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CHARACTERISTICS OF BLACK COTTON SOIL AND RED SOIL & DESIGN OF FLEXIBLE PAVEMENT

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***Abstract*— In the present study, using fly ash obtained from Raichur Thermal power station. With various proportions of this additive i.e. 10%, 20%, 30%, 40% & 50%, expansive soils is stabilized. Addition of fly ash results in decrease in plasticity of the expansive soil, and increase in workability. Marble power is to improve the engineering properties Black cotton soil with a proportion of 5%,10%,15%,20%,25% and studied the compaction characteristics and strength characteristics.**

***Keywords*— Additive, characteristics, fly ash, plasticity, workability**

I. INTRODUCTION

A. Black Cotton Soil

Black Cotton soils, which are also called as swell-shrink soil, have the tendency to shrink and swell with variation in moisture content. As a result of this variation in the soil, significant distress occurs in the soil, which is subsequently followed by damage to the overlying structures. During periods of greater moisture, like monsoons, these soils imbibe the water, and swell; subsequently, they become soft and their water holding capacity diminishes. As opposed to this, in drier seasons, like summers, these soils lose the moisture held in them due to evaporation, resulting in their becoming harder. Generally found in semi-arid and arid regions of the globe. Also called as Black Cotton soils or Regur soils, expansive soils in the Indian subcontinent are mainly found over the Deccan trap. Rich in lime, alumina, magnesia, organic content and iron, these soils lack in nitrogen, phosphorus. 20% of the total land area, on an average, of this country is roofed by expansive soils. These soils are suitable for dry farming and for the growth of crops like cotton, rice, jowar, wheat, cereal, tobacco, sugarcane, oilseeds, citrus fruits and vegetables; the reason behind it is owed to the moisture retentive capacity of expansive soils, which is high. Black cotton soil is one of the problematic soli that has greater tendency for shrinking or swelling due to change of water content. Table 1 shows the characteristics of Black soil

TABLE 1
CHARACTERISTICS OF BLACK SOIL

Sl.No	Property	Value
1.	Dry Density (γd)	1300 to 1800 kg/m^3
2.	Fines (<75μ)	70 to 100%
3.	2μ Fraction	20 to 60 %
4.	Liquid Limit (L.L.)	40 to 120%
5.	Plastic Limit (P.L.)	20 to 60%
6.	Activity	>1.25
7.	Soil Classification	CH
8.	Specific Gravity (G)	2.60 to 2.75
9.	Proctor Density	1350 to 1600 kg/m3
10.	Max. Dry Density	12 to 15 kN/m^3
11.	Free Swell Index	40 to 180%
12.	Swelling Pressure	50 to 800 kN/m^2
13.	C.B.R. (Soaked)	1 to 2.5
14.	Compression Index	0.2 to 0.5

B. Red Soil

Red soil is rich in iron oxide, but deficient in nitrogen and lime. Red soil is formed due to weathering of igneous and metamorphic rocks. It is highly impervious after it is mixed with concrete because of its size and its colour is in red due to the presence of iron in it. In India regions, the availability of red soil is in Tamilnadu, Karnataka, Andhra Pradesh, Orissa, Jharkhand and it is also available throughout the world. Table 2 shows the chemical composition of red soil.

TABLE 2
CHEMICAL COMPOSITION OF RED SOIL

Composition	Percentage By Weight (%)
Iron	3.61
Aluminium	2.92
Organic Matter	1.01
Magnesium	0.70
Lime	0.56
Potash	0.24
Soda	0.12
Phosphores	0.09
Nitrogen	0.08

II. METEDOLOGY

Fig. 1 shows the flow of adopted methodology

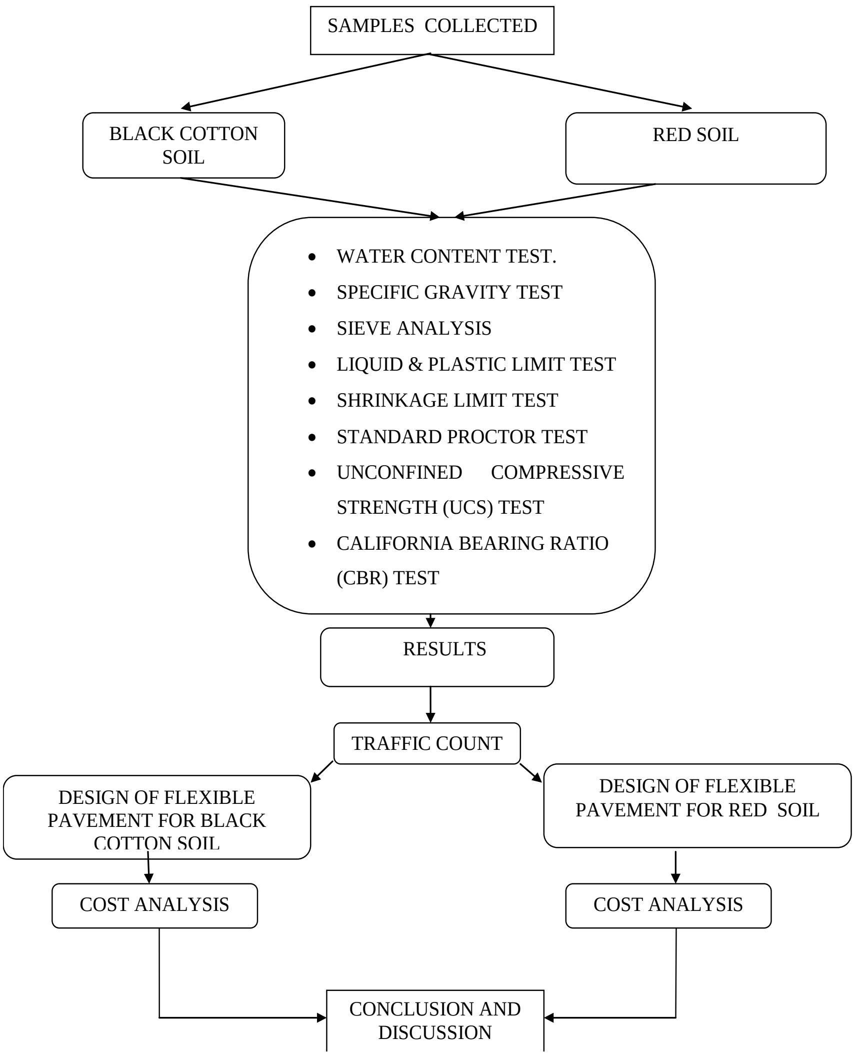


Fig. 1 flow chart of Methodology Adopted

Experiments Conducted

- Water Contain Test by Oven Dry Method[9]
- Specific Gravity By Density Bottle Method [10]
- Specific Gravity By Pycnometer Method[11]
- Sieve Analysis[12]
- Liquid limit by Casagrande Method[13]
- Plastic Limit[14]
- Shrinkage Limit[15]
- Maximum Dry Density And Optimum Moisture Content By Standard Proctor CompactionMethod[16]
- Unconfined Compressive Strength Test[17]
- California Bearing Ratio Test[18]

