CHAPTER-4

PHYSICO -CHEMICAL PROPERTIES

4.0 Physico-chemical properties of soils

Physical properties of soils do not involve any chemical change in their manifestations. Those properties which can be evaluated by observing and feeling the soil are known as physical properties of soils. They can be measured against some scales like intensity or strength or size. For example, colour, size, texture, density, moisture content, electrical conductivity etc Schematic diagram of some physicochemical properties of soil is given in fig.no.08

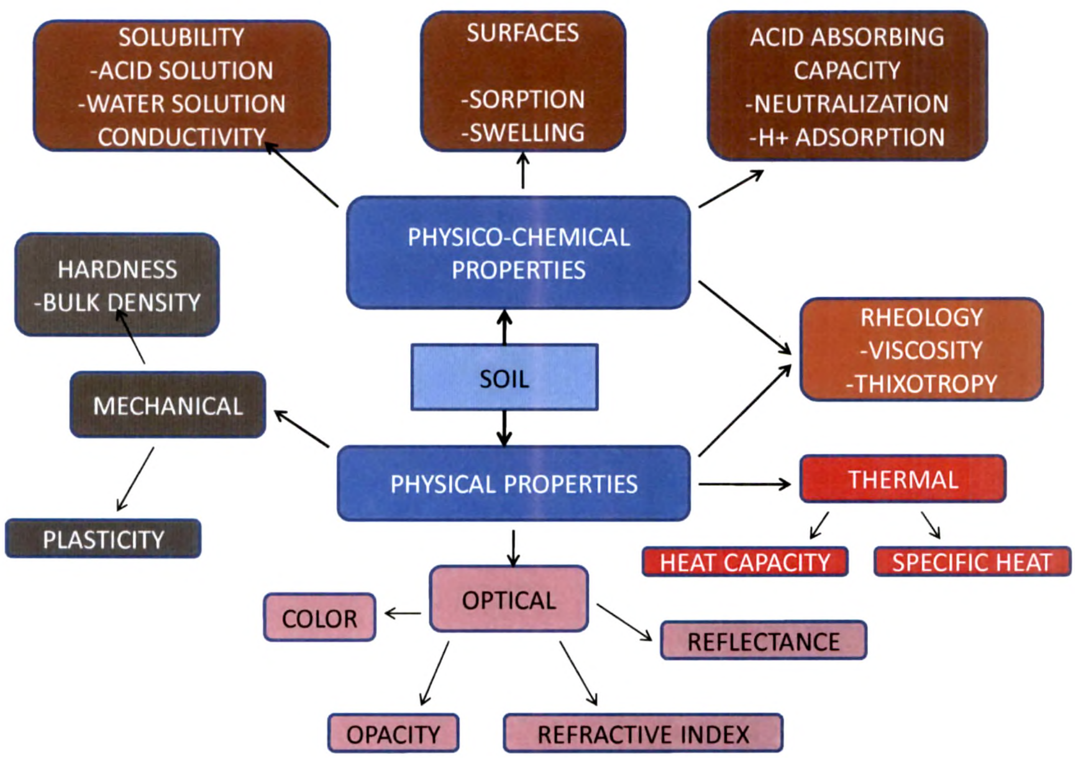

Fig. no: 08. Diagram of the main physical and physico- chemical properties of soil

4.1 Colour

Munsell colour chart (fig.no.09) was used to determine the colour of soils. Soil colour is described by the following three variables: (i) Hue is the dominant spectral colour. (ii) Value is the relative lightness of the soil colour. (iii)Chroma is the relative strength of purity of spectral colour. It increases with decreasing greyness.

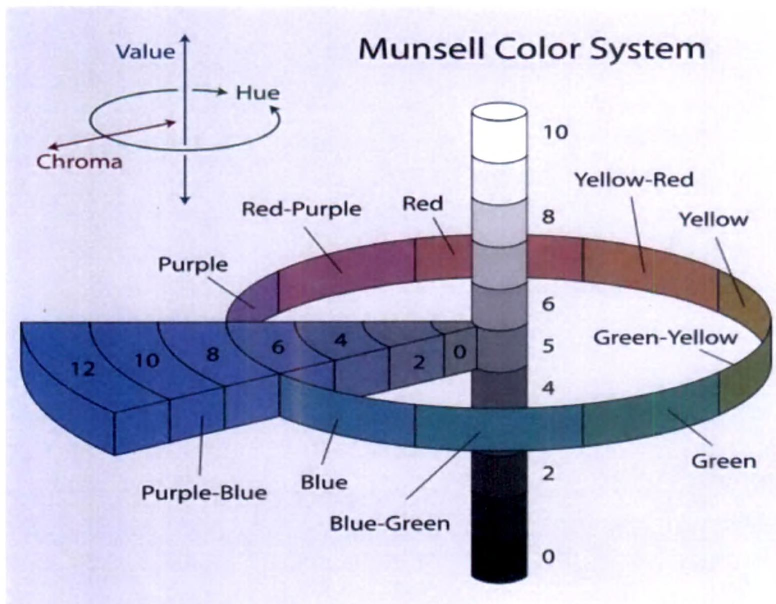

Fig. no: 09 Munsell color system

en.wikepedia.org/wikiMunsell_colour_system,www.sbg.ac.at/soil chart

Hue

Each horizontal circle Munsell is divided into five principal *hues*: **R**ed, **Y**ellow, **G**reen, **B**lue, and **P**urple, along with 5 intermediate hues halfway between adjacent principal hues. Each of these 10 steps is then broken into 10 sub-steps, so that 100 hues are given integer values. Two colors of equal value and chroma, on opposite sides of a hue circle, are complementary colours and mix additively to the neutral gray of the same value.

