Review of Effect of Waste Material on Thickness of Flexible Pavement in Expansive Soil

Dr. Kamaldeep Singh Grover[1], Jitendra Khatti[2]

[1] Professor, Civil Engineering Department, University Department, RTU, Kota
[2] Ph.D Scholar, Civil Engineering Department, University Department, RTU, Kota
kdsgrover@gmail.com,jitendrakhatti197@gmail.com

Abstract. Highways or roads are best source/ medium to connect a place to another place. Road is technically named as pavement and pavements are classified as flexible pavement and rigid pavement on basis of regional conditions. Laying the flexible pavement on expansive or black cotton soil adds another challenge to engineers. If not properly laid, the pavement may fail soon. For the prevention of these failures, many researchers have contributed by performing experiments on black cotton soil added with waste materials and discussion made "How thickness of pavement gets affected by waste materials?" In this research paper, the experimental study on design of flexible pavement test results of Atterberg's limit and California bearing test are summarized. Many researchers tried to improve the engineering properties of black cotton soil (BCS) by addition of Kota stone slurry, Recron 3s fibre, sugarcane bagasse ash, pond ash and coir fibre (CF) etc. In this research work, the flexible pavement is designed by stabilized expansive soil. The soil is stabilized by Sugarcane bagasse ash, Kota stone slurry, brick dust and marble dust. The liquid limit, plastic limit, plasticity index and soaked California bearing ratio test was performed in geotechnical laboratory.

Keywords: Thickness of Pavement, Expansive Soil, Sugarcane Bagasse Ash, Brick Dust, Marble Dust and Kota Stone Slurry

1 Introduction

In this world several types of soils are present. These soils are having different geotechnical properties. These properties are responsible for the behavior of soil and help in classify them. Soil can be classified based on expansive behavior, particle size and consistency limits of soil. On the basis of expansiveness of soil, it may be classified as expansive soil and non – expansive soils. Non – expansive soil consists of more gravel and sand (coarse) soil particles compare to silt and clay (fine) soil particles. The non – expansive soil is highly permeable and non – swell to low swell. On the other hand, expansive soil consists of more silt and clay soil particles as compared to non – expansive soil. These kind of soils are less permeable and medium to very high swell. Swell property is responsible for the music faced by geotechnical engineer because when water comes in contact with soil, soil changes the behavior. Due to change in behavior of soil, the super – structures get affected and damaged. Before the construction of structures on expansive soil, the soil must be treated by different techniques of stabilization. Many researchers and scientists have tried to improve the engineering properties of expansive soil by waste material like calcareous material, artificial fibre and natural fibres. In this experimental work following waste materials are used for stabilization: Sugarcane Bagasse Ash (SCBA), Pond Ash (PA), Kota Stone Slurry (KSS), Marble Dust (MD) and Brick Dust (BD).

[1] **Amit Kumar Jangid et. al. (2018)** For the determination of engineering properties the tests of liquid limit, plastic limit, plasticity index, dry density and CBR were performed in laboratory for BCS, BCS with Kota Stone Slurry, Recron 3s fibre and wooden saw dust material. LL, PL and PI values of BCS were determined experimentally as 41.41%, 18.46% and 22.95% respectively. By these properties, BCS is classified as "inorganic clay of medium plasticity (CI). An improvement in engineering properties of BCS was studied by mixing Kota Stone Slurry. The dosages of KSS were taken from 5.0% to 30.0% at 5.0% variation for improving engineering properties. From test results, it is also reported that when KSS is mixed in BCS, the LL is decreased from 41.41% to 13.01%, PL is decreased from 18.46% to 09.16% and PI is decreased from 22.95% to 03.85%. From the results of LL and PI, the expansive behavior of BCS is studied. When KSS is mixed in BCS, the soil changed it expansive behavior from CI to CL. [1], [7] From experimental study, MDD value of BCS is determined as 1.725 gm/cc at 17.4% OMC. It is also observed that when 15% KSS is mixed in BCS, the MDD of BCS is increased up to 1.755 gm/cc at 15.2% OMC. By further increasing the percentage of KSS, MDD is decreased. [7] During further study, proctor test was performed for BCS + 15% KSS + different percentage of Recron 3s fibre (addition of fibre from 0.5% to 2.5% at 0.5% variation). From the experimental study, it was reported that the MDD is decreased to 1.65 gm/cc at 18.8% OMC when 1% fibre is mixed in BCS + 15%KSS. [9] From the results of proctor test of BCS + 15% KSS + Fibre mix specimen, the MDD has not increased. Hence, it was decided to replace Recron 3s fibre with wooden saw dust. The dosage of wooden saw dust is taken from 2.5% to 12.5% at 2.5% variation in BCS + 15% KSS. The proctor test was performed for BCS + 15% KSS + different percentage of wooden saw dust mix specimen. From test results of proctor test, MDD has increased to 1.835 gm/cc at 10.0% OMC when 5.0% wooden saw dust is mixed in BCS + 15%KSS.

