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Micro Level Analysis of Stabilized Expansive Soil

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Abstract: An effort is made to stabilize the expansive soils with the addition of chemical additive at different curing periods & different quantities of additive. Apart from Index and Engineering properties, Chemical composition, XRD and SEM analysis were conducted on both untreated and treated soil sample. The test results of the engineering properties were compared with the chemical and micro level analysis to get a better understanding.
Keywords: SEM, UCS,CBR, XRD.

I. INTRODUCTION

Construction of safe and economic structures is the current need of the hour. For a structure to be safe, apart from the materials used for construction, the foundation and the soil on which structure is built, plays a vital role. Similarly, treating the existing unsuitable soil such as clay (for construction purpose) instead of transporting it from a distant site becomes more economical in some cases.

The stresses induced in the clayeysoilbecause of their peculiar swell-shrink behavior, results in significant damage to the structures built on them. These soils tend to swell in wet weather conditions and shrink in dry weather conditions. The high swell potential of these soils make them unsuitable for construction purpose. Hence these soils need either to be replaced or treated in order to make them suitable for construction purpose.

Series of experimental investigations were done on such expansive soils over the past many decades using different types of additives. Katsutada ONITSURA *et al.*[12],Lakshmi Keshav*et al.*[13], LasledjAbdelmadjid*et al.*[14], carried out similar investigations on the expansive soils using various additives and found satisfactory results.BibhaMehto*et. al.*[1],K.V. Madhurwar*et. al.*[11], Lekha B.M *et. al.*[15], Pallavi H.N*et. al.*[16],and Venugopal*et. al.*[17]did similar studies on clayey soils using RBI grade 81 as stabilizer and found improvement in soil properties.

In the current study, an attempt has been made to improve the properties of expansive soil in order to make it suitable for construction purpose by adding chemical additive RBI grade 81.

II. MATERIALS AND EXPERIMENTAL SETUP

(a) Soil samples:

Two soil samples were collected to carry out the study and their properties were determined after drying the samples in proper manner. Preliminary tests such as grain size analysis, specific gravity, consistency limits, free swell index, compaction test, CBR and UCS were conducted on the soil samples. Apart from the index properties, micro level analysis was done with the help of XRD and SEM.

Percentage of clay was found to be 70% and 66% for sample 1 and 2 respectively. Similarly, Liquid limit, Plastic limit, shrinkage limit, free swell index were 2.36 and 2.65, 75% and 72%, 38% and 39%, 7% and 6%, 110% and 105%. From standard proctor test, the maximum dry density (g/cc)were obtained as 1.6 and 1.54 & optimum moisture content (%) was found to be 20 and 24.5. The unconfined compressive strength (kPa) of the samples were found to be 138 and 122 for sample 1 and 2 respectively.

Based on the test results of the soil properties, the soil samples can be categorized as expansive soils of high to very high degree of expansion in accordance with IS:1498 classification system.

In addition to the tests for index and engineering properties, analysis for the chemical composition of the soil samples was carried out. Chemical composition results of the soil samples are given in table 1. It is clearly observed that the sample contains high silica, alumina content and a small fraction of organic content. But calcium oxide content in the given soil samples is very less.

Table 1: Chemical composition of soil samples

Description %	Sample 1	Sample 2
Loss on ignition	13.67	13.00
Insoluble residue	67.92	84.92
SO_3	0.34	0.12

SiO_2	53.17	53.36
Al_2O_3	13.77	14.79
Fe_2O_3	6.45	7.76
CaO	5.39	3.54
MgO	0.39	0.73

(b) Additive:

RBI grade 81 chemical is selected as the additive.RBI Grade-81 is an Inorganic soil stabilizer &pavement materialwhich is commercially in powdered form.

Table 2: Chemical composition of RBI grade 81

Constituent	Percentage by weight
Ca	52-56
Si	15-19
S	9-11
Al	5-7
Fe	0-2
Mg	0-1
Mn, K, Cu. Zn	0.1-0.3
H_2O	1-3
Fibres	0-1
Additives	0-4

The selection of the additive was done based on its chemical composition (table 2). The test results show that the additive is rich in calcium while in case of soil samples the calcium oxide content is very less. Hence an attempt has been made to improve soil properties by supplying calcium rich additives.

