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Comparative Study of Black Cotton Soil Stabilization with RBI Grade 81 and Sodium Silicate

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Abstract: Expansive soils are causing number of damages to the structures particularly light buildings and pavements compare to other natural hazards like earthquake, floods, etc. Thus, worldwide these soils are considered to be problematic soils and pose several challenges for engineers. So, as to utilize these soils in an effective way, proper treatment to the soil is required. With the same intention, an attempt is made 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 on the samples of soil and soil with stabilizers. Curing of samples is done for 7 days, 14 days and 28 days. RBI Grade 81 added to the soil in dry state in percentage (by weight) varying from 2% to 6% and sodium silicate 3% to 6% in solution (molar concentration). Comparisons of these two admixtures are done on the basis of test results obtained.

Keywords: Plasticity Index, Unconfined Compressive Strength, California Bearing Ratio, RBI Grade 81, Sodium Silicate

I. INTRODUCTION

Expansive soil deposits occur in the arid and semi-arid regions of the world and are problematic to the engineering structures because of their tendency to heave 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, etc. In Nagpur region, black cotton soils which are basically an expansive soil are found predominant. An exercise is carried out to improve the performance of this soil by using chemical admixtures RBI Grade 81 and Sodium silicate. Addition of admixtures done by weights and curing is done for 7 days, 14 days and 28 days in desiccators and using gunny bags. Atterberg's limits, Compaction, U.C.S. and soaked C.B.R. test carried out on the sample prepared and results are tabulated below.

II. LITERATURE REVIEW

A. RBI Grade 81: RBI Grade 81 is an odorless beige powder that is composed of a number of naturally occurring compounds. The pH of saturated paste is 12.5. It improves the structural properties of a wide range of soils. It is particularly effective with silty-clayey soil with low geo-mechanical qualities. RBI Grade 81 works by hydration reaction. Pore space is filled by a crystalline growth. Through the addition of low dosages of RBI Grade 81 the volume stability of the soil is increased significantly. The reaction of RBI Grade 81 with soil particles produces as an inter-particle matrix that binds soil particles together into a rigid mass. This binding of the soil particle, through both chemical bonds and frictional forces, serves to limit the pore volume of the created rigid stabilized soil system.

RBI Grade 81 is insoluble in water, non UV degradable, inert and chemically stable. It forms a dust free surface and is simple to apply and hardens fast. It is durable and permanent. It is environmental friendly and aesthetically pleasing. Strength of soil treated with RBI Grade 81 increases with age. RBI Grade 81 converts clay irreversibly into cementitious calcium silicate and aluminum hydrates. RBI Grade 81 creates a volume stable layer with very small capillary spaces. Application of RBI Grade 81 was carried out by researchers in the past and observations of investigation program are summarized below;

Sushant Bhuyan carried out an investigation program to study the influence of RBI Grade 81 and lime on the stabilization of blast furnace slag and flyash. He has carriedout standard proctor test and unconfined compressive strength test for different combinations of the stabilizing agents and reported that UCS of stabilized sample increases with increase in the days of curing however increase in strength with lime is more compare to RBI Grade 81.

Anitha K.R. et al studied the effect of stabilizer RBI Grade 81 in the stabilization of kaolinite, red soil and lateritic soil. The application of RBI Grade 81 stabilizer was studied by comparing the strength parameter of subgrade soil in terms of CBR value before and after the application of different percentages of RBI Grade 81 varying from 2% to 8%. From the test results it is observed that substantial reduction in plasticity index for soil with RBI Grade 81 viz 42 percent for kaolinite, 4 percent for red soil and 116 percent for laterite. Soaked CBR value increased for all three soils with RBI. OMC increased and MDD decreased with addition of RBI Grade 81 for red soil and kaolinite.

