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"Evaluation of the Properties of Expansive Soil Using Foundry Sand and Steel Slag"

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Abstract:
Background*: The volumetric changes of Block cotton soil creates many problems in structures & pavements , thus for a stable performance & long life of structures & roads, it is necessary to upgrade the properties of Block cotton soil. This project deals with upgrade the physical properties of Block cotton soil through addition of low cost industrial wastes such as foundry sand and steel slag sand. Laboratory tests were conducted on various proportions of admixtures with a Block cotton soil from 0% to 40% at an interval of 8%. In these study the tests conducted in laboratories are Atterbergs limits, Compaction tests, Unconfined compression strength tests and California bearing ratio tests. From this tests we got good results. The soaked CBR value improves up to 9.43% &8.15 for Foundry sand and steel slag respectively for 40% replacement. The UCS value improves up to 6.03%& 5.57% respectively for Foundry sand and steel slag for 40% replacement*
Materials and Methods*: For this experimental investigation black cotton soil is used as representative weak soil and steel slag and foundry sand as admixture. Black soil procured from Kowshika Village, Hassan . Is used as a representative soil in the present study. This soil was collected from an open excavation, at a depth of 1m to1.5m beneath the characteristics of ground surface. The soil used in this study is a Blackish Grey inorganic clayey soil of medium plasticity. Sufficient quality of soil was brought to geo technical engineering laboratory of Government Engineering College, Hassan. Soil was hand sorted to remove the vegetative matters and organic materials. It was air dried and sieved through 4.75mm and 425microns IS sieves and stored in the containers ready for use.*
Results*: The basic laboratory test results showed that the soil belongs to clayey soil with high plasticity, low permiability,low strength & undergo high volume changes. The addition of Foundry Sand(FS) ¬ &Steel Slag(SS) (40%) reduces the LL from 56% to 41.5 &35% respectively, and PL from28.57% to18.75&22.27% respectively. Reduction of LL & PL improves the drainage properties of soil sub grade. The addition of Foundry Sand increases the MDD upto 40% from 1.627 to 2.013, but¬ addition of Steel Slag increases the MDD upto 32% from 1.627 to1.7695 then decreases with further addition, it concludes that there exist a optimum % of Steel Slag which is responsible for increase in strength of soil. The increase in MDD helps to give a stable platform for working ,mainly in rainy seasons. Addition of FS¬ & SS (40%) increases the U C S value of the BCS from 113.4KN/m2 to 171.1KN/m2 for FS and 158.1KN/m2 for SS. thus improves the bearing strength of soil upto 5.57% and 6.03% for FS and SS respectively for foundations. Addition of FS¬ & SS (40%) increases the CBR value of the BCS from 2.4 to 5.663 for FS and 4.895 for SS. thus improves the strength of soil subgrade upto 9.43% and 8.15% for pavements.*
Key Word*: Liquid Limit(LL) ; Unconfined Compressive Strength (UCS); Maximum Dry Density (MDD), Black cotton Soil (BCS), California Bearing Ratio (CBR),*

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I. Introduction:

Black cotton soil is also known as expansive soils cover about $0.8X10^6$ km² area approximately 20% of surface In India, These soils essentially found in Madhya Pradesh, Gujarath,Maharastra,Andra Pradesh & Northern Karnataka. In Karnataka these soils are generally predominant in numerous parts of northern Karnataka, especially in Bijapur,Belgaum, Bagalkot,Gadag, &Hubli-Dharwad regions.But in southren karnataka found in small quantity.

Material And Methods

Black soil procured from Kowshika Village, Hassan is used as a representative soil in the present study. This soil was collected from an open excavation, at a depth of 1m to1.5m beneath the characteristics of ground surface. The soil used in this study is a Blackish Grey inorganic clayey soil of medium plasticity. Sufficient quality of soil was brought to geo technical engineering laboratory of GEC Hassan.

Foundry sand is the waste material generated by metal casting processes at metal foundries.. The sand is reused until it is physically degraded, at which point it is removed from the sand supply. The foundry sand is generally considered non plastic or low plasticity sand depending on the type and amount of binder.