[3]**Er. Jitendra Khatti et.al. (2018)** The **unsoaked** California bearing test was performed for BCS and mix specimen of KSS + BCS. It is reported that CBR value of BCS is determined experimentally as **10.95%.** When 15% KSS is mixed in BCS, the CBR value of BCS is increased to **17.52%**. By further increasing the percentage of KSS in BCS, the CBR value is decreased to 14.60%. [9] For further study of CBR value, the CBR test is performed for BCS + 15% KSS + different percentage of Recron 3s fibre (0.5% to 2.5% at 0.5% variation). From the results of BCS + 15%KSS + Recron 3s fibre mix specimens, it is observed that CBR value is decreased to **8.91%**. From the results of CBR test of BCS + 15%KSS + Fibre mix specimen, the CBR has decreased. Hence, it was decided to replace Recron 3s fibre with wooden saw dust. The dosage of wooden saw dust was selected 2.5% to 12.5% at 2.5% variation. From

the results of BCS + 15% KSS + different percentage of wooden saw dust mix specimen, it is reported that at 5% wooden saw dust CBR value of BCS has increased to **27.74%**.

[2] **Dharm Raj Suwalka et. al. (2018)** The investigation of improvement in geotechnical properties of black cotton soil by using pond ash (PA) was reported. LL, PL, PI, dry density and CBR value of BCS and BCS with different percentage of pond ash were determined. LL, PL and PI values of BCS were determined experimentally as 41.41%, 18.46% and 22.95% respectively. By these properties, BCS is classified as "inorganic clay of medium plasticity (CI). It is experimentally found that MDD of BCS is 1.725 gm/cc at 17.4% OMC. It is also experimentally found that when percentage of PA is increased up to 50%, the MDD of BCS is decreased to 1.68 gm/cc at 14.0% OMC.

[4] **Er. Jitendra Khatti (2018) –** The **unsoaked** CBR test was performed for black cotton soil and mix specimen of Pond Ash with BCS. It is reported that when 50% pond ash is mixed in BCS, CBR value of BCS is increased up to **31.02%**. It is also concluded that CBR value is increased with increase in percentage of pond ash in BCS.

[5], [6], [3], [8], [10], [4] The above researchers performed unsoaked CBR test to determine the CBR value of BCS and waste material + BCS. Using the above data, the flexible pavement was designed for single/ four lane by considering 3.5 and 4.5 vehicle damage factor for 10,12,15 and 20 years. From design of flexible pavement for different cases, it has observed that when traffic volume is varied from 310 to 790, the thickness of flexible pavement is varied from 465 mm to 575 mm. It is also reported that thickness of flexible pavement is directly proportional to traffic volume.

In present research paper, the brief description of geotechnical/ engineering properties of black cotton soil is given, which is determined in geotechnical laboratory. An attempt is made to improve the properties of BCS by mixing waste material i.e. Sugarcane Bagasse Ash (SCBA), Kota Stone Slurry (KSS), Marble Dust (MD) and Brick Dust (BD). The dosage of waste materials was selected from 2.5% to 20.0% at 2.5% variation. To study the effect of waste material on engineering properties of BCS, the Atterberg's limit test and CBR test is performed for waste material + BCS. The soaked CBR test is performed for BCS and BCS + waste material to design the flexible pavement. This paper is describing "How thickness of flexible pavement is getting affected by waste materials or stabilizing materials?" and "How much CBR value can be increased by waste materials?".