Experimental Results Comparison

Specific Gravity Comparison

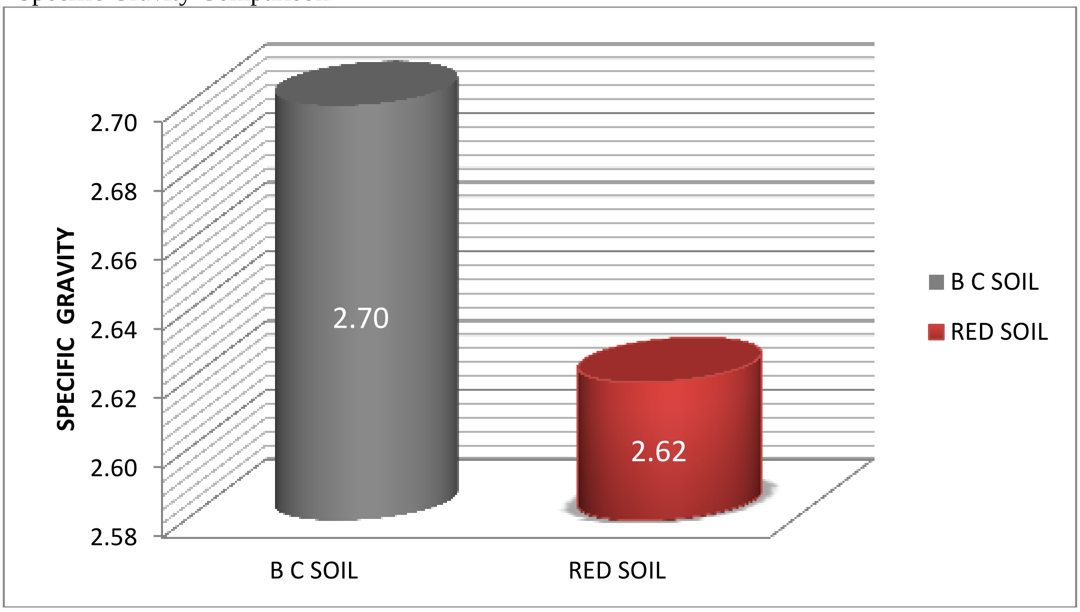


Fig. 2 Chart of Specific Gravity Comparison

As shown in the Fig 2 the Type of soil is taken on x-axis and specific gravity on y-axis. The specific gravity of Black cotton soil and Red soil is 2.70 and 2.62 respectively

Gravel Percentage Comparison

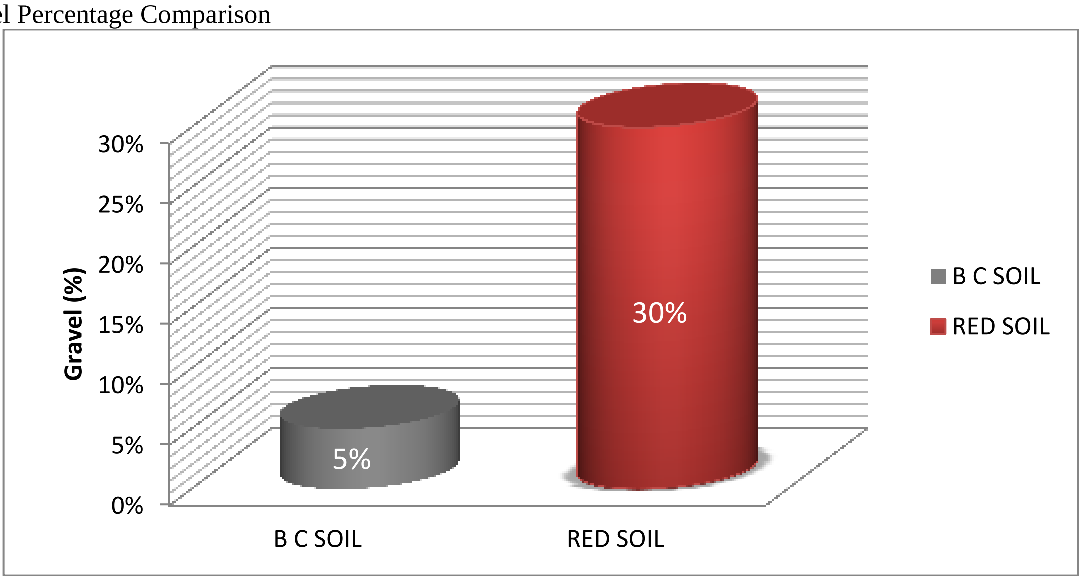


Fig. 3 Chart of Gravel Percentage Comparison

As shown in the Fig 3 the Type of soil is taken on x-axis and gravel percentage on y-axis. The gravel percentage of Black cotton soil and Red soil is 5% and 30% respectively

