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Effect of RBI-81 on Properties of Black Cotton Soil

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***Abstract*— Construction activities on Expansive soils are challenging since they pose several problems to the structures built on them. To utilize expansive soils in an effective way, proper ground improvement techniques are to be adopted. One of the most widely used technique is to stabilize the expansive soil by conventional admixtures like lime, cement, and flyash.**

In the present study, an attempt is made to modify engineering properties of a black cotton soil from Nagpur region, Maharashtra, India by stabilizing it with an eco friendly stabilizer RBI Grade 81 to make it suitable as a subgrade material. Tests such as Atterberg limits, Modified Proctor Compaction, California Bearing Ratio (C.B.R.), Unconfined Compressive Strength (U.C.S.), Consolidation, were carried out on the untreated and stabilizer treated soil with varying curing period of 7 ,14 and 28 days. The stabilizer was added to the soil in different percentages (by dry weight) varying from 1% to 6%. The results indicate that RBI-81 is effective in improving engineering properties of black cotton soil. However, an additional additive along with RBI-81 seems to be a better option especially for expansive soils.

***Keywords* - CBR, Expansive soil, RBI-81, Stabilizer, free swell.**

I. INTRODUCTION

Black cotton soils are problematic to the structures built on them because of their tendency to swell during the wet season and shrink during dry season. Different damages in the form of cracking, undulation, differential settlements, etc are experienced by the roads, buildings, irrigation canals, water and sewer lines, built on expansive soils. Such soils are easily compressible and have low bearing power. Hence are considered as poor foundation material and construction material.

The stability and performance of pavements are greatly influenced by the sub-grade as they serve as foundations for pavements. Roads on black cotton soils pose challenges in selecting suitable soil modification technique. The quality of a pavement depends on the strength of its sub-grade. A sub-grade soil must meet adequate strength requirements as per IRC -37 (2007). If not, there is a need to replace the natural soil by another soil with improved strength and compressibility characteristics or modify the existing soil to suit the requirements. The present study highlights the effect of stabilization of low strength expansive soil with a stabilizer RBI Grade 81. Stabilizer and RBI-81 are used as synonyms in this paper.

RBI Grade 81 is a light grayish powder insoluble in water, inert, eco friendly, chemically stable, and commercially available additive. The merits claimed are - it is durable, permanent and aesthetically pleasing, forms dust free surface and hardens fast. Based on literature review, it is found that strength of soil treated with RBI Grade 81 increases with age. The strength increases gradually for about one year after application to soil. Permeability of soil mass decreases with addition of RBI Grade 81 as it reduces pore spaces.

In order to investigate the advantages of using RBI-81, and to understand behavior of expansive soil upon addition of stabilizer, a basic study was taken up with an expansive soil, with medium compressibility.

II. LITERATURE REVIEW

The effect of addition of various inorganic and organic stabilizers on soil has been studied and improving properties have been noted down. Conventionally, lime is used as a stabilizer to improve properties of expansive soils. However, studies on the behavior of black cotton soil upon the addition of RBI-81 are very few.

Sushant et. al (2010), carried out an investigation to study the influence of RBI Grade 81 and lime on the stabilization of blast furnace slag and fly ash. Standard proctor test and unconfined compressive strength test for different combinations of the stabilizing agents were conducted. It was concluded that UCS of stabilized sample increases with increase in the period of curing. But the percentage of increase in strength was more upon lime addition compared to addition of RBI-81.

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Anitha et. al (2009), studied the effect of RBI Grade 81 in stabilizing kaolinite, red soil and lateritic soil. The different percentages of RBI Grade 81 varying from 2% to 8% was added and test results indicated 42% reduction in plasticity index for kaolinite, 4% for red soil and 116% for laterite. Soaked CBR value increased for all three soils treated with RBI-81. The OMC increased and MDD decreased with addition of RBI Grade 81 for red soil and kaolinite.

Vinay et. al. (2011) investigated the strength properties for two types of soils. A local loamy soil and clayey soil were stabilized with RBI-81. Durability test, flexural strength, permeability test were carried out on untreated soils and soils treated with 1, 2, 4% RBI-81. A considerable increase in the strength values of CBR, UCS was reported.

Madurwar et. al (2013) made an attempt to modify engineering properties of black cotton soils from Nagpur region, Maharashtra, India by using RBI Grade 81 and sodium silicate. Atterberg's limit, Compaction, California Bearing Ratio (C.B.R.), Unconfined Compressive Strength (U.C.S.) tests were carried out after curing of samples for 7 days, 14 days and 28 days. RBI Grade 81 percentage varied from 2% to 6% and sodium silicate 3% to 6% in solution (molar concentration). It was observed that there was a considerable decrease in the liquid limit and swell index with the increase in addition of stabilizer, and an increase in the CBR and UCC results with the increase in the dosage of the stabilizer.