2 Raw Material Source

Black cotton soil (BCS) – The soil specimen was collected from Borkhera, Kota.

Sugarcane Bagasse Ash (SCBA) – The SCBA was purchased from local market of Kota.

Kota Stone Slurry (KSS) – The Kota stone slurry specimen was collected from industrial dump yard, Kota

Marble Dust (MD) – The marble dust specimen was purchased from local market of Kota.
Brick Dust (BD) – The brick dust specimen was collected from Kaithoon, Kota.

3 Experimental Study

The following experiments were performed in geotechnical laboratory to study the effect of waste material on black cotton soil.

3.1 Atterberg's Limits

Liquid limit, plastic limit and plasticity index are known as Atterberg's limits. Atterberg's limits are determined for BCS and with addition of different waste material in BCS. The SCBA, KSS, MD and BD waste materials are mixed in BCS from 2.5% to 20.0% at 2.5% variation by dry weight of soil. In this experimental work, the liquid limit is determined by cone penetration test apparatus. Liquid limit of BCS is determined experimentally as 51.14%. The results of liquid limit of mix specimen of different waste material with BCS is shown in Table 1.

Table 1 Results of liquid limit of mix specimen of waste material + BCS

Per. of waste materials	**Liquid limit of mix specimen of waste materials with BCS (%)**			
	SCBA	**KSS**	**MD**	**BD**
2.5%	50.65	50.02	50.19	49.89
5.0%	49.33	48.32	48.86	48.78
7.5%	47.86	44.39	45.52	46.52
10.0%	45.55	41.27	42.28	43.89
12.5%	43.11	35.44	38.65	41.15
15.0%	41.69	32.29	36.55	39.45
17.5%	37.99	29.38	32.17	37.79
20.0%	35.15	27.63	29.45	36.12

From the experimental study, it is found that the liquid limit of BCS soil is decreased to 35.15%, when 20%SCBA is mixed in BCS. Similarly, when 20%KSS, 20%MD and 20%BD is mixed in BCS, the liquid limit of BCS soil is decreased to 27.63%, 29.45% and 36.12% respectively. The percentage decrease of liquid limit of BCS due to waste material is shown in Table 2.

Table 2 Percentage decrease in liquid limit of BCS due to waste materials (wrt BCS)

Per. of waste materials	**Per. decreased in liquid limit of BCS due to waste material (%)**			
	SCBA	**KSS**	**MD**	**BD**
2.5%	0.96	2.19	1.86	2.44
5.0%	3.54	5.51	4.46	4.61
7.5%	6.41	13.20	10.99	9.03
10.0%	10.93	19.30	17.32	14.18
12.5%	15.70	30.70	24.42	19.53
15.0%	18.48	36.86	28.53	22.86
17.5%	25.71	42.55	37.09	26.10
20.0%	31.27	45.97	42.41	29.37

From Table 2, it is observed that the liquid limit is decreased when percentage of SCBA, KSS, MD and BD are increased in BCS. The liquid limit of BCS is decreased by 31.27%, 45.97%, 42.41% and 29.37% when 20%SCBA, 20%KSS, 20%MD and 20%BD **are** mixed in BCS respectively. It **may be noted** that the maximum decrease in liquid limit of BCS is obtained when 20%KSS is mixed in BCS. The graphical presentation of percentage decrease in liquid limit is shown in fig. 1.

