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International Journal of ChemTech Research

CODEN (USA): IJCRGG ISSN: 0974-4290
Vol.7, No.2, pp 666-672, 2014-2015

ICONN 2015 [4th -6th Feb 2015]
International Conference on Nanoscience and Nanotechnology-2015
SRM University, Chennai, India

Micro level Analysis of RBI 81 Stabilized Expansive Soil

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Abstract : All over the world there are lots of places where clayey soil can be found. Design and construction of any kind of structure or pavement over this expansible and weak kind of soil is quite challenging and problematic for geotechnical engineers. Enhancing the properties of expansible and weak soil has become a popular research topic in the present scenario, which prevents the need of replacement of the soil and could be established with chemical inclusion. The present investigation includes the study of engineering properties of expansive soil using chemical additive, RBI grade 81(Road Building International grade 81) at various percentages and for different curing periods. Addition of the chemical additive RBI grade 81 contributes the strength development to the soil. The strength of the treated soil increases with the percentage increase in stabilizer and with increase in curing period. In addition to the tests for engineering properties, various micro level studies such as XRD, SEM and EDS have also been carried out. With these analyses, the improvement in strength at micro level was observed and analysed. The remarkable results have been noticed from the XRD analysis with the vast reduction in peak value, due to the increase in percentage of stabilizer as well as curing period. SEM micrographs also reveal reduction in pore spaces of the treated soil sample and structural change at micro level, which indicates the improvement in strength. The test analysis has also been extended with EDS, showing variation in elemental composition of the untreated and treated soils.

Keywords : Soil Stabilisation, RBI grade 81, MDD, OMC, UCS.

1. Introduction

The problem of weak and expansive soils is widespread throughout the world. Presence of expansive soils cause severe damage to structure, especially in lightly loaded buildings and pavements in roads, when compared to the other natural hazards like earthquakes and floods[1,2]. Expansive soils generally contain the clay mineral, montmorillonite, include sedimentary and residual soils, clay stones, and shales. In arid and semiarid climates, expansive soils exist in unsaturated and moisture-deficient conditions. The expansive nature of soil is noticeable very nearer to the ground surface when it is exposed to seasonal variations[3, 4].The clayey soils being expansive in nature causes severe distress to the structures founded on them and hence are unsuitable for construction purpose. In such cases, stabilization of such soils becomes essential in order to make them suitable for constructions. Soil stabilization is one such ground improvement technique that is used to enhance the properties of weak and expansible soil and to make it suitable for engineering practices.Various studies were carried out to treat and stabilize different types of problematic soils, using lime[5-9] and fly ash[10-14]. The effectiveness of different percentages (5%, 10% & 15%) of Cement Kiln Dust (CKD) as a soil stabilizer was evaluated based on UCC and SEM analysis[15]. Addition of RBI Grade 81 on expansive and various problematic soils at different curing periods were studied[16,17] which revealed better results for various properties like CBR, Atterberg limits, compaction and swell characteristics. From the study, the researchers reported that the problematic soils show better performance with the addition of RBI stabiliser of 2% to 6%.

The above studies lead to the further investigation on morphology and change in micro structure of the stabilized soil. The present investigation includes micro-level studies such as X-Ray diffraction, Scanning electron microscopy and Energy Dispersive X-ray Spectrometer in addition to study on enhancement of strength property of expansive soil using chemical additive, RBI grade 81(Road Building International grade 81) at various percentages (i.e. 2%, 4% and 6%) for different curing periods (i.e. 7 days, 14 days and 28 days).

2. Materials and Properties

Two types of soil samples (E1 and E2) were used in this investigation, collected from Thittakudi-Sirupakkam road and Perungudi in Chennai. The soil samples were collected from a depth of about 50 cm below the ground level in order to avoid the vegetation and organic matter. A series of laboratory tests (in accordance with IS: 2720) were conducted on the soil samples after drying them in a proper manner. Both the soil samples were identified as the clays of high compressibility as per IS:1498 (1970). The chemical composition and geotechnical properties of soils are shown in Table 1 and 2 respectively.

RBI grade 81 was used as the additive for stabilizing the soils. RBI 81is grey colour, powder based natural inorganic soil stabilizer and it was originally developed by RBI in South Africa.

