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Stabilization of Black Cotton Soil By Admixtures

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ABSTRACT

The preliminary characteristics of Black cotton soil is which possess poor shear strength with high swelling & shrinkage, thus the behaviour of the soil under the application of loads can be altered by changing its physical & engineering properties. When the BC soil is exposed to variation in climatic condition leads to increase or decrease in swelling & shrinkage ratio, these variations can be minimised by admixtures such as Manufactured sand, cement & fly ash. The present study deals with evaluation of physical & engineering properties of BC soil which is mixed with admixtures in a varying proportions & the results are tabulated by comparing it with standard codes & practises. The experimental study also revealed that with the increase of percentage of M-sand with cement & fly ash there is an increase in Maximum dry density values where as there is considerable reduction in optimum moisture content for the given soil by conducting standard proctor test also with the conduction of CBR test by varying the percentage of admixtures like Cement, M–sand and Fly ash in the soil mix, there is a gradual increase in the CBR values with the increase in percentage of stabilizers.

Keywords: Soil stabilisation, admixtures, physical properties of soil, unconfined compressive strength, CBR.

I. INTRODUCTION

Soil stabilization is the improvement of strength or bearing capacity of soil by controlled compaction, proportioning and/or addition of suitable admixtures or stabilizers. Soil is a naturally occurring material which are stabilised to increase the strength & durability under the design use conditions and increase in design life of the engineering project. Properties of soil will vary according to its location, physical properties & so on, Various methods are available to stabilize the soil and the method should be analysed in the laboratory initially with soil material before applying it on the field conditions.

The basic property of the soil should have good strength & load bearing capacity so that external loads can be transferred to the below layers effectively without undergoing any structural failure, hence it is required to enhance the desired properties of those soils. Stabilization of soil should be cost-effective, long-term physical and chemical alteration of soil will enhance their physical properties which can improve shear and unconfined compressive strength and permanently lower the soil's permeability to water.

The major Principles of Soil Stabilization are to Evaluate the soil properties, To decide lacking property of soil, Choosing the effective method for stabilization & Designing the Stabilized soil mix sample. Gradation of the soil is also a very important property which is considered where the soil may be well-graded which is desirable as it has less number of voids or uniformly graded which though sounds stable but has more voids thus, it is

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better to mix different types of soils together to improve the soil strength properties because it is very expensive to replace the inferior soil completely during construction.

Advantages of soil stabilisation are Effective utilization of locally available soils and other suitable stabilizing agents. It is more economical both in terms of cost and energy to increase the bearing capacity of the soil & to provide more stability to the soil in embankment construction leads to increase in workability & durability. Soil stabilization is also done for soil water-proofing thus preventing water from entering into the soil layers & also used to prevent erosion of soil in dry and arid weather conditions. By stabilizing the existing soil layer, cost associated with excavation of the existing soil, removing it from the site and replacing it with suitable materials can be eliminated. In areas where replacement of existing material is problematic mainly due to the location of site in a remote area where aggregate supply is cost prohibitive to import, soil stabilization becomes a cost effective alternative.

Soil stabilization is used in many sectors of the construction industry, Roads, parking lots, airport runways, building sites, landfills, the use of soil stabilization for slope protection, dam cores, impervious liners are feasible based on both economical & service life considerations. Water infiltration weakens the underlying soil & variable vehicular wheel loads moving on the surface layer will damage the pavement structure, the use of chemical stabilization in roadway design speaks directly to these issues of long-term life-cycle stability of the soil.

Stabilization of soil can be done by adding additives or without additives, the following are major methods of soil stabilisation:

- Mechanical Stabilization is suitable for low volume roads which involves the correct proportioning of aggregates and soil which are adequately compacted to get mechanically stable layer.
- Soil Cement Stabilization is an intimate mix of soil, cement and water, compacted to form a strong base course & to increase compressive strength of the soil layer. Soil Cement can be used as a sub-base or base course for all types of Pavements.
- Soil Lime Stabilization Soil-Lime has been widely used as a modifier or a binder for a high plastic soils which imparts binding action even for a granular soils.
- Soil-Bituminous Stabilization Bitumen Stabilized layer may be used as Sub-base or base course for all the roads in which the basic principles of this stabilization are Water Proofing and Binding of soil components which enhances its strength & the most commonly used materials are cut back & emulsion.
- Lime Fly ash Stabilization Can be used for construction of Embankments, Rigid and semi-rigid pavements. Fly ash properties vary widely & thus to be characterized before it is used for stabilization of soil layer. The major constituents of fly ash are oxides of silica, aluminum, iron, calcium & magnesium which Possesses many favorable properties for embankment & road construction, fly ash is also termed as environmentally safe material which enhances the properties of soil.

