Engineering and Agricultural Properties of Black Cotton and Red Sandy Soil

** Barnali Ghosh*

Abstract

Soils can differ largely from location to location. Soil colour depends on organic matter and mineral content and is influenced by drainage. Different types of soil are sand, silt, and clay but most soils are composed of a combination of different types. The characteristic strength of soil, however, is its shear strength, which can be found from two parameters, that is, shear strength parameters – cohesion, and the angle of internal friction (ø). Soils can be acidic, alkaline or neutral. Soil pH influences nutrient absorption and plant growth. Some plants like potatoes grow well in a more acidic soil (pH of 5.0–6.0). Carrots and lettuces prefer soils with a neutral pH of 7.0. In this paper the properties of black cotton soil (collected from Gulbarga, Karnataka) and red sandy soil (collected from Doddaballapur, Karnataka) are studied, and their engineering and agricultural properties are discussed.

Keywords : Angle of internal friction, black cotton soil, cohesion, pH, red sandy soil

I. INTRODUCTION

Among different types of clay soils, there are many that swell (heave) considerably when water is added to them or absorbed and shrink with loss of water. This type of soil is termed as expansive [1]. Black cotton soil in India is found in states like Tamil Nadu, Andhra Pradesh, and Karnataka. Black soil is extremely fine and clayey and has the capacity to hold a lot of moisture. It becomes sticky in the rainy season and develops cracks when dry. Black soil is good for producing cotton, oilseeds, wheat, linseed, millets, and tobacco. It is a highly clayey soil. The black color in black cotton soil is due to the presence of titanium oxide in small concentration. It has the tendency of expanding by absorbing water and then it swells and becomes soft and loses strength. They shrink in volume and develop cracks during summer. So for any construction on this soil, it is required to stabilize the soil.

Red soils consists of the third largest soil group of India. These soils can be found around Tamil Nadu, Karnataka, southern Maharashtra, Chhattisgarh, Telangana, Andhra Pradesh, Odisha, Jharkhand, and scattered patches are also seen in West Bengal, Uttar Pradesh, and parts of Rajasthan. Red soil has the least water holding capacity and has very good amount of iron (responsible for red colour), and phosphorus that is very harmful for the crops.

II. ENGINEERING PROPERTIES

A. Atterberg Limits of Soil

The Atterberg limits are primary measures of the nature of a fine grained soil. Depending on the water content of the soil, it has four states namely, solid, semi-solid, plastic, and liquid. In each state the consistency and behavior of a soil and its engineering properties are different.

Atterberg Limits tested in laboratory for black cotton (BC) and red soil is shown below. The test shows that the liquid limit for BC soil sample ranges around 58. Plastic Limit for the same ranges around 30, and Plasticity Index of BC Soil is found to be around 28. Soils with high plasticity index of more than 25 are expansive clays that make poor road beds or foundations [4]. Liquid limit for red sandy soil sample ranges around 45. Plastic limit for the same ranges around 28 and Plasticity Index of red sandy soil is found to be around 17.

Manuscript Received: September 8, 2019; Revised: September 22, 2019; Accepted: September 25, 2019. Date of Publication: November 5, 2019.

* B.Ghosh is Associate Professor with East Point College of Engineering and Technology, Jnana Prabha, Virgo Nagar Post, Bangalore – 560 049. (email : barnalighosh08@gmail.com)

DOI : 10.17010/ijce/2019/v2i2/149071

TABLE I.
ATTERBERG LIMITS OF BLACK COTTON AND RED SANDY SOIL IN PERCENTAGE

Soil Type	Liquid Limit	Plastic Limit	Plasticity Index
Black Cotton	58.6	30.3	28.3
Red Sandy	45.4	28.1	17.3

TABLE II.
RELATION BETWEEN SWELLING POTENTIAL WITH PLASTICITY INDEX [2]

Plasticity Index (PI)	Swelling Potential (%)
0-15	Low
10 - 35	Medium
20 - 55	High
35 and above	Very High

Tables I shows the Atterberg limits of black cotton and red sandy soil. Table II shows the relation between swelling potential and plasticity index.

B. Standard Proctor Compaction Test

Type of soil has a great influence on its compaction properties. Basically, clays and silt offer higher resistance to compaction and coarse grained soils are known for easy compaction. The coarse-grained soils produce higher densities compared to clays. A well-graded soil may be compacted to higher density [3].

Standard proctor compaction test was carried out as per IS:2720 (Part 29)-1975 for different percentage of water content. The corresponding values of dry density were observed for 10 %, 12%, 14%, 16% ,18%, and 20% moisture content in the soil specimens. Optimum moisture content (OMC) and maximum dry density (MDD) found for black cotton soil is 21% and 1.92 g/cc respectively, and for red sandy soil OMC and MDD is found to be 14.9% and 1.89 g/cc respectively.

