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DESIGN OF FLEXIBLE PAVEMENT BY BLACK COTTON SOIL WITH POND ASH

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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 pond ash 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 pond ash. In this research, the pond ash is mixed from 10% to 50% 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 pond ash 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, Thickness of Pavement, Pond Ash, Maximum Dry Density

I. INTRODUCTION

Over the world, the California bearing ratio is the 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. This is an empirical method of designing the flexible pavement. 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 is mixed with pond ash. The pond ash is mixed at varied percentage from 10% to 50% by weight of black cotton soil. 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 pond ash 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 pond ash or lime ash, 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. **Pandian (2002)** studied the effect of two types of Fly ashes Raichur Fly Ash (class F) and Neyveli Fly Ash (class
C) on the CBR characteristics of the black cotton soil. the fly ash contain was increased from 0% to 100%. Generally, the CBR strength is contributed by it is cohesion and friction. The CBR of BC soil, which consists of predominantly of finer particles, is contributed by cohesion. The CBR of fly ash, which consists predominantly of coarser particles, is contributed by it is frictional components. The addition of fly ash to BC soil increases the CBR of the mxi up to the first optimum level due to frictional resistance from fly ash in addition to the cohesion from BC soil. Further addition of fly ash beyond the optimum level causes a decrease up to 60% and then up to the second optimum level there is an increase. Thus, the variation of CBR of fly ash, BC soil mixes can be attributed to the relative contribution of frictional or cohesive resistance rom fly ash or BC soil, respectively.

Brooks (2009) studied “soil stabilization with fly-ash and rice husk ash” and reported that the rice husk ash (RHA) content of 12% and a fly-ash content of 25% are recommended for strengthening the expansive sub grade soil while a fly-ash content of 15% is recommended for blending into RHA to form a swell reduction layer. Fly-ash is an industrial waste obtained from thermal power plants by burning of coal. The test result showed a significant improvement in compaction and CBR characteristics. And fly-ash is found to be an effective waste material for the stabilization of expansive soil.

Ghosh et al. (2010) presented the laboratory test results of pond ash (unstabilized) and stabilized with different percentages of lime content of about 4%, 6%, and 10%) to determine the suitability of lime stabilized pond ash for base and sub-base construction of roads. Light and heavy compaction tests have been conducted to obtain the compaction characteristics of the lime stabilized pond ash. California Bearing Ratio tests also have been conducted on the specimens, compacted at MDD and OMC obtained from light compaction tests in both un-soaked and soaked conditions. In this paper the effect of lime content and curing period on the bearing ratio of stabilized pond ash is highlighted. Multiple empirical models have been developed to calculate the bearing ratio for the stabilized pond ash through multiple regression analysis method. Linear empirical relationship also has been presented to estimate the soaked bearing ratio from the un-soaked bearing ratio of lime stabilized pond ash. From experimental results, the pond ash-lime mixes have the potential for applications in road base and sub-base construction.

Jaya Prakash Babu V. et. al. (2016) modified the engineering properties of black cotton soil with fly ash and cement. The main aim of this study was, describe the strength behaviour of black cotton soil with fly ash as stabilizer. They mixed 30% to 40% fly ash and 6% to 8% cement in black cotton soil for determining the compactive parameters. From the results, they concluded that high expansive black cotton soil can be effectively utilized as a geo – technical material by addition of 30% to 40% fly ash and 6% to 10% cement. At these dosage of admixtures, the black cotton soil can be behaving non-plastic and no swelling can reduce the problems of volume change and bulk utilization of fly ash reduces it is deposal problem.

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 pond ash. The percentage of pond ash may have varied from 10% to 50% by 10% variation.

3.1 Material Used

- **Black Cotton Soil –** About 100 kg of soil sample for the present work was collected from the Borkheda, Kota.
- **Pond Ash –** The pond ash sample is collected from Kota Thermal Power Station, Kota.

3.2 Engineering Properties of Black Cotton Soil, Pond Ash, and Mix Specimen

The following engineering properties are determined by laboratory test for black cotton soil, pond ash and mix specimen.

Table 3.1 Engineering properties of BCS, Pond Ash and mix specimen

Properties	Black Cotton Soil	Pond Ash	Mix Specimen
Specific Gravity	2.44	2.15	-
Liquid Limit (%)	41.41	35.91	34.66 – 39.99
Plastic Limit (%)	18.46	Non – Plastic	14.45 – 19.45
Plasticity Index (%)	22.95	Non – Plastic	18.99 – 20.54
IS Classification	CI	CL	CI to CL
Maximum Dry Density (kg/cm^3)	1.725	1.240	1.654 – 1.685
Optimum Moisture Content (%)	17.4	26.2	14.0 – 17.5
Melting Point (^0C)	-	-	-
Diameter (Microns)	> 75	> 75	-
Colour	Red – Brown	Light Grey	Light Red – Brown

The Atterberg limits are determined for different percentage of pond ash with black cotton soil. The pond ash in black cotton soil mix specimen having 34.66% to 39.99%, 14.45% to 19.45% and 18.99% to 20.54%, liquid limit, plastic limit and plasticity index respectively.

