14th International Conference on Recent trends in Engineering, Applied Science and Management
Vedant College of Engineering & Technology, Bundi, Rajasthan (India) (ICRTESM-19)
16th February 2019 www.conferenceworld.in ISBN : 978-93-87793-71-2

# DESIGN OF FLEXIBLE PAVEMENT BY BLACK COTTON SOIL WITH SUGARCANE BAGASSE ASH

**Jitendra Khatti[1], Sumit Shringi [2], Dr. K. S. Grover[3], Dr. Biswajit Acharya[4]**

*[1] Scholar Ph.D. (Geotechnical Engineering), Civil Engineering Dept., UD, RTU, Kota, India*
*[2] Assistant Professor, Civil Engineering Dept., VCET, Bundi, Kota, India*
*[3] Professor, Civil Engineering Dept., UD, RTU, Kota, India*
*[4] Associate Professor, Civil Engineering Department, UD, RTU, Kota, India*

## ABSTRACT

According to IRC recommendation, the California bearing ratio (CBR) value of subgrade is used for design of flexible pavements. The design of pavement may affect by the material which is used as pavement material. Black Cotton soil is expansive soil which expand when it contacts with water and this is the major reason of failure of black cotton soil strata. The engineering properties of black cotton soil may be used by fibre, ash, lime and sludge etc. CBR value depends on the liquid limit ($W_l$), Plastic limit ($W_p$), plasticity index ($I_p$), maximum dry density, optimum moisture content, swelling pressure, degree of expansiveness and permeability of soil or mix specimen. These tests are performed in laboratory. This research paper deals with design of flexible pavement by using black cotton soil with different percentage of sugarcane bagasse ash. In this research, the sugarcane bagasse ash is mixed from 10% to 40% in black cotton soil. The engineering parameters are also determined by performed tests. For studying the behaviour of black cotton soil with different percentage of sugarcane bagasse ash, the Atterberg's limits (Liquid Limit, Plastic Limit, Plasticity Index), standard proctor test, California Bearing Ratio are performed.

***Keywords – California Bearing Ratio, Sugarcane Bagasse Ash, Effect on Plasticity Index, Degree of Expansiveness, Maximum Dry Density***

## I. INTRODUCTION

For the pavement design, the Black cotton soil is used as a base material and for improving the engineering properties of black cotton soil, the sugarcane bagasse ash is mixed from 10% to 40% by weight of black cotton soil. The sugarcane bagasse ash is a waste material, which may be used as stabilizing material for black cotton soil to improve engineering properties of soil. The black cotton soil is characterized by high shrinkage and swelling properties. Due to high swelling and shrinkage characteristics, the black cotton soil has been a big issue to highway and other civil engineering specializations California bearing ratio is an empirical test and over the world, it is used for designing the flexible pavement. The tests results are used in pavement design, in the duration of second world war. The CBR test is frequently used in the assessment of granular materials in base, subbase and subgrade layers of road and airfield pavements. CBR has become so globally popular that it is incorporated in many international standards ASTM 2000. Many researchers did work on black cotton soil with different materials for stabilization. In the past many researchers have carried out their research work for designing the flexible

pavement by black cotton soil using different types of admixture, stone dust, slurry, sugarcane bagasse ash and fibre. **T. Sudesh Reddy et.al.** performed experimental study on utilization of rural waste marginally enhances the properties of local soil; sugarcane bagasse ash remains can be utilized as substitution in neighborhood soil up as far as possible. The accompanying conclusions are made in view of the laboratory tests did in their examination. They observed that 20% sugarcane bagasse ash improved the engineering properties of black cotton soil. They also added fibre percentage 0% to 1.5% at variation in mix of black cotton soil with 20% sugarcane bagasse ash. From test results it is concluded the CBR value is also increasing in both case of mix. Similarly, **Jheelu Bajaj** studied about performance evaluation of black cotton soil stabilized with sugarcane bagasse ash and randomly distributed coir fibres. From test results, he concluded that CBR value is increasing with increasing percentage of SCBA in black cotton soil up to adding 20% SCBA.