Sand Percentage Comparison

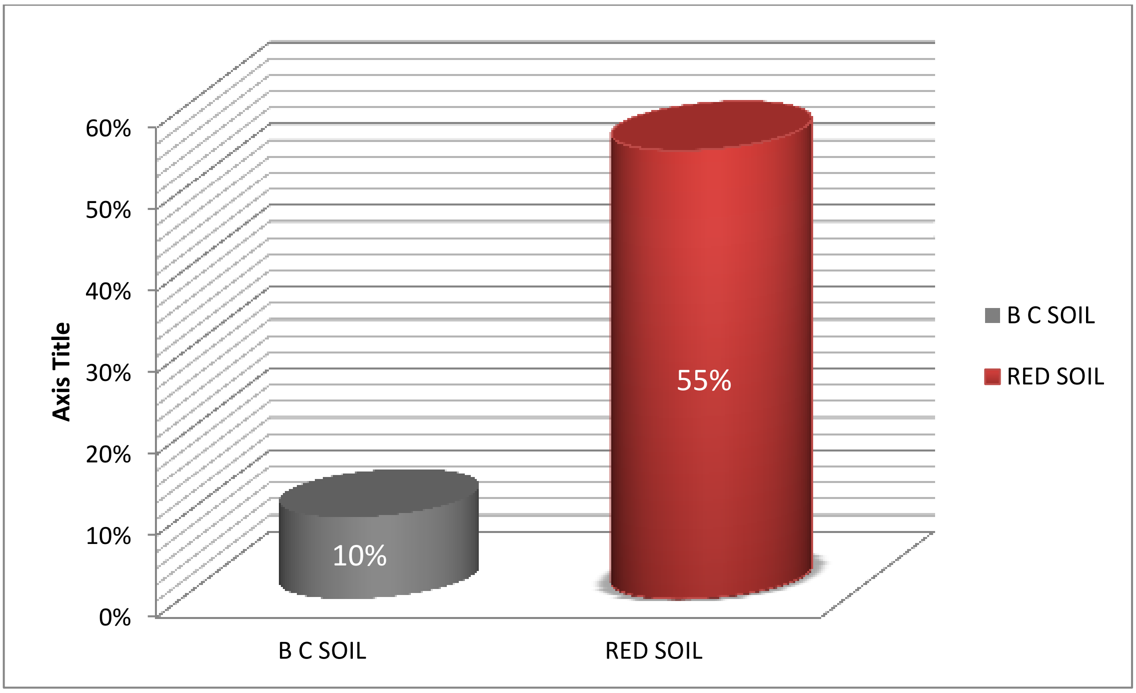


Fig. 4 Chart of Sand Percentage Comparison

As shown in the Fig 4 the Type of soil is taken on x-axis and sand percentage on y-axis. The sand percentage of Black cotton soil and Red soil is 10% and 55% respectively.

Percentage Fines Comparison

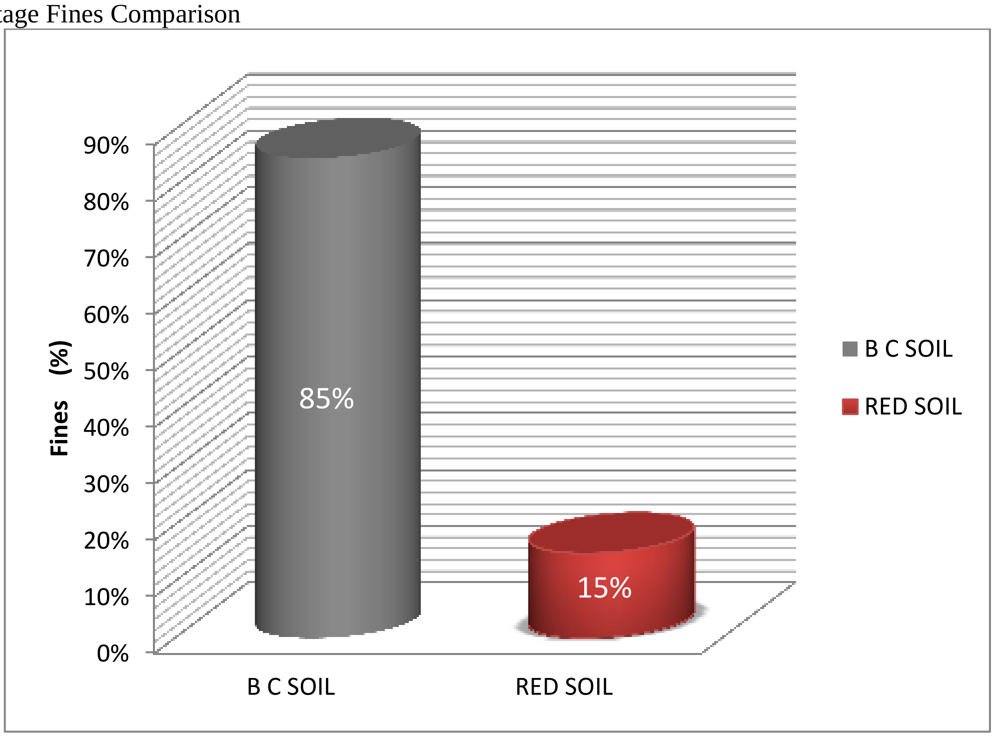


Fig. 5 Chart of Percentage Fines Comparison

As shown in the Fig 5 the Type of soil is taken on x-axis and fines percentage on y-axis. The fines percentage of Black cotton soil and Red soil is 85% and 15% respectively