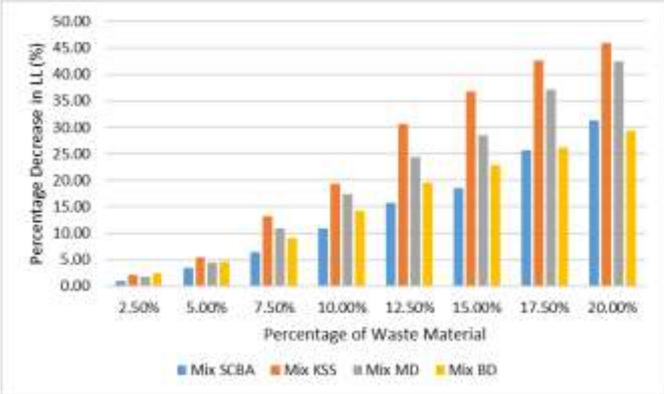

Fig. 1. Percentage decrease in liquid limit of BCS due to waste material (wrt BCS)

Similarly, the plastic limit test is performed by preparing 3mm soil thread. From test result, it is observed that PL of BCS is determined experimentally as 26.41%. The results of plastic limit of addition of different waste material with BCS is shown in Table 3.

Table 3 Results of plastic limit of mix specimen of waste material + BCS

Per. of waste materials	Plastic limit of mix specimen of waste materials with BCS (%)			
	SCBA	KSS	MD	BD
2.5%	26.23	25.93	25.85	25.87
5.0%	25.69	24.14	24.77	25.03
7.5%	24.34	22.79	23.54	24.47
10.0%	22.97	20.98	22.26	23.78
12.5%	21.14	18.61	21.09	22.54
15.0%	19.95	16.43	19.66	21.35
17.5%	17.36	13.65	16.43	19.97
20.0%	15.22	12.02	13.50	18.04

From the experimental study, it is found that the PL of BCS is decreased to 15.22% when 20%SCBA is mixed in BCS. Similarly, when 20%KSS, 20%MD and 20%BD are mixed in BCS, the plastic limit of BCS soil is decreased to 12.02%, 13.50% and 18.04% respectively. The percentage decrease of plastic limit of BCS is shown in Table 4.

Table 4 Percentage decrease in plastic limit of BCS due to waste materials (wrt BCS)

Per. of waste materials	Per. decreased in plastic limit of BCS due to waste material (%)			
	SCBA	**KSS**	**MD**	**BD**
2.5%	0.68	1.82	2.12	2.04
5.0%	2.73	8.60	6.21	5.23
7.5%	7.84	13.71	10.87	7.35
10.0%	13.03	20.56	15.71	9.96
12.5%	19.95	29.53	20.14	14.65
15.0%	24.46	37.79	25.56	19.16
17.5%	34.27	48.32	37.79	24.38
20.0%	42.37	54.49	48.88	31.69

From Table 4, it is observed that plastic limit is decreased when percentage of SCBA, KSS, MD and BD are increased in BCS. The plastic limit of BCS is decreased by 42.37%, 54.49%, 48.88% and 31.69% when 20%SCBA, 20%KSS, 20%MD and 20%BD are mixed in BCS respectively. It may be noted that maximum decrease in plastic limit of BCS is obtained when 20%KSS is mixed in BCS. The graphical presentation of percentage decrease in plastic limit is shown in fig. 2.

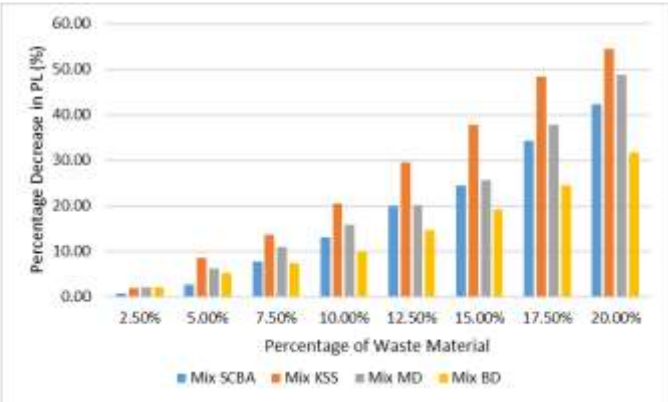

Fig. 2. Percentage decrease in plastic limit of BCS due to waste material (wrt BCS)

Plasticity index is the difference between the liquid limit and the plastic limit. The plasticity index is calculated for BCS and addition of different waste material in BCS. From the calculation, the PI of BCS is calculated as 24.73%. The PI has calculated for mix specimen of different waste material with BCS and it is shown in Table 5.