Steel slag sands are the by-products of processing molten iron into a specific type or grade of steel. The Steel slag sand can be used as a lightweight fill and in engineered fill applications to find new ways of utilizing them in construction industry.

In the current research work the steel slag is used as a replacement material for soil. The replacement for soil by steel slag is done from 10 to 40 percent by weight of soil. This method is followed to maintain the balance between the utilization of natural available soil and industrial waste product

Methodology: The aim of this investigation is to study the physical and engineering properties of the black cotton soil. The following tests were conducted on black cotton soil:

1.Grain size analysis
2. Specific gravity test
3. Atterbergs limit a) Liquid limit b) plastic limit
4. Standard proctor compaction test
5. Unconfined compression strength [U C S test] .
6. California bearing ratio test [CBR test]

The unconfined compressive strength is defined as the compressive stress at which an unconfined cylindrical specimen of soil will fail in a simple compression test. For soils UCS is important for finding the bearing capacity of foundation, dams etc. The undrained shear strength of clay is commonly determined by unconfined compression test.

Fig:1.0 U C S test apparatus

California Bearing Ratio CBR. The CBR value of a soil is an index which is related to the strength of the soil. The test was conducted in accordance with (IS2720 Part 16-1987) Thee CBR specimen were prepared with the different percentages of foundry sand and steel slag (0%,8%,16%,24%,32%,40%,48%) as per IS specifications. Standard proctor compaction was adopted with the help of Auto Compactor .For preparing a specimen a water of (1%+OMC) was added. CBR specimens were casted and soaked for 96 hours and the test was conducted after soaking the specimen. This was conducted as soaked CBR test in the case of soil specimen with foundry sand and steel slag.

Fig 2.0 California Bearing Ratio Apparatus

This section presents the basic geotechnical properties of black cotton soil such as Grain size distribution, specific gravity, water content, liquid limit, plasticity index etc, in (Table 1.1) and Light compaction characteristics determined for soils used in experimental work (untreated and treated)effect of foundry sand and steel slag on UCS &CBR value of Black Cotton soil. Similarly , some of the geo technical properties of Foundry sand and Steel slag sand such as Sieve analysis , specific gravity , MDD and OMC are tabulated in (Table 1.0) and (Table 2.0) TABLE 1.1 GEO TECHNICAL PROPERTIES OF BLACK COTTON SOIL

TABLE 1.1 GEO TECHNICAL PROPERTIES OF BLACK COTTON SOIL

SL NO	PROPERTIES	RESULTS	RELEVANT IS CODE
1	Grain Size Distribution (%)	Gravel-0 Sand-10 Silt and clay-25&65	IS 2720 Part 4
2	Specific Gravity (G)	2.644	IS 2720 Part 3
3	Liquid Limit (WL) (%)	56	IS 2720 Part 5
4	Plastic Limit (WP) (%)	28.57	IS 2720 Part 5
5	Plasticity Index (IP) (%)	36	IS 2720 Part 5
6	Optimum moisture content (OMC)(%)	18	IS 2720 Part 8
7	Max dry density(MDD)(G/cc)	1.627	IS 2720 Part 18
8	Unconfined compression strength (U C S)(kN/m2)	113.4	IS2720 Part10
9	California Bearing Ratio (C.B.R) (%)	2.44	IS 2720 Part 16

TABLE .1.2 PHYSICAL PROPERTIES OF SLAG SAND

	PROPERTY	VALUE
1	Colour	Black-grey
2	Specific gravity	2.88
3	Liquid limit	-
4	Plastic limit	-
5	Cu	2.5
6	Cc	1.37

TABLE 1.3 PHYSICAL PROPERTIES OF FOUNDRY SAND

	PROPERTY	VALUE
1	Colour	White ,light grey
2	Specific gravity	2.6235
3	Liquid limit	-
4	Plastic limit	-
5	Cu	2.64
6	Cc	1.25