## II. EXPERIMENTAL INVESTIGATIONS

Various such as Atterberg's limit (liquid limit and plastic limit), Shrinkage limit, Differential free swelling, swelling pressure, OMC and MDD, UCS, etc tests have been performed to design the flexible pavement by using black cotton soil with Kota stone slurry. The percentage of Kota stone slurry may have varied from 5% to 30% by 5% variation.

### 2.1 Material Used

- **Black Cotton Soil (BCS) –** About 150 kg of soil sample for the present work was collected from the Raisin Road, Bhopal, Madhya Pradesh.
- **Sugarcane Bagasse Ash (SCBA) –** Sugarcane bagasse ash for the present work was purchased from market.

### 3.1 Engineering Properties of Black Cotton Soil, Mix Specimen of Sugarcane Bagasse Ash

The following engineering properties are determined by laboratory test for black cotton soil, mix specimen of sugarcane bagasse ash.

Table 1 Engineering properties of BCS and mix specimen of SCBA

| Properties | Black Cotton Soil | Mix Specimen |
|---|---|---|
| Specific Gravity | 2.44 | 2.31 |
| Liquid Limit (%) | 73.00 | 59.00 – 46.00 |
| Plastic Limit (%) | 30.00 | 26.00 – 21.10 |
| Plasticity Index (%) | 43.00 | 33.00 – 24.90 |
| Differential Free Swell (%) | 58.00 | 50.00 – 27.25 |
| IS Classification | CH | CH – CI |
| Maximum Dry Density (gm/cm) | 1.66 | 1.98 – 1.91 |
| Optimum Moisture Content (%) | 19.10 | 16.36 – 17.80 |

Note – The mix specimen is prepared by 2.5% to 12.5% of SCBA in black cotton soil

The sugarcane bagasse ash is mixed with black cotton soil at 10%, 20%, 30% and 40%. The variation of tests results is shown in Table 1. When the percentage of sugarcane bagasse ash increases the liquid limit, plastic limit

decreases and plasticity index also decreases. Due to plasticity criteria, the black cotton soil behaviour changes from CH to CI.

### 3.2 California Bearing Ratio (CBR)

As per IRC recommendation, California bearing ratio value of subgrade is used for design of flexible pavements. California bearing ratio value is an important soil parameter for design of flexible pavements and runway of air fields. The test is performed according to IS 2720 (Part 16) – 1979. The California bearing ratio test is performed in laboratory for black cotton soil and mix specimen of SCBA. Table 2 is consisting of corrected CBR value of Black cotton soil and mix specimen of SCBA for soaked CBR test.

Table 2 CBR test load value for black cotton soil and mix specimen of SCBA

| Specimen/ Penetration | 2.5 mm | 5.0 mm | 7.5 mm | 10.0 mm | 12.5 mm |
|---|---|---|---|---|---|
| Black Cotton Soil (BCS) | 1.43% | 1.87% | 1.63% | 1.29% | 0.98% |
| BCS + 10% SCBA | 3.15% | 3.63% | 3.57% | 3.32% | 3.07% |
| BCS + 20% SCBA | 3.87% | 3.65% | 3.43% | 3.21% | 3.09% |
| BCS + 30% SCBA | 3.57% | 3.35% | 3.16% | 3.04% | 2.91% |
| BCS + 40% SCBA | 3.49% | 3.29% | 3.14% | 2.98% | 2.82% |

Note – All load parameters are in kgf

As per IRC recommendation, only 2.5 and 5.0 mm penetration value is considered. The maximum CBR value is taken for the design of flexible pavement. The maximum value of CBR is determined 3.87% for black cotton soil with 20% sugarcane bagasse ash mix specimen.