Table 5 Results of plasticity index of mix specimen of waste material + BCS

Per. of waste materials	Plasticity index of mix specimen of waste materials with BCS (%)			
	SCBA	**KSS**	**MD**	**BD**
2.5%	24.42	24.09	24.34	24.02
5.0%	23.64	24.18	24.09	23.75
7.5%	23.52	21.60	21.98	22.05
10.0%	22.58	20.29	20.02	20.11
12.5%	21.97	16.83	17.56	18.61
15.0%	21.74	15.86	16.89	18.10
17.5%	20.63	15.73	15.74	17.82
20.0%	19.93	15.61	15.95	18.08

From the experimental study, it is found that the PI of BCS is decreased 19.93% when 20%SCBA is mixed in BCS. Similarly, when 20%KSS, 20%MD and 20%BD are mixed in BCS, the plasticity index of BCS soil is decreased to 15.61%, 15.95% and 18.08% respectively. The percentage decrease in plasticity index of BCS is shown in Table 6.

Table 6 Percentage decrease in plasticity index of BCS due to waste materials (wrt BCS)

Per. of waste materials	Per. decreased in plasticity index of BCS due to waste material (%)			
	SCBA	**KSS**	**MD**	**BD**
2.5%	1.25	2.59	1.58	2.87
5.0%	4.41	2.22	2.59	3.96
7.5%	4.89	12.66	11.12	10.84
10.0%	8.69	17.95	19.05	18.68
12.5%	11.16	31.95	28.99	24.75
15.0%	12.09	35.87	31.70	26.81
17.5%	16.58	36.39	36.35	27.94
20.0%	19.41	36.88	35.50	26.89

From Table 6, it is observed that PI is decreased when percentage of SCBA, KSS, MD and BD are increased in BCS. The PI of BCS is decreased by 36.88%, 35.50% and 26.89% when 20%SCBA, 20%KSS, 20%MD and 20%BD are mixed in BCS respectively. It may be noted that maximum decrease in PI of BCS is obtained when KSS is mixed in BCS. The graphical presentation of percentage decrease in plasticity index is shown in fig. 3.

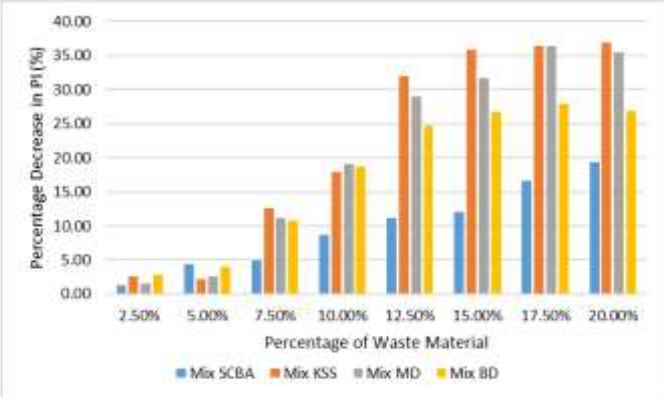

Fig. 3. Percentage decrease in plasticity index of BCS due to waste material (wrt BCS)

3.2 Classification of Soil/ Mix Specimen

The classification of soil and mix specimen of different waste material is done as per IS 1498 – 1970. From the test results of liquid limit and plasticity index of BCS, the soil specimen is classified as "Inorganic clays of high plasticity". It is also found that the classification of soil specimen has changed when waste material is mixed in BCS. The change in classification of soil due to waste material is shown in Table 7.

Table 7 Classification of mix specimen of waste material with BCS

Per. of waste materials	Classification of mix specimen of waste material with BCS (%)			
	SCBA	**KSS**	**MD**	**BD**
2.5%	CH	CH	CH	CI
5.0%	CI	CI	CI	CI
7.5%	CI	CI	CI	CI
10.0%	CI	CI	CI	CI
12.5%	CI	CI	CI	CI
15.0%	CI	CL	CI	CI
17.5%	CI	CL	CL	CI
20.0%	CI	CL	CL	CI

From Table 7, it is found that when the percentage of SCBA has increased in BCS, the soil changed its classification from inorganic clay of high plasticity to inorganic clay of medium plasticity. Similarly, when the percentage of KSS and MD have increased in BCS, the soil changed its classification from inorganic clay of high plasticity to inorganic clay of low plasticity. When the percentage of BD has increased in BCS, the soil changed its classification from inorganic clay of high plasticity to inorganic clay of medium plasticity.