Encouraged by the earlier studies, the present study was undertaken to bring out the effectiveness of RBI-81 on expansive soil so as to make it suitable as a subgrade material.

III. MATERIALS

Black Cotton soil: A black cotton soil procured from Nagpur was collected from an open excavation, at a depth of 1 m to 1.5 m below the natural ground surface. It is classified as blackish gray inorganic clayey soil of medium plasticity. The soil was pulverized before usage.

RBI Grade 81: RBI Grade 81 is a hydration activated powder based stabilizer which reacts with soil. Material for the testing work is received from M/S Alchemist Technology Limited, India. The bulk density was found to be 6.8 kN/m^3.
The properties of soil are indicated in Table I.

TABLE I

PROPERTIES OF EXPANSIVE SOIL

Sl. no	Properties	Result	IS Code
1.	Specific Gravity	2.7	IS 2720 Part 3
2.	Natural Moisture Content (%)	13.25	IS 2720 Part 2
3.	Liquid Limit (%)	49.4	IS 2720 Part 5
4.	Plastic Limit (%)	28.78	IS 2720 Part 5
5.	Shrinkage Limit(%)	14.05	IS 2720 Part 6
6.	Plasticity Index	20.7	IS 2720 Part 5
7.	Grain Size Distribution (%)		IS 2720 Part 4
	Gravel	8	
	Sand	20	
	Silt & Clay	72	
8.	Free Swell Index (%)	27.27	IS 2720 Part 11
9.	Swelling Pressure (kN/m²)	118	IS 2720 Part 15
10	Optimum Moisture Content	16.5	IS 2720 Part 8
11	Maximum Dry Density (kN/m³)	18.05	IS 2720 Part 8
12	AASHTO Classification	A-7-6	
13	California Bearing Ratio (%)	2.55	IS 2720 Part 16
14	Unconfined Compressive Strength (kN/m²)	133	IS 2720 Part 10
15	Modulus of Elasticity (E) kN/m²	3924	IS 2720 Part 10

IV. RESULTS & DICUSSIONS

A. MODIFIED PROCTOR COMPACTION TEST

The Modified Proctor test was conducted to determine the optimum moisture content (OMC) and maximum dry

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density (MDD) of untreated and treated soil. The stabilizer was added to the black cotton soil at varying percentages of 1%, 2%, 4% and 6%. For example, the mix A-2 has 98% soil and 2% stabilizer. The results of modified proctor tests are shown in Table II.

TABLE II

VARIATION IN OMC AND MDD OF BLACK COTTON SOIL WITH VARYING PERCENTAGES OF RBI GRADE-81

Soil mix	Materials Ratio (Stabilizer:Soil)	Optimum Moisture Content (%)	Maximum Dry Density (kN/m³)
A-0	Untreated BC soil	16.5	18.05
A-1	1:99	17.2	17.95
A-2	2:98	17.5	17.55
A-3	4:96	18.0	17.26
A-4	6:94	18.5	17.06

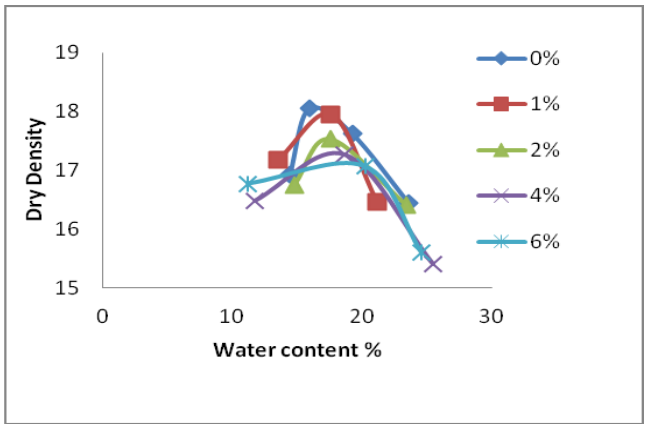

Fig.1 Modified Proctor curves for soil treated with different percentages of stabilizer

From the fig.1, it is observed that addition of RBI-81 to expansive soil decreases the maximum dry density and increases optimum moisture content slightly. The effect of RBI-81 on compaction is observed to be same as that of lime.