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II.REVIEW OF LITERATURE

Due to the presence of montmorillonite which is characterized by large volume change from wet to dry seasons and vice versa, black cotton soil also facilitates compaction for obtaining the desired density with comparatively less effort. The characteristics of Black Cotton Soil is which it forms a very poor foundation material for road construction & also possess low strength with excessive volume changes. The properties of the black cotton soil may be altered in many ways viz, mechanical thermal, chemical and other means stabilisation, it is very important to investigate the physical and engineering properties associated with the black cotton soil. In the present study black cotton soil specimens are derived from depth of 1 to 1.5 m were studied in the laboratory for investigation of physical and engineering properties. Various tests like grain size analysis, specific gravity, atterberg's limits, standard proctor compaction, consolidation and direct shear test were conducted on the soil specimens as per the Indian Standard Codes [1].

The black cotton soil found in semi – arid regions of tropical and temperate climate zones will be having high evaporation percentage when compared to precipitation. The sticky plastic nature of black cotton soils particles will make the soil extremely difficult to extract or dislodge & the cracks measuring 70 mm wide and over 1 m deep were observed in the study also it has shown that these cracks can extend up to 3m or more in case of high deposits [2].

The effect of lime in addition with black cotton soil in an incremental manner up to 6% to a high expansive BC soil used in the laboratory for investigation in the prevailing conditions (temperature and humidity) which will enhance the strength, penetration resistance and reduce swelling & shrinkage behaviour. Quick lime can be successfully used for treatment of BC Soil, which is a cost effective when compared to other admixtures such as cement and asphalt which will provide long life to the structures with least maintenance. If the soil is non-plastic and is having low plasticity index, lime alone is not satisfactory for stabilization but an addition of fly ash is needed to improvise the necessary changes in the soil [3].

Quantity of lime is varied from 2% to 4% of BC soil to observe the corresponding physical & engineering changes in the properties of soil. The value of MDD increases with increase in percentage of lime whereas OMC decreases and Swelling pressure is lowered by 29% at 4% lime & also there is considerable reduction in compressibility value of the soil which is stabilised by fly ash [4].

The property of black cotton soil can be effectively improved by using varying percentage of lime contents from 3% to 5%. By the experimental analysis in the laboratory it was observed that on an addition of 3% of lime to the BC soil there is a considerable decreases the liquid limit by 2.70% while with 5% addition of lime reflects a decrease 15.27% also there is an increase in MDD by 6.29% and 5.59% at 3% and 5% lime content respectively. The C.B.R. values of black cotton soil is improved considerably to 3.25 times and 4.76 times with the addition of 3% and 5% lime to the BC soil respectively [5].

The Liquid Limit of black cotton Soil continuously decreases with increase in percentage of lime content and Electric arc furnace (EAF) dust content, Plasticity index of black cotton soil will also decrease with increase in EAF dust & lime fine content. Optimum moisture content increases with decrease in dry density for an increase in lime content in the soil. Whereas the Optimum moisture content decreases with increase in MDD for an increase in EAF dust content. Unconfined compressive strength value of black cotton soil increases with

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increase in EAF dust content up to 6% of lime and then it decreases with increase in EAF dust content also the unconfined compressive strength value of black cotton soil increases with increase in curing period for the BC soil. Higher CBR value leads to lower total pavement thickness of flexible pavements which is economical for overall project as the materials required for construction is reduced [6].

The black cotton soils of Hubli -Dharwad region will possess high degree of expansion and swelling potential which require stabilization for their better performance. By studying the index parameters of soil to improve its properties with the addition of Dandeli Fly Ash. There is a decrease in liquid limit and plasticity index whereas increase in Shrinkage limit for the corresponding increase in the addition of DFA by a proportion ranging from 10% to 50% respectively. There is a decrease in optimum moisture content & increase in CBR value gradually also the value of UCC has been increases for no curing condition & for a curing period of 7 days, the trend of increase in the strength is found more pronounced [7].

