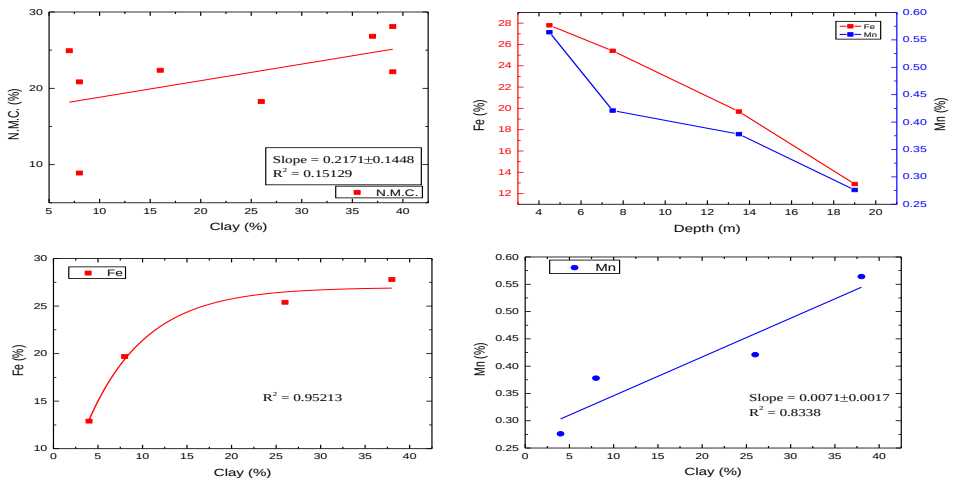


**Fig. 5.** Graph showing (clock wise) (a) the clay percentage with NMC (b) the depth vs. Fe and Mn concentration (c) the clay percentage vs. Mn and (d) the clay percentage vs. Fe concentration

From the result of Table and graphical presentation it has been found that the colour of the soil is red which contain more iron and as well as more percentage of clay. The percentage of iron increases with the increases of clay percentage. The manganese increases with the increases of iron. The consistency in terms of plasticity is high plastic as well as shrinkage limit varies. The stiffness has been varied from medium stiff to very stiff.

In the layer of 4.5m depth, it has been found that iron contains 27.8ppm where clay contains 38%,silt 44% and sand 18%. Manganese contains 0.564ppm, Chloride 110mg/kg and Sulphate 115mg/kg in which pH varies from 5.66-7.085.The soil contains organic matter in

the percentage of 5.77%. The character of the soil is red cohesive and high plastic in terms of plasticity and stiff to very stiff in terms of consistency. The moisture content varies from (22-23) %.The dry density varies from (14-16) $kN/m^3$.The specific gravity of the soil is 2.684.

In the layer of 7.5m depth, it has been found that iron contains 25.4ppm where clay contains 26%,silt 40% and sand 34%. Manganese contains 0.421ppm. The character of the soil is red to brown cohesive and high plastic in terms of plasticity and the sample is medium stiff to stiff in terms of consistency. The moisture content varies from (26-28)%. The specific gravity of the soil is 2.683.

In the layer of 9m depth, it has been found that iron contains 12.9ppm where soil contains clay 4%,silt 26% and sand 70%. The layer contains 0.564ppm of Manganese. The character of the soil is red to brown non-cohesive. The soil contains high percentage of sand and it has no plasticity with medium dense in terms of density index. Colour of soils showing the results of iron content. The specific gravity of the soil is 2.654.

In the layer of 13.5m depth, it has been found that iron contains 19.7ppm where the soil contains clay 8%, silt 30% and sand 62%.The character of the soil is light brown non-cohesive. It has no plasticity as soil contains high percentage of sand and medium dense in terms of density index. Here colour showing the result of content of iron. The layer contains 0.378ppm of Manganese. The specific gravity of the soil is 2.646.

From the graphical presentation of iron and manganese concentration in depth it has been observed that iron and manganese concentration is lessen with increases of depth. The exception has been occurred in case of 9m depth. In this layer, the iron and manganese concentration has been lessened where the soil contains high percentage of sand.

## Conclusion

In this study, a number of red soils are tested in the laboratory for determining engineering properties of soil as well as chemical properties. Representative four soils are selected for determining iron and manganese content and chemical tests. However, chloride and sulphate are tested for one layer soil only. From this study it is observed soils containing high percentage of clay have more iron and manganese concentration in compare with soils containing low percentage of clay. The pH of the soils has varied from acid level to neutral level. Natural moisture content has not increased as their plasticity. The stiffness has varied from medium stiff to very stiff. The very stiff soils are brittle if there is no sufficient natural moisture content.

## Recommendation

Red soils are the composition of physical and chemical properties. For its characterization, a vast analysis of geotechnical and chemical knowhow are very important. In this study, a tiny attempt has been undertaken for knowing red soils of Dhaka city of Bangladesh. Though it will be very crucial to characterize the red soils with a very few test and analysis. However, it is a familiarization with red soils. Here it is recommended that red soils properties are not suitable to foundation of construction. Therefore, it is very essential to analyze all the physical and chemical properties of red soils of Bangladesh minutely and hence it can be managed the red soils as per need.

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