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Design of Flexible Pavement By Black Cotton Soil And 20% Sugarcane Bagasse Ash With Coir Fibre (AR – 60)

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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 20% sugarcane bagasse ash (SCBA) and different percentage of Coir Fibre. In this research, the fibre (Aspect ratio 60) is mixed from 0.25% to 1.25% in mix of black cotton soil + 20% SCBA. 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, 20% Sugarcane Bagasse Ash, Coir Fibre (Aspect Ratio – 60), Maximum Dry Density, Differential Free Swell Index

I. INTRODUCTION

In geotechnical engineering, the expansive soils are major problem due to their minerals. Black cotton soil is also a type of black cotton soil which is consisting of high shrinkage and swelling properties. Due to these properties, the black cotton soil has been a big issue to highway and other civil engineering specialization. For improving the engineering or mechanical properties of black cotton soil numerous researchers used admixtures and waste materials etc. Among the waste materials it has been observed that sugarcane bagasse ash, kota stone slurry, lime and fly ash may improve engineering properties of black cotton soil. **Noorahemd A. H. et. al.** studied the stabilization of black cotton soil using coir + pith and bagasse ash as stabilizer. The CBR test and other test were performed for study the behavior of black cotton soil. From soaked CBR, it is observed that CBR value is increasing 1.90% to 4.04% and similarly, form unsoaked CBR value, it is observed that CBR value is increasing from 2.38% to 7.91% of soil mixed with varying percentage of coir fibre bagasse ash. **M. Bagra** performed experiment for stabilization of black cotton soil with reinforcement of jute fibre. From test results, it is observed that the fibre is increasing CBR and other properties of black cotton soil. 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. In this research paper, the engineering properties of black cotton soil is improved by 20% sugarcane bagasse ash and 0.25% to 1.5% of coir fibre used. For the study of behaviour of black cotton soil, standard proctor test, California Bearing Ratio test were performed in laboratory Hence, this experimental study is done for black cotton soil which is locally available in **Bhopal** region.

II. EXPERIMENTAL INVESTIGATIONS

Various such as Atterberg's limit (liquid limit and plastic limit), Differential free swelling, OMC, MDD and CBR etc tests have been performed to design the flexible pavement by using black cotton soil with 20% SCBA and different percentage of fibre. The percentage of coir fibre may have varied from 0.25% to 1.25% by 0.25% variation.

2.1 Material Used

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

2.2 Engineering Properties of Black Cotton Soil, Mix Specimen of Coir Fibre with 20% SCBA

The following engineering properties are determined by laboratory test for black cotton soil and mix specimen of fibre.

TABLE 3.1

ENGINEERING PROPERTIES OF BCS AND MIX SPECIMEN OF SCBA AND FIBRE

Properties	**Black Cotton Soil**	**Mix Specimen of SCBA**	**Mix Specimen of Fibre**
Specific Gravity	2.44	2.31	2.15
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/cc)	1.66	1.98 – 1.91	1.85 – 1.93
Optimum Moisture Content (%)	19.10	16.36 – 17.80	16.37 – 16.94

The Atterberg limits are determined mix specimen of SCBA with black cotton soil. From test results, it is observed that liquid limit and plastic limit is decreasing with increasing the percentage of SCBA in black cotton soil and plasticity chart also decreasing. It is also observed that when 20% SCBA is mixed in black cotton soil, the MDD is increasing up to 1.98 gm/cc and OMC is decreased. Similarly, in case of fibre this MDD is decreasing up to 1.93 gm//cc at 16.85% OMC.

2.3 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 20%SCBA with coir fibre. Table 3.2 is consisting of corrected CBR value of Black cotton soil and mix specimen of 20%SCBA with coir fibre for soaked CBR test.

TABLE 3.2

CBR TEST LOAD VALUE FOR BLACK COTTON SOIL AND MIX SPECIMEN OF 20%SCBA + FIBRE

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 + 20% SCBA	3.87%	3.65%	3.43%	3.21%	3.09%
BCS + 20% SCBA + 0.25% Fibre	6.27%	6.69%	6.62%	6.47%	6.21%
BCS + 20% SCBA + 0.5% Fibre	6.75%	6.70%	6.55%	6.15%	5.98%
BCS + 20% SCBA + 0.75% Fibre	6.95%	6.83%	6.23%	6.01%	5.86%
BCS + 20% SCBA + 1.00% Fibre	6.65%	6.87%	6.71%	6.43%	6.05%
BCS + 20% SCBA + 1.25% Fibre	6.68%	6.72%	6.47%	6.21%	5.82%

From the Table 3.2, it is observed that when 0.75% coir fibre is mixed in 20% SCBA and black cotton soil mix specimen, the CBR value is increased up to 6.95% for 2.5 mm penetration. As per IRC recommendation, only 2.5, 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 6.95% for black cotton soil with 20% sugarcane bagasse ash mix specimen of 0.75% coir fibre.

