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DESIGN OF FLEXIBLE PAVEMENT BY BLACK COTTON SOIL AND 15% KOTA STONE SLURRY WITH FIBRE

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ABSTRACT

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. Most of the expansive soils need stabilizations because expansive soils swell when it comes in contact with water and this is the major reason of failure of expansive soil strata. In this research, the black cotton soil is used with 15% Kota stone slurry and fibre is mixed at varied percentage. The engineering properties of black cotton soil may be improved by using 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, shrinkage, swelling pressure, degree of expansiveness and permeability of soil or mix specimen. These tests are performed in laboratory of University Teaching Department, Rajasthan Technical University, Kota. This research paper deals with design of flexible pavement by using black cotton soil with different percentage of Recron 3s fibre with 15% Kota stone slurry. In this research, the Recron 3s fibre is mixed from 0.5% to 2.5% in black cotton soil with 15% Kota stone slurry mix. The engineering parameters are also determined by performed tests. For studying the behaviour of black cotton soil with different percentage of Kota stone slurry for pavement, the Atterberg's limits (Liquid Limit, Plastic Limit, Plasticity Index), Sieve analysis, standard proctor test, California Bearing Ratio are performed.

Keywords: California Bearing Ratio, 15% Kota Stone Slurry, Recron 3s Fibre, Maximum Dry Density

I. INTRODUCTION

Over the world, the California bearing ratio is the method of designing the flexible pavement and this is an empirical method of designing the flexible pavement. This method was developed by California Highway Department in 1928. The test 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. For the pavement design, the Black cotton soil is used as base material and for stabilizing the black cotton soil, the 15% Kota stone slurry is mixed with Recron 3s fibre. The fibre is mixed at

varied percentage from 0.5% to 2.5% by weight of black cotton soil with 15% Kota stone slurry mix. The black cotton soil is highly swell and shrinkage characteristics soil, the black cotton soil has been a big issue to highway and other civil engineering specializations. The Kota stone slurry is a waste material, which may be used as stabilizing material for black cotton soil to improve engineering properties of soil.

II. LITERATURE REVIEW

For the designing of flexible pavement by black cotton soil and slurry with fibres, many researchers did work on the black cotton soil with different materials. In 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 and fibre. Some detailed literatures have been reviewed on this topic i.e. related to design of flexible pavement and material properties and some of the reviewed of the reviewed literatures are presented in proceeding paragraphs.

P. Rajendra Kumarr et. al (2017) studied to investigate the effect of fibres in geotechnical applications and to evaluate the strength of unsaturated soil by carrying out compaction test and CBR test on soil sample. The fibres are cut in length of 6 mm and 12 mm and mix randomly in varying percentage (0.5%, 1.0%, 2.0%, 4.0%) by dry weight of soil and compacted to maximum dry density at optimum moisture content. By performing the tests, it is found that CBR of reinforced soil for the aspect ratio 6 mm and 12 mm increases to 76.37%, 106.30% as compared to unreinforced soil. The percentage of unsoaked CBR value increases with the increase in the fibre content and also with increase of length of fibre. In soaked CBR of reinforced soil for the aspect ratios 6 mm and 12 mm increase to 58.47% and 98.30 as compared to the unreinforced soil.

P. Sowmya Ratna et. al. (2016) improved engineering properties of black cotton soil with adding lime with Recron 3s fibre. They studied about the compactive parameters of black cotton soil mixing with different percentage of lime and Recron 3s fibre with a view to determine the optimum percentage. They studied that MDD was decreased to 14.8 kN/m^3 from 15.9 kN/m^3 and OMC increased from 22% to 26.4% at 6% lime. The value of CBR for unsoaked sample, increases from 3 to 7.3% up to the addition of 4% of lime, then decreased to 6.4% with the addition of 6% of lime to the soil. Unsoaked CBR value goes increasing overall CBR values increases due to the reason that lime has effectively bonded the soil particles to form a closely packed mass that resists the ingress of water.

Mr. Vismay J Shah et. al. performed CBR for sub grade in saline condition in black cotton soil. They used fly ash and stone dust fibre with polypropylene fibre and lime in black cotton soil to improve the stability parameters of pavement. The mix percentage of fly ash, lime, stone dust and polypropylene fibre was 20%, 7%, 25% and 2% respectively for different chainage location. This was the major project of designing flexible pavement for bhanagar, Dholera state highway 6. After performing tests, the results were favourable and the value of CBR increases continuously with fly ash, lime, stone dust and polypropylene fibre.

III. 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.

3.1 Material Used

- **Black Cotton Soil –** About 100 kg of soil sample for the present work was collected from the Borkheda, Kota.
- **Kota Stone Slurry –** Kota stone slurry for the present work was obtained from Kota stone slurry industry, Anantpura, Kota.
- **Recron 3s Fibre –** Recron 3s fibre is purchased from market.