III. EXPERIMENTAL SETUP

Both the soil samples were treated with 2, 4 and 6% by weight of RBI grade 81 additive. The treated samples were cured for a period of 7, 14 28 and 60 days. The specimens for UCS test were prepared in accordance with IS 2720 (part X). About three specimens were prepared for each trial then placed in air tight plastic covers whichin turn were placed over wetted rice husk covered with wet gunny bags in order to maintain a constant temperature and to avoid moisture loss from the prepared samples. The CBR test was conducted in accordance with IS 2720 (part XVI). The curing for CBR specimen was done by placing wetted rice husk and the CBR mouldin turn was placed over wetted sand bags. The samples were soaked for four days before conducting the test.

IV. TEST RESULTS AND DISCUSSION

(a) Unconfined compressive strength:

Unconfined compression test was conducted on prepared specimen of 38 mm diameter and 76 mm height at various quantities of RBI 81 and the samples were cured for a period of 7 days, 14 days and 28 days before testing. The test was conducted in accordance with IS 2720 (Part X). Effect of the additive on soil samples in terms of various quantities and curing periods is shown in table 4.

(a) Failure pattern of untreated soil sample

b) Failure pattern of RBI treated soil sample X with 6% RBI and 28 days curing period

Figure 1: Failure patterns of soil sample with and without additive

Figure 1 shows the failure pattern of untreated and RBI treated soil samples in UCS test. The change in the failure pattern of the soil sample indicates change in morphology of the soil sample after treatment.
Figure 2 demonstrate the effect of percentage of additive on percentage increase in UCS values for sample 1 for different curing periods. It can be clearly observed that with the increase in the percentage of additive, the rate of increase in UCS is more for higher curing period. Similar results were observed for sample 2.

(b) *California Bearing Ratio:*

California bearing ratio was conducted on 4 days soaked samples i.e. 11th day (7+4 days), 18th day (14+4 days), 32nd day (28+4 days) and 64th day (60+4 days) from the date of preparation of the sample. Figure 3 depicts the effect of curing period on the CBR values of soil 2.

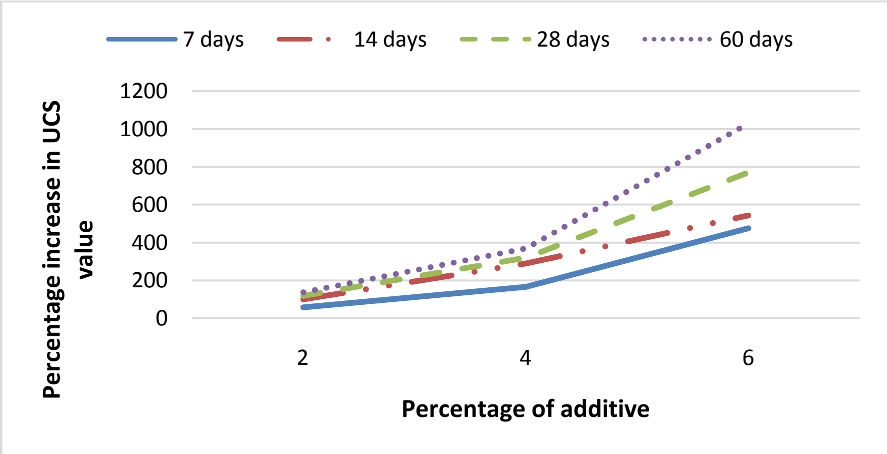


Figure 2: Effect of percentage of additive on percentage increase in UCS values for sample 1

It can be clearly observed that with the increase in the curing period as well as with the percentage of additive, the rate of increase in CBR is increasing. Similar results were observed for sample 1.

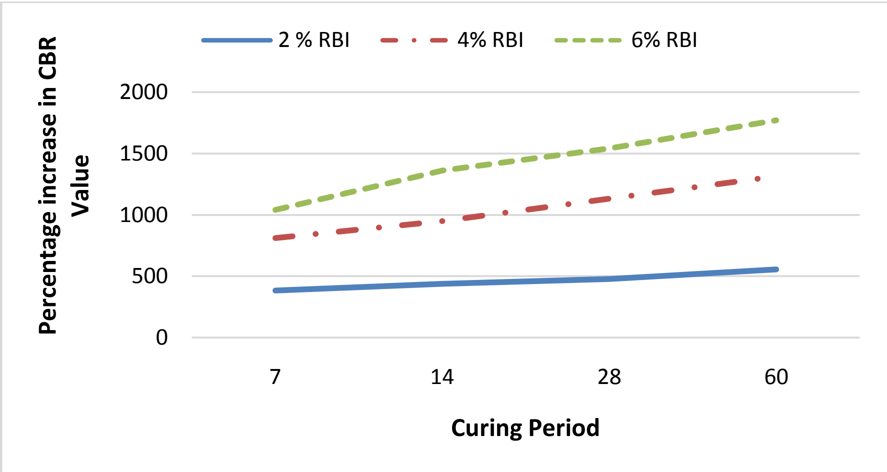


Figure 3: Effect of curing period on the percentage increase in CBR values for sample 2.