Liquid Limit Comparison

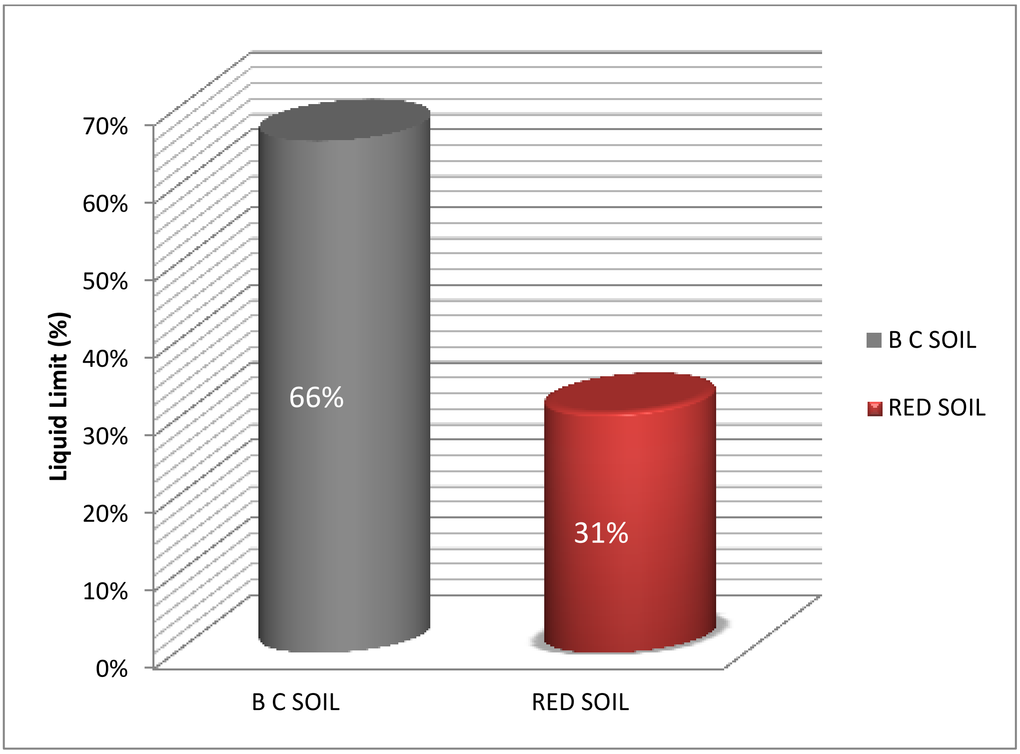


Fig. 6 Chart of Liquid Limit Comparison

As shown in the Fig 6 the Type of soil is taken on x-axis and liquid limit on y-axis. The liquid limit of Black cotton soil and Red soil is 66% and 31% respectively

Plastic Limit Comparison

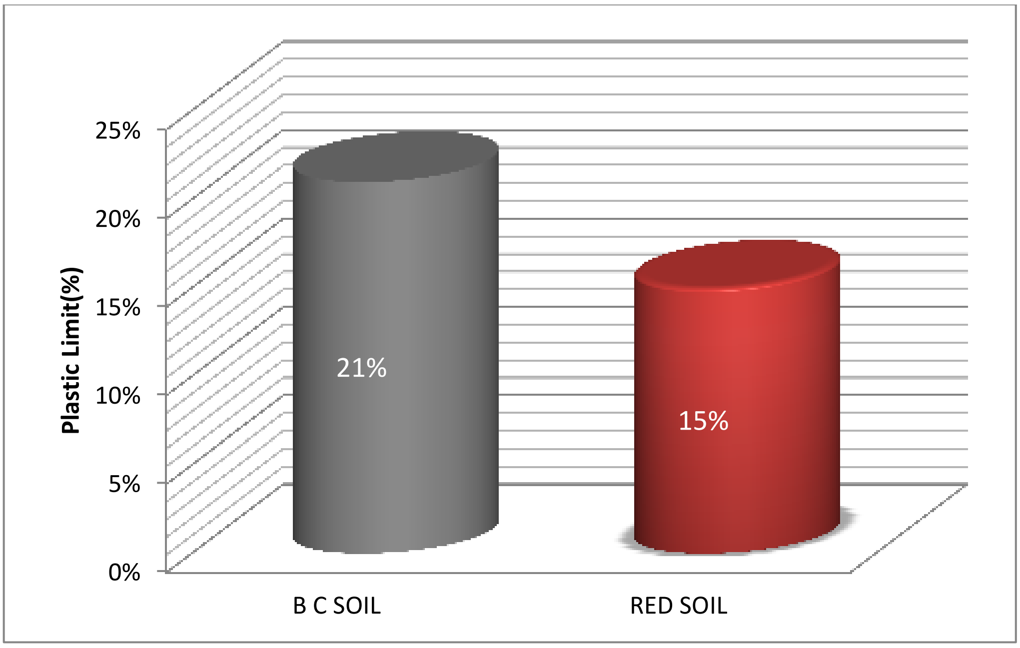


Fig. 7 Chart of Plastic Limit Comparison

As shown in the Fig 7 the Type of soil is taken on x-axis and plastic limit on y-axis. The plastic limit of Black cotton soil and Red soil is 21% and 15% respectively

Shrinkage Limit Comparison

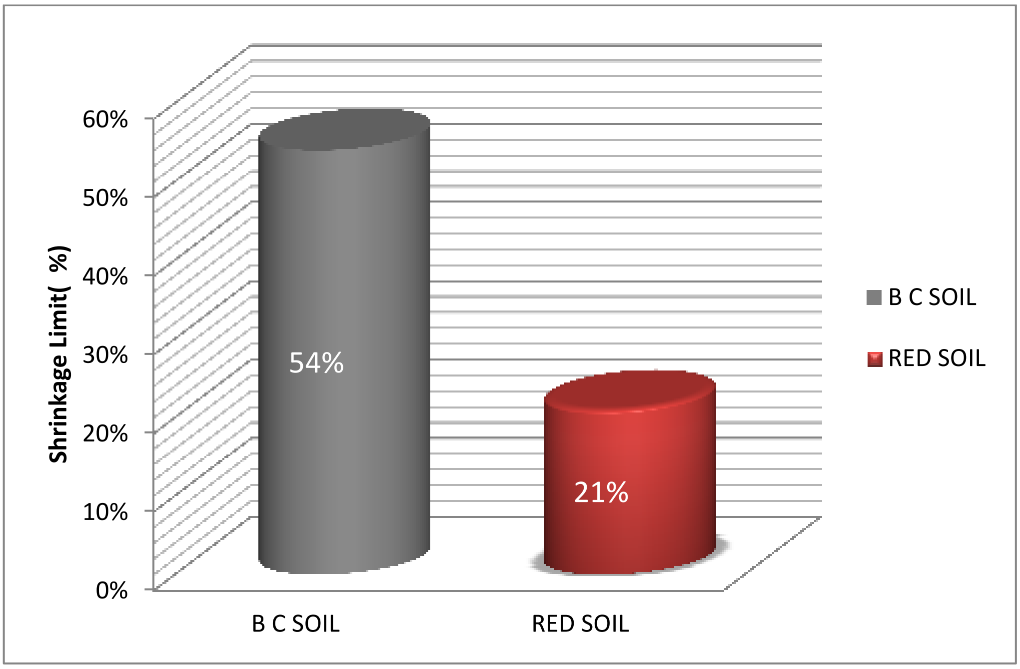


Fig. 8 Chart of Shrinkage Limit Comparison

As shown in the Fig 8 the Type of soil is taken on x-axis and shrinkage limit on y-axis. The shrinkage limit of Black cotton soil and Red soil is 54% and 21% respectively

