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BLACK COTTON SOIL STABILIZATION USING BAGASSE ASH AND LIME

Amruta P. Kulkarni, Mithun. K. Sawant, Vaishnavi V. Battul, Mahesh S. Shindepatil, Aavani P.
Department of Civil Engineering, Dr. D. Y. Patil Institute of Engineering,
Management & Research, Pune, India

ABSTRACT

The construction on black cotton soil (expansive soil) has always been a difficult task for the engineers as the structure resting on black cotton soil cracks without any warning. Black cotton soil is found in M.P., Karnataka, Maharashtra and Andhra Pradesh in our country. Soil proportion changes depending upon their constituents, i.e. water content, density, bulk density, angle of friction, shear strength etc. The properties of black cotton soil can be modified by stabilizing the soil with the use of additives or by mechanical means. The scarcity and rising cost of traditional stabilizers like Lime and Cement has led to the research into clay soil stabilizing potential of bagasse ash that is cheaper, readily available and environmental friendly and has a serious disposal problem. In this paper attempt has been made to stabilize the black cotton soil by using mixture of bagasse ash and lime. Bagasse is a fibrous residue of sugarcane stalks that remains after extraction of sugar and when incinerated gives the ash. The chemical analysis on bagasse ash was found to contain mainly silica, and potassium, iron, calcium, aluminium, magnesium as minor components and exhibit pozzolanic properties. The research investigated the properties of expansive clay soil when stabilized by lime, ash and combination of lime and ash. The aim is to economically improve the engineering properties of the black cotton soil such that the structure built on this soil can efficiently withstand applied loads.

Key words: Black Cotton Soil, Bagasse ash, Stabilization, Lime, LL, PL, P.I, DFS, OMC, CBR.

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1. INTRODUCTION

The foundation of a building or road is an essential part for effective transmission of load to the subsoil present beneath it. The quality of soil has large impact on type of structure and its design. The expansive soils are examples of weak soils, which encountered in foundation engineering for bridges, highways, buildings, embankments etc. Expansive soil undergoes volume changes when they come in contact with water. They show alternate swelling and shrinkage properties. It expands during rainy season and shrinks during summer season. Expansive soil covers nearly 20% of the land mass in India. In Maharashtra region the expansive soils are identified by name “Black 1Cotton” soil. These soils possess weak properties due to presence of clay minerals known as “Montmorillonite”. Typical behaviour of soil results into failure of structure in form of settlements cracks etc. Therefore it is important to remove the existing weak soil and replaced it with a non-expansive soil or improves the properties of weak soil by stabilization.

The scarcity and rising cost of traditional stabilizers like Lime and Cement has led to the research into clay soil stabilizing potential of bagasse ash that is cheaper, readily available and environmental friendly and has a serious disposal problem.

2. MATERIALS & EXPERIMENTAL PROCEDURES

2.1. Materials

2.1.1. Black Cotton Soil or expansive soil

Is a clay or soil that is prone to large volume changes (swelling and shrinking) that are directly related to changes in water content. Soils with a high content of expansive minerals can form deep cracks in drier seasons or years; such soils are called vertisols. Soils with smectite clay minerals, including montmorillonite and bentonite, have the most dramatic shrink-swell capacity.

Table 1 Properties of Black Cotton Soil

Loss of Ignition	-	16.18
Alumina	Al2o3	12.24
Titanium	Tio2	0.24

Grading of soil using sieve analysis was done to determine the grain size distribution by dry sieve method for black cotton soil. The coefficient of uniformity and coefficient of curvature was obtained to be 9.62 and 0.685 respectively. Hence it can be concluded that the soil used is very well graded, as the soil size was found to be below 0.075mm and considerable amount of soil was retained in receiver hence it can be said that the above soil is clayey according to USCS Soil Classification System.