This may be attributed to cat-ion exchange process between the additive and soil wherein negatively charged clay particles attract cat-ions leading to reduction in thickness of diffuse double layer. This is also proved when liquid limit and plasticity values are observed.

All these changes results in a flocculated structure which has low compressibility and strong bond due to attraction between particles (Mitchelle, 1977). Hence dry density decreases. The flocculated structures are light in weight with high void ratio and more water content. Therefore OMC increases slightly upon addition of RBI-81. The soil transforms itself from sticky plastic material which was difficult to compact to a less plastic, stiff, easily compactable material which has better load carrying capacity.

B. ATTERBERG LIMITS

Liquid limit and plastic limit test was conducted on BC soil at varying percentages (1%, 2%, 4% and 6% and 8%) of stabilizer. The results are shown in Table III and Fig.2 below.

TABLE III

PLASTICITY CHARACTERISTICS

Soil mix	Stabilizer %	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)
A-0	0%	49.14	28.78	20.36
A-1	1%	48.2	29.53	18.67
A-2	2%	46.8	30.18	16.62
A-3	4%	44.75	32.32	12.43
A-4	6%	43.35	33.12	10.23
A-5	8%	42.8	34.70	8.1

International Journal of Recent Development in Engineering and Technology
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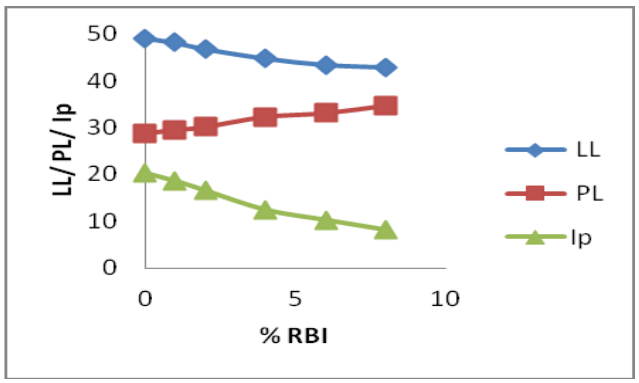

Fig.2 Variation of liquid limit, plastic limit and plasticity index of BC soil with varying percentages of stabilizer

From Fig.2, it is seen that liquid limit and plasticity index of the soil decreases upon addition of stabilizer. Generally characteristic changes in plasticity of treated soil are attributed to cat-ion exchange, flocculation or agglomeration (Thompson 1967).

C. CBR TEST

Soaked CBR test was conducted on both untreated and treated expansive soil. The test was performed on soil samples with 1%, 2%, 4%, 6% stabilizer. The treated samples were cured for different curing periods (4, 7, 14, 28 days) and test was conducted, as per IS 2720 (Part 16). Two trials were conducted and the average CBR value is considered. The CBR values at 2.5mm penetration were found to be higher than the CBR value at 5 mm penetration. Hence the CBR is taken as penetration at 2.5 mm only. A treated soil with curing period of 7 days was soaked further for 4 days and tested. A term defined as 'Soaked CBR ratio' is calculated.

Soaked CBR ratio is defined as Ratio of soaked CBR of treated soil cured for 'n' days to the soaked CBR of untreated soil, where n is the curing period

The soaked CBR ratio = soaked CBR of treated and cured soil / soaked CBR of untreated soil

TABLE IV

RESULTS OF CBR TEST ON UNTREATED AND TREATED BC SOIL

Soil Mix	Soaked CBR value % , cured for				Soaked CBR RATIO for 4 days	Soaked CBR RATIO for 28 days
	4days	7days	14days	28days		
A-0	2.55	-------	-------	------	-------	-------
A-1	4.01	5.10	6.20	6.93	1.5	2.7
A-2	5.10	6.20	8.40	10.94	2.0	4.3
A-3	6.56	8.02	9.85	12.40	2.5	4.8
A-4	8.02	10.21	14.23	19.70	3.1	7.7

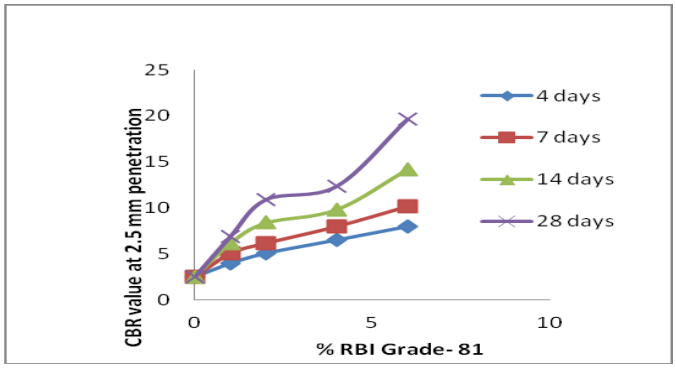

Fig.3 Variation of CBR strength of BC soil with increase in the dosage of RBI Grade-81 stabilizer