### 3.3 Flexible Pavement Design as per IRC 31 – 2001

For the designing the flexible pavement, the IRC 31 – 2001 is used. This code based on the value of California bearing ratio. Following formula is used for designing the flexible pavement –

$$= 365 \times [(1+\ ) - 1] \times \qquad \times \qquad \times$$

Where

$$= \qquad \times (1+\ )$$

n – Design life in year

F – Vehicle damage factor

r – Annual growth rate of commercial vehicles

P – Number of commercial vehicles as per last count

D – Land distribution factor

x – Number of years between the last count and the year of completion of construction

A – Initial traffic in year of completion of terms of the number of commercial vehicles per day

### 3.4 Design Parameters of Flexible Pavement

For the designing the flexible pavement following design data are taken for 570 traffic volume –

Design life in year (n) – 10

Vehicle damage factor (F) – 4.5

Value of California bearing ratio – 3.87%

Annual growth rate of commercial vehicles (r) – 7.5%

Number of commercial vehicles as per last count (P) – 570 Nos

Land distribution factor (D) – 0.75 (Two Lane Single Carriageway Road)

Number of years between the last count and the year of completion of construction (x) – 1

Initial traffic in year of completion of terms of the number of commercial vehicles per day (A) – 615.6 ≈ 615

Table 3 shows, traffic volume count survey,

Table 3 Traffic volume count survey

| Time | Bus/Truck (Laden) | | | Bus/Truck (Unladen) | | | Bus/Truck (Overloaded) | | | Agricultural Tractor Trailor (Laden) | | | Agricultural Tractor Trailor (Unladen) | | | Agricultural Tractor Trailor (Overloaded) | | | Cars/ Vans / Jeeps / Three Wheeler | | | (Laden) | | | (Unladen) | | | (Overloaded) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Days | D-1 | D-2 | D-3 | D-1 | D-2 | D-3 | D-1 | D-2 | D-3 | D-1 | D-2 | D-3 | D-1 | D-2 | D-3 | D-1 | D-2 | D-3 | D-1 | D-2 | D-3 | D-1 | D-2 | D-3 | D-1 | D-2 | D-3 | D-1 | D-2 | D-3 |
| 7 to 8 AM | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 5 | 3 | 3 | 3 | 3 | 1 | 1 |
| 8 to 9 AM | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 4 | 4 | 4 | 5 | 4 | 4 | 5 | 3 | 5 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 1 | 4 | 1 | 3 |
| 9 to 10 AM | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 4 | 4 | 4 | 5 | 3 | 5 | 3 | 3 | 5 | 5 | 3 | 6 | 3 | 3 | 1 | 3 | 3 | 3 |
| 10 to 11 AM | 5 | 5 | 6 | 5 | 5 | 4 | 4 | 5 | 5 | 6 | 7 | 6 | 4 | 6 | 5 | 3 | 3 | 3 | 9 | 8 | 9 | 3 | 5 | 3 | 3 | 3 | 5 | 5 | 3 | 3 |
| 11 to 12 AM | 4 | 5 | 5 | 6 | 4 | 6 | 4 | 6 | 4 | 5 | 4 | 6 | 4 | 4 | 5 | 5 | 5 | 6 | 9 | 10 | 13 | 3 | 3 | 5 | 6 | 7 | 7 | 3 | 3 | 5 |
| 12 to 1 PM | 4 | 4 | 5 | 5 | 4 | 4 | 5 | 4 | 4 | 5 | 5 | 4 | 5 | 4 | 4 | 5 | 3 | 3 | 13 | 10 | 10 | 3 | 3 | 3 | 3 | 3 | 5 | 4 | 3 | 3 |
| 1 to 2 PM | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 4 | 5 | 4 | 4 | 4 | 4 | 5 | 3 | 3 | 3 | 8 | 8 | 7 | 3 | 5 | 5 | 5 | 3 | 3 | 3 | 3 | 3 |
| 2 to 3 PM | 4 | 5 | 6 | 5 | 4 | 6 | 6 | 4 | 4 | 4 | 5 | 5 | 5 | 4 | 4 | 3 | 3 | 5 | 6 | 6 | 7 | 5 | 5 | 5 | 4 | 5 | 3 | 5 | 6 | 5 |
| 3 to 4 PM | 4 | 5 | 6 | 4 | 5 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 5 | 4 | 4 | 3 | 3 | 3 | 6 | 3 | 3 | 3 | 3 | 4 | 5 | 3 | 4 | 3 | 3 | 3 |
| 4 to 5 PM | 5 | 6 | 4 | 4 | 4 | 6 | 4 | 6 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 3 | 3 | 6 | 3 | 5 | 5 | 5 | 5 | 4 | 2 | 3 | 3 | 1 | 3 |
| 5 to 6 PM | 5 | 4 | 5 | 4 | 5 | 6 | 4 | 5 | 4 | 5 | 4 | 4 | 5 | 4 | 7 | 3 | 3 | 3 | 3 | 3 | 5 | 3 | 2 | 3 | 5 | 3 | 4 | 3 | 3 | 5 |
| 6 to 7 PM | 6 | 4 | 6 | 4 | 5 | 6 | 4 | 6 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 5 | 5 | 3 | 10 | 13 | 11 | 3 | 5 | 5 | 4 | 3 | 3 | 5 | 3 | 3 |
| 7 to 8 PM | 5 | 4 | 4 | 4 | 5 | 6 | 4 | 4 | 4 | 4 | 4 | 5 | 6 | 4 | 4 | 3 | 3 | 3 | 13 | 13 | 13 | 3 | 5 | 3 | 5 | 3 | 3 | 3 | 3 | 3 |
| Total | 58 | 58 | 64 | 57 | 57 | 65 | 56 | 62 | 53 | 59 | 58 | 61 | 59 | 54 | 59 | 49 | 45 | 46 | 92 | 86 | 94 | 45 | 50 | 55 | 52 | 44 | 45 | 47 | 36 | 43 |
| Average | 60 | | | 60 | | | 57 | | | 59 | | | 57 | | | 47 | | | 91 | | | 50 | | | 47 | | | 42 | | |
| Total Average (P) | 570 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