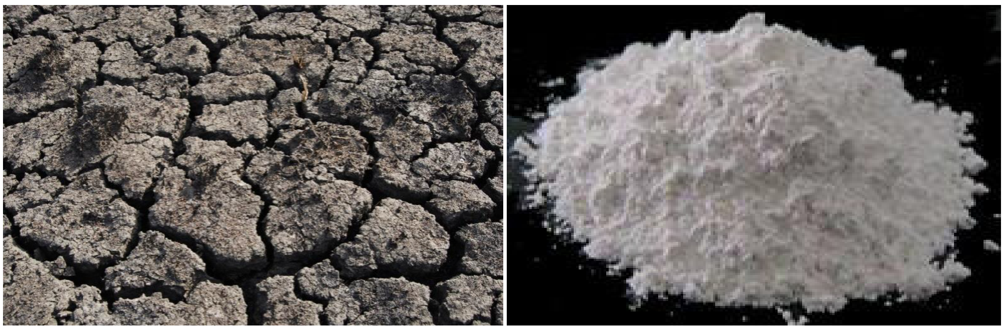


Figure 1 Sample of Black Cotton Soil and Lime

2.1.2. Bagasse

Is a fibrous material obtained from sugar cane plant after the extraction of sugar cane juice. Sugar factory waste bagasse is used as bio fuel and in manufacturing of paper. Sugar industry produces 30% bagasse for each lot of crushed sugar cane, when this bagasse is burnt the resultant ash is known as Bagasse Ash". Bagasse shows the presence of amorphous silica, which is an indication of pozolonic properties. The use of bagasse ash as stabilizing material for black cotton soil can be checked under various tests.

2.1.3. Bagasse ash

Is a pozzolanic material which is very rich in the oxides of silica and aluminum and sometimes calcium (Guilherme et al, 2004). Pozzolans usually require the presence of water in order for silica to combine with calcium hydroxide to form stable calcium silicate, which has cementitious properties.

2.1.4. Lime

Is a general term for calcium containing inorganic materials, in which carbonates, oxides and hydrates are predominating. Strictly speaking, lime is calcium oxide or calcium hydroxide. Lime stabilization is the most widely used means of chemically transforming unstable soils into structurally sound construction foundations. The use of lime in stabilization creates a number of important engineering properties in soils, including improved strength; improved resistance to fracture, fatigue, and permanent deformation; improved resilient properties; reduced swelling; and resistance to the damaging effects of moisture.

Table 2 Properties of Bagasse Ash and Lime

Description	Abbreviation	Ash (%)	Lime (%)
Silica	SiO2	69.23	0.00
Iron	Fe2O3	3.09	0.08
Calcium	Ca0	2.81	95.03
Magnesium	MgO	1.54	0.04
Sodium	Na20	0.26	0.05
Potassium	K2O	6.44	0.03
Loss of Ignition	-	16.36	4.33
Alumina	Al2O3	1.90	0.13
Titanium	Tio2	0.07	-
Sulphur trioxide	SO3	-	0.02
Manganese	MnO	0.60	0.60
Phosphorus	P2O5	-	0.00
Water	H2O	-	0.04

Material was collected from suitable location and different trials were taken on BCS to know its engineering properties. After the results were obtained, proportions of bagasse ash and lime were decided and samples were moulded accordingly. All the samples were tested for different parameters to improve engineering property of BCS.

2.2. Sample Preparation

Four samples were prepared by varying percentage of Bagasse Ash and Lime and were studied for different engineering properties as mentioned above. Proportion (parts per volume) of bagasse Ash and Lime used are shown in Table 4.

Table 3 Used Proportions of Bagasse Ash and Lime

Sr. No.	Bagasse Ash	Lime
1.	1	4
2.	2	3
3.	3	2
4.	4	1

2.3. Experimental Procedure

2.3.1. Atterberg Limits

Atterberg Limits such as Liquid Limit, Plastic Limit and Plasticity Index were determined for black cotton soil and black cotton soil with varying proportions of bagasse ash and lime. For determination of Atterberg's Limits, 100 grams of Black Cotton Soil sample was weighed passing 425 Micron sieve. Accordingly 1:4 (BA: Lime) was weighed using weighing balance and was mixed with black cotton soil. Similarly for other proportions same procedure was followed. The figure below shows the weight of Black Cotton Soil weighed for determination of Liquid Limit. Same amount of Black Cotton Soil was taken for determination of Plastic Limit. Second figure below shows the mixing of weighed bagasse ash and lime in proportion. Mixing was done thoroughly to have equal distribution of lime and bagasse ash all through the BCS.