B Sodium Silicate: Sodium silicate grouts are the most popular grouts due to their environmental and safety compatibility. Moreover, sodium silicates have been developed into a wide variety of different grout systems. Practically, all systems are assumed on reacting a silicate solution to form a colloid which polymerizes further to form a gel that binds sediment particles or soil together and fills voids. Sodium silicate grouts have been used to cut off water flowing through permeable foundations and to stabilize or strengthen foundations composed of fractured rock and granular materials. Also, granular materials that have been saturated with silicate grout develop quite low hydraulic conductivity if the gel is not allowed to dry out and shrink. Even though shrinkage may occur, a low degree of hydraulic conductivity is usually obtained. Treatment with sodium silicate grout will enhance the strength and the load-bearing capacity of any groutable granular material coarser than the 75-µm sieve. Factors that influence strength are particle-size distribution, grain size, particle shape, the ability of the grout to adhere to the particle surfaces, absorption, moisture content, method of loading and curing environment. Also Sodium silicate solutions are basic. As this alkaline solution is neutralized, colloidal silica will aggregate to form a gel if the sodium silicate is present in concentrations above 1 or 2 percent (by volume). Sodium silicate and a reactant solution can be injected as separate solutions, or the sodium silicate can be premixed with the reactant to form a single solution that is injected;

Hossein Moayedi et al carriedout number of experiments using composition of alkaline earth metals grout to treat organic soils, in order to provide a better understanding of the engineering behavior of organic soil after stabilization. Series of batch tests conducted using composition of sodium silicate system binders to find their effects on physic-chemical properties of the organic soil. The results show that in the batch tests unconfined compressive strength (UCS), increases of up to 220% of the soil's baseline strength can be achieved by adding the 3 mol/L Na_2Sio_3, while UCS results enhanced to 270% having an activator $CaCl_2$ and/or $Al_2(SO_4)_3$ additives.

Bujang B.K. Haut et al reported that Soft clay soil can be stabilized by the adding of small percentages, by weight, of sodium silicate for enhancing many of the engineering properties of the soil. Series of tests were carriedout on the kaolinite. From the test results it is observed that addition of 5mol/L sodium silicate showed the highest unconfined compressive strength (UCS) results. However the effect of chemical molarities on UCS become less and less, with longer curing time. This is because of its solubility after immersing through water. It means after injection and finishing the chemical reaction if the adjust environment become fully saturated the bonding between clay structures probably will lost and caused significant reduction in UCS.

III. MATERIAL

Soil: Soil for the work was collected from Katol road area of Nagpur city. Tests were carried out to determine the various properties of soil and results are tabulated in table 1 given below;

TABLE I
PROPERTIES OF SOIL

Sr. No.	Laboratory Test	Result	Relevant IS Codes
1	Grain Size Distribution	74.69% fine	IS 2720 Part IV
2	Specific Gravity (G)	2.65	IS 2720 Part III
3	Water Content (Natural) (w)	9.29%	IS 2720 Part II
4	Liquid Limit (W_L)	56.50%	IS 2720 Part V
5	Plastic Limit (W_P)	29.10%	IS 2720 Part V
6	Plasticity Index (I_P or P.I)	27.40%	IS 2720 Part V
7	Free Swell Index (F.S.I)	30	IS 2720 Part XI
8	Optimum Moisture Content (O.M.C.)	20.02%	IS 2720 Part VIII
9	Maximum Dry Density (M.D.D.)	1.63 g/cc	IS 2720 Part VIII
10	California Bearing Ratio (C.B.R.)	2.33%	IS 2720 Part XVI
11	Unconfined Compressive Strength (U.C.S.) at OMC	2.69 Kg/cm^2	IS 2720 Part X

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Vol. 2, Issue 2, February 2013

RBI Grad 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. Chemical composition and properties of RBI Grade 81 are tabulated in table 2 (provided by the supplier);