Table 1: Chemical composition of soil samples

Chemical composition	SO_3	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	LOI	IR
Sample E1	0.34	53.17	13.77	6.45	5.39	0.39	13.67	67
Sample E2	0.12	53.36	14.79	7.76	3.54	0.73	13	85

Table 2: Geotechnical properties of soil samples

Properties		Symbol	Sample E1	Sample E2
Free swell index, %		FSI	110	105
Specific Gravity		G	2.36	2.65
Particle Size Distribution	Sand, %	S	4	2
	Silt, %	M	26	32
	Clay,%	C	70	66
Liquid limit, %		W_l	75	72
Plastic limit, %		W_p	38	39
Plasticity Index		I_p	37	33
Shrinkage limit		W_s	7	6
Compaction Characteristics	MDD, g/cc	γ_d	1.6	1.54
	OMC, %	OMC	20	24.5
Soil Classification			CH	CH

3. Sample Preparation and Testing

Examination were carried out to study the strength property of the untreated and RBI treated expansive soil and to correlate the same with micro level analysis. Unconfined Compression (UCC) test and micro level analysis were carried out with Scanning Electron Microscopy (SEM), Energy Dispersive X-ray Spectrometer (EDS) and X- Ray Diffraction (XRD) were carried out on the untreated and RBI treated soil samples.

The UCC test was conducted on RBI treated soil at various proportions of 0, 2, 4, and 6% for curing periods of 7 days, 14 days and 28 days respectively. The UCC samples were prepared by static compaction using a split mould at Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) that were obtained from by standard proctor compaction test. The prepared samples were cured, by placing them in air - tight polythene covers which in turn were placed over wetted rice husk base and the whole assembly was covered with wet gunny bags, in order to prevent moisture loss.

SEM, EDS and XRD tests were carried out on the samples collected from the middle section of the UCC specimen, for untreated as well as for RBI treated specimens. The soil samples were dried completely before commencing the tests.

4. Results and Discussion

4.1 Unconfined Compression Test

Unconfined compression test was conducted on prepared sample of 38 mm diameter and 76 mm height at various dosages of RBI 81 and the samples were cured for a period of 7 days, 14 days and 28 days before testing. Table 3 shows the variation in Unconfined Compressive Strength (UCS) values for untreated and RBI treated soil samples E1 and E2. Effectiveness of percentage stabilizer and curing period on both the soil samples E1 and E2 were studied. The UCS values reveal an increasing trend with the increase in percentage stabilizer and curing period. The maximum increase in the UCS value was found to be 8.67 times for sample E1 and 6.30 times for sample E2 as that of untreated soil. Figure 1 shows the effect of percentage stabilizer on UCS value of both the soil samples E1 and E2. It is observed from the Figure 1 and Table 3, that RBI grade 81 additive was found to be more effective for soil E1 compared to soil E2.

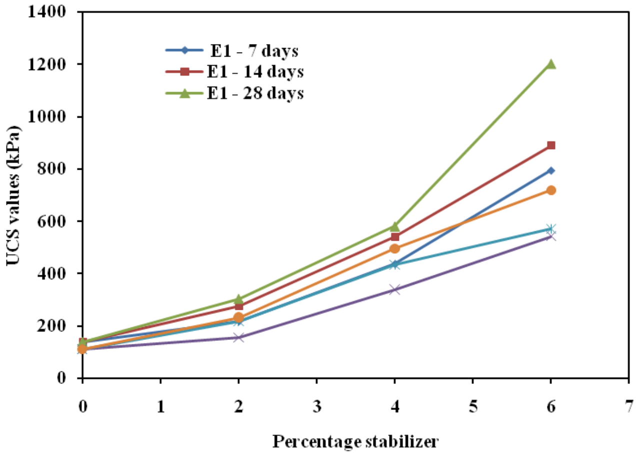


Figure 1 Effect of percentage stabilizer on UCS values of sample E1 and E2.

4.2 Micro level studies on soils

In order to compare and explain the strength development in the treated soil, micro level studies such as SEM, EDS and XRD were carried out.

Table 3: UCS values of untreated and treated soil samples E1 and E2

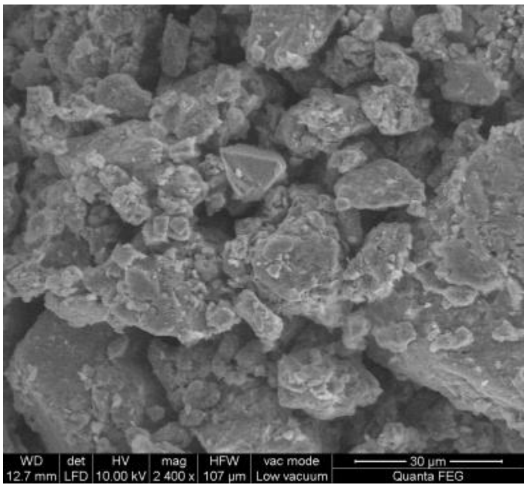
RBI 81 (%)	UCS values (kPa)					
	Sample E1			Sample E2		
	Curing period (days)			Curing period (days)		
	7	14	28	7	14	28
0	138.53			112.23		
2	217.59	276.76	302.71	156.69	217.67	233.52
4	436.73	539.73	579.61	339.45	435.34	496.20
6	794.75	888.23	1201.53	541.48	571.10	718.03