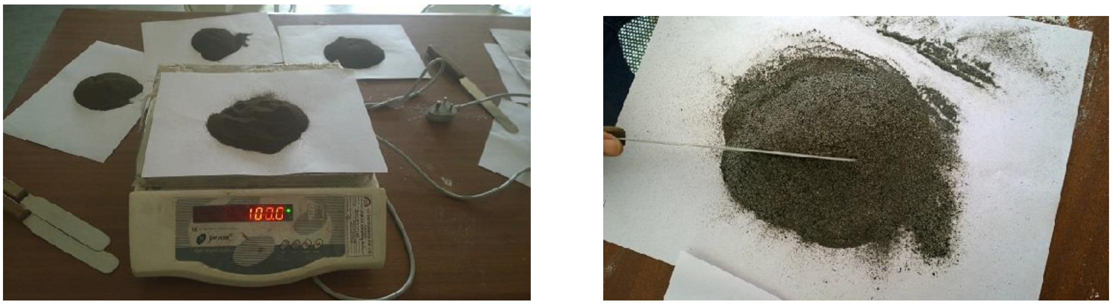


Figure 2 Weighing of BCS for determination of liquid limit and Mixing of samples

Figure 3 Determination of Plastic limit

2.3.2. Differential free swell test

Dry about 50 gm of soil in an oven at 100 - 110° c, sieve the soil thoroughly 425 micron is sieve. Take two specimens of this soil each weighing 10 gms. Fill one cylinder with kerosene oil and the other with distilled water. Pour gently one soil specimen in the first cylinder containing kerosene and the other specimen in the second cylinder-containing distilled water. Remove the entrapped air by gently shaking or by stirring with clean glass rods. Leave the soil specimen in the cylinders. Kerosene is non polar liquid causing no swelling of the soil. The level of the soil specimen in the graduated cylinder containing kerosene oil therefore is read as the original volume of the soil sample. The level of the soil specimen in the second cylinder containing distilled water is taken as the free swell level.

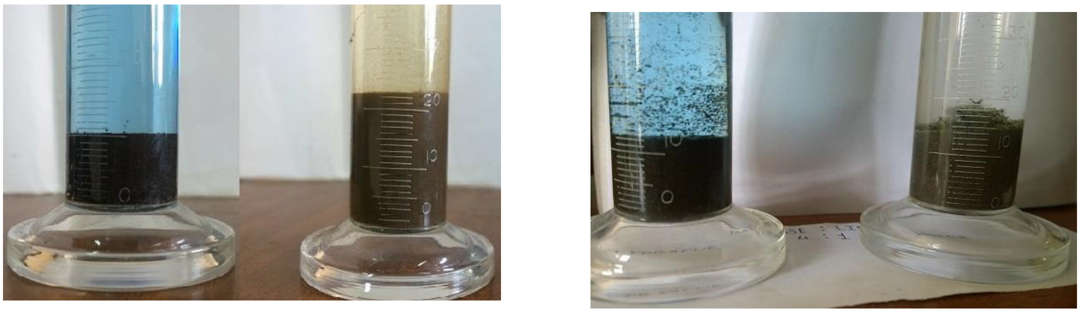


Figure 4 Determination of DFS for BCS and BA: L

3. EXPERIMENTAL ANALYSIS AND RESULTS

3.1. Atterberg Limits

3.1.1. Determination of liquid limit

Table 4 Observation table for liquid limit of BCS

No. of Blows	Blows for reading obtained	Mass of wet soil (M1) in grams	Mass of oven dry soil (M2) in grams	Mass of Water (M3) in grams	Water Content (%)
15 – 20	16	62	36	26	72.22
20 - 25	21	24	14	10	71.44
25 - 30	28	67	39	28	70.57
30 - 35	34	51	30	21	70