(c) *Free Swell Index:*

Free Swell Index test was conducted on both untreated and treated soils in accordance with IS: 2720 (Part – XL). The sample for free swell index was taken from middle portion of the tested UCS specimen which was then oven dried and sieved through 425 micron sieve. Free swell index (Figure 4) shows a decreasing trend with the increase in RBI content and curing periodi.e the swell potential of the soil sample was found to be decreased on addition of RBI grade 81.

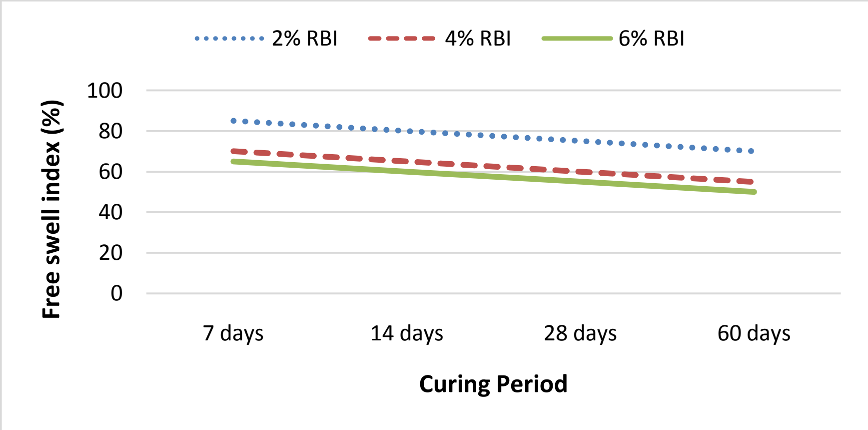


Figure 4: Effect of additive and curing period on swell potential of soil sample 1

(d) Chemical composition:

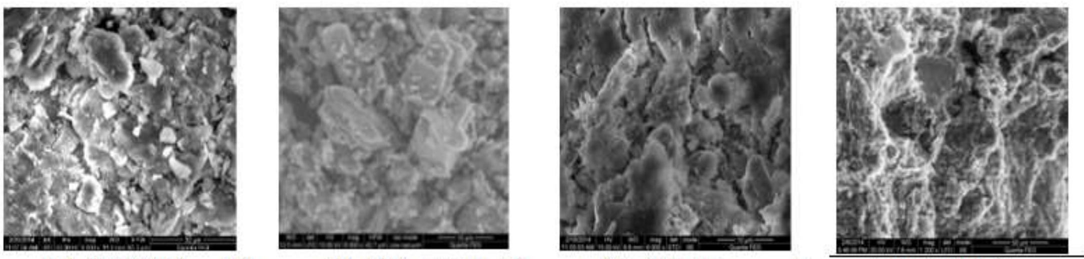
Chemical composition analysis for both the soil sample were done for different dosages and curing periods. Table 3 depicts the chemical composition in percentage weight for raw additive, untreated and RBI treated soil sample 1. It is observed that the Si and Al percentage is high in raw soil sample. The percentage of Ca which is responsible for strength characteristics is less in raw soil is being supplemented by calcium rich additive. With the increase in percentage ofadditive and curing period, there was a considerable decrease in the Si, Al and Ca percentages for treated soil sample. This indicates the formation of hydration products such as calcium-silicate-hydrates (C-S-H), calcium-aluminate-hydrates (C-A-H) and calcium-aluminium-silicate-hydrates (C-A-S-H).

