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

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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 2.5% to 12.5% 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 2.5% to 12.5% by weight of black cotton 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. 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. 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. **Amruta P. Kulkarni et. al.** performed experimental study on stabilization of black cotton soil using bagasse ash and lime. The performed experiment on black cotton soil and they observed that plasticity index is decreasing and CBR value increasing when optimum ratio of bagasse ash to lime was used. 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 sugarcane bagasse ash. The percentage of SCBA may have varied from 2.5% to 12.5% by 2.5% variation.

2.1 Material Used

- **Black Cotton Soil (BCS) –** About 150 kg of soil sample for the present work was collected from the Goverdhan Pura, Bundi Road, Kota.
- **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 3.1 Engineering properties of BCS and mix specimen of SCBA

Properties	Black Cotton Soil	Mix Specimen
Specific Gravity	2.44	2.31
Liquid Limit (%)	54.88	57.36 – 33.94
Plastic Limit (%)	26.64	27.64 – 19.48
Plasticity Index (%)	27.94	29.72 – 14.47
Differential Free Swell (%)	55.00	50.00 – 19.05
Swelling Pressure (kg/cm^2)	0.90	1.35 – 0.60
IS Classification	CH	CI – CL
Maximum Dry Density (kg/cm^3)	1.708	1.740 – 1.678
Optimum Moisture Content (%)	18.2	16.4 – 21.6

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 2.5%, 5.0%, 7.5%, 10.0% and 12.5%. The variation of tests results is shown in Table 3.1. When the percentage of sugarcane bagasse ash increases the

liquid limit and plastic limit decreases and plasticity index also decreases. Due to plasticity criteria, the black cotton soil behaviour changes from CH to CL.

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 3.2 is containing CBR value of Black cotton soil and mix specimen of SCBA.

Table 3.2 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)	111.28	158.08	178.36	194.48	203.84
BCS + 2.5% SCBA	121.68	167.44	189.28	202.80	219.96
BCS + 5.0% SCBA	125.84	178.88	210.08	219.44	241.28
BCS + 7.5% SCBA	121.68	147.16	172.64	187.20	204.88
BCS + 10.0% SCBA	105.04	125.84	147.16	162.24	177.84
BCS + 12.5% SCBA	105.56	120.12	131.04	142.48	162.76

Note – All load parameters are in kgf

According to IS 2720 (Part 16) – 1979, after obtaining the load from CBR machine, the correction in load is applied to determine corrected load. This load is known as test load. The corrected test load is shown in Table 3.3, for black cotton soil and mix specimen.

Table 3.3 CBR corrected load value for black cotton soil and mix specimen

Specimen/ Penetration	2.5 mm	5.0 mm	7.5 mm	10.0 mm	12.5 mm
Black Cotton Soil (BCS)	131	164	181	198	209
BCS + 2.5% SCBA	133	173	192	205	224
BCS + 5.0% SCBA	139	188	211	222	250
BCS + 7.5% SCBA	128	151	178	190	210
BCS + 10.0% SCBA	122	142	160	172	190
BCS + 12.5% SCBA	118	130	139	159	181

Note – All load parameters are in kgf

As per IRC recommendation, only 2.5 and 5.0 mm penetration value is considered. From the corrected test value, the California bearing ratio is determined and shown in Table 3.4.

Table 3.4 CBR value for Black cotton soil and mix specimen

Specimen/ Penetration	2.5 mm	5.0 mm	7.5 mm	10.0 mm	12.5 mm
Black Cotton Soil (BCS)	9.56%	7.98%	6.88%	6.23%	5.81%
BCS + 2.5% SCBA	9.71%	8.42%	7.30%	6.45%	6.22%
BCS + 5.0% SCBA	10.15%	9.15%	8.02%	6.98%	5.97%
BCS + 7.5% SCBA	9.34%	7.35%	6.77%	5.97%	5.83%
BCS + 10.0% SCBA	8.91%	6.91%	6.08%	5.41%	5.28%
BCS + 12.5% SCBA	8.61%	6.33%	5.29%	5.00%	5.03%