With the presence of clayey content in soil & by conducting physical property tests there is an increase in the plasticity index by classifying the Soil specimens as A, B and C which retains almost same percentage of clay particles and have medium range of plastic indices. Whereas Liquid limit, Plastic limit, Specific Gravity and Dry Density of soil specimen A was found to be higher than the soil specimen B and C. The value of value of angle of internal friction of soil specimen C was observed to be higher than soil specimens B and A. Predicted values of the parameters viz. Plasticity index (PI), Optimum Moisture Content (OMC), Compression Index (Cc) and Angle of Internal Friction (ϕ) for the soil specimens A, B and C from empirical models derived through regression analysis were observed to be very close to the experimental values. With the increase in the plasticity index induces decrease in the angle of internal friction and the compaction Characteristics were observed to be fair for black cotton soils [8].

The liquid limit can be considered as the measure of quantity of water attracted by soil particles for a given value of shear strength thus making it possible to correlate with compressibility. The black cotton soil is very hard when it is dry but loses its strength completely in wet condition. Studies has shown that 40 to 60% of black cotton soil will have its particle size less than 0.001 mm [9].

III. MATERIALS & METHODOLOGY

1. Materials

a) Black Cotton Soil of pertaining Sieve size as per IS standards.
b) M-Sand of pertaining Sieve size as per IS standards.
c) Ordinary Portland Cement of 53 Grade.
d) Fly ash of pertaining Sieve size as per IS standards.
e) Potable water for mixing the constituents.

IV. METHODOLOGY

Preliminary tests were conducted on the materials as per IS standards & specifications where the plain black cotton soil was initially tested for its physical properties & then it is tested for engineering properties by

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Compaction & CBR test. M-sand, Fly ash & cement are varied accordingly with percentages to evaluate the characteristics of strength variation by Compaction & CBR test.

The main aim of the methodology is to -

- To evaluate the strength characteristics of BC soil with different percentages of M-Sand, Fly ash and cement with varying proportions.
- To improve the engineering properties of the BC soil by adding admixtures and make it suitable for construction.
- To determine the effects of M-sand, cement and fly ash as stabilizing agents on BC soil.

2. Tests (physical properties) conducted on BC soil

- Specific Gravity Test.
- Moisture content.
- Particle Size Distribution.
- Liquid limit test.
- Plastic limit
- Plasticity Index.

The above tests were conducted as per ASTM standards with 4 trials on each tests & the average results are tabulated.

3. Tests (Engineering properties) conducted on BC soil with admixtures

- Standard Proctors Compaction Test.
- California Bearing Ratio Test.

TABLE:1 PHYSICAL PROPERTIES OF BLACK COTTON SOIL

Si no	Properties		Test method	Average Value	Permissible value
1	Colour			Black	
2	Specific Gravity		IS-2720 Part-3 (1980)	2.6	2.6-2.75
3	Moisture content			12.5%	-
4	Grain size distribution	Coefficient of uniformity (C_U)	IS-2720 Part-4 (1985)	3.5	> 1
		Coefficient of Curvature (C_C)		1.32	Between 1 & 3
		Liquid limit	IS-2720	50%	35-50%
		Plastic limit		21.75%	Less than or

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5	Atterberg limits		Part-5 (1985)		equal to 40
		Plasticity index (PI)		28%	Greater than 10

TABLE:2 ENGINEERING PROPERTIES OF BLACK COTTON SOIL

Si no	Properties	Test method	Average value	Permissible value
1	Standard Proctor Compaction Test	IS:2720 (Part 29) - 1975	OMC = 20%	Up to 21%
			MDD = 2.02 g/cc	1.92 to 2.02
2	CBR Test	IS:2720 (Part 16) - 1987	2.5 mm penetration = 2.012 %	--
			5.0 mm penetration = 1.98 %	

TABLE:3 TABULAR COLUMN OF STANDARD PROCTOR TEST FOR PLAIN BC SOIL

% Of water added to the soil	12 %	14%	16%	18%	20%	22%	24%	26%
Wt of empty Mould (W_1) in Kgs	5.61	5.61	5.61	5.61	5.61	5.61	5.61	5.61
Wt of mould + compacted soil (W_2) in Kgs	7.54	7.69	8.2	7.54	7.52	7.51	7.49	7.47
Wt of soil only (W_s) in Kgs	1.89	1.91	1.93	1.95	2.02	1.91	1.89	1.87
Bulk								

ISBN: 978-93-86171-60-3

Density γb = Ws / V (gm /cc)	1.88	1.92	1.94	1.96	1.98	1.94	1.92	1.9
Dry Density γd = (γb / 1 + W) gm /cc	1.76	1.8	1.93	1.98	2.02	2.0	1.98	1.97