C. Shear Tests

The shear strength of soil is the resistance to deformation by shear displacement of soil for the action of shear stress. The shear strength of soil can be divided into two components known as Shear Strength parameters; the Cohesion (c) and the angle of internal friction (ϕ). To find out the value of (c) and (ϕ), unconfined compression tests have been conducted for both black cotton and red sandy soil. The UCS tests have been conducted in accordance with IS: 2720 (Part 10) – 1991. The tests were conducted on the samples compacted at optimim moisture content and maximum dry density. Angle of internal friction for black cotton soil was found to be (Φ) 20^0 and cohesion (c) 36.5 kN/m^2 and 32^0 and 28.3 kN/m^2 for red sandy soil.

III. AGRICULTURAL TESTS

A. Soil pH (Soil Reaction)

Soil pH refers to a soil's acidity or alkalinity and is the measure of hydrogen ions (H+) in the soil (addressed in NM 8). A high amount of H+ corresponds to a low pH value and vice versa. Soil pH is a master variable that affects a wide range of soil properties - chemical, biological, and indirectly even the physical. Technically, if pH is 7.0 it is called as neutral, <7.0 acidic, and > 7.0 alkaline. But, when pH is < 6.3 then the crop is affected. Hence, in practical if soil pH is 6.5 – 7.5, it is called normal soil pH < 6.5 is acidic soil. and pH > 7.5 as alkaline soil (Table III).

Where aH+ = activity of H+ ions

However, it is more convenient to use H+ ion concentration rather than activity then the equation becomes

$$pH = \text{Log} \frac{1}{aH^+} = -\log aH^+$$

TABLE III.
NATURE OF SOIL

pH	Nature	Rating
< 6.5	Acidic	Requires liming
6.5 - 7.5	Normal soil	No treatment
7.5- 8.5	Saline or calcareous soil	Require leaching of soluble salts
> 8.5	Alkaline reaction	Requires an amendment

TABLE IV.
SOIL TYPE DETAILS

Soil Type	Black Cotton	Red Sandy
Location	Gulbarga	Doddaballapur
Weight of the sample	10g	10g
Volume of water added	25 ml	25 ml
pH of the soil	6.5	7.5

$$(H^+) = 10^{-pH}$$

Here, pH test is done with the help of a pH meter and reagents used as standard buffer solutions, pH 4.0, 7.0, and 9.2.

B. Interpretation

1) Determination of Soil pH (soil reaction)

Table IV shows the determinants.

2) Available Nitrogen Content in Soil

Nitrogen is a very important component for all life. It is a part of many cells, amino acids, proteins, and even our DNA . It is also needed to make chlorophyll in plants, which is used in photosynthesis.

Nitrogen as free gas (N_2) can't be used by many living beings. It has to be converted or fixed through a process called fixation. Nitrogen can be fixed biologically through lightning and industrially. The available nitrogen in a soil represents a fraction of the total nitrogen that can be absorbed by plants. This constitute on an average, only 0.5 – 2.5 % (rarely 5%) of the total Nitrogen in soil at any given time.

Here, available Nitrogen content is found out with the help of a *Kjeldahl distillation set* (Fig. 1) and *reagents* used are 1 ml of 1N H_2SO_4. The amount of available N is calculated using the relationship 1 ml of 1N H_2SO_4 = 0.014 g of N. Weight of soil taken is 5 g, volume of 0.01 H_2SO_4 taken is 1.9 ml for both black cotton and red sandy soil. Available N can be calculated using the following formula.

$$\text{Available N (Kg/ha)} = \frac{(TV) \times N.\text{ of } H_2SO_4 \times 0.014 \times 2.24 \times 10^6}{\text{Weight of soil}}$$

Available Nitrogen content in Black Cotton Soil sample = 240 Kg/ha and available Nitrogen content in red sandy Soil sample = 215 Kg/ha

Table V shows the Nitogen content of soil.