**Results for 570 traffic volume survey**

The test results are determined for the 3.87% CBR value and 11 msa.

a. Total thickness of pavement – 763 mm
b. Thickness of granular base – 250 mm
c. Thickness of granular sub base – 380 mm
d. Thickness of wearing course (BC) – 40 mm
e. Thickness of binder course (DBM) – 93 mm

For the designing the flexible pavement following design data are taken for 490 traffic volume –

Design life in year (n) – 10

Vehicle damage factor (F) – 3.5

Value of California bearing ratio – 3.87%

Annual growth rate of commercial vehicles (r) – 7.5%

Number of commercial vehicles as per last count (P) – 490 Nos

Land distribution factor (D) – 1 (Single Lane Carriageway Road)

Number of years between the last count and the year of completion of construction (x) – 1

Initial traffic in year of completion of terms of the number of commercial vehicles per day (A) – 529.2 ≈ 529

Table 4 shows, traffic volume count survey,

Table 4 Traffic volume count survey

| Time | Bus/Truck (Laden) | | | Bus/Truck (Unladen) | | | Bus/Truck (Overloaded) | | | Agricultural Tractor Trailor (Laden) | | | Agricultural Tractor Trailor (Unladen) | | | Agricultural Tractor Trailor (Overloaded) | | | Cars/ Vans / Jeeps / Three Wheeler | | | (Laden) | | | (Unladen) | | | (Overloaded) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Days | D-1 | D-2 | D-3 | D-1 | D-2 | D-3 | D-1 | D-2 | D-3 | D-1 | D-2 | D-3 | D-1 | D-2 | D-3 | D-1 | D-2 | D-3 | D-1 | D-2 | D-3 | D-1 | D-2 | D-3 | D-1 | D-2 | D-3 | D-1 | D-2 | D-3 |
| 7 to 8 AM | 2 | 2 | 2 | 2 | 3 | 5 | 3 | 5 | 5 | 2 | 5 | 5 | 3 | 2 | 5 | 3 | 2 | 5 | 2 | 3 | 3 | 5 | 3 | 5 | 3 | 3 | 2 | 2 | 3 | 3 |
| 8 to 9 AM | 3 | 2 | 3 | 3 | 3 | 2 | 2 | 3 | 5 | 5 | 3 | 5 | 5 | 3 | 5 | 5 | 5 | 5 | 3 | 2 | 2 | 2 | 3 | 2 | 5 | 3 | 3 | 2 | 3 | 2 |