Maximum Dry Density Comparison

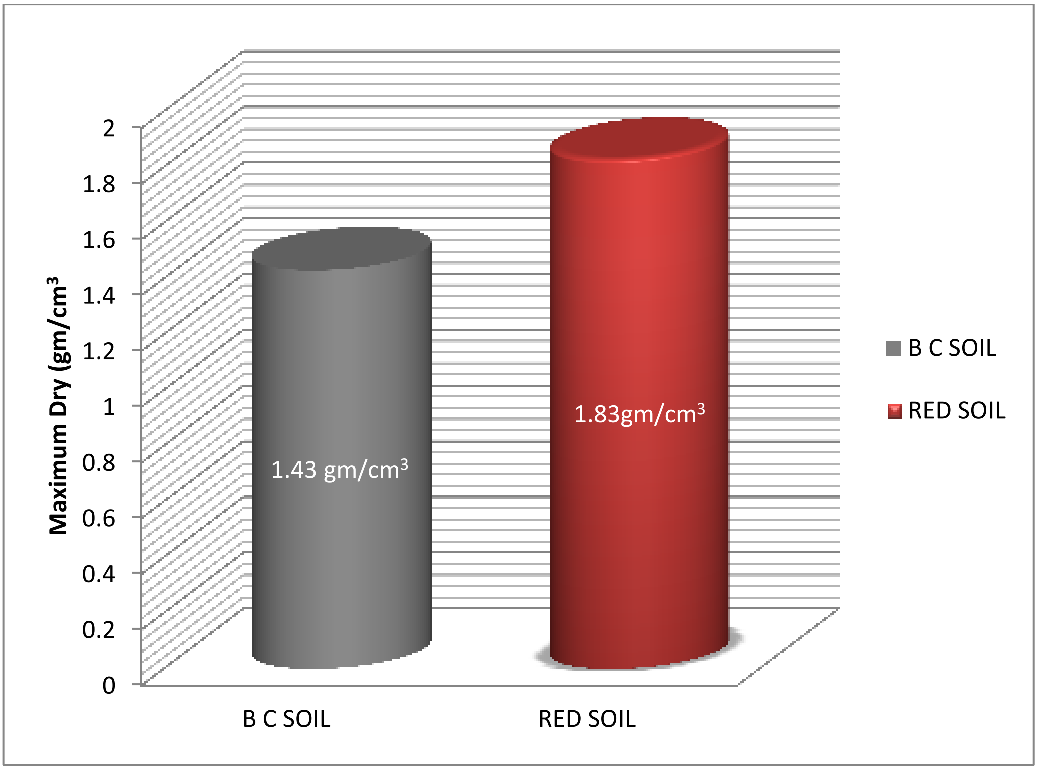


Fig. 9 Chart of Maximum Dry Density Comparison

As shown in the Fig 9 the Type of soil is taken on x-axis and MDD on y-axis. The MDD of Black cotton soil and Red soil is 1.43 gm/cm^3 and 1.83gm/cm^3 respectively

Optimum Moisture Content Comparison

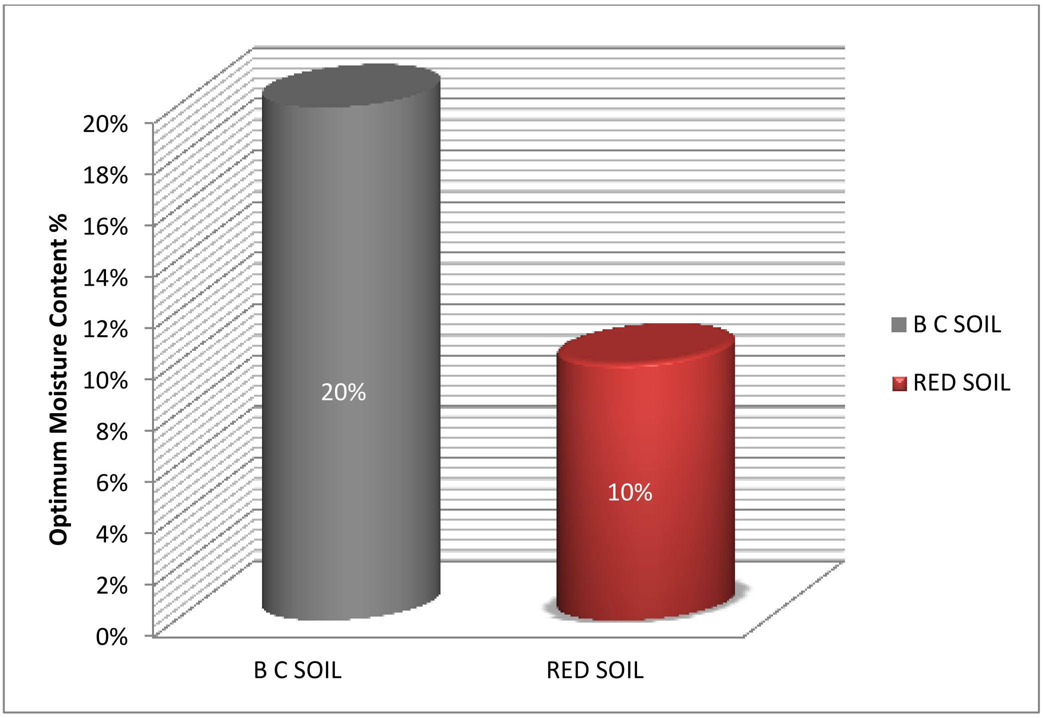


Fig. 10 Chart of Optimum Moisture Content Comparison

As shown in the Fig 10 the Type of soil is taken on x-axis and OMC on y-axis. The OMC of Black cotton soil and Red soil is 20 % and 10 % respectively.