II. Atterberg Limits

a) Liquid Limit

TABLE 2.1:INFLUENCE OF FOUNDRY SAND ON LIQUID LIMIT

% of admixture	Liquid limit%
0	56
8	53.5
16	52
24	49
32	45
40	41.5

b) Plastic limit

TABLE .2.2: INFLUENCE OF STEEL SLAG ON PLASTIC LIMIT

% of admixture	Plastic limit%
0	28.57
8	25.92
16	22.2
24	23
32	22.58
40	22.27

TABLE.2.3: INFLUENCE OF FOUNDRY SAND ON PLASTIC LIMIT

% of admixture	Plastic limit %
0	28.57
8	25
16	22.25
24	18.75
32	18.75
40	-

C) PLASTICITY INDEX

TABLE 2.4: INFLUENCE OF STEEL SLAG ON PLASTICITY INDEX

% of admixture	Plasticity index%
0	27.43
8	26.21
16	25.8
24	21.43
32	17.52
40	12.73

TABLE.2.5: INFLUENCE OF FOUNDRY SAND ON PLASTICITY INDEX

% of admixture	Plasticity index%
0	27.43
8	28.5
16	29.75
24	30.25
32	26.25
40	-

III. Standard Proctor Compaction Test:

The characteristics of compaction are determined for the soils used in experimental work .The light compaction test was conducted to determine the OMC and MDD of block cotton soil (With and without addition of foundry sand & steel slag sand). Foundry sand and slag sand was added to the Black Cotton soil at varying percentages of 8%, 16%,21%, 32% , 40%.

TABLE 3.1(A) VARIATION IN OMC AND MDD OF BLACK COTTON (BC) SOIL WITH VARYING PERCENTAGE OF FOUNDRY SAND

BC soil	MDD	1.5436	1.5360	1.5663	1.6078	**1.6271**	1.5864	1.5546
	OMC	10	12	14	16	18	20	22
BC soil +8% FS	MDD	1.6397	1.6497	1.6583	**1.666**	1.5981		
	OMC	10	12	14	15	16		
BC soil +16% FS	MDD	1.6552	1.6686	**1.6788**	1.683	1.7584	1.661	
	OMC	8	10	12	13	14	15	
BC soil +24% FS	MDD	1.742	1.7645	1.782	**1.7848**	1.7132		
	OMC	8	10	11	12	13		
BC soil +32% FS	MDD	1.8722	1.8724	**1.8745**	1.7936			
	OMC	8	9	10	11			
BC soil +40% FS	MDD	1.933	1.948	1.934	1.924	1.974	**2.013**	1.944
	OMC	8	10	12	14	16	17	18

TABLE 3.2(B) VARIATION IN OMC AND MDD OF BLACK COTTON (BC) SOIL WITH VARYING PERCENTAGE OF STEEL SLAG

BC soil	MDD	1.5436	1.5360	1.5663	1.6078	**1.6271**	1.5864	1.5546
	OMC	10	12	14	16	18	20	22
BC soil +8% SS	MDD	1.709	**1.714**	1.6732	1.634			
	OMC	8	10	12	14			
BC soil +16%SS	MDD	1.711	1.719	**1.708**	1.675			
	OMC	8	10	11	12			
BC soil +24% SS	MDD	1.708	1.70	1.704	**1.757**	1.705	1.657	
	OMC	8	10	12	14	15	16	
BC soil +32% SS	MDD	1.7037	1.719	1.753	1.750	**1.769**	1.759	1.702
	OMC	8	10	12	13	14	15	16
BC soil +40% SS	MDD	1.705	1.736	1.753	**1.755**	1.704		
	OMC	10	12	14	16	18		

TABLE .3.3: COMPACTION CHARECTERISTICS OF BLOCK SOIL (TREATED AND UNTREATED) WITH FOUNDRY SAND

Materials	**OMC (%)**	**MDD (gm/cc)**
BC soil	18	1.6271
BC soil +8% FS	14.8	1.716
BC soil +16% FS	14	1.719
BC soil +24% FS	11.8	1.7157
BC soil +32% FS	9.8	1.771
BC soil +40% FS	16.9	1.756