Liquid limit for 25 blows: BCS=70.9%

Table 5 Observation table for liquid limit of BA: L

No. of Blows	Blows for reading obtained		Mass of wet soil (M1) in grams		Mass of oven dry soil (M2) in grams		Mass of Water (M3) in grams		Water Content (%)	
	1:4	**4:1**	**1:4**	**4:1**	**1:4**	**4:1**	**1:4**	**4:1**	**1:4**	**4:1**
15 – 20	16	16	25.5	34.0	16.5	20	6	14	54.54	70
20 - 25	22	24	26.0	28.5	16	17	10	11.5	51.98	67.64
25 - 30	30	28	35.0	40.5	22	24.5	13	16	49.53	66.72
30 - 35	34	32	34.0	36.5	20	22	14	14.5	48.58	65.9

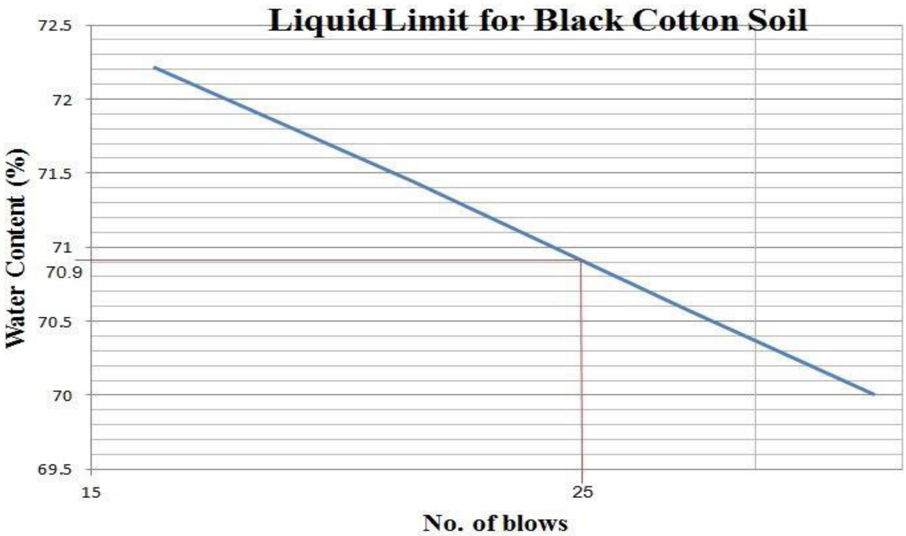
Liquid limit for 25 blows: BA: L 1:4=51.00% and 4:1=67.39 %

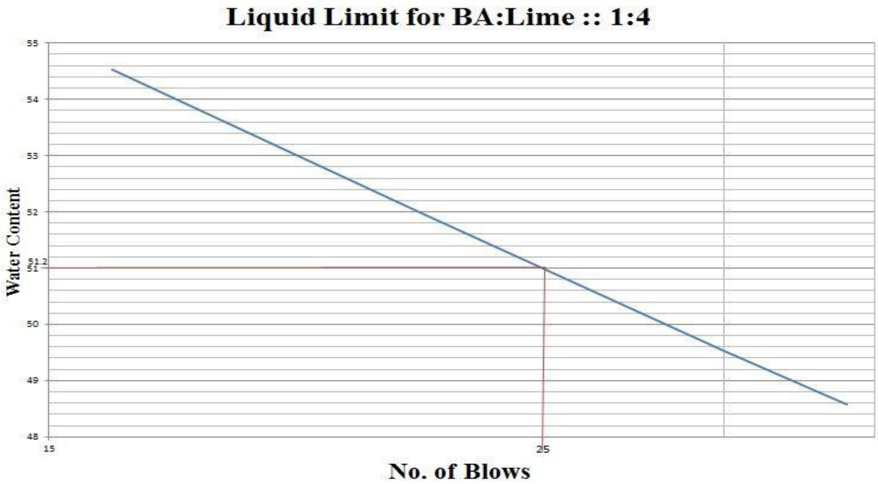
Table 6 Observation table for liquid limit of BA: L