From Fig.3, it is observed that as the percentage addition of RBI-81 increases, the CBR value increases. Also, upon curing, the treated soil gains strength gradually over a period of time from zero days to 28 days. The minimum desired CBR for a subgrade as per IRC 37 (2007), is 10%. Hence addition of 4% of RBI-81 is taken as minimum dosage for the soil.

The strength gain can possibly be attributed to reactions between silica/alumina present in soil with RBI-81 leading to formation of cementing agents. Cementing agents create bonding effect between particles so as to increase the strength of soil mixtures (F. H. Chen, 1988). This needs to be investigated in detail.

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From the initial studies conducted on expansive soil samples treated with RBI-81, it was found that an increase in strength of samples if cured beyond 28 days was marginal. Hence, a curing period of 28 days is sufficient to assess the effect of RBI-81 on expansive soil.

D. UCC TEST

UCC Test was conducted on samples prepared at their MDD and OMC with different percentages of stabilizer (1%, 2%, 4% and 6%) and cured for 7 days, 14 days and 28 days. The results are shown in Table V Stress v/s strain curves were plotted as shown in fig.5 and fig.6 and modulus of elasticity determined.

TABLE V

UCC VALUE AND E VALUE OF BC SOIL AT DIFFERENT DOSAGES OF RBI GRADE – 81

Mix	UCS value (kN/m²)			E- value (kN/m²)		
	7 days	14 days	28 days	7 days	14 days	28 days
A-0	133.4	-----	-----	3924	------	------
A-1	208.9	231.5	240.3	5395.5	5542.6	5984.1
A-2	224.6	239.3	257.0	5493.6	6209.7	6278.4
A-3	289.3	320.7	329.6	6670.8	6965.1	8829
A-4	364.9	371.7	374.7	6867	7970.6	9123.3

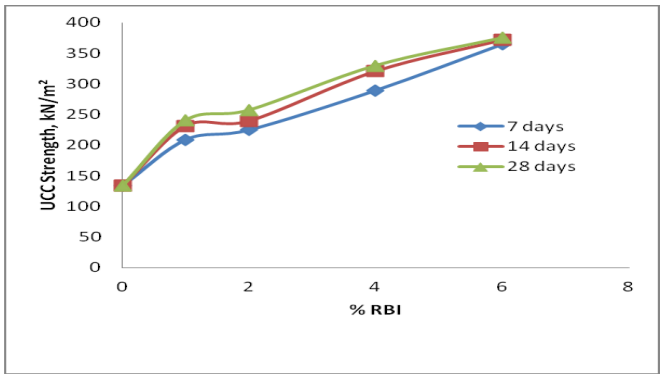

Fig.4 Increase in UCC strength of soil with varying dosage of RBI Grade – 81 at different curing periods

The unconfined compressive strength of untreated soil is 133.4 kN/m² which increased to 374.7 kN/m² upon 6% addition of RBI-81 and cured for 28 days. The increase is about 3 times.

It is also observed that there is no significant difference in UCC strength between soil samples treated with 4% and 6% RBI-81. Therefore 4% addition of RBI-81 can be considered as dosage for further investigation on swell pressure.

Fig.5 and fig.6 shows the stress strain curve obtained for treated soil treated cured for 7 days and 28 days respectively. Modulus of elasticity 'E' was calculated. Soil treated with 6% RBI-81, cured for 28 days exhibits 'E' value of 9123.3 kN/m² as against 3924 kN/m² for an untreated soil sample. Increase in 'E' value supplements decrease in plasticity characteristics of soil upon treatment.