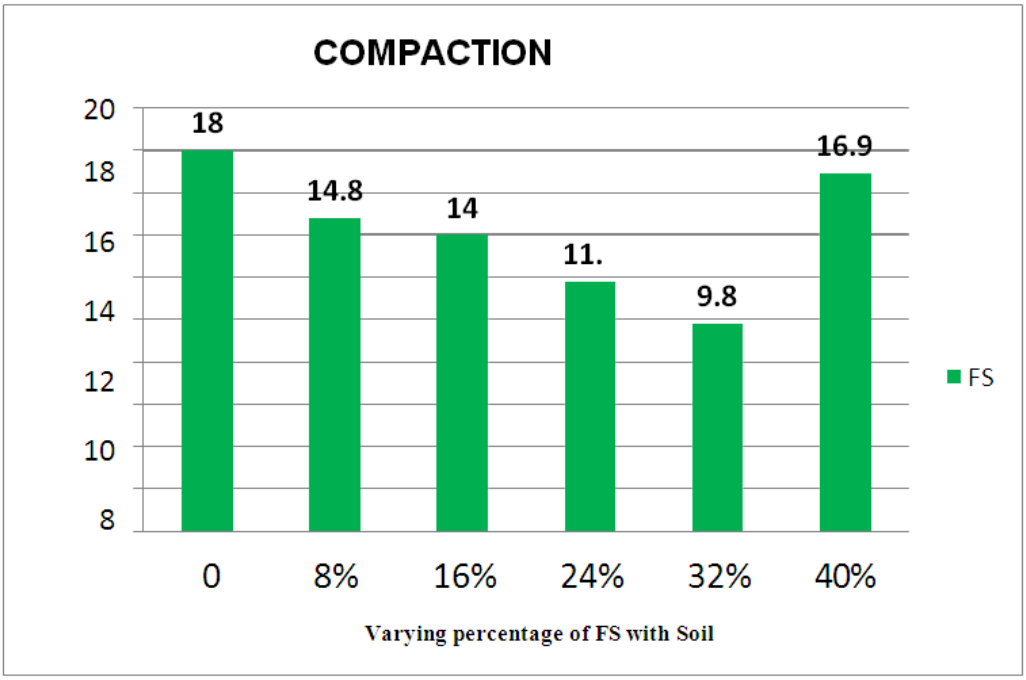


FIG 3.3 (B) INFLUENCE OF FOUNDRY SAND ON OMC OF EXPENSIVE SOIL

TABLE 3.3: COMPACTION CHARACTERISTICS OF BLOCK COTTON SOIL (TREATED AND UNTREATED)WITH STEEL SLAG.

Materials	OMC(%)	MDD(gm/cc)
BC soil	18	1.6271
BC soil +8% SS	9.6	1.716
BC soil +16% SS	9.8	1.719
BC soil +24% SS	14	1.757
BC soil +32% SS	14.6	1.771
BC soil +40% SS	15.4	1.756

Generally adding of sand or silt to fine grained soils increases the MDD and decreases the OMC. Decrease in OMC mainly due to increase in size of the particles is coarser then BC soil, addition of coarser particle reduces the water holding capacity due to reduction of clay content.

