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A DETAILED STUDY OF C.B.R. METHOD FOR FLEXIBLE PAVEMENT DESIGN

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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 (Wl), Plastic limit (Wp), plasticity index (Ip), 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 Kota stone slurry. In this research, the Kota stone slurry is mixed from 5% to 30% 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 Kota stone slurry, the Atterberg's limits (Liquid Limit, Plastic Limit, Plasticity Index), Sieve analysis, standard proctor test, California Bearing Ratio are performed.

Keywords – California Bearing Ratio, Kota Stone Slurry, Effect on Plasticity Index, Degree of Expansiveness, Maximum Dry Density

I. INTRODUCTION

California bearing ratio is an empirical test and over the world, it is used for designing the flexible pavement. This method was developed by California Highway Department in 1928. 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. 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 Kota stone slurry is mixed from 0% to 30% 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 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 the flexible pavement by black cotton soil with slurry, many researchers did work on the black cotton soil with different materials. 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 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. A. Sivasubramani et. al. (2017) studied to evaluate the potential of Bagasse Ash (BA) and egg shell powder (ESP) to stabilize soft and expansive soil. the physical properties of clay, BA and ESP have been studied by conducting laboratory tests. The CBR test were performed for black cotton soil with ESP. The percentage of BA varied from 5% to 25%, 3% ESP is added and tests were performed. After obtaining results, it is observed that the thickness of the pavement of stabilized soil is found lesser than the thickness of the pavement of virgin soil.

B. R. K. Sai Ganesh Kumar et. al. (2015) determined the CBR value for black cotton soil with quarry dust, quarry dust is a by-product from the crushing process during quarrying activities is one of the waste product. They stabilized the black cotton soil by adding quarry dust in percentage of 10%, 20%, 30% and 40%. After performing the experiments, they came to know, the CBR value is increased 87.5% to black cotton soil and swelling pressure is decreased 88%.

Er. Devendra Kumar Choudhary et. al. (2014) studied about the CBR method for designing the flexible pavement. They studied two different soil sample. The samples are clayey silt and Kopra and CBR test conducted on it. After obtaining results, the thickness of pavement is less while using Kopra compare to clayey silt and it is also determined that, thickness of crust varied with the change in value of CBR. With higher value of CBR the crust thickness is less.

Abhijitsinh Parmar et. al. (2013) also performed CBR test for designing the flexible pavement with using black cotton soil as base material. They designed pavement by using lime and fly ash as admixture in black cotton soil. After conducting experiments, it was observed that the optimum moisture content and maximum dry density were improved by 11.1% and 10.74% respectively. The free swell index was also improved by 13.74%.

Saurabh Jain et. al. (2013) described various method for designing the rigid and flexible pavement. They also did cost analysis for each method. They also determined Atterberg's limit, swelling potential and compactive parameters for design of pavement. They concluded that flexible pavements are more economical for lesser volume of traffic. The life of flexible pavement is near about 15 year and initial cost is less but for rigid pavement the life of pavement is about 40 year and initial cost is more than flexible pavement. The maintenance cost is very less for rigid pavements.

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.

3.2 Engineering Properties of Black Cotton Soil, Kota Stone Slurry and Mix Specimen

The following engineering properties are determined by laboratory test for black cotton soil, Kota stone slurry and mix specimen.

Table 3.1 Engineering properties of BCS, KSS and mix specimen

Properties	Black Cotton Soil	Kota Stone Slurry	Mix Specimen
Specific Gravity	2.44	2.35	-
Liquid Limit (%)	41.41	34.28	13.01 – 40.38
Plastic Limit (%)	18.46	21.77	09.16 – 18.01
Plasticity Index (%)	22.95	12.51	03.85 – 22.37
Shrinkage Limit (%)	14.58	-	12.99 – 20.44
Differential Free Swell (%)	53.55	-	04.55 – 36.84
Swelling Pressure (kg/cm^2)	1.1	-	00.09 – 01.09
IS Classification	CI	CL	CI to CL
Maximum Dry Density (kg/cm^3)	1.725	1.635	1.615 – 1.755
Optimum Moisture Content (%)	17.4	17.1	14.5 – 16.2
Colour	Red – Brown	Grey Dirty White	Light Red - Brown

Note – The mix specimen is prepared by 5% to 30% of Kota stone slurry in black cotton soil

The Kota stone slurry is mixed with black cotton soil at 5%, 10%, 15%, 20%, 25% and 30%. The variation of tests value is shown in Table 3.1. When the percentage of Kota stone slurry increases 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.

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 and mix specimen.

Table 3.2 CBR test 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)	111.28	157.04	177.32	188.76	199.68
BCS + 5% KSS	168.48	235.04	280.8	317.72	348.4
BCS + 10% KSS	187.20	255.32	291.72	322.40	349.96
BCS + 15% KSS	199.68	292.76	339.56	369.2	376.48
BCS + 20% KSS	173.16	239.20	281.32	313.56	345.28
BCS + 25% KSS	166.40	230.36	266.24	281.32	287.04
BCS + 30% KSS	173.16	220.48	260.52	276.12	276.12

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)	150	172	188	198	210
BCS + 5% KSS	210	264	302	337	365
BCS + 10% KSS	218	270	304	332	360
BCS + 15% KSS	240	318	350	372	378
BCS + 20% KSS	210	264	300	330	365
BCS + 25% KSS	209	252	278	286	290
BCS + 30% KSS	200	258	272	278	270

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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)	10.95%	8.37%	7.15%	6.23%	5.83%
BCS + 5% KSS	15.33%	12.85%	11.48%	10.60%	10.14%
BCS + 10% KSS	15.91%	13.14%	11.56%	10.44%	10.00%
BCS + 15% KSS	17.52%	15.47%	13.31%	11.70%	10.50%
BCS + 20% KSS	15.33%	12.85%	11.41%	10.38%	10.14%
BCS + 25% KSS	15.26%	12.26%	10.57%	8.99%	8.06%
BCS + 30% KSS	14.60%	12.55%	10.34%	8.74%	7.50%

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 17.52% for black cotton soil with 15% Kota stone slurry 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 –

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

Where

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

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

3.5 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) – 15

Vehicle damage factor (F) – 3.5

Value of California bearing ratio – 17.52%

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
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 17.52% CBR value and 8 msa.

a. Total thickness of pavement – 510 mm
b. Thickness of granular base – 250 mm
c. Thickness of granular sub base – 180 mm
d. Thickness of wearing course (BC) – 30 mm
e. Thickness of binder course (DBM) – 50 mm

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

Design life in year (n) – 15

Vehicle damage factor (F) – 3.5

Value of California bearing ratio – 17.52%

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,

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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 17.52% CBR value and 11 msa.

a. Total thickness of pavement – 550 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) – 60 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. The Kota stone slurry is low plasticity material and black cotton soil is inorganic clay of medium plasticity but when amount of Kota stone slurry increases, the black cotton soil changes behaviour from CI to CL. The maximum dry density is also increased 1.725 kg/cm3 to 1.755 kg/cm3, when 15% Kota stone slurry is mixed with black cotton soil. The maximum dry density is obtained for 15% mix specimen and maximum CBR value also is obtained for 15% mix specimen, which is 17.52%. 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 8 and 11 are determined for 310 and 410 traffic volume respectively. The total thickness of pavement is 510 mm and 550 mm determined for 8 msa and 11 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.
- 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 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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