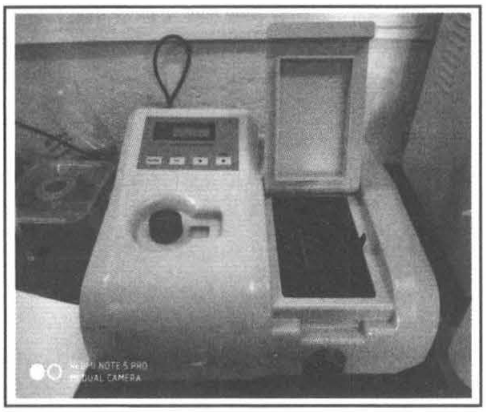

Fig.1. Kjeldahl Distillation Set

TABLE V.
NITROGEN CONTENT OF SOIL

Available Nitrogen (kg/ha)	Rating
< 280	Low
280 to 560	Medium
> 560	High

TABLE VI.
POTASSIUM CONTENT OF SOIL

Available K_2O (kg/ha)	Rating
< 141	Low
141 to 336	Medium
> 336	High

3) Available Potassium Content in Soil

The total potassium (K) content of a soil varies from 0.05 to 2.5%. The available K in a soil is generally the sum of water soluble and exchangeable potassium. The reserve forms of K in soils are the non-exchangeable K and the mineral K. The neutral normal ammonium acetate extract contains both water-soluble and exchangeable K. K extraction by this extractant is considered as a suitable index of K availability in most soils. When soil is equilibrated with neutral normal ammonium acetate, ammonium ions exchange with the exchangeable K ions of the soil. The K content in the equilibrium solution is estimated with a flame photometer. The K content in the sample is calculated by referring to the potassium standard curve. Table VI shows the potassium content of soil.

Here, available potassium content is found out with the help of a Flame photometer and *reagents* used were Working K Std. solution (100 ppm). Prepare 100 ml of 100 ppm K solution using 1000 ppm K solution as 1 ml of 1N H_2SO_4. Neutral N ammonium acetate solution (NH_4OAc): Dissolve 77.09 g of NH_4OAc in distilled water and make up the volume to 1 litre. Adjust the solution pH to 7.0, by adding acetic acid or NH_4OH solution as required.

Std. K solution (1000 ppm): Dissolve 1.91 g of KCl

(AR) in distilled water and make up the volume to 1 litre.

Available potassium can be calculated using the following formula

$$\text{Available } K_2O\ (\text{Kg/ha}) = \frac{\text{Graph ppm x Vol. of extractant x } 2.24 \text{ x } 1.20}{\text{Weight of soil}}$$

For black cotton soil, weight of the soil sample taken is 5 g, volume of the extractant is 25ml, flame photometer reading of sample is 15 ppm, Conc. Of K read from the std. curve is 6 ppm and it was found that the available potassium (K) in BC soil sample is 201.6 Kg/ha. For red soil, weight of the soil sample taken is 5 g, volume of the extractant is 2.5ml, flame photometer reading of sample is 5 ppm, Conc. of K read from the Std. Curve: 6ppm (Graph ppm), and the available potassium (K) in red sandy soil sample is 152 Kg/ha. Table VI shows the K content of soil.

4) Determination of available phosphorus(P) content in soil

Olsen's method

The available P in the soil is extracted with $NaHCO_3$ at a nearly constant pH of 8.5. The $NaHCO_3$ controls the ionic activity of Ca through precipitation of Ca as $CaCO_3$. This extractant also extracts some P from aluminium and iron phosphates in acid and neutral soils by way of suppressing Al and Fe activities. The content of P in the extract is estimated spectrophotometrically by adding ammonium moldybdate and thereafter, reducing the molybdenum-phosphate complex with stannous chloride in the acidic medium. The heteropoly complexes (Phosphomolybdates) are formed after reduction which imparts blue colour to the solution. The intensity of the blue colour is measured at 660 nm using spectrophotometer and by referring the standard curve the content of P in soil extract is obtained.

TABLE VII.
PHOSPHOROUS CONTENT OF SOIL

Available P_2O_5 (kg/ha)	Rating
< 22.5	Low
22.5 to 56.00	Medium
> 56.00	High

Reagents

0.5 M $NaHCO_3$: Dissolve 42 gm of sodium bicarbonate in distilled water and make up the volume to 950 ml approximately. Adjust the pH of the solution to 8.5 with dilute HCl or NaOH solutions and make up the volume to 1 litre with distilled water.

Darco-G 60 activated charcoal- made free from soluble P by repeated leaching with $NaHCO_3$.

1.5 % Ammonium molybdate: Dissolve 15 g of ammonium molybdate in 300 ml of hot distilled water (Filter this if necessary), cool, and add 350 ml of 10 N HCl then make up the volume to a litre using distilled water.

Stannous Chloride solution (40%): Dissolve 4 g of stannous chloride in 10 ml of concentrated HCl.

Working Stannous Chloride solution: Dilute 0.5 ml of the stock solution to 66 ml with distilled water. Prepare this solution just before use.

Standard P solution (5 ppm): Dissolve 0.02195 g of potassium dihydrogen phosphate (AR) in one liter of water.

Available phosphorus can be calculated using the following formula

$$\text{Available } P_2O_5\ (\text{Kg/ha}) = \frac{\text{Graph ppm x Vol. of extractant x Vol. made x } 2.24 \text{ x } 2.29}{\text{Wt. of soil x Aliquot}}$$

Table VII shows the Phosphorous content of soil.