Value

Value, or lightness, varies vertically along the color solid, from black (value 0) at the bottom, to white (value 10) at the top. Neutral grays lie along the vertical axis between black and white. Several color solids before Munsell's plotted luminosity from black on the bottom to white on the top, with a gray gradient between them, but these systems neglected to keep perceptual lightness constant across horizontal slices. Instead, they plotted fully-saturated yellow (light), and fully saturated blue and purple (dark) along the equator.

Chroma

Chroma, measured radially from the center of each slice, represents the "purity" of a color, with lower chroma being less pure (more washed out, as in pastels. Note that there is no intrinsic upper limit to chroma. Different areas of the color space have different maximal chroma coordinates. For instance light yellow colors have considerably more potential chroma than light purples, due to the nature of the eve and the physics of color stimuli. This led to a wide range of possible chroma levels—up to the high 30s for some hue–value combinations (though it is difficult or impossible to make physical objects in colors of such high chromas, and they cannot be reproduced on current computer displays). Vivid soil colors are in the range of approximately 8.

Results

Properties like colour, and clay content can be visible from the photographs of soils. Photographs of four soils under study are given in Fig. no. 10 a, b, c, d and colour schemes of Munsell colour chart is given in Fig.no. 11, 12, 13, 14 of Black, Brown Dwarka and Vadodara. respectively.