Note – All CBR value is in percentage

The maximum CBR value is taken for the design of flexible pavement. The maximum value of CBR is determined 10.15% for black cotton soil with 5.0% 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 year 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 vehicle per day

3.4 Design Parameters of Flexible Pavement

For the designing the flexible pavement following design data are taken for 410 traffic volume –

Design life in year (n) – 12

Vehicle damage factor (F) – 4.5

Value of California bearing ratio – 10.15%

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

Number of commercial vehicles as per last count (P) – 410 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) – 442.8 ≈ 445

Table 3.5 shows, traffic volume count survey,

Table 3.5 Traffic volume count survey

											Agricultural			Agricultural			Agricultural													
Time	Bus/Truck			Bus/Truck			Bus/Truck			Tractor Trailor			Tractor Trailor			Tractor Trailor			Cars/ Vans / Jeeps				(Laden)			(Unladen)			(Overloaded)		
		(Laden)			(Unladen)			(Overloaded)			(Laden)			(Unladen)			(Overloaded)			/ Three Wheeler											
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	1	2	2	2	3	4	3	4	4	2	4	5	3	2	4	3	2	4	2	3	3	4	3	5	3	3	2	2	1	1
8 to 9 AM	2	2	3	3	2	2	2	3	4	4	3	2	2	3	3	3	1	4	3	2	2	2	3	2	4	3	1	1	1	2
9 to 10 AM	3	3	2	3	2	3	3	2	4	5	6	6	4	3	2	1	3	5	4	4	5	5	4	6	2	3	1	1	0	1
10 to 11 AM	2	3	4	2	2	4	1	1	2	2	2	3	3	4	3	4	4	2	4	2	3	2	3	4	3	4	3	3	2	2
11 to 12 AM	2	3	3	3	4	4	3	4	5	5	3	3	3	4	2	5	4	6	6	4	3	2	3	5	6	7	7	1	2	3
12 to 1 PM	4	2	4	5	4	3	1	2	3	5	5	2	2	3	3	5	2	3	4	4	2	2	2	2	2	3	1	1	2	2
1 to 2 PM	3	2	1	4	3	4	1	3	4	5	4	3	3	2	1	3	2	4	4	3	2	4	3	2	2	4	4	1	3	1
2 to 3 PM	5	1	2	3	4	5	2	2	5	4	3	2	5	3	4	2	4	5	2	5	4	4	3	5	3	5	4	3	6	2
3 to 4 PM	3	2	4	4	5	3	3	4	5	5	2	1	5	3	2	1	3	3	2	4	2	4	2	1	1	4	2	1	2	1
4 to 5 PM	7	5	9	3	3	2	4	5	4	3	4	3	3	4	2	5	4	3	4	2	1	5	3	4	3	2	3	3	1	3
5 to 6 PM	8	4	9	4	5	6	3	3	2	5	3	4	5	4	7	3	4	2	3	2	7	4	4	1	2	2	3	1	2	3
6 to 7 PM	6	3	9	3	5	6	2	1	2	3	4	2	5	2	4	5	2	4	3	3	2	3	2	2	1	3	4	4	2	1
7 to 8 PM	5	2	0	4	5	6	3	3	3	4	4	1	1	2	3	2	4	3	2	4	5	4	5	3	5	4	3	2	3	2
Total	51	34	52	43	47	52	31	37	47	52	47	37	44	39	40	42	39	48	43	42	41	45	40	42	37	47	38	24	27	24
Average		46			47			38			45			41			43			42			42			41			25	
Total Average (P)															410															

Results for 410 traffic volume survey

The test results are determined for the 10.15% CBR value and 10 msa.

a. Total thickness of pavement – 540 mm

b. Thickness of granular base – 250 mm
c. Thickness of granular sub base – 200 mm
d. Thickness of wearing course (BC) – 40 mm
e. Thickness of binder course (DBM) – 50 mm