| 9 to 10 AM | 3 | 3 | 2 | 3 | 2 | 3 | 3 | 2 | 5 | 5 | 6 | 6 | 5 | 3 | 2 | 5 | 3 | 5 | 5 | 5 | 5 | 5 | 5 | 6 | 2 | 3 | 3 | 2 | 3 | 2 |
| 10 to 11 AM | 5 | 3 | 5 | 2 | 2 | 5 | 5 | 3 | 5 | 2 | 5 | 3 | 3 | 5 | 3 | 5 | 5 | 2 | 5 | 2 | 5 | 2 | 3 | 5 | 3 | 5 | 3 | 3 | 2 | 2 |
| 11 to 12 AM | 5 | 3 | 3 | 3 | 5 | 5 | 3 | 5 | 5 | 5 | 3 | 3 | 3 | 5 | 2 | 6 | 5 | 6 | 6 | 5 | 3 | 3 | 3 | 5 | 6 | 7 | 7 | 2 | 2 | 3 |
| 12 to 1 PM | 5 | 2 | 5 | 5 | 5 | 3 | 5 | 2 | 3 | 5 | 5 | 2 | 5 | 3 | 5 | 5 | 2 | 3 | 5 | 5 | 2 | 2 | 2 | 2 | 2 | 3 | 5 | 2 | 2 | 2 |
| 1 to 2 PM | 3 | 2 | 3 | 5 | 3 | 5 | 5 | 3 | 5 | 5 | 5 | 3 | 3 | 5 | 5 | 3 | 2 | 5 | 5 | 3 | 2 | 5 | 3 | 2 | 2 | 5 | 5 | 2 | 3 | 2 |
| 2 to 3 PM | 5 | 3 | 2 | 3 | 5 | 5 | 5 | 5 | 5 | 5 | 3 | 2 | 5 | 3 | 5 | 2 | 5 | 5 | 2 | 5 | 5 | 5 | 3 | 5 | 3 | 5 | 5 | 3 | 6 | 3 |
| 3 to 4 PM | 3 | 5 | 5 | 5 | 5 | 3 | 3 | 5 | 5 | 5 | 2 | 2 | 5 | 3 | 2 | 5 | 3 | 3 | 2 | 5 | 2 | 5 | 5 | 5 | 5 | 5 | 2 | 2 | 2 | 2 |
| 4 to 5 PM | 7 | 5 | 5 | 3 | 3 | 5 | 5 | 5 | 5 | 3 | 5 | 3 | 3 | 5 | 2 | 5 | 5 | 3 | 5 | 2 | 5 | 5 | 3 | 5 | 3 | 2 | 3 | 3 | 3 | 3 |
| 5 to 6 PM | 8 | 5 | 5 | 5 | 5 | 6 | 3 | 5 | 2 | 5 | 3 | 5 | 5 | 5 | 7 | 3 | 5 | 2 | 3 | 5 | 5 | 5 | 5 | 5 | 2 | 2 | 3 | 3 | 2 | 3 |
| 6 to 7 PM | 6 | 3 | 9 | 3 | 5 | 7 | 2 | 3 | 2 | 3 | 5 | 3 | 5 | 2 | 5 | 5 | 5 | 5 | 5 | 3 | 2 | 3 | 2 | 2 | 5 | 3 | 5 | 5 | 2 | 2 |
| 7 to 8 PM | 5 | 2 | 0 | 5 | 5 | 6 | 3 | 3 | 3 | 5 | 5 | 5 | 6 | 2 | 3 | 2 | 5 | 3 | 2 | 5 | 5 | 5 | 5 | 3 | 5 | 5 | 3 | 2 | 3 | 2 |
| Total | 60 | 40 | 49 | 47 | 51 | 60 | 47 | 49 | 55 | 55 | 55 | 47 | 56 | 46 | 51 | 54 | 52 | 52 | 50 | 50 | 46 | 52 | 45 | 52 | 46 | 51 | 49 | 33 | 36 | 31 |
| Average | 50 | | | 53 | | | 50 | | | 52 | | | 51 | | | 53 | | | 49 | | | 50 | | | 49 | | | 33 | | |
| Total Average (P) | 490 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