Fig. no: 10 a Kerala Black

Fig. no: 10 b Kerala Brown

Fig. no: 10 c Dwarka

Fig. no:10 d Vadodara

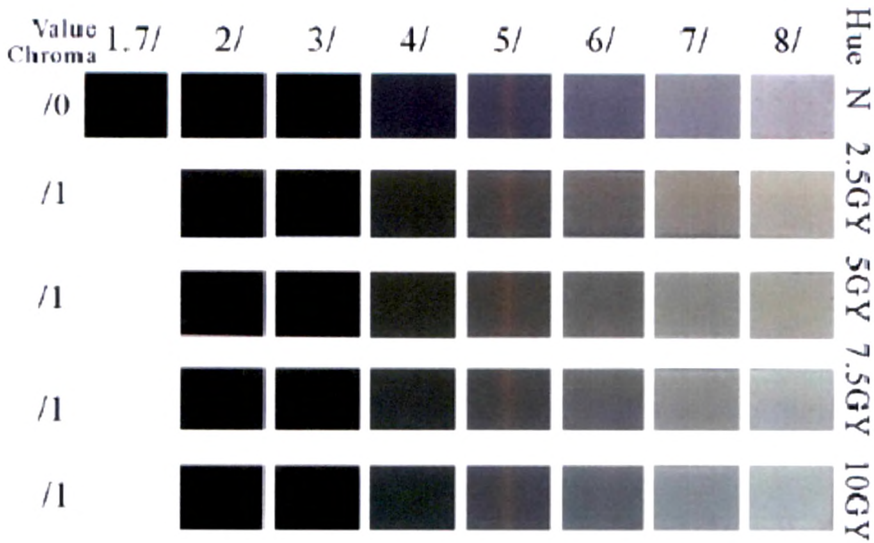

Fig. no: 11 Detailed colour chart for Kerala Black

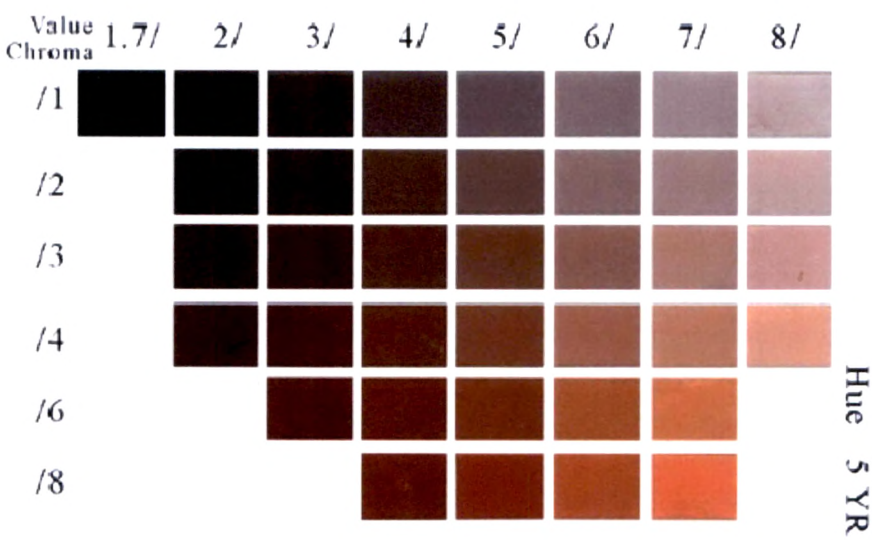

Fig. no: 12 Detailed colour chart for Kerala Brown

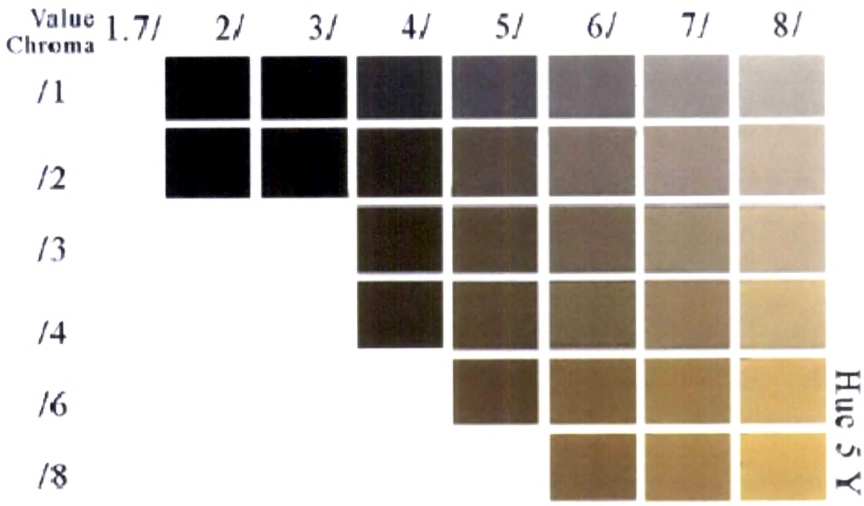

Fig. no: 13 Detailed colour chart for Dwarka

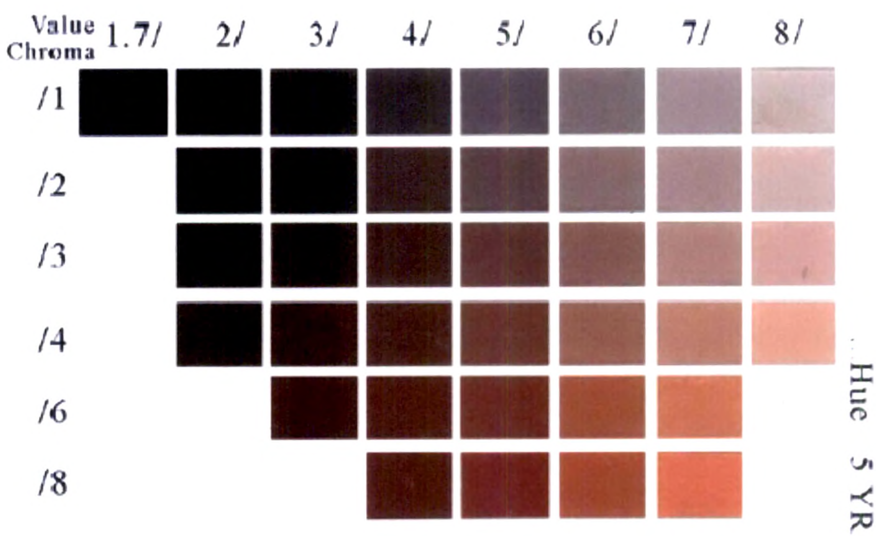

Fig. no: 14 Detailed colour chart for Vadodara

Photograph of Vadodara showed sandy texture i.e. the soil would crumble if crushed with hand while lump of Kerala Brown appeared very hard. Similarly Dwarka soil was available in hard, compact, layered lumps which were very difficult to break down. Kerala Black appeared very hard and dense lump.

The colour of these soils was matched with Munsell Colour chart as shown above and accordingly, colour code was assigned to them. Colour of the soil represents its iron, sodium, potassium and clay content, and so colour is the primary step in deciding soil's fertility as well as its clinical use. Hence correlation of colour with its mineral and clay content is given in table no11.(Note: Detailed methodology for mineral content is described later in section 5.2 and that for clay content in section 4.2 and 4.3).

Table No.11 Relationship between colour and composition

Sr.No	Characteritstic	Kerala Black	Kerala Brown	Dwarka	Vadodara
01	Colour,Munsell notation	Hue N Value 1.7 Chroma 0 Black	Hue 5YR Value 2 Chroma 1 Brownish black	Hue 5Y Value 8 Chroma 4 Yellow	Hue 5YR Value 3 Chroma 2 Dark reddish brown
02	Iron content(measured by LEO 435VP SEM, Oxford ISIS-300 EDS)	7.72%	9.51%	3.49%	7.12%
03	Sodium content(measured by LEO 435VP SEM, Oxford ISIS-300 EDS)	0.51%	0.75%	_	0.68%

04	Potassium content (measured by LEO 435VP SEM, Oxford ISIS-300 EDS)	1.32%	1.38%	1.31%	1.63%
05	Clay content	38%	42%	26%	18%

As seen in the detailed Munsell color chart, it could be observed that Black had darker hue i.e. N and Dwarka had only yellow hue while Brown and Vadodara had mixed yellow-red hue. As expected from visual colour analysis, Iron, sodium and clay content of Kerala brown was found to be highest compared to other soils and least in Dwarka .

Discussion:

Soil colour is the property which exerts least influence on the other soil properties, but is important because it is largely a synthesis and expression of all other soil properties. Clearly, the observation of a given soil colour can be useful in the description, mapping, and classification of soils and may elucidate problems associated with soil genesis or soil evaluation. (Pitty AF 1979, Viscarra RA 2008, Cattle SR 2009). Soil colour has also been used to quantify soil organic carbon and iron contents (Viscarrra RA 2008).