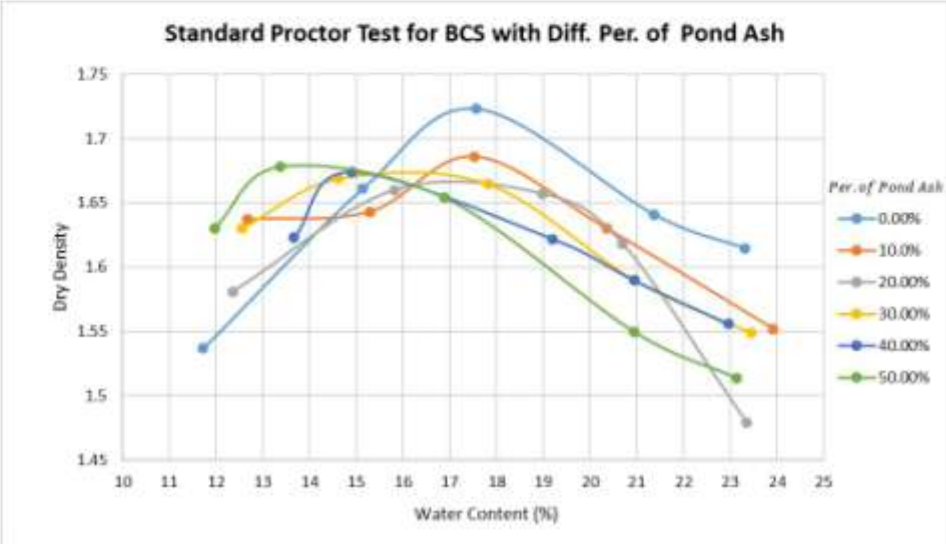

Fig. 3.1 Standard proctor test for BCS with different percentage of pond ash

The pond ash is mixed from 10% to 50% and proctor test is performed for these percentage mix specimens. The variation in maximum dry density is determined from 1.654 kg/cm^3 to 1.685 kg/cm^3. The maximum dry density is 1.685 kg/cm^3 is obtained for 10% pond ash mix specimen at 17.5% moisture content. The variation of proctor tests value is shown in Table 3.1. When amount of pond ash increases in black cotton soil, the liquid limit and plastic limit decreases and plasticity index varies. Due to plasticity criteria, the black cotton soil behaviour changes from CI to CL. The results of standard proctor test are shown in fig. 3.1.

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 different percentage of pond ash.

Table 3.2 CBR test load value for black cotton soil with different percentage of pond ash

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 + 10% PA	79.04	105.04	121.68	132.08	141.44
BCS + 20% PA	173.16	261.56	313.56	364.00	402.48
BCS + 30% PA	178.88	266.24	334.88	386.88	442.00
BCS + 40% PA	282.88	444.08	552.24	636.48	723.84

BCS + 50% PA	298.48	464.88	589.16	672.88	713.44

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 different percentage of pond ash.

Table 3.3 CBR corrected load value for black cotton soil with different percentage of pond ash

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 + 10% PA	90	112	125	135	145
BCS + 20% PA	247	305	355	396	430
BCS + 30% PA	240	315	370	425	480
BCS + 40% PA	415	530	625	705	795
BCS + 50% PA	425	570	653	703	740

Note – All load parameters are in kgf

After performing and correcting value of load, it is observed that when 50% pond ash is mixed with black cotton soil, the corrected load is obtained 425 kgf and 570 kgf for 2.5 mm and 5.0 mm penetration respectively. Hence, 50% pond ash mix specimen gives better results among the all pond ash mix specimen and the determined load is more than to black cotton soil. For case of 5.0 mm penetration, the 50% pond ash mix specimen having 570 kgf load value which is more than to CBR value of black cotton soil. By increasing the penetration of the plunger, the value of CBR also 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 + 10% PA	06.57%	05.45%	04.75%	04.25%	04.03%
BCS + 20% PA	18.03%	14.84%	13.50%	12.45%	11.94%
BCS + 30% PA	17.52%	15.33%	14.07%	13.36%	13.33%
BCS + 40% PA	30.29%	25.79%	23.76%	22.17%	22.08%
BCS + 50% PA	31.02%	27.74%	24.83%	22.11%	20.56%

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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 31.02% for black cotton soil with 50% pond ash mix specimen for 2.5 mm penetration.

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 –

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

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

3.5 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 – 31.02% ≈ 31%

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

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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 31.02% CBR value and 5 msa.

a. Total thickness of pavement – 475 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) – 50 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 – 31.02% ≈ 31%

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 31.02% 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 pond ash from CI to CL. The maximum dry density is also decreased 1.685 kg/cm^3 from MDD of black cotton soil. The maximum CBR value also is obtained for 50% pond ash with black cotton soil, which is 31.02%. 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 475 mm and 490 mm determined for 5 msa and 6 msa respectively.

V. CONCLUSIONS

- With increasing the percentage of pond ash in black cotton soil, the black cotton soil changes behaviour CI to CL. The pond ash is inorganic clay of low plasticity material.
- From the proctor test, the maximum dry density is not increasing due to higher amount of pond ash which cannot be used as stabilizing material for black cotton soil.
- It is clearly defined that quantity of traffic is directly proportional to the N value.
- 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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