3.2 Engineering Properties of Black Cotton Soil, Kota Stone Slurry, Recron 3s Fibre and Mix Specimen

The following engineering properties are determined by laboratory test for black cotton soil, Kota stone slurry and mix specimen. The properties of Recron 3s is taken from booklet of the Recron 3s fibre.

Table 3.1 Engineering properties of BCS, KSS and mix specimen

Properties	Black Cotton Soil	Kota Stone Slurry	Recron 3s Fibre	Mix Specimen
Specific Gravity	2.44	2.35	1.34	-
Liquid Limit (%)	41.41	34.28	-	34.56
Plastic Limit (%)	18.46	21.77	-	14.09
Plasticity Index (%)	22.95	12.51	-	20.47
IS Classification	CI	CL	-	CI to CL
Maximum Dry Density (kg/cm^3)	1.725	1.635	-	1.645 – 1.700
Optimum Moisture Content (%)	17.4	17.1	-	17.0 – 19.2
Melting Point (^0C)	-	-	$240^0 – 260^0C$	-
Diameter (Microns)	> 75	> 75	35 – 40	-
Colour	Red – Brown	Grey Dirty White	White	Light Red – Brown

The Atterberg limits are determined with 15% Kota stone slurry with black cotton soil. The 15% Kota stone slurry in black cotton soil mix specimen having 34.56%, 14.09% and 20.47%, liquid limit, plastic limit and plasticity index respectively. The fibre is mixed from 0.5% to 2.5% and proctor test is performed for these percentage mix specimens. The variation in maximum dry density is determined from 1.645 kg/cm^3 to 1.700 kg/cm^3. The maximum dry density is decreased 1.7 kg/cm3 to MDD of black cotton soil and mix specimen of 15% Kota stone slurry. The variation of

tests value is shown in Table 3.1. When 15% Kota stone slurry is mixed in black cotton soil, the liquid limit and plastic limit decreases and plasticity index also decreases. Due to plasticity criteria, the black cotton soil behaviour changes from CI to CL. The results of standard proctor test is shown in fig. 3.1.

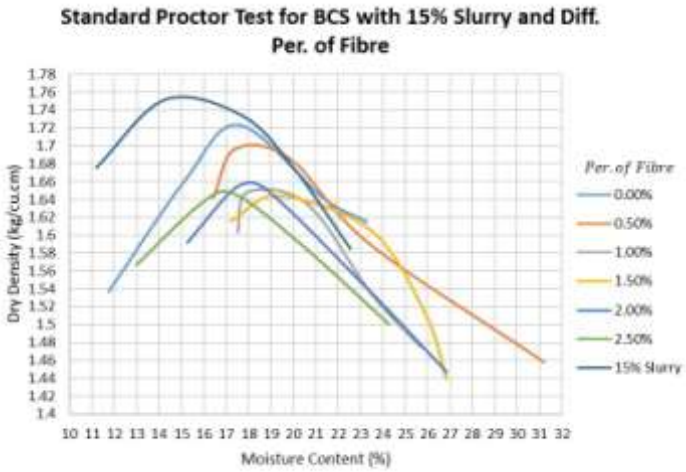

Fig. 3.1 Standard proctor test for BCS with 15% KSS and different percentage of fibre

3.3 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 of University Teaching Department, RTU, Kota for black cotton soil and mix specimen of soil. Table 3.2 is containing CBR value of Black cotton soil with 15% Kota stone slurry and mix specimen of fibre.

Table 3.2 CBR test load value for black cotton soil, 15% Kota stone slurry and mix specimen of fibre

Specimen/ Penetration	2.5 mm	5.0 mm	7.5 mm	10.0 mm	12.5 mm
Black Cotton Soil (BCS)	111.28	157.04	177.32	188.76	199.68
BCS + 15% KSS	199.68	292.76	339.56	369.2	376.48
BCS + 15% KSS + 0.5% Fibre	95.68	141.44	197.60	251.68	282.88
BCS + 15% KSS + 1.0% Fibre	106.08	156.52	215.28	276.64	322.40
BCS + 15% KSS + 1.5% Fibre	121.68	178.88	241.28	287.04	334.88
BCS + 15% KSS + 2.0% Fibre	116.48	172.64	246.48	293.28	354.12
BCS + 15% KSS + 2.5% Fibre	114.92	167.96	244.40	303.68	369.72

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 with 15% Kota stone slurry and mix specimen of fibre.