4.3 Scanning Electron Microscopy (SEM)

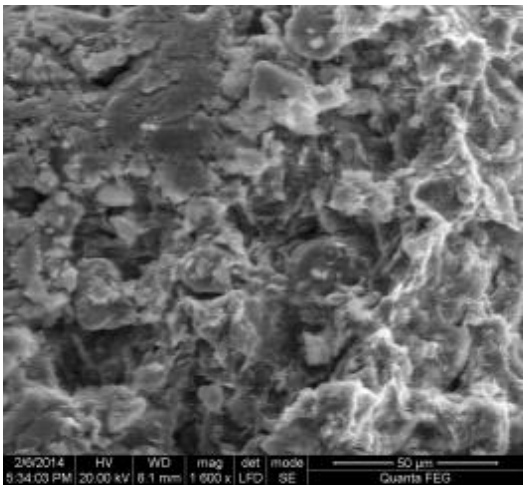
SEM analysis was conducted on untreated and RBI treated soil samples.SEM micrographs reveal the change in microstructure of the treated soil and it can be observed clearly that there is a considerable reduction in pore spaces in treated soil sample when compared to untreated soil samples (Figure-2). This reduction in pore spaces is due to the formation of hydration products within the voids, formed as a result of chemical reaction between the soil sample and the additive. It is found that the formation of hydration products is enhanced with the increase in percentage of stabilizer and curing period. This may be due to the availability of reactants and reaction time.

4.4 Energy Dispersive X-ray Spectrometer (EDS)

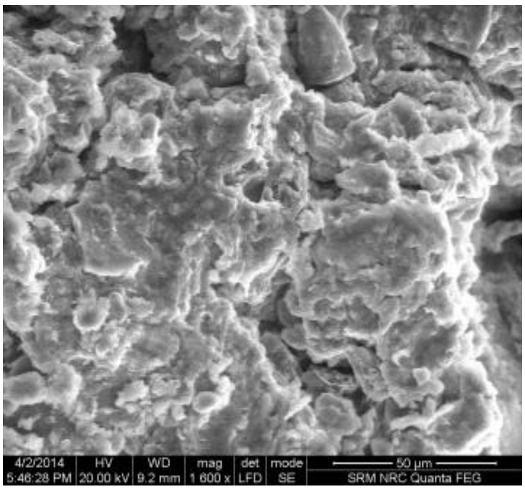
EDS spectra were obtained from Bruker Energy Dispersive X-ray Spectrometer along with SEM. Figure 3 and 4 shows the EDS spectra for raw soil sample E1 and raw additive. Figure 5,6 and 7 represents EDS spectra for sample E1 with 2, 4 and 6% additive at curing period of 7, 14 and 28 days. A variation in composition of elements was observed from EDS spectra of test samples. This change in elemental composition indicates the change in chemical composition of soil as well as the soil structure.



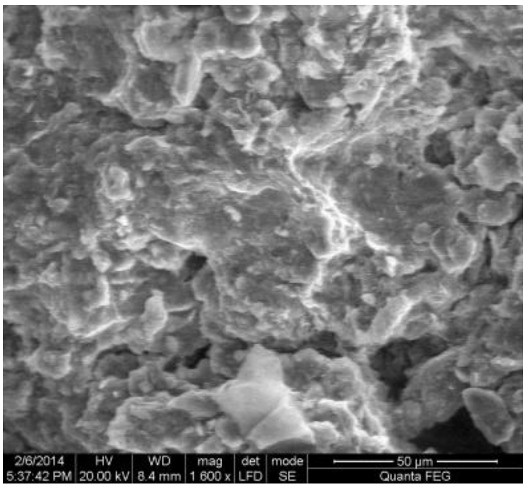
(a) Virgin soil E1



(b) Soil E1+ 2% RBI - 7 days



(c) Soil E1+ 4% RBI - 14 days



(d) Soil E1+ 6% RBI - 28 days

Figure 2 SEM micrograph for untreated and treated soil sample for different percentages of RBI at different curing periods.