For the designing the flexible pavement following design data are taken for 450 traffic volume –

Design life in year (n) – 10

Vehicle damage factor (F) – 3.5

Value of California bearing ratio – 10.15%

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

Number of commercial vehicles as per last count (P) – 450 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) – 486 ≈ 485 Table 3.6 shows, traffic volume count survey,

Table 3.6 Traffic volume count survey

											Agricultural			Agricultural			Agricultural													
Time	Bus/Truck			Bus/Truck			Bus/Truck			Tractor Trailor			Tractor Trailor			Tractor Trailor			Cars/ Vans / Jeeps				(Laden)			(Unladen)			(Overloaded)		
		(Laden)		(Unladen)			(Overloaded)				(Laden)			(Unladen)			(Overloaded)			/ Three Wheeler											
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	4	3	4	4	2	4	5	3	2	4	3	2	4	2	3	3	4	3	5	3	3	2	2	1	1
8 to 9 AM	2	2	3	3	2	2	2	3	4	4	3	5	4	3	5	4	5	4	3	2	2	2	3	2	4	3	1	2	1	2
9 to 10 AM	3	3	2	3	2	3	3	2	4	5	6	6	4	3	2	5	3	5	4	4	5	5	4	6	2	3	1	2	3	2
10 to 11 AM	4	3	4	2	2	4	4	3	5	2	5	3	3	4	3	4	4	2	4	2	5	2	3	4	3	4	3	3	2	2
11 to 12 AM	5	3	3	3	4	4	3	4	5	5	3	3	3	4	2	5	4	6	6	4	3	3	3	5	6	7	7	2	2	3
12 to 1 PM	4	2	4	5	4	3	5	2	3	5	5	2	5	3	4	5	2	3	4	4	2	2	2	2	2	3	5	2	2	2
1 to 2 PM	3	2	3	4	3	4	4	3	4	5	4	3	3	4	5	3	2	4	4	3	2	4	3	2	2	4	4	2	3	2
2 to 3 PM	5	3	2	3	4	5	5	4	5	4	3	2	5	3	4	2	4	5	2	5	4	5	3	5	3	5	4	3	6	3
3 to 4 PM	3	5	4	4	5	3	3	4	5	5	2	2	5	3	2	4	3	3	2	4	2	4	5	4	4	4	2	2	2	2
4 to 5 PM	7	5	4	3	3	5	5	5	4	3	4	3	3	4	2	5	4	3	4	2	5	5	3	4	3	2	3	3	1	3
5 to 6 PM	8	4	5	4	5	6	3	4	2	5	3	4	5	4	7	3	4	2	3	4	5	4	4	5	2	2	3	3	2	3
6 to 7 PM	6	3	9	3	5	7	2	3	2	3	4	3	5	2	4	5	5	4	4	3	2	3	2	2	4	3	4	4	2	2
7 to 8 PM	5	2	0	4	5	6	3	3	3	4	4	5	6	2	3	2	4	3	2	4	5	4	5	3	5	4	3	2	3	2
Total	57	39	45	43	47	56	45	44	50	52	50	46	54	41	47	50	46	48	44	44	45	47	43	49	43	47	42	32	30	29
Average		47			49			46			49			47			48			44			46			44			30	
Total Average (P)															450															

Results for 450 traffic volume survey

The test results are determined for the 10.15% CBR value and 9 msa.

a. Total thickness of pavement – 530 mm
b. Thickness of granular base – 250 mm
c. Thickness of granular sub base – 190 mm
d. Thickness of wearing course (BC) – 40 mm
e. Thickness of binder course (DBM) – 50 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 1.708 gm/cc to 1.740 gm/cc, when 5.0% 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 10.15%. The two-traffic volume count sample is taken for design of flexible pavement. First traffic volume count is 410 and second is 450. The MSA values 10 and 9 are determined for 410 and 450 traffic volume respectively. The total thickness of pavement is 540 mm and 530 mm determined for 10 MSA and 9 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.

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