Table 3.3 CBR corrected load value for black cotton soil, 15% Kota stone slurry and mix specimen of fibre

Specimen/ Penetration	2.5 mm	5.0 mm	7.5 mm	10.0 mm	12.5 mm
Black Cotton Soil (BCS)	150	172	188	198	210
BCS + 15% KSS	240	318	350	372	378
BCS + 15% KSS + 0.5% Fibre	122	178	235	275	302
BCS + 15% KSS + 1.0% Fibre	131	185	245	298	342
BCS + 15% KSS + 1.5% Fibre	138	193	253	296	344
BCS + 15% KSS + 2.0% Fibre	139	200	268	318	380
BCS + 15% KSS + 2.5% Fibre	122	183	260	320	384

Note – All load parameters are in kgf

After performing and correcting value of load, it is observed that when 2.0% fibre is mixed with black cotton soil and 15% Kota stone slurry, the load is obtained 139 and 200 kgf for 2.5 mm and 5.0 mm penetration respectively. Hence, 2.0% fibre mix specimen gives better results among the all fibre mix specimen but the determined load is less than to black cotton soil and 15% Kota stone slurry with black cotton soil mix specimen. In case of 5.0 mm penetration, the 2.0% fibre mix specimen having 200 kgf load value which is more than to CBR value of black cotton soil but it is less than to 15% Kota stone slurry mix specimen CBR value. By increasing the penetration of the plunger, the value of applied load increases.

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)	10.95%	08.37%	07.15%	06.23%	05.83%
BCS + 15% KSS	17.52%	15.47%	13.31%	11.70%	10.50%
BCS + 15% KSS + 0.5% Fibre	08.91%	08.66%	08.94%	08.65%	08.39%
BCS + 15% KSS + 1.0% Fibre	09.56%	09.00%	09.32%	09.37%	09.50%
BCS + 15% KSS + 1.5% Fibre	10.07%	09.39%	09.62%	09.31%	09.56%

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BCS + 15% KSS + 2.0% Fibre	10.15%	09.73%	10.19%	10.00%	10.56%
BCS + 15% KSS + 2.5% Fibre	08.91%	08.91%	09.89%	10.06%	10.67%

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 15% Kota stone slurry and 2.0% fibre mix specimen.

3.4 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 –

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

Where

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

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

3.5 Design Parameters of Flexible Pavement

For the designing the flexible pavement following design data are taken for 310 traffic volume –

Design life in year (n) – 10

Vehicle damage factor (F) – 3.5

Value of California bearing ratio – 10.15% ≈ 10%

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

Number of commercial vehicles as per last count (P) – 310 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 vehicle per day (A) – 333.25 ≈ 335 Table 3.5 shows, traffic volume count survey,

Table 3.5 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	3	3	2	1	1	3	2	3	2	2	3	2	2	3	3	2	2	6	7	5	2	1	2	1	0	1	1	1	1
8 to 9 AM	3	4	4	1	2	2	2	3	3	3	4	3	3	4	3	2	3	2	5	5	6	1	0	1	1	1	1	1	0	1
9 to 10 AM	4	5	5	2	2	2	1	1	2	2	5	2	2	3	2	1	3	2	6	7	7	0	1	0	0	1	0	0	1	0
10 to 11 AM	5	4	5	2	3	3	1	1	1	4	2	2	3	2	2	4	1	1	4	5	6	1	1	1	1	1	1	0	0	1
11 to 12 AM	4	5	6	4	1	1	0	0	1	3	5	5	3	5	3	2	2	1	7	6	7	0	0	2	1	0	1	0	0	1
12 to 1 PM	4	4	5	2	1	1	0	1	1	5	6	4	4	3	4	2	1	1	7	7	6	2	1	0	1	1	0	1	0	0

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1 to 2 PM	3	4	4	2	3	1	1	0	1	3	4	5	3	4	3	1	2	1	6	7	4	0	2	0	0	1	0	0	0	0
2 to 3 PM	5	1	4	1	4	2	0	0	1	2	5	3	2	4	3	2	2	2	5	5	6	1	1	1	1	1	1	0	1	0
3 to 4 PM	4	6	3	2	3	1	0	1	0	3	2	2	3	2	2	2	1	2	6	7	7	1	1	1	1	1	1	1	0	0
4 to 5 PM	6	5	7	1	2	2	1	0	0	6	1	5	4	3	3	2	3	2	4	5	6	0	0	1	0	0	1	0	0	1
5 to 6 PM	4	4	6	2	2	2	0	0	1	3	5	2	3	4	2	1	2	1	7	6	7	1	2	1	1	1	1	0	1	0
6 to 7 PM	3	3	5	1	1	3	1	2	2	4	3	3	4	3	3	4	2	2	7	7	6	1	0	1	1	0	1	1	0	1
7 to 8 PM	5	2	5	4	1	2	2	3	2	5	5	2	5	4	2	2	3	2	5	6	7	2	1	1	1	1	1	0	1	0
Total	52	50	62	26	26	23	12	14	18	45	49	41	41	43	35	28	27	21	75	80	80	12	11	12	10	9	10	5	5	6
Average	55			25			15			45			40			25			78			12			10			5		
Total Average (P)	310																												