TABLE III
RBI GRADE 81

Sr. No.	Chemical Composition		Physical Significance	
1	Ca	CaO 52-56	Odor	Odorless
2	Si	SiO_2 15-19	pH	12.5 (Saturated Paste)
3	S	SO_3 9-11	Specific Gravity	2.5
4	Al	Al_2O_3 5-7	Solubility	In water 0.2 pts/ 100 pt
5	Fe	Fe_2O_3 0-2	Freezing Point	None, Solid
6	Mg	MgO 0-1	Flammability	Non-flammable
7	Mn, K, Cu, Zn	Mn, K, Cu, Zn 0-3	Shelf Life	12 month (Dry Storage)
8	Fibers (Polypropylene)	0-1	Storage	Dry Storage Avoid moisture contact
9	Additives	0-4	Bulk Density	700 kg/ m^3

Sodium Silicate: Sodium silicates are commonly used as a grouting material. Following are the typical characterization of sodium silicate (table 3)

TABLE IIII
SODIUM SILICATE

Sr. No.	Particulars	Value
1	Total Alkalinity (Na_2O)	11.55
2	Silicate (SiO_2)	28.12
3	Ratio by weight Na_2O: SiO_2	1 to 2.43
4	Molecular ratio Na_2O: SiO_2	1 to 1.66

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IV. RESULT AND DISCUSSION

Consistency limits, Compaction, soaked CBR and UCS tests were carried out confirming to IS 2720 guidelines on stabilized soil samples at different concentrations of RBI Grade 81 and Sodium Silicate at the end of prescribed curing periods i.e. after 7 days, 14 days and 28 days curing. Summary of result are given in the Table 4 and Table 5 for RBI 81 and Sodium Silicate respectively;

TABLE 4
TEST RESULTS WITH RBI 81

Sr. No.	Particulars	Soil	Soil + 2% RBI 81			Soil + 4% RBI 81			Soil + 6% RBI 81		
1	Liquid Limit (W_L) (%)	56.50	53.50			52.40			51.70		
2	Plastic Limit (W_P) (%)	29.10	30.85			33.35			33.89		
3	Plasticity Index (I_P) (%)	27.40	22.65			19.05			17.81		
4	Free Swell Index (F.S.I)	30	20			10			5		
5	Optimum Moisture Content (O.M.C.) (%)	20.02	24.25			25.09			26.40		
6	Maximum Dry Density (MDD) (g/cc)	1.63	1.575			1.565			1.563		
7	California Bearing Ratio (C.B.R.) (%)	2.33	7D	14 D	28D	7D	14 D	28D	7D	14 D	28D
			8.03	10.03	11.22	16.24	18.87	19.8	19.76	26.27	32.63
8	Unconfined Compressive Strength (U.C.S.) (Kg/cm^2)	2.69	2.97	3.62	4.08	3.96	4.44	4.69	4.73	5.56	6.01

TABLE 5
TEST RESULTS WITH SODIUM SILICATE

Sr. No.	Particulars	Soil	Soil + 3% Sodium Silicate			Soil + 4.5% Sodium Silicate			Soil + 6% Sodium Silicate		
1	Liquid Limit (W_L) (%)	56.50	57.05			58.66			56.84		
2	Plastic Limit (W_P) (%)	29.10	36.54			46.74			43.54		
3	Plasticity Index (I_P) (%)	27.40	20.51			11.92			13.30		
4	Free Swell Index (F.S.I)	30	50			50			40		
5	California Bearing Ratio (C.B.R.) (%)	2.33	7D	14 D	28D	7D	14 D	28D	7D	14 D	28D
			2.03	1.48	0.23	1.25	0.74	0.23	1.48	0.31	0.23
6	Unconfined Compressive Strength (U.C.S.) (Kg/cm^2)	2.69	3.89	3.64	2.30	4.74	3.88	1.27	3.61	3.29	1.06

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A. Consistency Limit: Liquid limit and Plastic limit of the soil mixed with varying percentage of RBI 81 and Sodium Silicate are given in table 4 & table 5 respectively. Study of Atterberg's limit indicate that LL and PI reduces with increasing percentage of RBI 81 whereas increases with sodium silicate addition. Observed variation of W_L and I_P under stabilizer dose given below in the fig. 1.