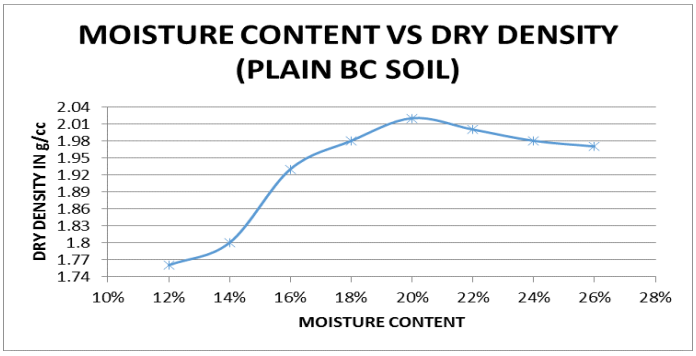

FIGURE:1 MOISTURE CONTENT VS DRY DENSITY (g/cc) FOR PLAIN BC SOIL

TABLE:4 TABULAR COLUMN OF CBR TEST FOR PLAIN BC SOIL

Dial gauge reading in mm	Proving ring reading		Load (P) in Kgs
	DIV	DIV*PRC	
0	1.0	58.8	5.99
0.5	2.4	164.6	16.78
1.0	3	176.4	17.98
1.5	3.4	199.2	20.3
2.0	4	235.2	23.97
2.5	4.6	270.4	27.57
3.0	5.2	305.7	31.16
3.5	5.8	341.0	34.76
4.0	6.2	364.5	37.16
4.5	6.6	388.0	39.56
5.0	6.8	399.8	40.75

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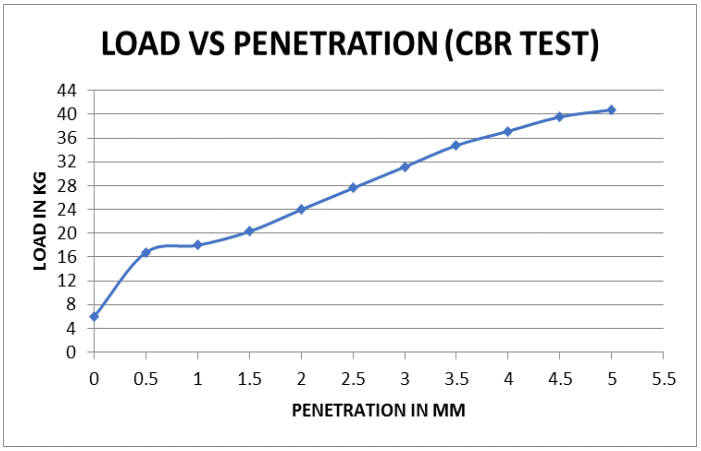

Figure:2 Load Vs Penetration For Plain Bc Soil

4. EXPERIMENTAL DESIGN

MIX DESIGN

The properties of natural black cotton soil (passing through 425µ IS sieve) are determined & then the soil is stabilized with M-sand (Particle size <4.75mm) by varying the proportions of Fly ash (passing through 75µ IS sieve) and cement (passing through 75µ IS sieve). The initial amount of sand for stabilization is taken in the proportion of 10% & 20% by dry weight of soil and the amount of cement was taken as 2% by dry weight of soil, further 2% cement is replaced with 5% & 8% of fly ash by its varying proportions . The proportions of mix samples were prepared and a set of laboratory tests were performed to determine the index properties with CBR values.

The varying proportions of admixtures in BC soil is listed below:

1. Black cotton soil.
2. BC-Soil +10% M-Sand +2% Cement.
3. BC-Soil +20% M-Sand +2% Cement
4. BC-Soil +20% M-Sand +5%flyash.
5. BC-soil+20%M-sand +8%flyash.

IV. RESULTS & DISCUSSION

1. Standard compaction Test conducted on black cotton soil with admixtures

With the varying percentages of Manufactured sand with cement & fly ash for the calculation of Maximum dry density & Optimum moisture content. It has been found that with the increase in percentage of M-sand with cement & fly ash there is an increase in Maximum dry density values where as there is considerable reduction in optimum moisture content for the given soil.

ISBN: 978-93-86171-60-3

TABLE:5 TABULAR COLUMN OF STANDARD PROCTOR TEST FOR BC-Soil +10% M-Sand +2% Cement.