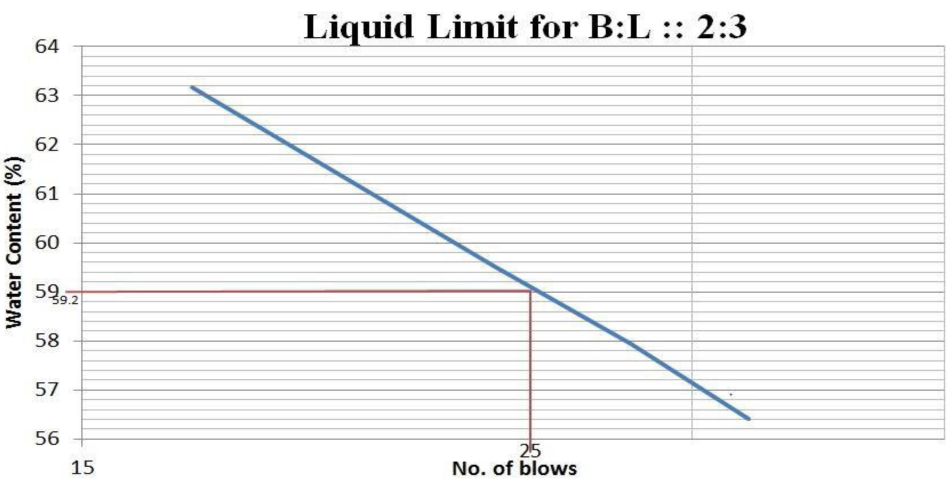
No. of Blows	Blows for reading obtained		Mass of wet soil (M1) in grams		Mass of oven dry soil (M2) in grams		Mass of Water (M3) in grams		Water Content (%)	
	2:3	**3:2**	**2:3**	**3:2**	**2:3**	**3:2**	**2:3**	**3:2**	**2:3**	**3:2**
15 – 20	17	19	31	31.5	19	19	12	12.5	63.15	65.78
20 - 25	24	22	33.5	34.5	21	20.5	12.5	14	59.52	68.29
25 - 30	28	29	24.5	29	15	17.5	9.5	11.5	57.93	62.85
30 - 35	32	31	31	35	19	21	12	14	56.41	66.66

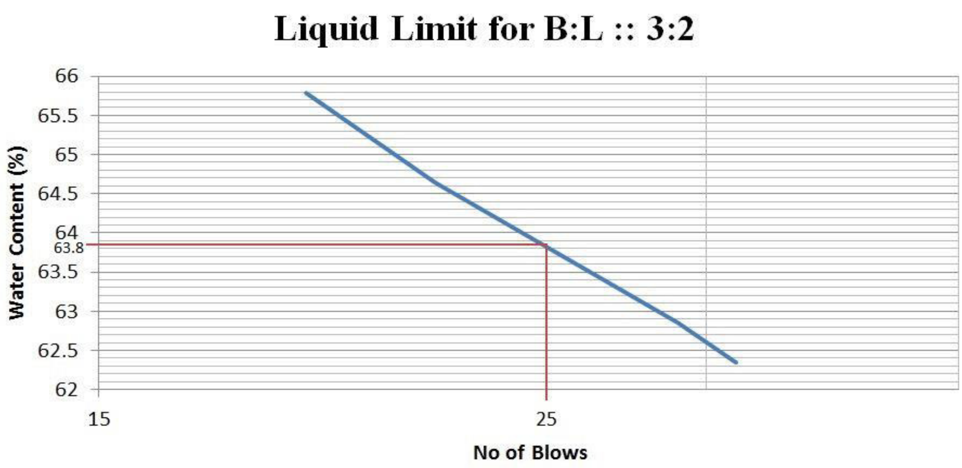
Liquid limit for 25 blows: BA: L 2:3=59.20% and 3:2=62.80 %