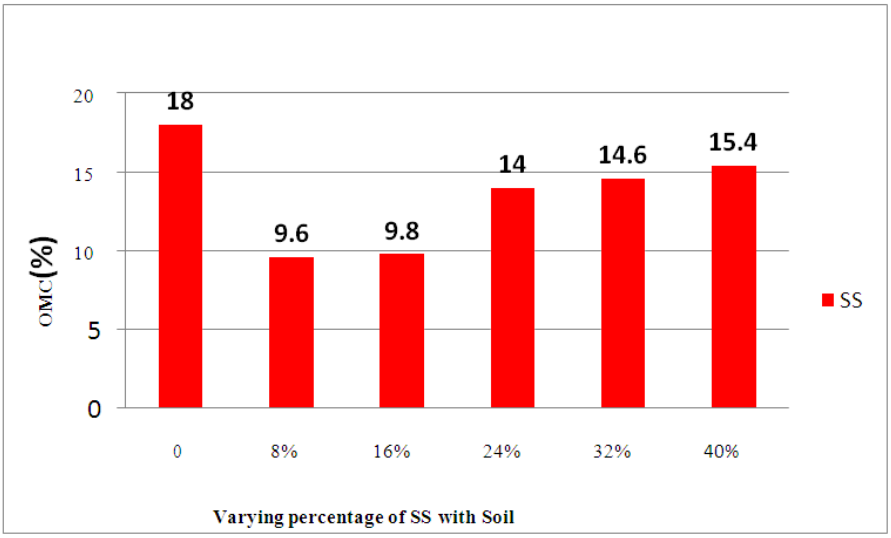


FIG4 3.4 (B) INFLUENCE OF SLAG SAND ON OMC OF EXPENSIVE SOIL

4.0: U C S TEST

TABLE .4.1: U C S VALUES FOR BLACK COTTON SOIL TREATED WITH VARYING FOUNDRY SAND.

% of admixture replacement	Unconfined compression strength (KN/m2)
0%	113.4
8%	136.58
16%	142.13
24%	161.31
32%	163.12
40%	171.1

TABLE 4.2: U C S VALUES FOR BLACK COTTON SOIL TREATED WITH VARYING STEEL SLAG SAND

% of admixture replacement	Unconfined compression strength (KN/m2)
0%	113.4
8%	127.6
16%	130.612
24%	140.56
32%	151.4
40%	158.1

5.0: C B R TEST

CBR test was conducted on both modified and unmodified BC soil. BC soil was treated with varying percentages of Foundry Sand and Steel slag. The FS added was 8%, 16%, 24%, 32%, 40% and 48% .Correspondingly SS added was 8%, 16%, 24%, 32%, 40%and 48%. And CBR test was conducted as pr IS 2720 (part 16) ,It was found CBR value at 2.5mm penetration is higher then CBR value at 5mm penetration. Hence the CBR is taken as penetration at 2.5mm only. The experimental values for different trials are shown below.

TABLE 5.1 (A) LOAD-PENETRATION RELATIONS OF CBR TEST ON UNTREATED AND TREATED BLACK COTTON SOIL WITH STEEL SLAG

Penetration in mm	Load (KN) for varying of Steel Slag					
	BC Soil	8%	16%	24%	32%	40%
0	0	0	0	0	0	0
0.5	0.250	0.289	0.329	0.368	0.460	0.487
1	0.289	0.316	0.342	0.408	0.513	0.605
1.5	0.316	0.355	0.381	0.500	0.618	0.684
2	0.329	0.408	0.473	0.539	0.84	0.756
2.5	0.329	0.434	0.513	0.605	0.750	0.776
3	0.335	0.447	0.552	0.644	0.776	0.789
4	0.348	0.460	0.605	0.671	0.828	0.802
5	0.355	0.487	0.631	0.736	0.868	0.828
7.5	0.381	0.506	0.658	0.776	0.907	0.848
10	0.408	0.526	0.697	0.802	0.921	0.868
12.5	0.421	0.552	0.723	0.828	0.934	0.881

The Table shows the Load-Penetration behaviour of the soil for the different percentage of Foundry sand content. It is evident that inclusion of Foundry sand increases the load bearing capacity of the black cotton soil with optimum percentage Foundry sand content. Different CBR curves with Foundry sand content like 8%, 16%, 24%, 32% and 40%. The values with the 32% of steel slag sand content show the maximum value.

TABLE 5.1(B) LOAD-PENETRATION RELATIONS OF CBR TEST ON UNTREATED AND TREATED BLACK COTTON SOIL WITH STEEL SLAG

Penetration in mm	Load (KN) for varying of Foundry sand					
	soil	8%	16%	24%	32%	40%
0	0	0	0	0	0	0
0.5	0.250	0.276	. 0.302	0.329	0.355	0.375
1	0.289	0.289	0.316	0.355	0.408	0.395
1.5	0.316	0.316	0.342	0.381	0.460	0.447
2	0.329	0.335	0.368	0.434	0.539	0.625
2.5	0.329	0.355	0.434	0.513	0.579	0.671
3	0.335	0.368	0.447	0.526	0.605	0.684

4	0.348	0.395	0.473	0.539	0.625	0.710
5	0.355	0.408	0487	0.552	0.631	0.736
7.5	0.381	0.434	0.560	0.565	0.658	0.756
10	0.408	0.447	0.526	0.585	0.697	0.776
12.5	0.421	0.473	0.552	0.605	0.710	0.802

The Table shows the Load-Penetration behaviour of the soil for the different percentage of steel content. It is evident that inclusion of steel slag increases the load bearing capacity of the black cotton soil with optimum percentage Steel slag content. Different CBR curves with Steel slag content like 8%, 16%, 24%, 32% and 40%. The values with the 40% of steel slag content show the maximum value.