% Of water added to the soil	12 %	14%	16%	18%	20%	22%	24%	26%	28%	30%
Wt of empty Mould (W_1) in Kgs	5.57	5.57	5.57	5.57	5.57	5.57	5.57	5.57	5.57	5.57
Wt of mould + compacted soil (W_2) in Kgs	7.54	7.55	7.57	7.64	7.63	7.58	7.54	7.5	7.48	7.44
Wt of soil only (W_s) in Kgs	1.97	1.98	2	2.06	2.04	2.01	1.97	1.93	1.91	1.87
Bulk Density γb = Ws / V (gm /cc)	2	2.01	2.03	2.09	2.05	2.04	2	1.96	1.94	1.9
Dry Density γd = (γb / 1 + W) gm /cc	1.97	1.98	2.01	2.04	2.03	2.02	2.01	1.99	1.98	1.96

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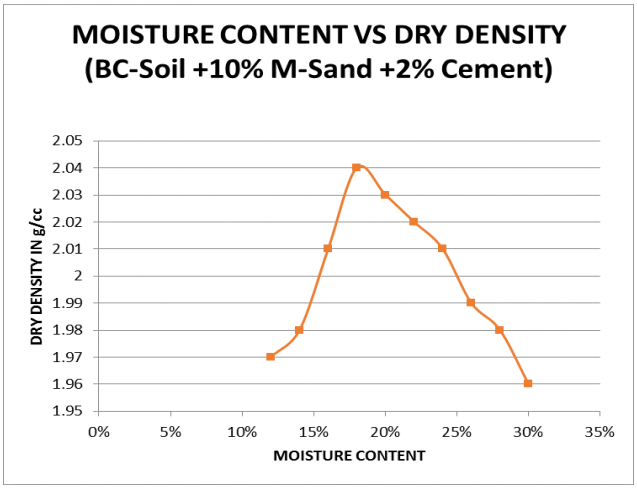

FIGURE:3 MOISTURE CONTENT VS DRY DENSITY (g/cc) FOR BC-Soil +10% M-Sand +2% Cement.

TABLE:6 TABULAR COLUMN OF STANDARD PROCTOR TEST FOR BC-Soil +20% M-Sand +2% Cement.

% Of water added to the soil	12 %	14%	16%	18%	20%	22%	24%	26%	28%	30%
Wt of empty Mould (W_1) in Kgs	5.57	5.57	5.57	5.57	5.57	5.57	5.57	5.57	5.57	5.57
Wt of mould + compacted soil (W_2) in Kgs	7.55	7.58	7.62	7.61	7.61	7.53	7.45	7.43	7.42	7.4
Wt of soil only (W_s) in Kgs	1.98	2.01	2.05	2.04	2.04	1.96	1.88	1.86	1.85	1.83
Bulk Density γb = Ws / V (gm /cc)	2.01	2.04	2.08	2.07	2.07	1.99	1.91	1.89	1.88	1.86

ISBN: 978-93-86171-60-3

Dry Density γd = (γb / 1 + W) gm /cc	2.03	2.04	2.06	2.03	2.02	2.01	2	1.98	1.97	1.96

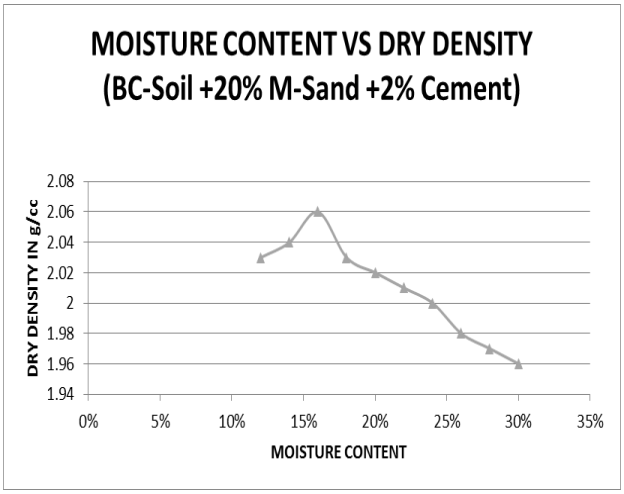

FIGURE:4 MOISTURE CONTENT VS DRY DENSITY (g/cc) FOR BC-Soil +20% M-Sand +2% Cement.

TABLE:7 TABULAR COLUMN OF STANDARD PROCTOR TEST FOR BC-Soil +20% M-Sand +5% Fly ash.