3.3 California Bearing Test

The CBR value of BCS and waste material + BCS has obtained by soaked California bearing test. The test of soaked CBR is done after four days soaking of specimen. CBR value of BCS is determined experimentally as 2.1%. Similarly, soaked CBR test has done for mix specimen of waste material + BCS and test results are shown in Table 8.

Table 8 Soaked CBR value of BCS and mix specimen of waste material with BCS

Per. of waste materials	CBR value of mix specimen of waste material with BCS (%)			
	SCBA	**KSS**	**MD**	**BD**
2.5%	2.19	2.35	2.45	2.23
5.0%	2.32	2.69	2.76	2.29
7.5%	2.17	3.03	2.83	2.42
10.0%	2.11	3.16	2.91	2.57
12.5%	2.01	3.31	3.05	2.49
15.0%	1.82	3.59	3.12	2.42
17.5%	1.69	3.44	2.88	2.33
20.0%	1.51	3.08	2.54	2.19

From Table 8, it is found that the CBR value of BCS is increased to 2.32% when 5.0% SCBA is mixed with BCS. Similarly, the CBR value of BCS is increased to 3.59%, 3.12% and 2.57% when 15.0% KSS, 15.0% MD and 10.0% BD is mixed with BCS respectively. The flexible pavement is designed as per IRC 37: 2001 for 2.32%, 3.59%, 3.12% and 2.57% CBR value.

3.4 Design of Flexible Pavement

The design of flexible pavement is done as per IRC 37:2001, "Guideline for Design of Flexible Pavement. The flexible pavement is designed for BCS, mix specimen of 5.0% SCBA, 15.0% KSS, 15.0% MD and 10.0% BD with BCS. The following parameter are selected for design of flexible pavement:

Design life (in years) – n = 10 years
Vehicle damage factor – F = 3.5
CBR value (CBR) = 2.1, 2.32%, 3.59%, 3.12% and 2.57%
Annual growth rate of commercial vehicle (%) – r = 7.5%
Number of commercial vehicles as per last count – P = 310 and 410
Lane distribution factor – D = 0.75 (2 Lane)
Number of years between last count and year of completion – x = 1 year
Initial traffic in year of completion of terms of number of vehicles – A = 334 and 441
Value of MSA – N = 5 and 6
Thickness of granular base (mm) – T_{gb}
Thickness of granular sub – base (mm) – T_{gsb}
Thickness of wearing course – BC (mm) – T_{wc}
Thickness of binder course – DBM (mm) – T_{bc}
Total thickness of pavement (mm) – T

As per IRC 37: 2001 provision, the permissible variation for 5% CBR is ±1. Hence, flexible pavement is going to be designed for 3.1%, 3.32%, 4.59% (≈5.0%), 4.12 and 3.57% (≈4.0%). The flexible pavement has designed for two traffic volume 310 and 410. The result of thickness of pavement is shown in Table 9.

Table 9 Thickness of pavement for CBR values of BCS and Waste Material + BCS

Thickness of pavement (mm)	Number of commercial vehicles as per last count for CBR of BCS and mix specimen of waste material with BCS									
	BCS (CBR - 3.1%)		5.0% SCBA (CBR - 3.32%)		15.0% KSS (CBR – 5.0%)		15.0% MD (CBR – 4.12%)		10.0% BD (CBR – 4.0%)	
	310	410	310	410	310	410	310	410	310	410
T	690	705	690	705	580	605	620	640	620	640
T_{gb}	250	250	250	250	250	250	250	250	250	250
T_{gsb}	335	345	335	345	250	260	285	294	285	294
T_{wc}	25	30	25	30	25	32	25	21	25	21
T_{bc}	70	80	70	80	55	63	70	75	70	75