**Results for 490 traffic volume survey**

The test results are determined for the 3.87% CBR value and 10 msa.

a. Total thickness of pavement – 700 mm
b. Thickness of granular base – 250 mm
c. Thickness of granular sub base – 330 mm
d. Thickness of wearing course (BC) – 40 mm
e. Thickness of binder course (DBM) – 80 mm

## 4 DISCUSSIONS ON TEST RESULTS

After the obtaining results, it is clearly defined that black cotton soil changes it engineering properties with sugarcane bagasse ash. The sugarcane bagasse is low plasticity material and black cotton soil is inorganic clay of high plasticity but when amount of SCBA increases, the black cotton soil changes behaviour from CH to CI. The maximum dry density is also increased 1.66 gm/cc to 1.98 gm/cc, when 20% SCBA is mixed with black cotton soil. The maximum dry density is obtained for 5.0% mix specimen and maximum CBR value also is obtained for 5.0% mix specimen, which is 3.87%. The two-traffic volume count sample is taken for design of flexible pavement. First traffic volume count is 570 and second is 490. The MSA values 11 and 10 are determined for 570 and 450 traffic volume respectively. The total thickness of pavement is 763 mm and 700 mm determined for 11 MSA and 10 MSA respectively.

## 5 CONCLUSIONS

- With increasing the percentage of SCBA in black cotton soil, the black cotton soil changes behaviour CH to CI. The SCBA is inorganic clay of low plasticity material.
- It is clearly defined that when the quantity of traffic increases, the value of N decreases.
- When quantity of traffic increases the total thickness of flexible pavement decreases.
- It is also defined, the million standard axles (msa) value is directly proportional to the thickness of pavement and number of traffic.

## 6 ACKNOWLEDGEMENTS

I would like to express my profound gratitude and indebtedness to Dr. K. S. Grover, Dr. Biswajit Acharya and my who have always been a constant motivation and guiding factor throughout the research time in and out as well. Dr. K. S. Grover is professor of civil engineering department and Dr. Biswajit Acharya is associate professor of

civil engineering department in University Department, RTU, Kota. It has been a great pressure for me to get an opportunity to work under them and complete the research work successfully.

## REFERENCES

[1] Jheelu Bajaj, Vikash Kumar Singh, "Performance Evaluation of Black Cotton Soil Stabilized with Sugarcane Bagasse Ash and Randomly Distributed Coir Fibres", IJIRST, Vol. 02, Issue – 11, April 2016.

[2] C.E.G. Justo and A. Veeraragavan S. K. Khanna, Highway Engineering, Khanna Publication, Delhi.

[3] Dr. B. C. Punamia, Ashok Jain, Arun Jain, Soil Mechanics and Foundations, Laxmi Publications, New Delhi.

[4] Dr. K. R. Arora, Soil Mechanics and Foundation Engineering, Standard Publications, New Delhi.

[5] Indian Standard Code : IS 1498 – 1970, Classification and identification of soils for general engineering purposes (first revision).

[6] Indian Standard Code : IS 2720 (Part 5) – 1985, Determination of liquid limit and plastic limit (second revision).

[7] Indian Standard Code : IS 2720 (Part 7) – 1980, Determination of water content, dry density relation using light compaction (second revision).

[8] Indian Standard Code : IS 2720 (Part 16) – 1979, Laboratory determination of CBR.

[9] Indian Standard Code : IS 2720 (Part 40) – 1977, Determination of free swell index of soils.

[10] Indian Standard Code : IS 2720 (Part 41) – 1977, Determination of swelling pressure of soils.

[11] Indian Road Congress : 37 – 2001, Design of Flexible Pavement.