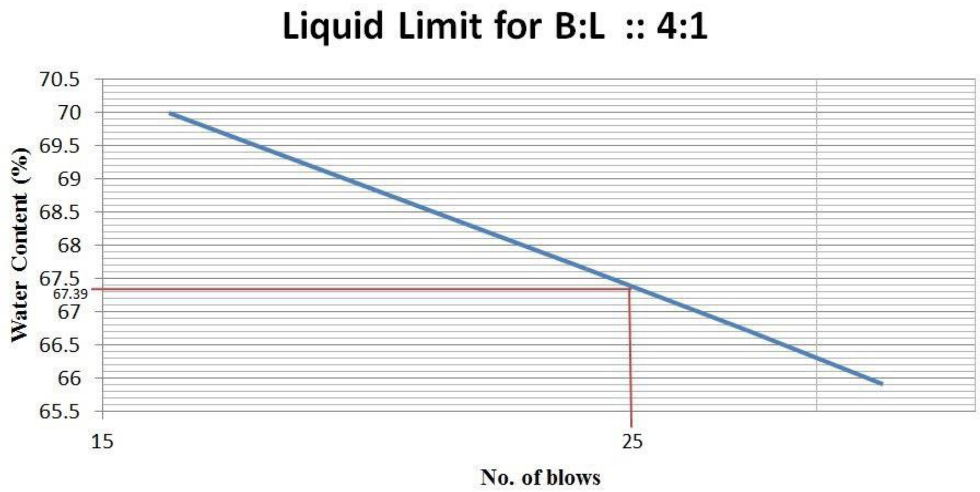
Graph 1: Liquid Limit for Black Cotton Soil
Graph 2: Liquid Limit for BA: L:1:4
Graph 3: Liquid Limit for BA: L:2:3
Graph 4: Liquid Limit for BA: L:3:2
Graph 5: Liquid Limit for BA:L:4:1











3.1.2. Determination of Plastic limit

Table 7 Observation table for plastic limit

Sr. No.	Sample	Mass of wet Soil (M1) in grams	Mass of oven dry soil (M2) in grams	Mass of water in grams	Water Content (%)
1.	BCS	31.36	24	7.36	30.67
2.	BA : Lime (1 : 4)	50.774	38.5	12.274	31.881
3.	BA : Lime (2:3)	18.89	14	4.89	34.97
4.	BA : lime (3:2)	7.36	5.5	1.86	33.83
5.	BA : Lime (4:1)	20.0625	15	5.06	33.75

Plasticity Index is given by the formula, PI = LL – PL. For BCS, PI = 70.9 – 30.67 = 40.23% Similarly PI for other sample was computed. The table below shows the PI for all the 5 samples.

Table 8 Observation table for plasticity index

Sr. No.	Sample	LL	PL	PI
1.	BCS	70.900	30.670	40.23
2.	B:L (1:4)	51.001	31.881	19.12
3.	B:L (2:3)	59.200	34.970	24.23
4.	B:L (3:2)	62.800	33.830	28.97
5.	B:L (4:1)	67.390	33.750	33.64

The plasticity Index of BCS was found to be 40.23 before stabilization whereas after mixing it with BA and Lime there was remarkable decrease in Plasticity Index. Three of the four proportions (1:4, 2:3, 3:2) stabilized had reduced their Plasticity Index to fall within the range of Moderate Plastic.

3.2. Differential Free Swell Test

Table 9 Observation table for free swell index

Sr. No.	Sample	Volume of Sample in Kerosene (cc)	Volume of sample in water (cc)	Free Swell Index %
1.	BCS	10.5	23	119.04
2.	BA : Lime (1 : 4)	10.5	12.5	19.04
3.	BA : lime (2 : 3)	12	13	8.33
4.	BA : Lime (3:2)	12.5	14.5	16
5.	BA : Lime (4 : 1)	12.2	15	22.95

From the above results, it was observed that BCS is highly expensive soil having swelling index more than 100%. After the stabilization, the results obtained were highly satisfactory. The swelling index in case of 2:3 was reduced to 8.33% which is remarkable reduction in swelling potential. For other samples swelling potential was reduced to considerable limits.