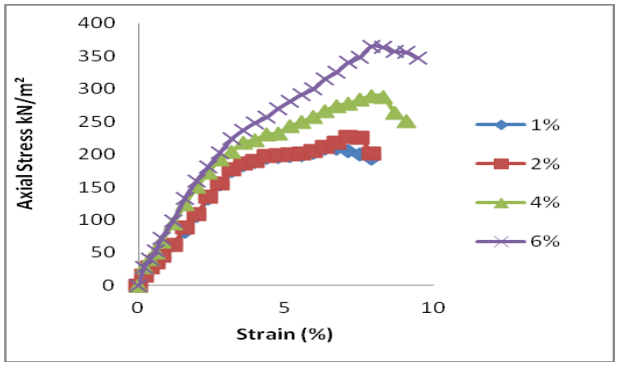

Fig .5 Stress v/s strain curves for untreated and treated soil samples cured for 7 days

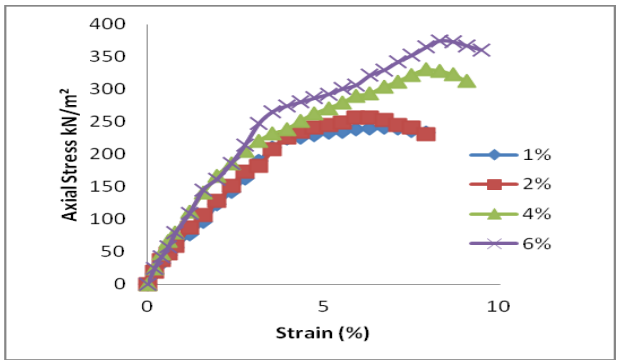

Fig .6 Stress v/s strain curves for untreated and treated soil samples cured for 28 days

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E. FREE SWELL TEST

Differential Free swell test was conducted on untreated and treated soil samples as per IS 2720 Part 11. The Table VI shows the results of Free Swell test conducted on treated and untreated BC soil.

TABLE VI

DIFFERENTIAL FREE SWELL

Mix	% Swell
A-0	27.27
A-1	16.66
A-2	12.5
A-3	8.33
A-4	8.33

It has been observed from the Table VI that there is a considerable decrease in the free swell of BC Soil with increase in the addition of RBI Grade-81 .Untreated BC soil exhibit a free swell value of 27.3%. Upon the treatment with RBI-81, it was observed that the Free swell value of soil treated with 6% RBI Grade-81 reduced to 8.3%.

This clearly indicates that similar to lime, RBI Grade-81 is also effective in reducing swelling characteristics of BC soil.

F. CONSOLIDATION TEST

Consolidation test was conducted as per IS: 2720 Part 15 (1997) on untreated and treated soil with optimum percentage (4% stabilizer) It has been observed that there is a considerable decrease in the swelling characteristics of soil upon addition of stabilizer .

From the fig.7 it can be observed that the swell pressure for the untreated BC soil was 115 kN/m² and was reduced to 9.5 kN/m² upon addition of 4% stabilizer.

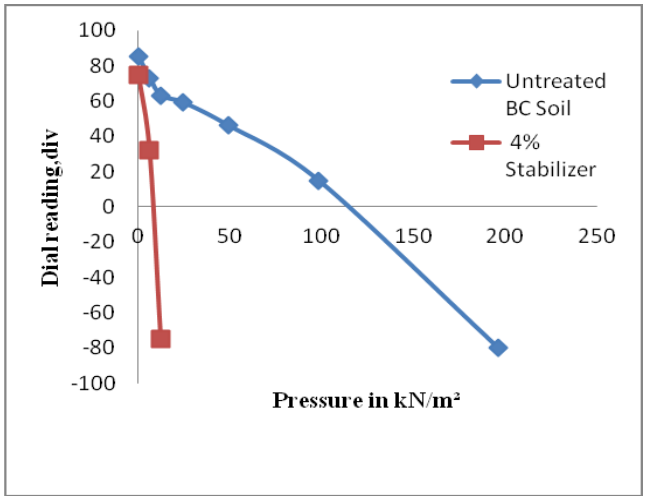

Fig.7 Swelling characteristics of untreated BC soil and BC soil treated with 4% RBI Grade-81 stabilizer

V. CONCLUSION

The following conclusions can be drawn from the present study

1. The stabilizer RBI-81 is effective in reducing the plasticity characteristics of the expansive soil.

2. The soaked CBR values of soil, increased three folds with addition of 6% stabilizer. Soaked CBR value of sample cured for 28 days increased 7.7 times. This indicates stabilizer improves the strength of expansive soil under soaking conditions. This also shows that unsoaked CBR values definitely increases immediately. The strength of expansive soil improves further upon curing the sample appropriately.

3. The expansive soil used in present study is suitable as a subgrade when stabilized with 4% RBI-81 based on CBR values.

4. The swelling pressure reduces upon addition of stabilizer by 90%.

5.However, If the expansive soil needs to be used as a sub-base material, then addition of RBI-81 alone as stabilizer may not be recommended since required UCC value for sub-base is not met.

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