Soil colour depends on the types of soil constituents (Schwertmann U 1993) and it is also easily accessible and relatively stable over time, which explains why it is used for soil identification and qualitative determinations of soil characteristics, e.g. the presence of soil constituents such as iron oxides (Torrent J 1983), organic matter (Lindbo DL 1998) and water content (Bedidi A 1992).

Iron is usually the most important mineral colouring agent in soils, especially in clays. In ferruginous soils, the two common forms of free iron oxide produce red to yellow-brown colours (Kerala Brown and Vadodara). Calcium carbonate can also be significant (Dwarka) when present in large amounts and colours may become whitish-grey. Organic matter may influence soil's colour to an over-riding degree.

The more humified the oranic matter, (Kerala Black) the darker the colour as humins and humic acids contrast with the lighter coloured fulvic acids. **This is reflected by the table no 11 where in due to large amount of iron in Vadodara and Kerala Brown, its colour is brown. Moreover Dwarka is rich in carbonates (Section 5.3 and 5.4) and so its colour is greyish yellow and Kerala Black has great amount of organic matter (humic acid) (Section 5.8) and so its colour is Black.**

The **texture** of a soil can influence its colour. In a sandy soil, with little colloidal organic matter, colours are like grayish- white and certain types of clays can form a dark clay- organic complex. In India, black soils usually comprise 40-60% clay, most of which is montmorillonite (Kerala Black) whereas the red soils have a much lower clay fraction (Vadodara) and kaolinitic soil types with iron oxides predominate (Singh S 1954). Where sodium and potassium carbonates are dominant, surface horizons tend to be black or brown, due to their dissolving organic matter, and contrast markedly with the white incrustations of the saline soils which are largely chlorides or sulphates.

Thus, to summarize the influence of soil colour on other properties, it can be said that due to high iron, sodium, and clay content in Kerala Brown , its colour was brown and since Dwarka had less iron content, its colour was whitish yellowish. Kerala Black had less iron compared to brown but as it was rich in clay, sodium, potassium and organic matter, its colour was black.

4.2.a Particle size analysis (Wet sieve)

Method: (IS 2720)

Weighed amount of soil was taken, spread out in large tray and covered with water. No dispersing agent was added. The mix was thoroughly stirred and left for soaking. The soil soaked specimen was washed thoroughly over the nest of sieves.i.e.4.75mm, 75micron, and 2 micron sieve, nested in order of their fineness with the finest sieve at the bottom. Washing was continued until the water passing each sieve was substantially clean. Care was taken to see that the sieves were not overloaded in the process. The fraction retained on each sieve was emptied carefully without any loss of material in separate trays. It was oven dried at 105 to 110 ^{0}C and each fraction weighed separately.

The results of wet sieve analysis are given in table no: 12

Table no.12 Sieve analysis (I.S.2720 wet)

Sr.no.	Sieve analysis	Kerala Black	Kerala Brown	Dwarka	Vadodara
01	Gravel %(>4.75mm	0	0	0	0
02	Sand % (4.75mm to0.075mm)	3	3	1	22
03	Silt % (0.075mm to 0.002mm	59	55	73	60
04	Clay % (<0.002mm)	38	42	26	18

The graphical representation of size distribution is as given in fig. nos. 15(Kerala Black), 16(Kerala Brown), 17 (Dwarka), and 18(Vadodara).