It is observed that plastic limit of RBI Grade 81mixed soil increases with the increasing proportion, comparatively substantial improvement in W_P observed with Sodium silicate upto 4.5% but thereafter reduces. P.I. of mixed soil improved by 35% and 51% under 6% RBI and Sodium silicate respectively.

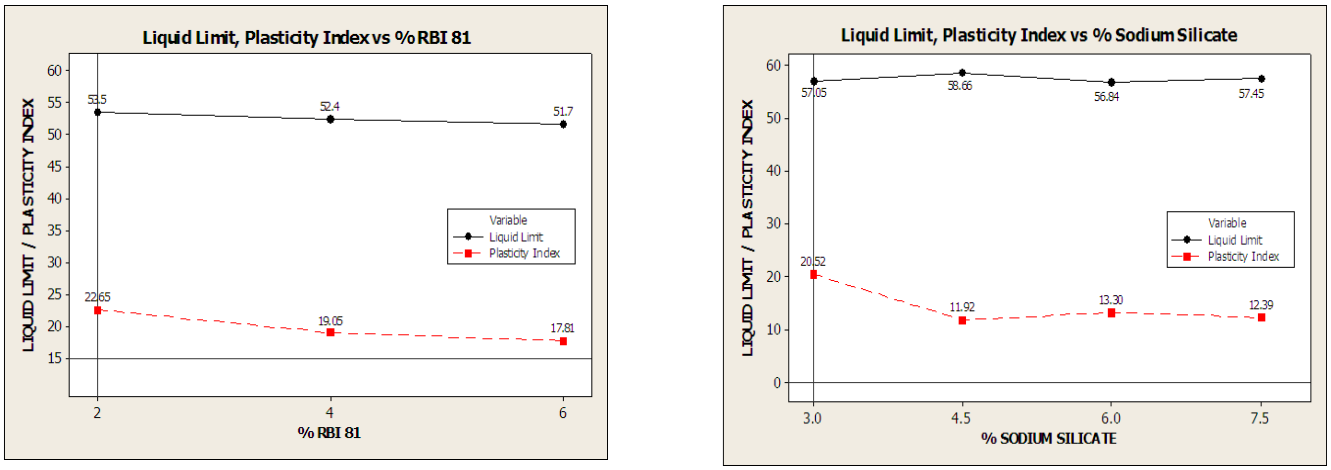

Fig 1: W_L, PI Variation under RBI 81 and Sodium Silicate

B. Free Swell Index: Swelling potential of mixed soil with RBI Grade 81 reduces by 83% whereas Swell Index increases with sodium silicate and increase of about 166% observed for 6% sodium silicate addition. FSI indicates potential of expansiveness of soil which is not desirable for soil treated with sodium silicate and pose limitation of sodium silicate to be used as stabilizer for black cotton soil.