3.3. Standard Proctor Compaction Test

Table 10 Observation table for standard proctor compaction test

Sr. No.	Determination	1	2	3	4	5	6	7	8
					a. Density				
1.	Mass of empty mould (gm)	5758	5766	5766	5758	5765	5498.5	5809.5	5764
2.	Mass of mould + compacted Soil (gm)	9219	9258	9381	10079	9935.5	9740.5	9845.5	9873
3.	Mass of compacted soil (gm)	3461	3492	3615	4321	4171.5	4242	4036	4109

b. Water Content									
1.	Mass of wet soil (gm)	52	69	63	43	53	60	61.5	61.5
2.	Mass of dry soil (gm)	48	64	56	36	43	46.5	47	46
3.	Mass of water (gm)	4	5	7	7	10	13.5	14.5	15.5
4.	Water Content (%)	8.33	9.09	14.28	19.44	23.25	29.03	30.85	33.69

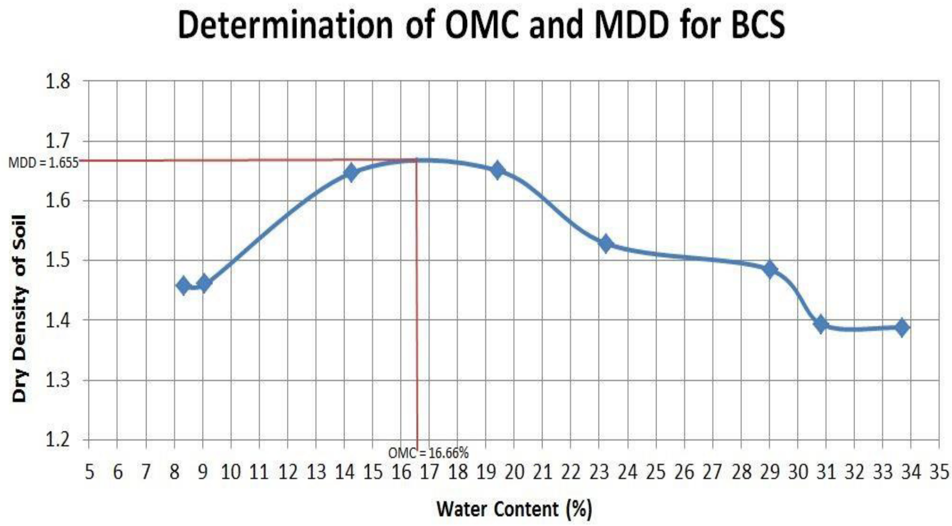


Figure 11 Determinations of OMC and MDD for BCS

From the graph obtained as per above readings, the OMC for BCS was found to be 16.66%.This value of OMC was further used in preparation of sample for determining CBR for black cotton soil.

3.4. California Bearing Ratio

Table 11 Determination of California Bearing Ratio (CBR)

Compaction Rammer Wt.	2.60 Kg.	No. Of Layers	3	No. Of Blows	56
Wt. of base plate and mould	175 mm	Optimum Water Content	16.66 %	Liquid Limit (W_1)	70.90 %
Height of mould (h)	175 mm	Wt. Of Mould + Base Plate	6.486 Kg.	Plastic Limit	30.67 %
Diameter of mould	150 mm	Wt. Of Mould + Base Plate +Soil	11.24 Kg.	Dia. Of Plunger	50 mm
Height of Sample in mould	125 mm	Wt. Of Surcharge	4.739 Kg.	Area Of Plunger	1962.50 mm