TABLE .5.2(A) :CBR VALUES FOR BLACK COTTON SOIL TREATED WITH VARYING FOUNDRY SAND.

Percentage of Foundry sand	CBR Values for	
	2.5 mm	5.0mm
0	2.4	1.728
8	3.168	2.368
16	3.743	3.072
24	4.415	3.583
32	5.47	4.223
40	5.663	4.031

FIG 5.1 (A) CBR CURVES FOR BC SOIL TREATED WITH DIFFERENT DOSAGES OF FOUNDRY SAND

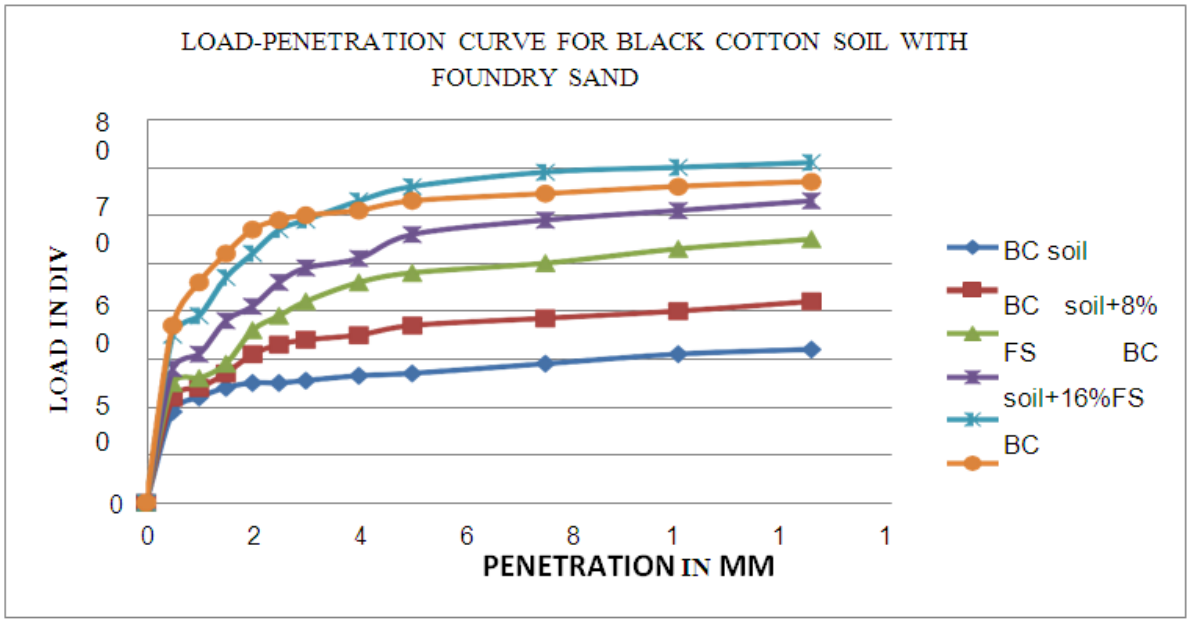
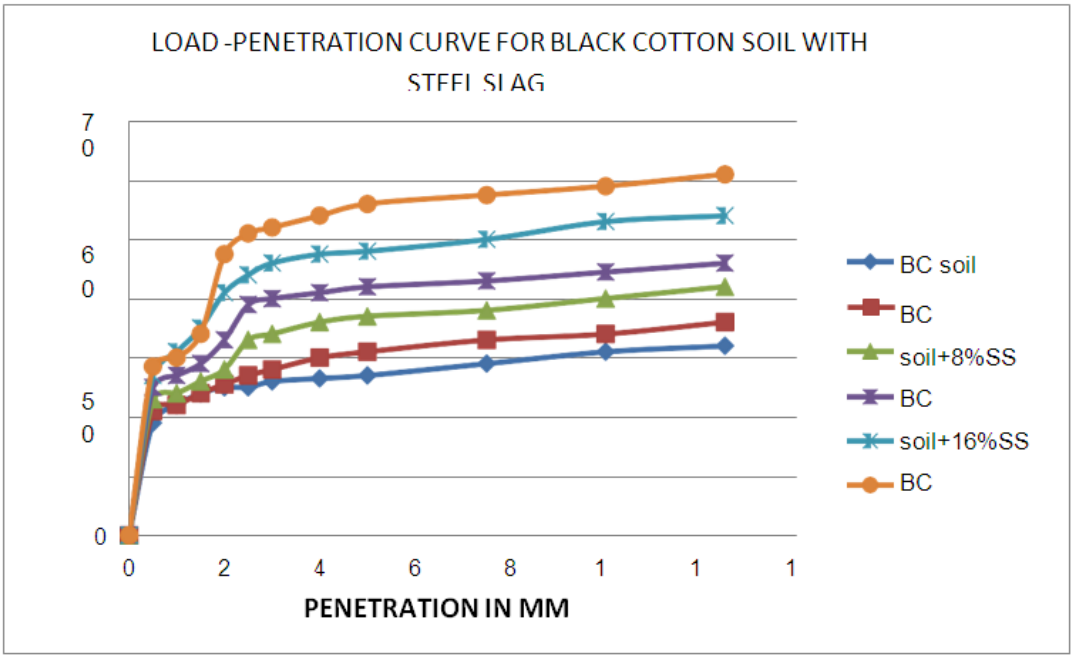