% Of water added to the soil	12 %	14%	16%	18%	20%	22%	24%	26%	28%	30%
Wt of empty Mould (W_1) in Kgs	5.68	5.68	5.68	5.68	5.68	5.68	5.68	5.68	5.68	5.68
Wt of mould + compacted soil (W_2) in Kgs	7.58	7.64	7.62	7.61	7.61	7.53	7.45	7.43	7.42	7.4

ISBN: 978-93-86171-60-3

Wt of soil only (W_s) in Kgs	1.9	1.96	1.94	1.93	1.93	1.85	1.88	1.75	1.74	1.72
Bulk Density γb = Ws / V (gm /cc)	2.04	2.08	2.06	2.05	2.04	2.03	1.98	1.96	1.92	1.88
Dry Density γd = (γb / 1 + W) gm /cc	2.03	2.065	2.05	2.03	2.02	2.01	2	1.98	1.97	1.96

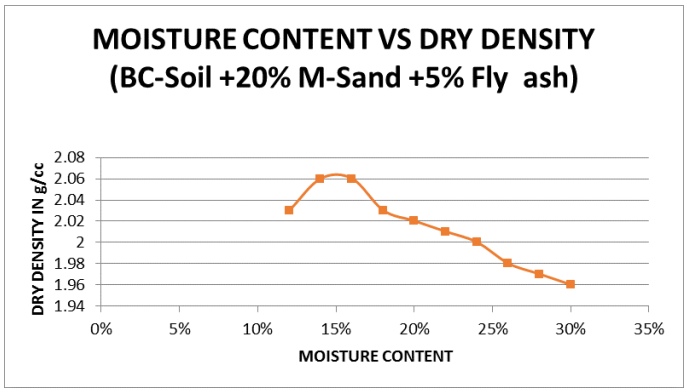

FIGURE:5 MOISTURE CONTENT VS DRY DENSITY (g/cc) FOR BC-Soil +20% M-Sand +5% Fly ash.

TABLE:8 TABULAR COLUMN OF STANDARD PROCTOR TEST FOR BC-Soil +20% M-Sand +8% Fly ash.

% Of water added to the soil	12 %	14%	16%	18%	20%	22%	24%	26%	28%	30%
Wt of empty Mould	5.68	5.68	5.68	5.68	5.68	5.68	5.68	5.68	5.68	5.68

ISBN: 978-93-86171-60-3

(W_1) in Kgs										
Wt of mould + compacted soil (W_2) in Kgs	7.64	7.62	7.61	7.6	7.59	7.57	7.55	7.52	7.49	7.44
Wt of soil only (W_s) in Kgs	1.96	1.94	1.93	1.9	1.89	1.87	1.85	1.82	1.79	1.74
Bulk Density γb = Ws / V (gm /cc)	2.08	2.07	2.06	2.05	2.04	2.03	1.98	1.96	1.92	1.88
Dry Density γd = (γb / 1 + W) gm /cc	2.07	2.06	2.06	2.03	2.02	2.01	2	1.98	1.97	1.96

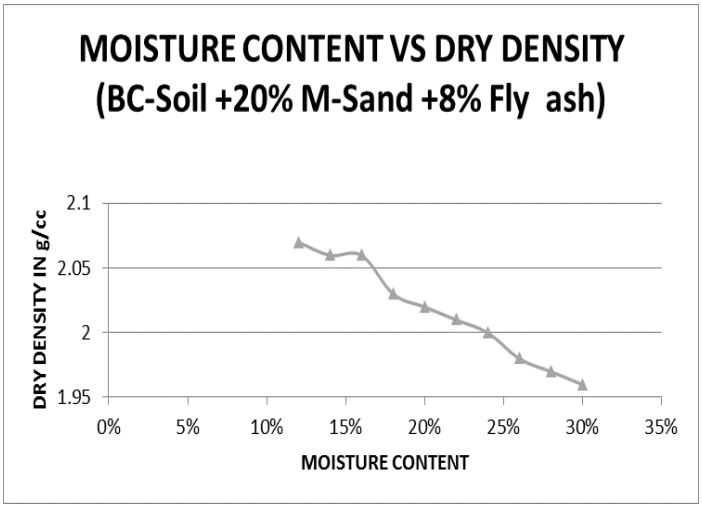

FIGURE:6 MOISTURE CONTENT VS DRY DENSITY (g/cc) FOR BC-Soil +20% M-Sand +8% Fly ash.