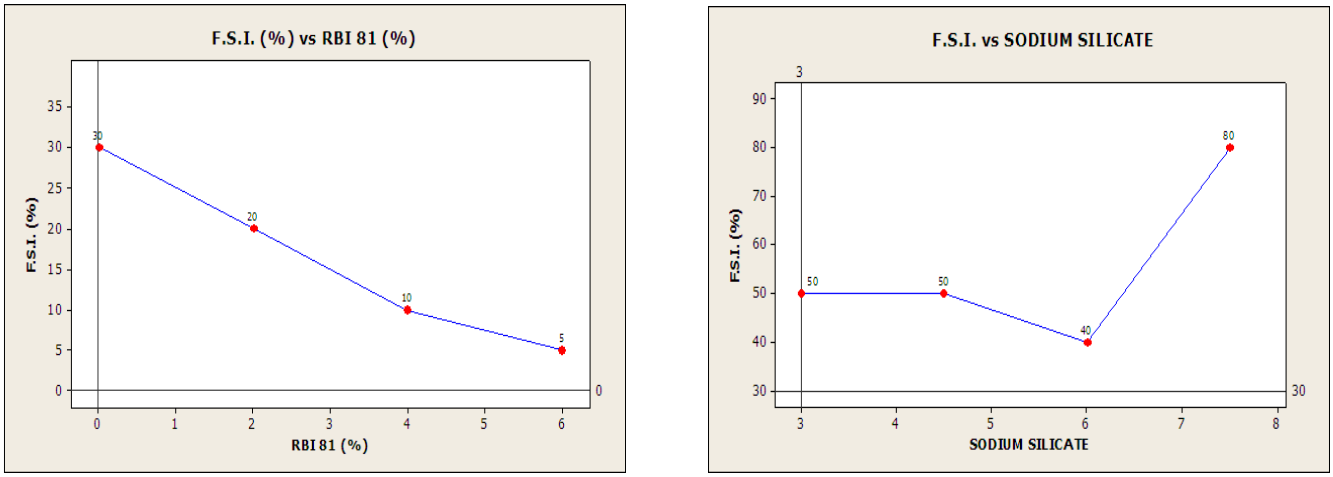

Fig. 2: FSI Variation under RBI 81 and Sodium Silicate

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Vol. 2, Issue 2, February 2013

C. Unconfined Compressive Strength: Initially UCS of stabilized soils using both the stabilizers increased but with the increase in days of curing the strength of soil stabilized with sodium silicates reduces whereas increase observed with RBI Grade 81. Trend of reduction in strength observed with Sodium silicate is similar to that reported by Bujang B.K Haut (2011) could be due to solubility of sodium silicate after immersion through water, shows its limitation to be used alone as an stabilizer for soils. UCS variation against days of curing given in the fig.3 below;

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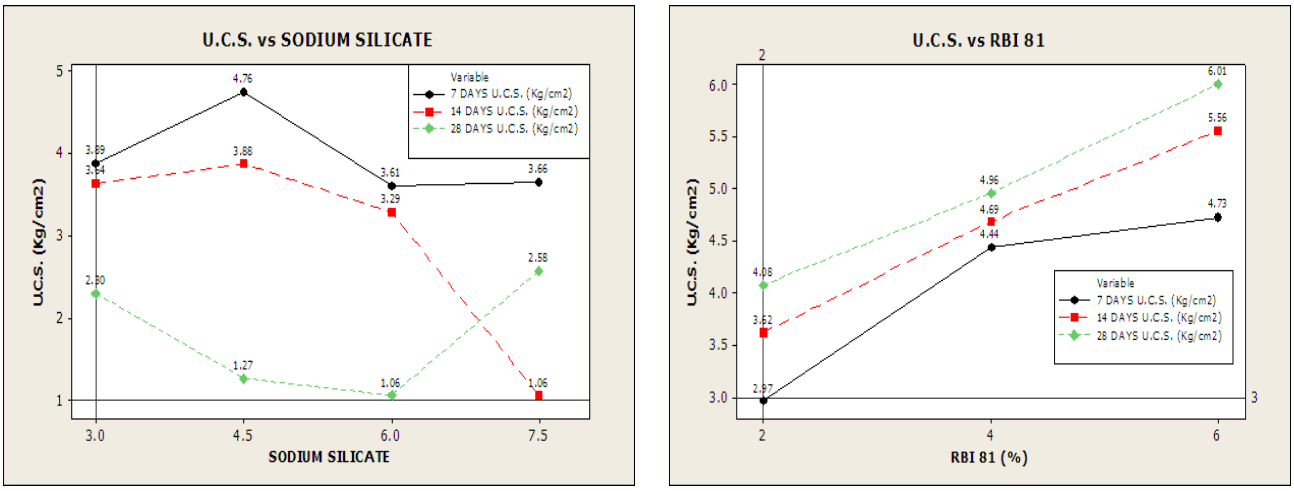

Fig. 3: UCS Variation under RBI 81 and Sodium Silicate

D. California Bearing Ratio: CBR measure shearing resistance of a soil under controlled moisture and density condition. CBR is obtained as the ratio of load required for certain depth of penetration of piston into compacted soil specimen at OMC and density to the standard load required for same penetration tested on standard sample of crushed stone. Soaked CBR test carried out on the mixed soil sample to resemble field condition

Marginal improvement in CBR occurred for initial 7 days curing. Sudden increase in soaked CBR value with 6% addition of RBI as shown in table 4 indicates RBI is effective admixture for fine grained soil. In case of sodium silicate, CBR decrease with increase in addition and days of curing as well indicate limitation of sodium silicate to be used as stabilizer for subgrade treated.