Volume of Sample	2209 cm^3	Density Of Soil Before Soaking	20.61 KN/m^3	Density Of Soil After Soaking	21.52 KN/m^3

Table 12 Determination of load for CBR for BCS and BA: L: 2:3

Specimen	Black Cotton Soil		Bagasse Ash : Lime :: 2:3	
Penetration	2.50	5.00	2.50	5.00
Stress KN/m^2	219.10	237.30	1922.90	2533.65
Unit Standard stress (KN/m^2)	7000	10500	7000	10500
CBR %	3.13	2.26	27.47	24.13

CBR test was performed only for black cotton soil and sample containing BA: L ratio 2:3, as this sample was found to have satisfactory results for plasticity index and selling index. From the above results it was observed that mixing bagasse ash and lime in proportion 2:3 has increased the CBR of black cotton soil to remarkable limits. In India as per IRC codes the CBR value for sub grade has to be more than 7%, whereas the stabilization with BA and lime has CBR value equals to 24.13 under soaked condition (worst case). Clearly the results obtained are satisfactory.

4. RESULTS AND DISCUSSIONS

In Sieve Analysis, the BCS was found to be well graded. Each sieve including receiver had retained some amount of soil which clearly shows the distribution of the size of soil particles. Coefficient of uniformity, Cu was found to be 9.62 whereas, Coefficient of curvature, Cc was found to be 0.685

In Atterberg limits, Black cotton soil was found to have Plasticity Index (P.I.) of 40.23%, which considerably decreased by blending the soil with Bagasse Ash (BA) and Lime. However it was found that with increase in proportion of lime the PI reduces whereas with increase in addition of bagasse ash, PI decreases. For different proportions, the results obtained were as below:

Table 13 Concluded Values of Plasticity Index

Sr. No.	Sample	PI
1.	BCS	40.23
2.	B:L (1:4)	19.12
3.	B:L (2:3)	24.23
4.	B:L (3:2)	28.97
5.	B:L (4:1)	33.64

Hence, it can be clearly seen from the table that P.I. decreases with increase in lime.

In Differential Free Swell Test, it was observed that BCS has high swelling potential with addition of water. This may be caused due to presence of montmorilonite mineral present in the soil. BCS without stabilisation was found to have selling potential of 119.04 % after keeping it 24 hours in water for observation. After the stabilisation with BA and lime, remarkable results were observed decreasing the swelling potential of soil to as low as 8.33%. For different proportions, the results obtained were as below:

Table 14 Concluded Values of Swell Index

Sr. No.	Sample	Free Swell Index %
1.	BCS	119.04
2.	BA : Lime (1 : 4)	19.04
3.	BA : lime (2 : 3)	8.33
4.	BA : Lime (3:2)	16
5.	BA : Lime (4 : 1)	22.95

In Standard Proctor Test, it was found that the BCS has Optimum Moisture Content = 16.66%. Maximum Dry Density can be obtained by compacting the soil at its OMC. The value of OMC was further used for determination of CBR.

In California Bearing Ratio Test, it was found that alone BCS has very low CBR which was found to be 2.26 for soaked conditions. After the stabilisation CBR value was found only for 2:3 proportion of Bagasse Ash: Lime. CBR value remarkably increased to 24.13% again for soaked condition.

5. CONCLUSION

From the summary above, there was noticeable decrease of plasticity index and increase of California bearing ratio of Stabilized Black Cotton Soil when optimum ratio of Bagasse Ash to Lime was used hence in conclusion, Bagasse Ash can be used in stabilization of black cotton soil.

For each 10 tons of sugarcane crushed, a sugar factory produces nearly 3 tons of wet bagasse. Bagasse Ash is a major waste of sugar industry and has serious waste disposal problems. Using Bagasse Ash for stabilization not only solves the disposal problem but also its optimum usage in subgrade soil stabilization will bring down the construction cost of the pavements.

As per this project, taking into account all the results and observations, the best proportion for stabilization for Black Cotton Soil is recommended to be 2:3 of Bagasse Ash: Lime.

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