2.4 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 –

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

Where

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

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

2.5 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) – 5
Vehicle damage factor (F) – 4.5
Value of California bearing ratio – 6.95% ≈ 7%
Annual growth rate of commercial vehicles (r) – 7.5%
Number of commercial vehicles as per last count (P) – 520 Nos
Land distribution factor (D) – 0.75 (Two Lane Single Carriageway Road)
Number of year 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) – 561.6 ≈ 562
Table 3.5 shows, traffic volume count survey,

TABLE 3.5
TRAFFIC VOLUME COUNT SURVEY

Time	*HVC* Bus/Truck (Laden)			*HVC* Bus/Truck (Unladen)			*HVC* Bus/Truck (Overloaded)			*MVC* Agricultural Tractor Trailor (Laden)			*MVC* Agricultural Tractor Trailor (Unladen)			*MVC* Agricultural Tractor Trailor (Overloaded)			*LVC* Cars/ Vans / Jeeps / Three Wheeler			*HYWA* (Laden)			*HYWA* (Unladen)			*HYWA* (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	3	3	3	3	3	4	3	4	4	4	4	6	3	4	4	3	4	4	2	6	6	4	6	6	3	3	2	2	1	1
8 to 9 AM	6	3	6	6	3	3	3	3	4	4	3	6	4	3	6	4	6	4	6	4	4	2	6	2	4	3	1	2	1	2
9 to 10 AM	3	6	3	6	3	3	3	3	4	6	6	6	4	3	4	6	3	6	4	4	6	6	4	6	2	3	1	2	3	2
10 to 11 AM	4	3	4	6	3	4	4	3	6	4	6	3	3	4	3	4	4	4	4	2	6	2	6	4	3	4	3	3	2	2
11 to 12 AM	6	3	3	3	4	4	3	4	6	6	3	3	3	4	4	6	4	6	6	4	6	6	6	6	6	7	7	2	2	3
12 to 1 PM	4	6	4	6	4	3	6	3	3	6	6	4	6	3	4	6	4	3	4	4	2	2	2	2	2	3	6	2	2	2
1 to 2 PM	3	6	3	4	3	4	4	3	4	6	4	3	3	4	6	3	4	4	4	6	2	4	6	2	2	4	4	2	3	2
2 to 3 PM	6	3	3	3	4	6	6	4	6	4	3	4	6	3	4	4	4	6	2	6	4	6	6	6	3	6	4	3	6	3
3 to 4 PM	3	6	4	4	6	3	3	4	6	6	4	4	6	3	4	4	3	3	2	4	2	4	6	4	4	4	2	2	2	2
4 to 5 PM	7	6	4	3	3	6	6	6	4	3	4	3	3	4	4	6	4	3	4	2	6	6	6	4	3	2	3	3	1	3
5 to 6 PM	8	4	6	4	6	6	3	4	3	6	3	4	6	4	7	3	4	4	6	4	6	4	4	6	2	2	3	3	2	3
6 to 7 PM	6	3	9	3	6	7	3	3	3	3	4	3	6	4	4	6	6	4	4	6	2	6	2	2	4	3	4	4	2	2
7 to 8 PM	6	3	0	4	6	6	3	3	3	4	4	6	6	4	3	4	4	3	2	4	6	4	6	6	6	4	3	2	3	2
Total	65	55	52	55	54	59	50	47	56	62	54	55	59	47	57	59	54	54	50	56	58	56	66	56	44	48	43	32	30	29
Average	57			56			51			57			54			56			55			59			45			30		
Total Average (P)	520																													

Results for 520 traffic volume survey

The test results are determined for the 6.95% CBR value and 4 msa.

a. Total thickness of pavement – 493 mm
b. Thickness of granular base – 250 mm
c. Thickness of granular sub base – 170 mm
d. Thickness of wearing course (BC) – 23 mm
e. Thickness of binder course (DBM) – 50 mm

For the designing the flexible pavement following design data are taken for 570 traffic volume –
Design life in year (n) – 5
Vehicle damage factor (F) – 3.5
Value of California bearing ratio – 6.95% ≈ 7%
Annual growth rate of commercial vehicles (r) – 7.5%
Number of commercial vehicles as per last count (P) – 570 Nos
Land distribution factor (D) – 1 (Single Lane Carriageway Road)
Number of year 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 ≈ 616
Table 3.6 shows, traffic volume count survey,

TABLE 3.6
TRAFFIC VOLUME COUNT SURVEY

Time	*HVC* Bus/Truck (Laden)			*HVC* Bus/Truck (Unladen)			*HVC* Bus/Truck (Overloaded)			*MVC* Agricultural Tractor Trailor (Laden)			*MVC* Agricultural Tractor Trailor (Unladen)			*MVC* Agricultural Tractor Trailor (Overloaded)			*LVC* Cars/ Vans / Jeeps / Three Wheeler			*HYWA* (Laden)			*HYWA* (Unladen)			*HYWA* (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 6.95% CBR value and 5 msa.

a. Total thickness of pavement – 555 mm
b. Thickness of granular base – 250 mm
c. Thickness of granular sub base – 230 mm
d. Thickness of wearing course (BC) – 25 mm
e. Thickness of binder course (DBM) – 50 mm

III. DISCUSSIONS ON TEST RESULTS

After the obtaining results, it is clearly defined that black cotton soil changes it engineering properties due to sugarcane bagasse ash (SCBA) from CH to CL. The maximum dry density is also increased 1.98 gm/cc from MDD of black cotton soil 20% SCBA mix specimen. The maximum CBR value also is obtained for 0.75% fibre mix specimen with 20% SCBA in black cotton soil, which is 6.95%. The two-traffic volume count sample is taken for design of flexible pavement. First traffic volume count is 520 and second is 570. The msa values 4 and 5 are determined for 520 and 570 traffic volume respectively. The total thickness of pavement is 493 mm and 555 mm determined for 6 msa and 7 msa respectively.

IV. CONCLUSIONS

- With increasing the percentage of SCBA in black cotton soil, the black cotton soil changes behaviour CH to CI.
- From the proctor test, the maximum dry density is increasing up to 1.93 gm/cc due to fibre and fibre can be used as stabilizing material for black cotton soil with 20%SCBA.
- It is observed that when the quantity of traffic increases, the value of N also increases.
- When quantity of traffic increases the total thickness of flexible pavement also increases.
- It is also observed, the million standard axles (msa) value is directly proportional to the thickness of pavement and number of traffic.
- When traffic volume increases the total thickness of pavement increases due to granular sub base and wearing course.

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