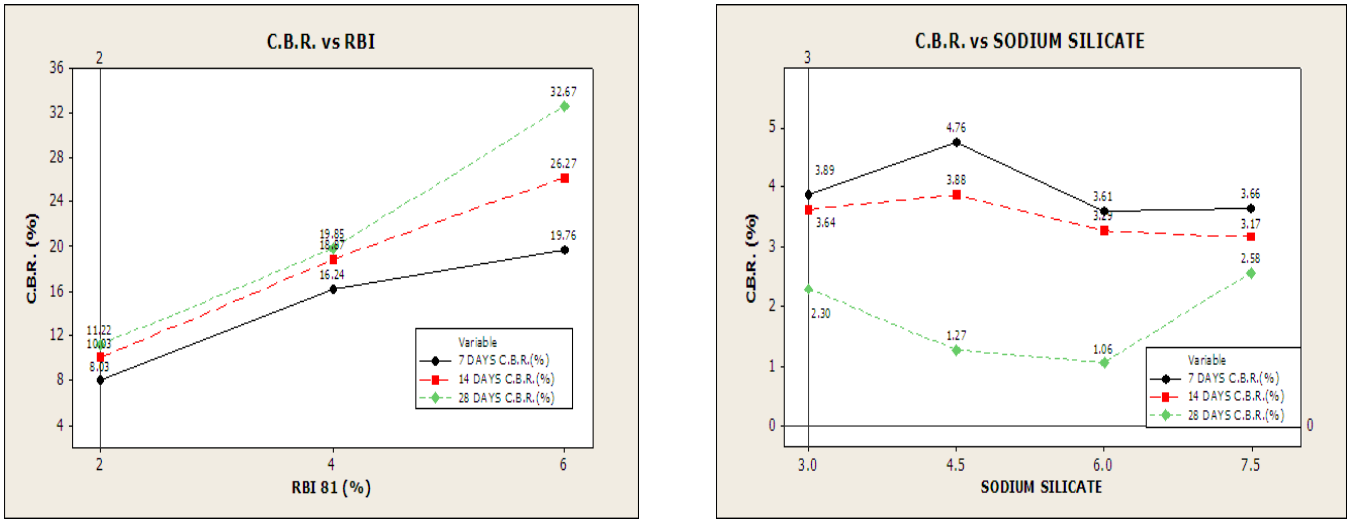

Fig. 4: CBR Variation under RBI 81 and Sodium Silicate

V. CONCLUSION

Scope of the work was to propose chemical stabilization for enhancing engineering properties of black cotton soils using RBI Grade 81 and sodium silicate. Following conclusions are made on the basis of test results

- Liquid limit decrases as the admixture content increases whereas reverse trend observed with plastic limit as it increases with the increase of admixture, results in net reduction of plasticity index.
- Unconfined Compressive strength, CBR (soaked) values increase with increase in RBI 81 addition suggest its suitability as good stabilizer to improve performance of soft soils
- Free swell index decreases as the addition of RBI 81 incrases and it goes on increse with addtion of sodium silicate. Similarly, UCS and CBR also reduces with incraseing dose of sodium silicate in soil pose limitation of sodium silicate used as stabilizer.
- Solubility of sodium silicate in water limits its use alone as a stabilizer in soil, whereas sodium silicate if applied with lime or cement for stabilization may found suitable because sodium silicate helpes in incrasing pH of soil environment which is necessary for the strength developments.

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