Unconfined Compressive Strength Comparison

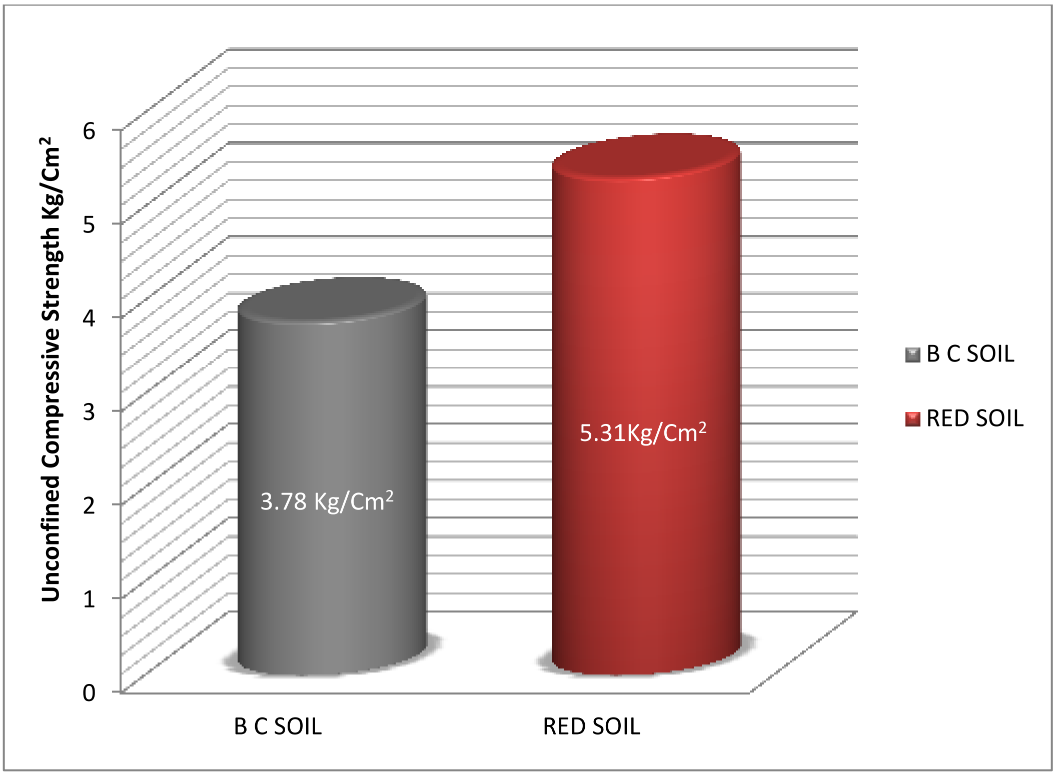


Fig. 11 Unconfined Compressive Strength Comparison

As shown in the Fig. 11 the Type of soil is taken on x-axis and UCS on y-axis. The UCS of Black cotton soil and Red soil is 3.78 Kg/Cm^2 and 5.31Kg/Cm^2 respectively

California Bearing Ratio Comparison

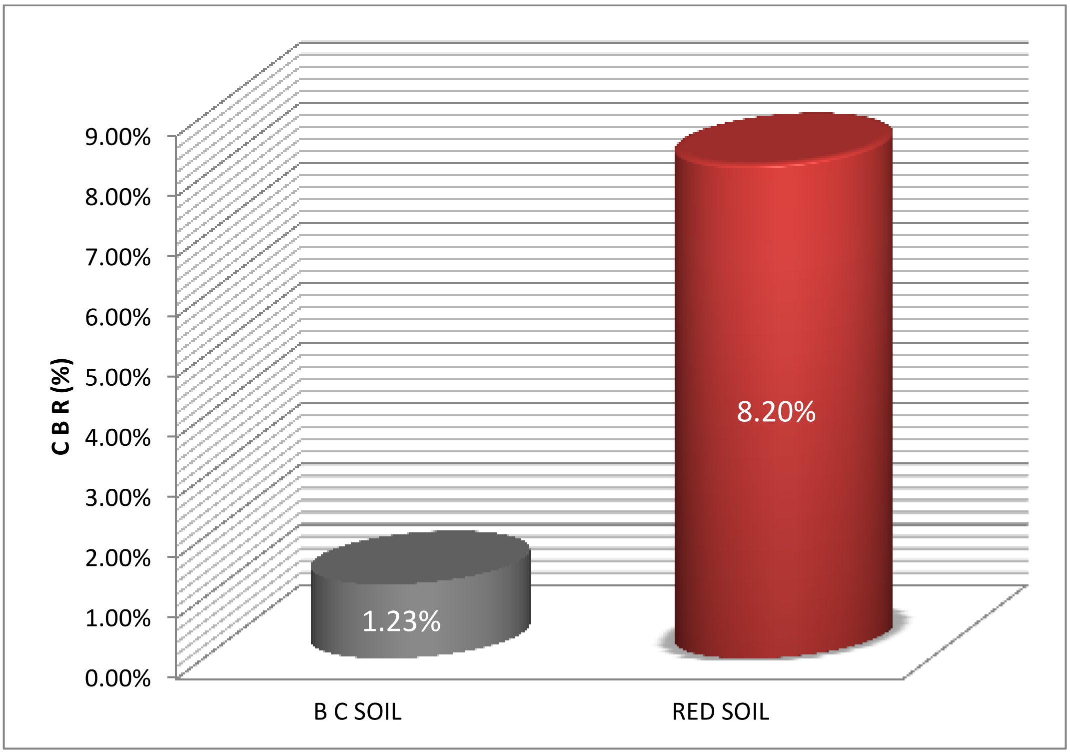


Fig. 12 Chart of California Bearing Ratio Comparison

As shown in the Fig 12 the Type of soil is taken on x-axis and CBR value on y-axis. CBR vslue of Black cotton soil and Red soil is 1.23% and 8.20% respectively

Traffic Volume Count Survey

TABLE 3
TRAFFIC COUNT VALUE TABLE

TIME	**HCV BUS / TRUCK**			**MCV TRAILOR/ TRACTOR**			**LCV CAR**		
	DAY			**DAY**			**DAY**		
	1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
7AM - 8 AM	1	1	0	1	2	1	1	2	2
8AM – 9AM	0	1	1	0	1	2	15	17	19
9AM – 10AM	1	1	2	2	0	0	2	3	2
10AM – 11AM	1	0	2	1	3	1	1	2	1
11 AM-12PM	1	0	1	1	1	2	0	2	1
12PM -01 PM	1	1	0	2	1	1	0	1	1
01PM-02PM	0	0	1	1	1	2	2	4	3
02PM – 03PM	1	1	1	0	0	1	1	3	2
03PM-04PM	0	1	1	0	2	3	2	4	4
04PM-05PM	0	1	0	2	1	1	4	5	6
05PM -06PM	0	0	1	3	0	3	13	18	15
06PM-07PM	1	1	0	1	1	1	2	4	5
07PM-08PM	0	0	1	0	0	1	2	`4	6
AVERAGE	**7**	**8**	**11**	**14**	**15**	**19**	**46**	**71**	**68**
	9			**16**			**62**		

PROCEDURE TO DESIGN SUBGRADE BY CBR METHOD USING CODE IRC-372001[19]

Design procedure

Based on the performance of existing designs and using analytical approach, simple design charts and a catalogue of pavement designs are added in the code. The pavement designs are given for sub grade CBR values ranging from 2% to 10% and design traffic ranging from 1 msa to 150 msa for an average annual pavement temperature of 35 C. The later thicknesses obtained from the analysis have been slightly modified to adapt the designs to stage construction. Using the following simple input parameters, appropriate designs could be chosen for the given traffic and soil strength:

- Design traffic in terms of cumulative number of standard axles; and
- CBR value of sub grade.