Table 3: Chemical composition (CC) for soil, additive, and RBI treated soil 1

CC (Wt.%)	**RBI**	**Soil**	**Soil + 2% RBI**	**Soil + 4% RBI**	**Soil + 6% RBI**
			7 days	**14 days**	**28 days**
O	57.68	59.74	59.39	58.58	63.91
Si	7.19	18.30	14.78	12.26	8.73
C	15.44	14.77	12.85	16.85	21.20
Al	2.86	4.18	5.19	5.11	3.71
Fe	0.11	1.33	2.45	1.61	0.64
Ca	12.96	0.81	4.10	3.32	0.72
Mg	1.64	0.87	0.93	1.05	1.08
S	2.13	0.01	-	0.44	-

(e) Scanning Electron Microscopy (SEM):

SEM analysis was conducted on untreated soil samples, additive, treated samples for both the soils. SEM micrograph result for both the sample showed a reduction in void on addition of RBI grade 81 at different percentages of additive and for different curing periods.The change in morphology in the treated sample when compared to untreated soil sample may be because of formation of hydration products as observed from chemical composition analysis.Figure 5 shows SEM micrographs of untreated soil sample 2, soil stabilizer (RBI 81), soil sample treated with 6% additive for a curing period of 14 days and 28 days.



(a) Untreated soil sample 2

(b) RBI grade 81 additive

(c) Sample 2 treated with 6% additives and 14 days cured

(d) Sample 2 treated with 6% additives and 28 days cured

(f) X-Ray diffraction (XRD):

X-Ray diffraction was carried out in order to identify any microstructural or mineralogical changes in the RBI treated soil sample. The test was conducted on oven dried and pulverized UCC tested samples passing through 75 micron sieve. Figure 6 depicts comparison of XRD pattern for sample 1 with 2% and 6% RBI treated soil for a curing period of 7 days and 60 days respectively. A clear reduction in the peak at 28° can be observed with the increase in curing period as well as percentage additive indicating change in morphology of the soil sample.

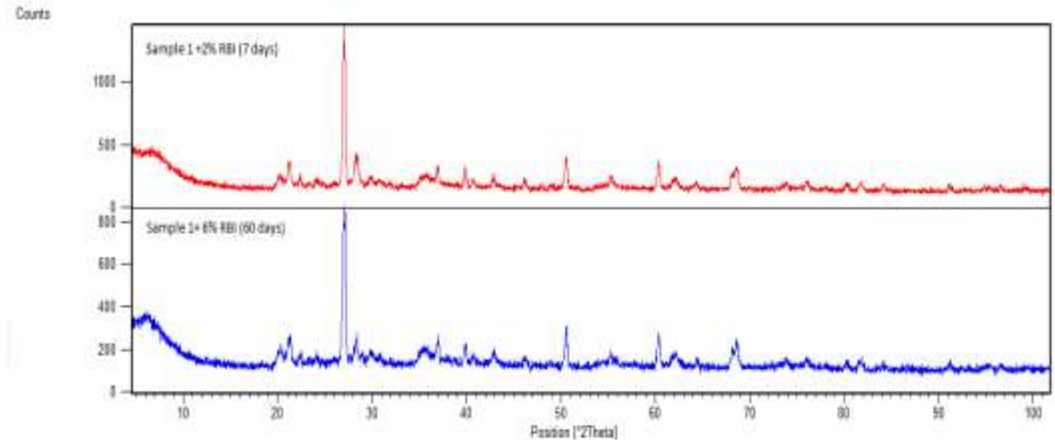


Figure 6: Comparison of XRD pattern for sample 1 with 2% (7 days cured) and 6% (60 days cured) additive

V. CONCLUSION

With the addition of RBI 81, the strength properties of the soils were found to be improved both in terms of percentage additive as well as curing period. But the rate of increase in the UCS values was higher for higher percentage and higher curing period.

A considerable increase in the CBR values was observed which gives a clear indication of the effectiveness of additive on the bearing capacity of the soil samples.

The failure pattern as obtained from the UCS test of the RBI treated sample when compared to untreated sample indicates change in morphology of the soil structure. This change can be compared with the SEM micrographs which shows reduction in pore spaces and formation of cementitious substance.

The swell potential of the soil samples decreased with the increase in percentage additive and curing period which can be correlated with the chemical analysis of the soil samples, (table 3), where a reduction in Al and Si can be clearly seen. This can be as result of formation of C-S-H and C-A-S-H as seen in SEM micrographs. Reduction in peaks in the XRD of the soil samples on addition of RBI 81 indicates change in morphology of the soil, which satisfies the results obtained from the engineering properties in terms of improvement in strength and reduction of swell potential.

For the two samples selected in this study, based on the test results obtained, it can be observed that the improvement in engineering properties may be attributed to thechange in micro structure of the soil which is proved by the micro level analysis.

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