Results for 310 traffic volume survey

The test results are determined for the 10.15% CBR value and 5 msa.

a. Total thickness of pavement – 465 mm
b. Thickness of granular base – 250 mm
c. Thickness of granular sub base – 150 mm
d. Thickness of wearing course (BC) – 25 mm
e. Thickness of binder course (DBM) – 40 mm

For the designing the flexible pavement following design data are taken for 410 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) – 410 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 vehicle per day (A) – 440.75 ≈ 440 Table 3.6 shows, traffic volume count survey,

Table 3.6 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	3	3	2	3	3	3	2	3	2	2	3	2	2	3	3	2	2	6	7	5	2	3	2	1	2	1	2	1	1
8 to 9 AM	3	4	4	3	2	2	2	3	3	3	4	3	3	4	3	2	3	3	5	5	6	3	2	1	1	3	2	1	2	2
9 to 10 AM	4	5	5	2	3	2	3	4	2	2	5	2	2	3	2	1	3	2	6	7	7	2	2	3	2	1	2	3	3	2
10 to 11 AM	5	4	5	3	3	3	4	1	3	4	2	2	3	2	2	4	1	1	4	5	6	3	3	1	1	2	1	2	2	1
11 to 12 AM	4	5	6	4	4	2	2	3	1	3	5	5	3	5	3	2	2	3	7	8	8	2	3	2	2	4	3	2	2	3
12 to 1 PM	4	4	5	5	1	3	3	1	1	5	6	4	4	3	4	2	3	3	9	9	6	2	2	2	1	2	1	2	1	2
1 to 2 PM	3	4	4	2	5	4	2	2	3	3	4	5	3	4	3	3	2	2	8	7	4	3	2	3	3	1	2	1	2	1
2 to 3 PM	5	1	4	4	4	2	3	3	2	2	5	3	2	4	3	2	2	2	5	5	6	2	3	1	1	2	1	2	3	3
3 to 4 PM	4	6	3	2	3	5	2	1	2	3	2	2	3	2	2	2	2	3	6	8	9	3	2	3	2	2	3	3	2	2
4 to 5 PM	6	5	7	5	5	2	1	3	2	6	1	5	4	3	3	2	3	2	7	7	6	2	3	2	2	2	4	2	2	1
5 to 6 PM	4	4	6	2	2	4	2	2	1	3	5	2	3	4	2	3	2	3	8	6	7	3	2	3	3	2	3	2	1	2
6 to 7 PM	3	3	5	3	4	3	3	2	3	4	3	3	4	3	3	4	2	2	9	7	8	2	2	3	3	2	2	1	2	2
7 to 8 PM	5	2	5	4	3	3	2	3	2	5	5	2	5	4	2	2	3	2	5	8	8	2	2	2	2	3	3	2	3	2
Total	52	50	62	41	42	38	32	30	28	45	49	41	41	43	35	32	30	30	85	89	86	31	31	28	24	28	28	25	26	24
Average	55			40			30			45			40			31			87			30			27			25		
Total Average (P)	410																													

Results for 410 traffic volume survey

The test results are determined for the 10.15% CBR value and 6 msa.

a. Total thickness of pavement – 490 mm
b. Thickness of granular base – 250 mm
c. Thickness of granular sub base – 160 mm
d. Thickness of wearing course (BC) – 30 mm
e. Thickness of binder course (DBM) – 50 mm

IV. DISCUSSIONS ON TEST RESULTS

After the obtaining results, it is clearly defined that black cotton soil changes it engineering properties due to Kota stone slurry from CI to CL. The maximum dry density is also decreased 1.700 kg/cm3 from MDD of black cotton soil and 15% Kota stone slurry mix specimen. The maximum CBR value also is obtained for 2.0% fibre mix specimen with 15% Kota stone slurry in black cotton soil, which is 10.15%. The two-traffic volume count sample is taken for design of flexible pavement. First traffic volume count is 310 and second is 410. The msa values 5 and 6 are determined for 310 and 410 traffic volume respectively. The total thickness of pavement is 465 mm and 490 mm determined for 5 msa and 6 msa respectively.

V. CONCLUSIONS

- With increasing the percentage of Kota stone slurry in black cotton soil, the black cotton soil changes behaviour CI to CL. The Kota stone slurry is inorganic clay of low plasticity material.
- From the proctor test, the maximum dry density is not increasing due to this reason Recron 3s fibre cannot be used as stabilizing material for black cotton soil.
- It is clearly defined 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 defined, 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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