Interpretation

Weight of the black cotton soil sample taken is 5 g, volume of the extractant is 50 ml, volume of aliquot taken is 5ml, final volume after development of colour : 0.6ml, graph ppm is 5ppm, and available P_2O_5 in BC soil sample is found to be 30.78 kg/ha.

Weight of the red soil sample taken is 5g, volume of the extractant taken is 50ml, volume of aliquot taken is 5ml, final Volume after development of colour is 0.6ml, graph ppm is 5 ppm, and available P_2O_5 in red sandy soil sample is 27 Kg/ha.

5) Comparison of agricultural tests on soil

Table VIII shows the comparison of tests on soil.

IV. DISCUSSION

As black cotton soil is having Plasticity Index as 28.3, it comes under medium to high plasticity zone. Red sandy

TABLE VIII.
COMPARISON OF N, K, and P CONTENT IN SOIL

Soil Type	pH	Nitrogen (N) (Kg/ha)	Potassium (K) (Kg/ha)	Phosphorous (P) (Kg/ha)
Black Cotton	6.5	240	201.6	30.78
Red Sandy	7.5	215	152	27

soil is having Plasticity Index as 17.3, and comes under low to medium plasticity zone.

Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) found for Black cotton soil is 21 % and 1.92 g/cc respectively. OMC and MDD are found as 14.9% and 1.89 g/cc respectively for red sandy soil. So we can conclude that dry density and optimum moisture content is higher in black cotton soil compared to red sandy soil.

Angle of internal friction for black cotton soil was found to be (Φ) 20^0 and Cohesion (c) 36.5 kN/m^2 for black cotton soil and 32^0 and 28.3 kN/m^2 for red sandy soil respectively. Φ value is higher in red sandy soil, C value is higher in black cotton soil.

pH value for Black Cotton soil is 6.5 and for Red Sandy soil it is 7.5. As pH 6.5 to 7.5 comes in the category of normal soil, we can state that Black cotton comes under normal pH value, whereas with 7.5 pH, red sandy soil becomes little saline or calcareous.

Available Nitrogen content in black cotton soil sample is 240 Kg/ha and in red sandy soil, the sample is 215 Kg/ha. As if available Nitrogen content is < 280 Kg/ha, it is considered low Nitrogen content, both black cotton and red soil is in the same category.

Available potassium (K) in BC soil sample is 201.6 Kg/ha and the available potassium (K) in red sandy soil sample is 152 Kg/ha. Potassium range 141 to 336 is in the medium category. According to the values, both the types of soil are under medium range.

Available P_2O_5 in BC soil sample is found to be 30.78 Kg/ha and available P_2O_5 in red sandy soil sample is 27 Kg/ha. Both the types of soil are in the medium range category.

Black soil is moderately rich in potassium and phosphorus but has poor nitrogen content. For this reason, crops like cotton, chilly, tobacco, oil seeds, ragi, jowar, and maize grow well in it. It is the most suitable for the growth of cotton because of high moisture retention properties.

Root crops grow well in sandy soil mainly because there is less compression in sandy soil. So, carrots, beets, etc. can fill out much easier than in clay soil. Red soil consists of high iron content and is good for crops like Bengal gram, red gram, green gram, groundnut, and castor seed.

REFERENCES

[1] P. D. Coduto, M. C. R. Yeung, and W. A. Kitch, *Geotechnical Eng., Principles and Practices*. New Delhi : PHI Learning Private Ltd., 2010.

[2] J. E. Bowels, *Found. Design and Eng.*, 4th ed. New York : McGraw Hill Inc., 1988.

[3] "Study rep. on compaction equipments and construction machinery rep. no. ge- r-76, september – 2005". Geotechnical Eng. Directorate, Res. Designs & Standards Org., Manak nagar, Lucknow-11, India.

[4] N.C. Brady and R. R. Weil. *Elements of the nature and properties of soils.* Upper Saddle River, New Jersey: Prentice-Hall, Inc., 2000.

About the Author

Barnali Ghosh has more than 15 years of experience in teaching in different Engineering colleges. She completed B.E. in Civil Engineering from Tripura Engineering College (currently NIT Agartala), M. Tech. in Soil Mechanics and Foundation Engineering from Jadavpur University, Calcutta. She is pursuing Ph.D. from VTU, Belgaum in Geotechnical Earthquake Engineering. She has published papers in various national and international journals and conferences. She is a life member of Indian Society for Technical Education (ISTE) and Institute of Engineers. She is Associate Professor at East Point College of Engineering & Technology, Bangalore.