4 Discussion

From the experimental study, it is found that the LL, PL, PI of BCS is determined experimentally as 51.14%, 26.41% and 24.73% respectively. For improving LL, PL and PI of BCS, the SCBA, KSS, MD and BD waste materials are mixed from 2.5% to 20.0% at 2.5% variation in BCS. From test results of Atterberg limit, it is observed that when percentage of SCBA is increased in BCS, the LL of BCS is decreased by 0.96% to 31.27%, PL of BCS is decreased by 0.68% to 42.37% and PI of BCS is decreased by 1.25% to 19.41%. Similarly, when percentage of KSS is increased in BCS, the LL of BCS is decreased by 2.19% to 45.97%, PL of BCS is decreased by 1.82% to 54.49% and PI of BCS is decreased by 2.59% to 36.88%. Same as, when percentage of MD is increased in BCS, the LL of BCS is decreased by 1.86% to 42.41%, PL of BCS is decreased by 2.12% to 48.88% and PI of BCS is decreased by 1.58% to 35.50%. In case of BD, when percentage of BD is increased in BCS, the LL of BCS is decreased by 2.44% to 29.37%, PL of BCS is decreased by 2.04% to 31.69% and PI of BCS is decreased by 2.87% to 26.89%. From the test results of soaked CBR test, the CBR value of BCS is determined experimentally as 2.1%. For improving the CBR of BCS, SCBA, KSS, MD and BD are mixed at different percentage. From the test results of soaked CBR of waste material + BCS, it is observed that when 5.0%SCBA, 15.0% KSS, 15.0% MD and 10.0% BD is mixed in BCS, the CBR of BCS is increased by 10.48%, 70.95%, 48.57% and 22.38% respectively. From the design of flexible pavement, it is also observed that CBR value is inversely proportional to thickness of pavement.

From the above results it may be concluded that by addition of Kota stone slurry, marble dust and brick dust in BCS, the LL, PL and PI decrease by some amount. It may be also observed that by addition of these materials CBR improves leading to decrease in thickness of flexible pavement. This may be due to calcareous nature of the waste materials. Therefore, these materials may be used as stabilizing materials for BCS. In comparison to the above three materials, the sugarcane bagasse ash consists of ferric oxide + silica + alumina < 70%. Therefore, SCBA may not be able to decrease LL, PL and PI. Also, not much change in CBR is observed by adding sugarcane bagasse ash in BCS. Hence, thickness of flexible pavement may not change much.

5 Conclusions

From the above experimental study, the following conclusions are drawn:

1. The test results of liquid limit, plastic limit and plasticity index have shown that Kota stone slurry and marble dust are more suitable material to improve engineering properties of BCS, compare to sugarcane bagasse ash and brick dust
2. Inorganic clay of high plasticity soil has changed its behavior to inorganic clay of low plasticity soil by mixing 15% KSS and 15% MD.
3. Experimentally it is found that the CBR value of BCS, BCS + 5.0% SCBA, BCS + 15.0% KSS, BCS + 15.0% MD and BCS + 10.0% BD is 2.1%, 2.32%, 3.59%, 3.12% and 2.57% respectively.
4. An increase in CBR test results may be observed when waste material is added with BCS. This is evident that when 5.0%SCBA, 15.0%KSS, 15.0% MD and 10.0% BD is mixed in BCS, the CBR value is increased by 10.48%, 70.95%, 48.57% and 22.38% respectively.
5. When flexible pavement is designed on virgin BCS and it is observed that the total thickness of pavement is designed 690 mm and 705 mm with 310 and 410 traffic volume respectively, the total thickness of pavement is calculated as 690 mm and 705 mm.
6. A decrease in thickness of flexible pavement is observed when waste material is mixed in BCS. This is evident that when 15.0% KSS is mixed in BCS, the thickness of flexible pavement is decreased by 15.94% and 14.18% for traffic volume 310 and 410 respectively. Similarly, in case of MD and BD, the thickness of pavement is decreased by 10.14% and 9.22% for traffic volume 310 and 410 respectively.

From the above experimental study, it may be concluded that KSS, MD and BD may be used as stabilizing material for improving CBR value of BCS. The addition of KSS, MD and BD in BCS also help in decreasing the thickness of flexible pavement.

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