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TABLE:9 STANDARD PROCTOR RESULTS FOR VARIOUS COMBINATION OF ADMIXTURES

Si no	Type of soil	OMC in %	MDD (g/cc)
1	PLAIN BC SOIL	20	2.02
2	BC-Soil +10% M-Sand +2% Cement.	18	2.04
3	BC-Soil +20% M-Sand +2% Cement	16	2.06
4	BC-Soil +20% M-Sand +5%flyash.	14	2.065
5	BC-soil+20%M-sand +8%flyash	12	2.07

2. California Bearing Ratio Test conducted on black cotton soil with admixtures

By considering the 2.5mm & 5.0mm penetration values for the soil mixture it has been noticed that CBR values for 2.5mm penetration is more than 5.0mm penetration values. With the conduction of CBR test by varying the percentage of admixtures like Cement, M–sand and Fly ash in the soil mix, there is an increase in the CBR values with the increase in percentage of stabilizers.

TABLE:10 TABULAR COLUMN OF CBR TEST FOR BC-Soil +10% M-Sand +2% Cement.

Dial gauge reading in mm	Proving ring reading		Load (P) in Kgs
	DIV	DIV*PRC	
0	1	129.36	13.18
0.5	4.1	241.08	24.57
1.0	4.8	287.75	28.77
1.5	5.4	217.52	32.36
2.0	6.2	364.56	37.17
2.5	8.15	479.78	48.9
3.0	9.2	540.96	55.14
3.5	9.6	564.48	57.54
4.0	10.1	593.88	60.53
4.5	10.4	611.52	62.33
5.0	10.8	635.04	64.73

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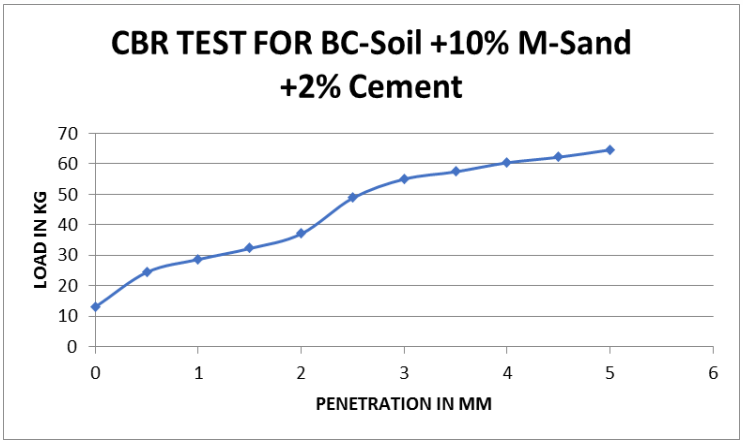

FIGURE:7 LOAD VS PENETRATION FOR BC-Soil +10% M-Sand +2% Cement.

TABLE:11 TABULAR COLUMN OF CBR TEST FOR BC-Soil +20% M-Sand +2% Cement.

Dial gauge reading in mm	Proving ring reading		Load (P) in Kgs
	DIV	DIV*PRC	
0	1.8	105.84	10.78
0.5	1.8	105.84	10.78
1.0	3.2	188.16	19.18
1.5	5.6	329.28	33.56
2.0	8.8	517.44	52.74
2.5	11.72	689.45	70.281
3.0	13	764.4	77.7
3.5	14.2	834.96	85.11
4.0	15.4	905.52	92.3
4.5	16.2	952.52	97
5.0	17.2	1011.36	103.09

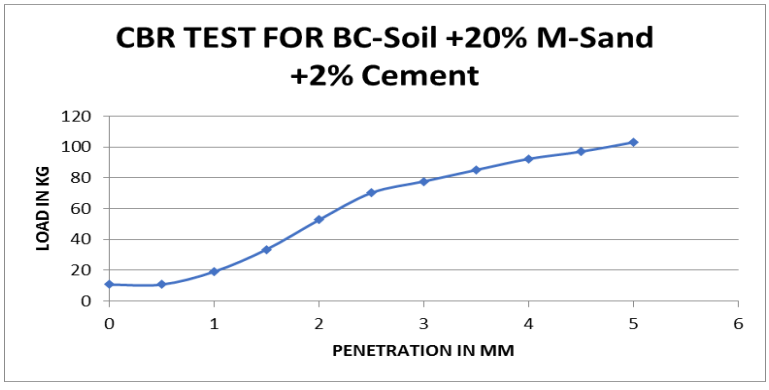

FIGURE:8 LOAD VS PENETRATION FOR BC-Soil +20% M-Sand +2% Cement.