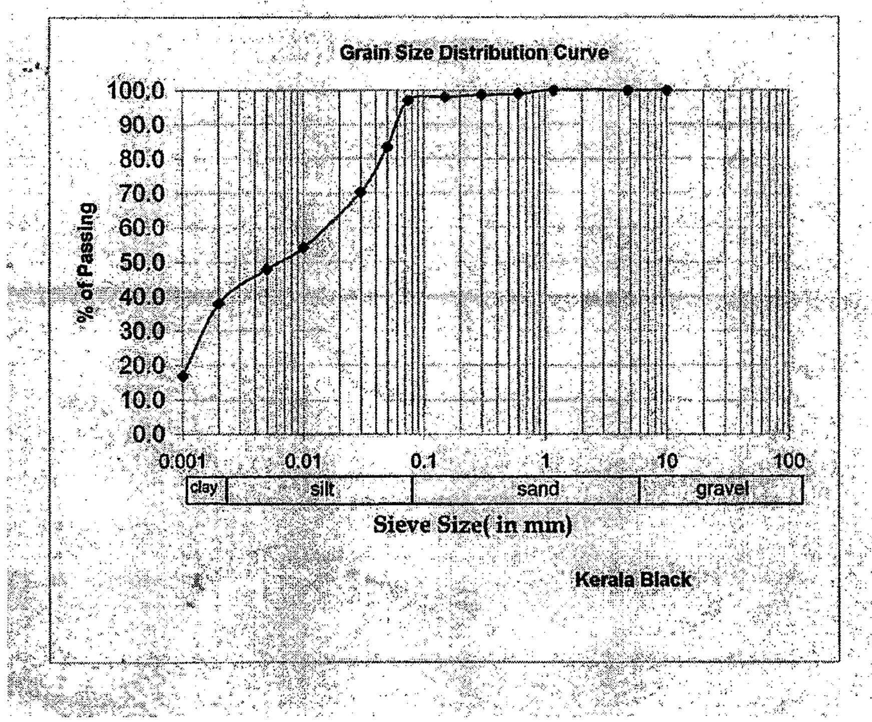

Fig.no.15 Grain size distribution of Kerala Black

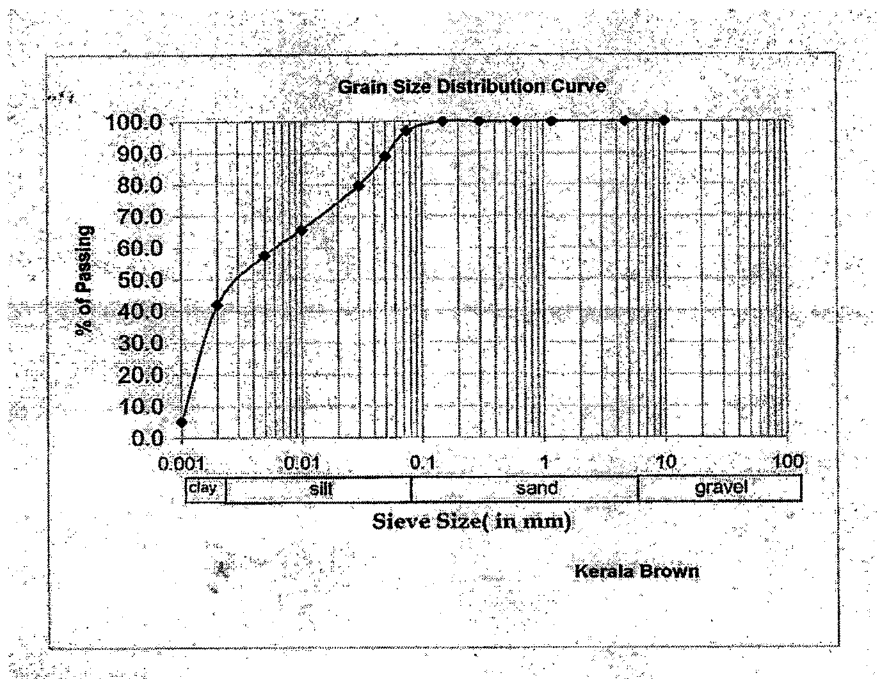

Fig.no. 16 Grain size distribution of Kerala Brown

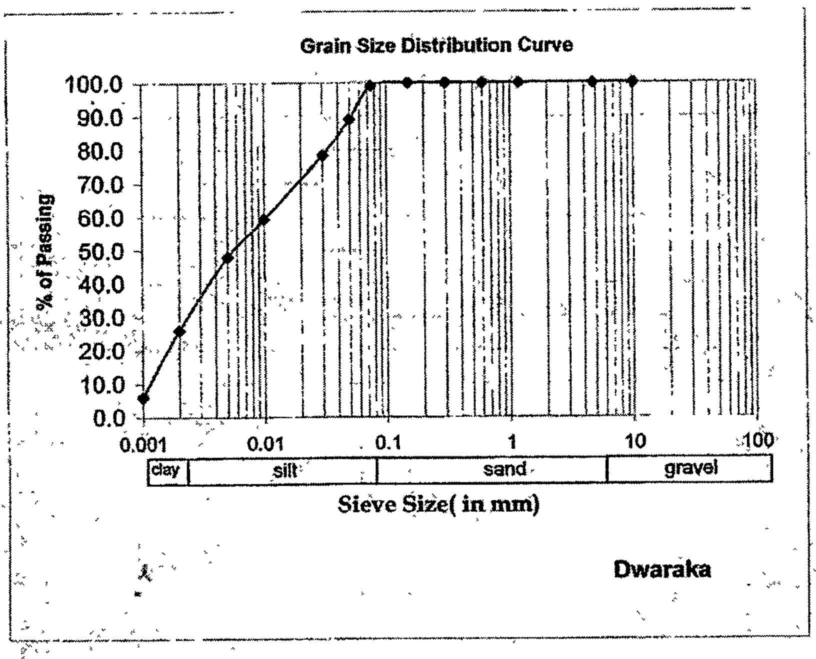

Fig. no. 17 Grain size distribution of Dwarka

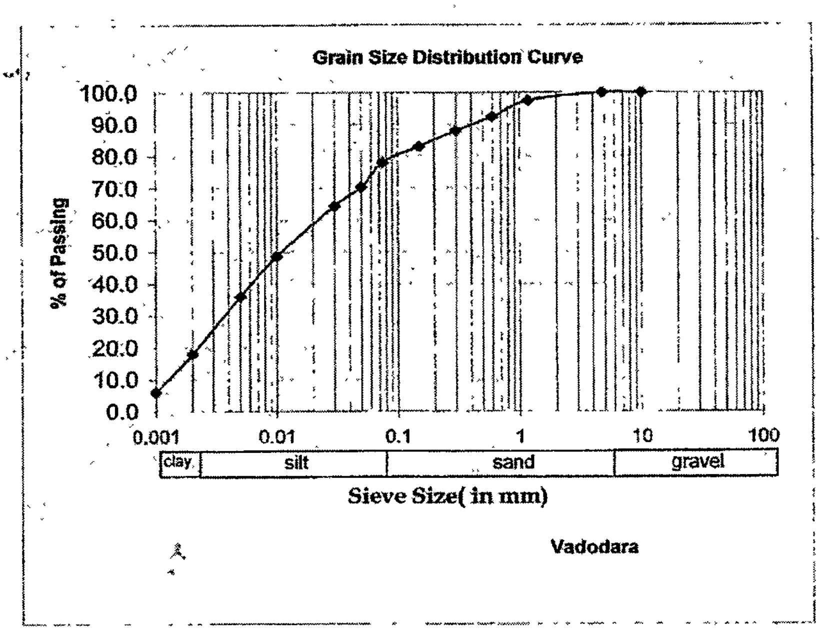

Fig. no.18 Grain size distribution of Vadodara

Results & Discussion

Wet sieve analysis process determines the actual size of soil particles because on addition of water, the soil disintegrates into its smallest particle and the adhered water soluble components are washed away. Whereas dry particle size analysis includes all colloidal water soluble components adhered to it.

Silt particles are micro sand particles. They are very irregular in shape. Usually some clay particles adhere with the silt particles. Hence silt particles possess some plasticity and stickiness. All four soils are rich in silt and so they have good stickiness property which helps them to adhere to the skin.

It could be observed that since the soil was collected beneath the ground at about 3 to 4 ft depth there was no presence of gravel in any of the samples. Moreover as described earlier in the section 4.1 (soil colour) , the colour and photograph of Vadodara suggested sandy texture, which was confirmed by wet sieve analysis data. (Vadodara has 22% of sand content.) As compared to the highest content of silt (73%) in Dwarka , the content of clay was considerably less (26%). Less clay content was also reflected by light colour of Dwarka, whereas clay content as measured by wet sieve analysis in Kerala Brown was in accordance with colour analysis. More the clay content more the organic matter, so this may lead us to conclude that Kerala Brown must be containing more organic matter.

4.2.b Particle size analysis (Dry sieve analysis)

Method:

The soil clumps were size reduced by hammer mill manually and passed through 44# sieve and subjected to sieve analysis (dry) in Jayant rotap sieve shaker using Jayant sieves (ASTM Sieves). The results are tabulated in table no: 13

Table no . 13 Particle size distribution by sieve analysis (dry)

				Average weight in % gms			
Sr.No.	Sieve size #	Micron size range	Av.Micron Size	Kerala Black	Kerala Brown	Dwarka	Vadodara
1	44 to 60	355 to 250	302.5	56±0.04	43.9±0.06	34.2±0.06	21.02±0.08
2	60 to 85	250 to 180	215	6.5±0.4	9.3±0.04	5.7±0.07	5.6±0.02
3	85 to 120	180 to 120	150	7±0.04	9.3±0.3	6.6±0.03	7.4±0.5
4	120 to 150	120 to 105	112.5	5±0.06	6.5±0.01	3.8±0.05	8.4±0.07
5	150 to 170	105 to 90	97.5	1±0.02	0.9±0.01	0.9±0.01	1.8±0.01
6	170 to 200	90 to 75	82.5	5±0.02	5.6±0.03	5.7±0.05	17.75±0.03
7	200 to 500	75 to 25	50	12±0.02	12.1±0.02	25.7±0.05	25.7±0.05
8	< 500	<25	<25	8±0.04	12.1±0.06	17.1±0.04	12.1±0.02

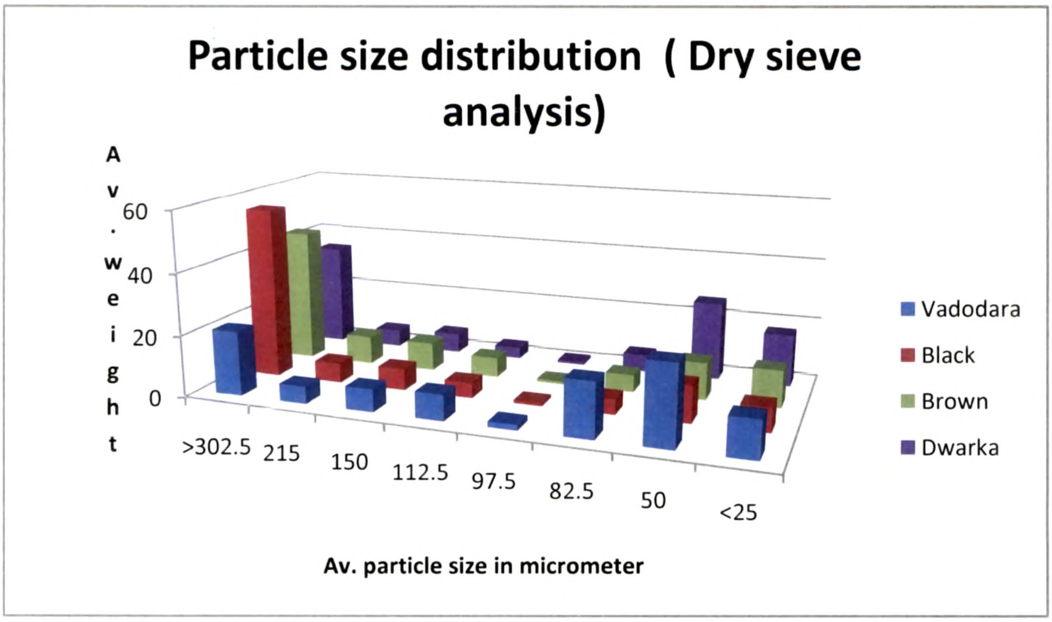

Fig.No 19: Particle size distribution on weight basis.