Design traffic

The method considers traffic in terms of the cumulative number of standard axles (8160 kg) to be carried by the pavement during the design life. This requires the following information:

1. Initial traffic in terms of CVPD
2. Traffic growth rate during the design life
3. Design life in number of years
4. Vehicle damage factor (VDF)
5. Distribution of commercial traffic over the carriage way.

Initial traffic Initial traffic is determined in terms of commercial vehicles per day (CVPD). For the structural design of the pavement only commercial vehicles are considered assuming laden weight of three tonnes or more and their axle loading will be considered. Estimate of the initial daily average traffic flow for any road should normally be based on 7-day 24-hour classified traffic counts (ADT). In case of new roads, traffic estimates can be made on the basis of potential land use and traffic on existing routes in the area. **Traffic growth rate** Traffic growth rates can be estimated (i) by studying the past trends of traffic growth, and (ii) by establishing econometric models. If adequate data is not available, it is recommended that an average annual growth rate of 7.5 percent may be adopted. **Design life** For the purpose of the pavement design, the design life is defined in terms of the cumulative number of standard axles that can be carried before strengthening of the pavement is necessary. It is recommended that pavements for arterial roads like NH, SH should be designed for a life of 15 years, EH and urban roads for 20 years and other categories of roads for 10 to 15 years. **Vehicle Damage Factor** The vehicle damage factor (VDF) is a multiplier for converting the number of commercial vehicles of different axle loads and axle configurations to the number of standard axle-load repetitions. It is defined as equivalent number of standard axles per commercial vehicle. The VDF varies with the axle configuration, axle loading, terrain, type of road, and from region to region. The axle load equivalency factors are used to convert different axle load repetitions into equivalent standard axle load repetitions. For these equivalency factors refer IRC:37 2001. The exact VDF values are arrived after extensive field surveys.

Vehicle distribution

A realistic assessment of distribution of commercial traffic by direction and by lane is necessary as it directly affects the total equivalent standard axle load application used in the design. Until reliable data is available, the following distribution may be assumed.

- **Single lane roads:** Traffic tends to be more channelized on single roads than two lane roads and to allow for this concentration of wheel load repetitions, the design should be based on total number of commercial vehicles in both directions.
- **Two-lane single carriageway roads:** The design should be based on 75 % of the commercial vehicles in both directions.
- **Four-lane single carriageway roads:** The design should be based on 40 % of the total number of commercial vehicles in both directions.
- **Dual carriageway roads:** For the design of dual two-lane carriageway roads should be based on 75 % of the number of commercial vehicles in each direction. For dual three-lane carriageway and dual four-lane carriageway the distribution factor will be 60 % and 45 % respectively.

Design traffic

The design traffic is considered in terms of the cumulative number of standard axles in the lane carrying maximum traffic during the design life of the road. This can be computed using the following equation:

$$N = \frac{365 \times [(1+r)^n - 1]}{r} \times A \times D \times F$$

where N is the cumulative number of standard axles to be catered for the design in terms of million standards axle (msa), A is the initial traffic in the year of completion of construction in terms of the number of commercial vehicles per day, D is the lane distribution factors, F is the vehicle damage factor, n is the design life in years, and r is the annual growth rate of commercial vehicles (r=-0.075 if growth rate is 7.5 percent per annum). The traffic in the year of completion is estimated using the following formula:

$$A = P(1 + r)^x$$

where P is the number of commercial vehicles as per last count, and x is the number of years between the last count and the year of completion between the last count and the year of completion of the project.

Pavement thickness design charts

For the design of pavements to carry traffic in the range of 1 to 10 msa, use chart 1 and for traffic in the range 10 to 150 msa, use chart 2 of IRC:37 2001. The design curves relate pavement thickness to the cumulative number of standard axles to be carried over the design life for different sub-grade CBR values ranging from 2 % to 10 %. The design charts will give the total thickness of the pavement for the above inputs. The total thickness consists of granular sub-base, granular base and bituminous surfacing. The individual layers are designed based on the the recommendations given below and the subsequent tables.

Pavement composition

Sub-base Sub-base materials comprise natural sand, gravel, laterite, brick metal, crushed stone or combinations thereof meeting the prescribed grading and physical requirements. The sub-base material should have a minimum CBR of 20 % and 30 % for traffic upto 2 msa and traffic exceeding 2 msa respectively. Sub-base usually consist of granular or WBM and the thickness should not be less than 150 mm for design traffic less than 10 msa and 200 mm for design traffic of 1:0 msa and above. **Base** The recommended designs are for unbounded granular bases which comprise conventional water bound macadam (WBM) or wet mix macadam (WMM) or equivalent confirming to MOST specifications. The materials should be of good quality with minimum thickness of 225 mm for traffic up to 2 msa an 150 mm for traffic exceeding 2 msa. **Bituminous surfacing** The surfacing consists of a wearing course or a binder course plus wearing course. The most commonly used wearing courses are surface dressing, open graded premix carpet, mix seal surfacing, semi-dense bituminous concrete and bituminous concrete. For binder course, MOST specifies, it is desirable to use bituminous macadam (BM) for traffic upto o 5 msa and dense bituminous macadam (DBM) for traffic more than 5 msa.

Calculation of Pavement Thickness

Case 1 : Black Cotton Soil

Available Data:

1. Design of CBR of Subgrade Soil : 1.23%
2. Design Life of Pavement : 15 years
3. Annual Growth rate : 7.5 %
4. Distribution of Commercial vehicle for Single Lane : Single Lane
5. Computation of Design traffic for the end of Design life : 0.75

N = {365×[(1+r)^n-1]/r}×{A×D×F) }

N = The commulative no. of standard axles to be catered for in the design in terms of msa.