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TABLE:12 TABULAR COLUMN OF CBR TEST FOR BC-Soil +20% M-Sand +5% Fly ash.

Dial gauge reading in mm	Proving ring reading		Load (P) in Kgs
	DIV	DIV*PRC	
0	0	0	0
0.5	4	235.2	23.97
1.0	7.8	458.64	46.75
1.5	9.8	576.24	58.74
2.0	11	646.8	65.96
2.5	12.04	708.18	72.19
3.0	13	764.4	77.92
3.5	14.8	870.24	88.7
4.0	15.2	893.76	91.10
4.5	16	940.8	95.9
5.0	17.55	1031.94	105.19

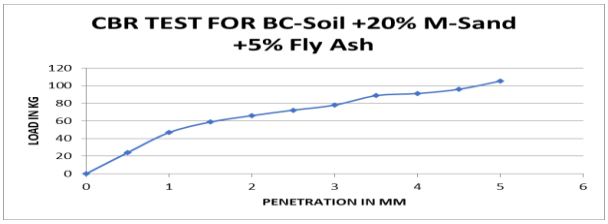

FIGURE:9 LOAD VS PENETRATION FOR BC-Soil +20% M-Sand +5% Fly ash.

TABLE:13 TABULAR COLUMN OF CBR TEST FOR BC-Soil +20% M-Sand +8% Fly ash.

Dial gauge reading in mm	Proving ring reading		Load (P) in Kgs
	DIV	DIV*PRC	
0	0	0	0
0.5	6.4	376.32	38.32
1.0	8.2	482.16	49.15
1.5	10.9	640.92	65.34
2.0	12.02	706.97	72.04
2.5	12.61	741.83	75.62
3.0	13.4	787.92	80.31
3.5	14.8	870.24	88.7
4.0	15.6	917.28	93.5
4.5	16.8	987.84	100.69
5.0	17.93	1050.57	107.5

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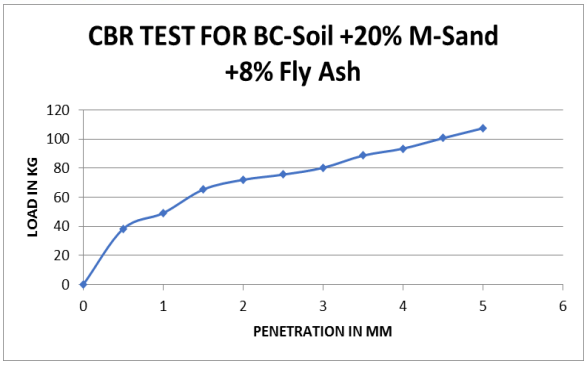

FIGURE:10 LOAD VS PENETRATION FOR BC-Soil +20% M-Sand +8% Fly ash.

TABLE:14 CBR TEST RESULTS FOR VARIOUS COMBINATION OF ADMIXTURES

Si no	Type of soil	CBR % FOR 2.5 mm PENETRATION	CBR % FOR 5.0 mm PENETRATION
1	PLAIN BC SOIL	2.012	1.98
2	BC-Soil +10% M-Sand +2% Cement.	3.57	3.15
3	BC-Soil +20% M-Sand +2% Cement	5.13	5.01
4	BC-Soil +20% M-Sand +5%flyash.	5.27	5.11
5	BC-soil+20%M-sand +8%flyash	5.52	5.23

V. CONCLUSION

Based on the various laboratory tests as per IS standards for the porous concrete by varying the composition the following conclusions are drawn:

1. Replacement of some percentage of cement with fly ash will increase the engineering properties of Black Cotton soil which also increase its stability.
2. With the conduction of CBR test by varying the percentage of admixtures like Cement, M–sand and Fly ash in the soil mix, there is an increase in the CBR values with the increase in percentage of stabilizers.
3. It has been found that with the increase in percentage of M-sand with cement & fly ash there is an increase in Maximum dry density values where as there is considerable reduction in optimum moisture content for the given soil.
4. Fly ash is environmental friendly material & can be used for construction purposes which also leads to increase in bonding properties of BC soil which also leads to reduction in swell & shrink behaviour of BC soil.
5. It is one of the economical method of soil stabilisation of BC soil where the raw materials are cheaper when compared to other methods of stabilisation of soil.

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Bibilography

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