Result & Discussion

It could be observed that in all the four samples, maximum distribution was below 75 microns indicating good richness in clay particles. Since most of the organic matter is adhered to clay particles all the samples were rich in organic matter also.

4. 3 Texture

Soil texture depends on the relative proportion of sand, silt and clay in the soil.

The textural classification of soil was done on the basis of USDA system (Fig.no;20) for determining soil texture (Gupta PK 2007).

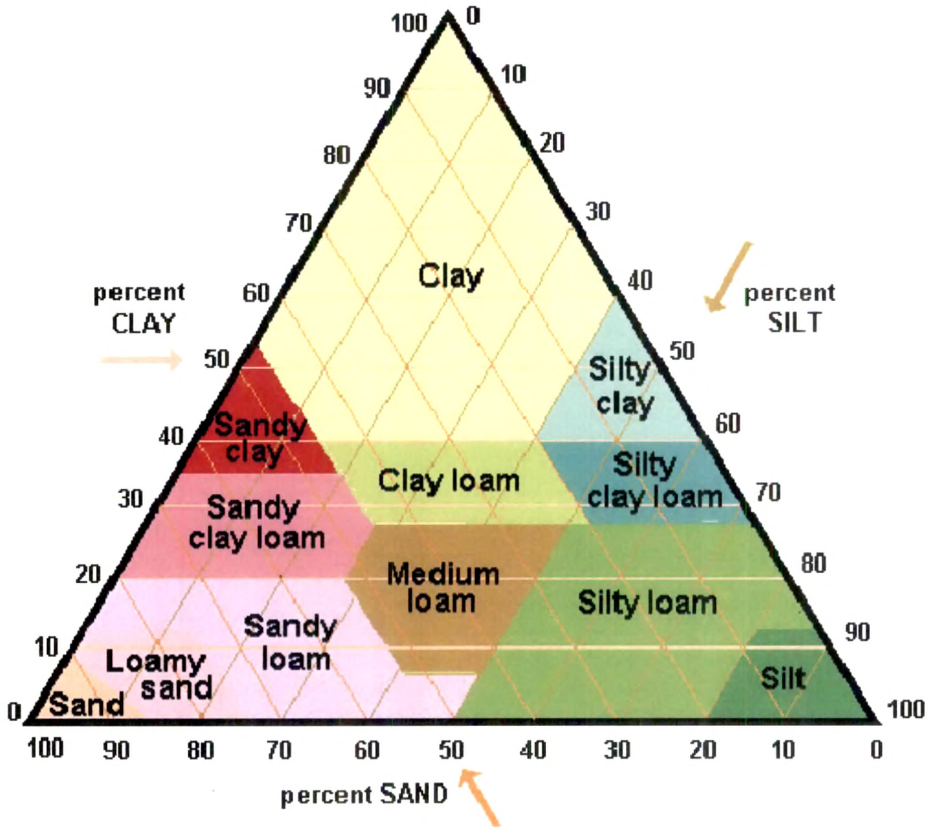

Fig.No 20: Triangular textural diagram. (USDA)

The percentages of silt (59% for Black) and clay (38% for Black) on the silt and clay side lines respectively of the triangular textural diagram were located. Then lines were drawn through these points, inwards, parallel to the clay side in the first case and to the sand side in the second case. The textural name of the compartment in which they intersect was the textural name of the soil concerned. If they intersect just on the line between the two compartments, then the textural name of the finer compartment is to be taken.

From the texture diagram (fig.no.20) it was observed that Kerala black and Kerala brown fell in the texture region of silty clay loam {(59% silt and 38% clay, black), (55%silt and 42% clay, kerala brown)}. While Dwarka (73%silt & 26%clay) and Vadodara (60%silt &18%clay) could be classified in the region of silty loam.

Discussion

From the particle size data and textural diagram it could be concluded that Kerala Black and Kerala Brown had silty clayey loamy texture and that Dwarka and Vadodara had silty loamy texture.

From the physical examination of soil's texture, one can draw the conclusion that if it contains clay part, then it will adsorb large amount of water molecules and mineral ions on its surface. This can affect swelling index of soils and also may play an important role in their therapeutic efficacy.

4.4 Bulk density

Method

Bulk density was measured by filling the bulk density bottle with soil sample and weighing it accurately.

$$\text{Bulk density of soil} = \frac{\text{weight of soil solids}}{\text{Vol. of dry soil solids}}$$

Table no: 14 Bulk density : (gm/cc)

Bulk density	Kerala black	Keala brown	Dwarka	Vadodara
gm/cc	2.314	2.472	2.82	2.79

Result and discussion

The bulk density data in table no. 14 showed that Kerala Black soil had least bulk density. This may be due to the fact that it contains highest amount of humus (organic carbon) and is finer in texture amongst the four soils.

A clayey soil (Black and Brown) in which soil particles are united to form soil aggregates have a lower bulk density than a sandy (Vadodara) soil in which soil particles lie close to each other, because dry soils of a finer texture have more spaces filled with air around the mineral particles than those of a coarser texture. Bulk density of soils decreases when their percentage of humus increases (Kolay AK 1991). The results of Humic acid content of soil (section 5.8) supports this data.