A = Initial Traffic in the year of completion of completion of construction in term of no. of CVPD

A = P (1+r)^x

P = No. of commercial vehicles as per last count

x = No. of years between the last count and the year of completion of construction

D = Lane distribution factor

F = Vehicle damage factor

n = Design Life in Years

r = Annual growth rate of commercial vehicles

Design Calculation of Pavement thickness:

1. Commercial Vehicle at last count "P" =277 CV/Day
2. r =7.50%
3. x =1

4. A =87
5. D =1
6. F =3.5
7. N =2.9 msa (say 3 msa)
8. Total thickness of pavement for design CBR 1.23% and Design traffic = 3 msa, of IRC 37, 2001
1.23% & design traffic 3 msa of IRC37, 2001
Total Thickness = 665 mm
9. Total thickness to be provided = 665 mm
10. Pavement composition interpolated as per IRC37-2001
(a) Granular Sub base = 335 mm
(b) Base course = 225 mm
(c) Dense Bituminous Macadam (DBM) =50 mm
(d) Binder Course =20 mm
Total Pavement Thickness = 665 mm

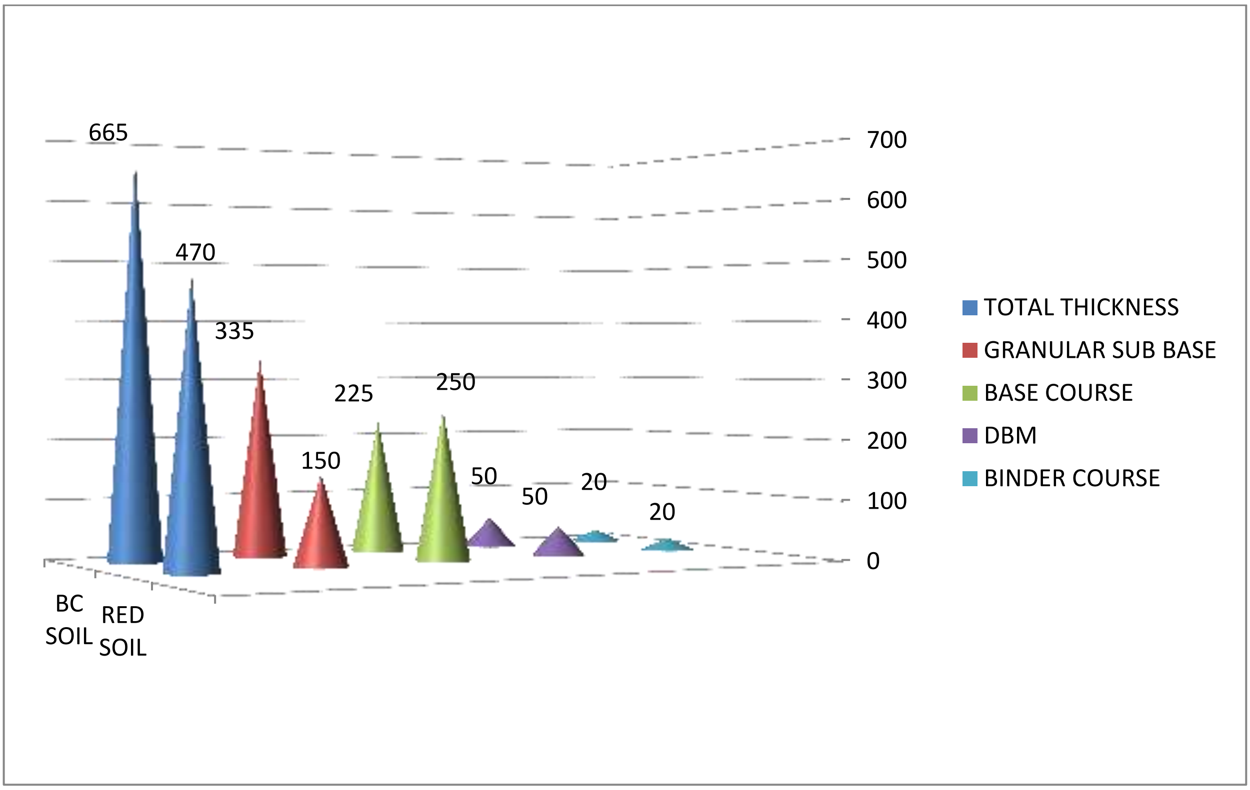
Case 2 : Red Soil
Available Data:
1. Design of CBR of Subgrade Soil : 8.2%
2. Design Life of Pavement : 15 years
3. Annual Growth rate : 7.5 %
4. Distribution of Commercial vehicle for Single Lane : Single Lane
5. Computation of Design traffic for the end of Design life : 0.75

N = {365×[(1+r)^n-1]/r}×{A×D×F) }

N = The commulative no. of standard axles to be catered for in the design in terms of msa.
A = Initial Traffic in the year of completion of completion of construction in term of no. of CVPD
A = P (1+r)^x
P = No. of commercial vehicles as per last count
x = No. of years between the last count and the year of completion of construction
D = Lane distribution factor
F = Vehicle damage factor
n = Design Life in Years
r = Annual growth rate of commercial vehicles

Design Calculation of Pavement thickness:
1. Commercial Vehicle at last count "P" =277 CV/Day
2. r =7.50%
3. x =1
4. A =87
5. D =1
6. F =3.5
7. N =2.9 msa (say 3 msa)
8. Total thickness of pavement for design CBR 8.2% and Design traffic = 3 msa, of IRC 37, 2001
8.2% & design traffic 3 msa of IRC37, 2001
Total Thickness = 470 mm
9. Total thickness to be provided = 470 mm
10. Pavement composition interpolated as per IRC37-2001
(a) Granular Sub base = 150 mm
(b) Base course = 250 mm
(c) Dense Bituminous Macadam (DBM) =50 mm
(d) Binder Course =20 mm
Total Pavement Thickness = 470 mm

THICKNESS COMPARISON



III. CONCLUSIONS

As the black cotton soil has more clay particles than the red soil the black cotton soil is more problematic in nature.The Maximum Dry Density (MDD) and Unconfined Compressive Strength (UCS) is more for Red soil compared to Black Cotton Soil. The thickness of crust varies with the change in the value of C.B.R. With higher value of C.B.R. the crust thickness is less and vice versa.From this laboratory test it has been observed that the Red soil is suitable for the construction purpose for soil sub grade in comparison with the Black cotton soil (Clayey silt) on the basis of higher values of C.B.R. Due to the saving in crust less quantity of material will be applicable so that, huge amount of money can be saved. Due to the higher values of C.B.R the Red soil will be more durable in comparison to Black Cotton soil (Clayey silt).

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