FIG 5.1(B) CBR CURVES FOR BC SOIL TREATED WITH DIFFERENT DOSAGES OF STEEL SLAG



The CBR value of the untreated soil corresponding to 2.5 mm and 5.0 mm penetration were found to be 2.4 and 1.728 respectively, which were increased to 4.895 and 3.583 respectively, when soil was treated with 40% of Steel slag .

The maximum value of CBR at 2.5mm and 5.0mm penetration is 4.895% and 3.583% respectively ,When 40% waste steel slag content was mixed with the soil. It can be referred that the CBR value kept increasing up till 40%. This reveals that 40% Steel slag content gives us the maximum bearing strength

IV. Conclusion

The BC soil was initially tested for the basic properties ,basic properties of BCS are very weak ,then after the addition of admixtures FS and SS wastes for BCS gave considerable improvement in the geo technical properties of BCS.

With those geo technical properties test results the conclusions are drawn

- The basic laboratory test results showed that the soil belongs to clayey soil with high plasticity, low permiability,low strength & undergo high volume changes.
- The addition of FS &SS (40%) reduces the LL from 56% to 41.5 &35% respectively, and PL from28.57% to18.75&22.27% respectively. Reduction of LL & PL improves the drainage properties of soil subgrade.
- The addition of FS increases the MDD upto 40% from 1.627 to 2.013, but addition of SS increases the MDD upto 32% from 1.627 to1.7695 then decreases with further addition,it concludes that there exist a optimum % of SS which is responsible for increase in strength of soil. The increase in MDD helps to give a stable platform for working ,mainly in rainy seasons.
- Addition of FS & SS (40%) increases the U C S value of the BCS from 113.4KN/m2 to 171.1KN/m2 for FS and 158.1KN/m2 for SS. thus improves the bearing strength of soil upto 5.57% and 6.03% for FS and SS respectively for foundations.
- Addition of FS & SS (40%) increases the CBR value of the BCS from 2.4 to 5.663 for FS and 4.895 for SS. thus improves the strength of soil subgrade upto 9.43% and 8.15% for pavements.

On the basis of this study it conclude that FS & SS is used for stabilization of weak soil subgrade material to improve the strength of soil for pavement effectively compared to foundations & hence increase in CBR value will results in reduced crust thickness of road, resulting in saving of construction cost.

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