4.5 Moisture content

Method:

Soil was heated at 105 to 110 ^{0}C until steady weight was obtained and its moisture content was calculated by the following formula.

$$\text{Moisture percentage} = \frac{\text{Wt of moist soil - Wt of oven dried soil}}{\text{Wt of oven dried soil}} \times 100$$

Results and discussion

Table no: 15 Moisture content of soils

Sr.No.	Soil	Moisture content in %
01	Kerala Black	4.9
02	Kerala Brown	3.73
03	Vadodara	6.32
04	Dwarka	4.8

The results in table no.15 show that Kerala Brown possessed least moisture content (3.73%) and Vadodara had 6.32% moisture. Hardness of soil depends on moisture and clay content. Kerala Brown had highest clay content and least moisture content and hence was very hard. Vadodara had minimum clay content and maximum moisture content and was least hard (Kolay AK 1991).

4.6 Swelling Index

Method (Kolay AK. 1991)

10 gm of soil sample was poured in each of the two glass graduated cylinders of 100ml capacity. One cylinder was filled with kerosene and the other with distilled water up to 100ml mark. The soils in both the cylinders were allowed to settle for 24 hrs. The final volume of soils in each of the cylinders was read.

$$\text{Swell index} = \frac{\text{Volume of soil in water} - \text{Volume of soil in kerosene}}{\text{Volume of soil in kerosene}} \times 100$$

Table no : 16 Swelling index

Swelling index	Kerala Black	Kerala Brown	Dwarka	Vadodara
%	60%	120%	33%	33%

Result & Discussion

Soils of finer texture possess maximum total water-holding capacity whereas the soils of medium texture i.e. loam to light clay loam, possess minimum available water holding capacity and Kerala Brown and Black have finer texture compared to other two so they have high swelling index as indicated in table no. 16.

The most important clay minerals in Black (Kerala Black) soil and red (Vadodara) soil are montmorillonite and kaolinite respectively. As the cation exchange capacity of Montmorillonite (80 to 150 milliequivalent per 100 gms) is much higher than that of kaolinite (3 to 15 milliequivalent per 100 gms), a montmorillonitic soil (Kerala Black) can retain much more moisture than a kaolinitic soil (Vadodara) when moist, (high swelling index) but the same soil on heating, loses more water than kaolinitic soil (Vadodara) which is reflected in the data of moisture content .

4.7 pH

Method (Kolay AK 1991)

1:2 Soil water suspension was prepared by weighing 40 gm of soil into a 250 ml Erlenmeyer flask and adding 80 ml of distilled water. The flask was stoppered and the mixture shaken on reciprocating shaker for one hour. It was then filtered through Whatman no.40 filter paper and its pH was measured by Elico pH meter.

Table no:17 pH (1:2 ratio)

	Kerala Black	Kerala Brown	Dwarka	Vadodara
pH	5.89± 0.02	7.39±0.01	7.34±0.01	7.79±0.03

Results and discussion

pH of Kerala Black was acidic while that of Kerala Brown , Vadodara, Dwarka was nearly neutral as shown in table no.17.

In soil water system some of the adsorbed hydrogen ions dissociate from the surface of the soil colloids in to the soil solution. These dissociated H^+ ion give rise to active or soluble acidity. But there are many more hydrogen ions still adsorbed on the soil colloids which give rise to potential acidity of the soil.

Thus effective hydrogen ion concentration includes hydrogen from all sources such as those arising by dissociation of soluble acids and those dissociated from soil colloids. **Low acidity of Black soil may be attributed to high concentration of calcium compared to other soils (as described later in section 5.6) because sodium ions are held less strongly by the micelle calcium ions and are therefore more easily hydrolysed than calcium ions and hence the pH of sodium saturated soils is higher than that of calcium saturated soils.**

4.8 Electrical Conductivity

Soils possess at least small amounts of various soluble salts. These salts may be acidic, neutral or basic. They may arise from different sources such as:

1. Primary minerals found in soil and in the exposed rocks of the earth crust and

2. Surface and ground waters.

Soluble salts present in soil dissociate into their respective cations and anions when dissolved in water and impart conductivity. Higher the concentration of ions in solution, more is its electrical conductance. Thus the measurement of EC can be directly related to the soluble salt concentration. Although, the relationship between conductivity and salt concentrations varies somewhat depending on the ionic composition of the solution, the electrical conductivity provides a rapid and reasonably accurate estimate of solute concentration.

Method (Kolay AK 1991)

Suspensions of soil in the ratio 1:2 was prepared in distilled water, kept aside for half hour with intermittent shaking and then centrifuged until clear. Electrical conductivity of the clear supernatant was measured by Elico CM 180 conductivity meter.

Settings :

range 2-200 mS , Cell constant 1 , temperature 20°c

Table No: 7 Electrical conductivity of soil: water suspension (1:2ratio)

Conductivity	Kerala Black	Kerala Brown	Dwarka	Vadodara
mS	9.5± 0.4	4.97±0.09	1.51±0.08	0.95±0.02

Result and discussion

Kerala black was found to have the highest electrical conductivity and Kerala brown , Dwarka and Vadodara were in decreasing order .

High electrical conductivity of Black soil indicates the presence of high soluble salts concentration which can dissociate into ions (Gupta P.K. 2007). Probably, this may affect the absorption of ions into the skin.

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