Table 4 depicts the chemical composition in percentage weight for raw additive, untreated and RBI treated soil sample E1. 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 stabilizer 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 4: Chemical composition (CC) for soil, additive, and RBI treated soil E1

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	-

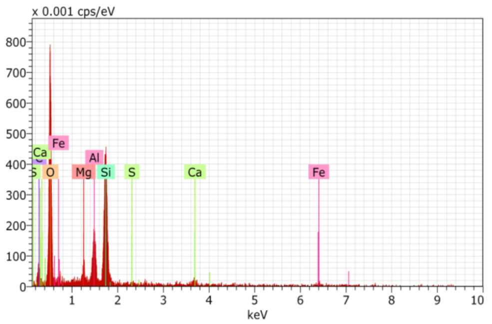


Figure 3 EDS spectra untreated soil E1

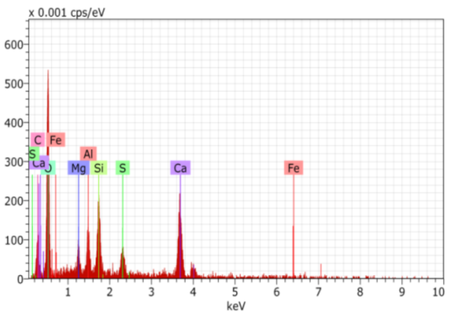


Figure 4 EDS spectra for chemical additive RBI 81

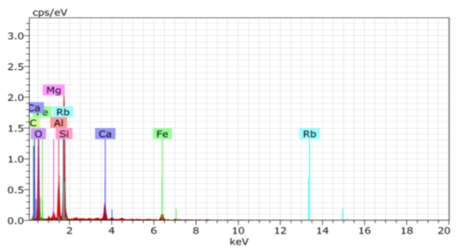


Figure 5 EDS spectra for soil E1 treated with 2% RBI 81 at 7 days curing period.

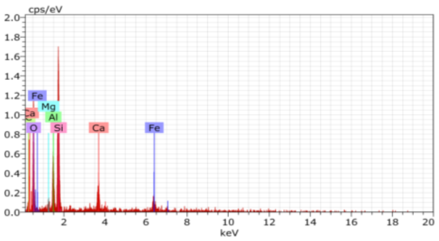


Figure 6: EDS spectra for soil E1 treated with 4% RBI 81 at 14 days curing period.

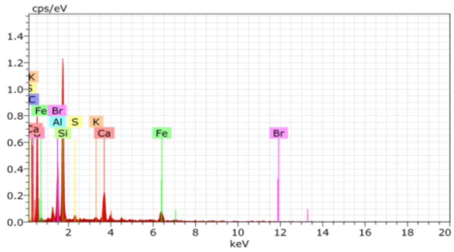


Figure 7 EDS spectra for soil E1 treated with 6% RBI 81 at 28 days curing period

4.5 X – Ray Diffraction (XRD):

XRD analysis is conducted on the untreated and RBI 81 treated soil sample in order to identify the change in microstructure and mineralogical composition with the help of diffraction pattern. A plot has been drawn, by taking position of 2 theta angle along abscissa and the intensity in terms of counts along ordinate. The XRD gives different peaks for the different basal spacing. An increase in the number of peak was observed (Figure 8) with the increase in stabilizer dosage as well as curing period. This change in peak indicates the change in morphology of the soil on treatment with RBI 81.

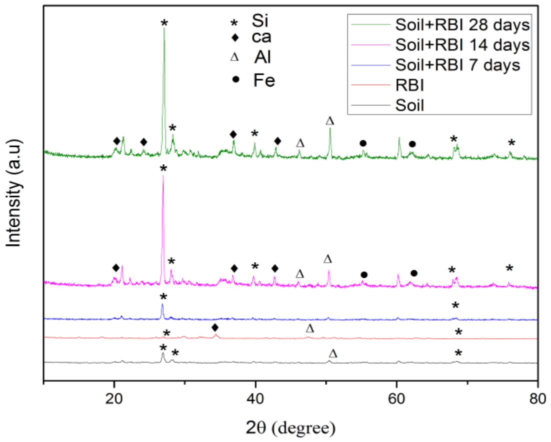


Figure 8: XRD pattern for soil E1, RBI additive and 4% RBI treated soil sample cured at 7, 14 and 28 days.

5. Conclusion

- Both the soil samples E1 and E2 used in this investigation are identified as Highly compressible Clay (CH) as per IS: 1498 (1970).
- Both the soil samples show an increase in UCS values with the increase in stabilizer dosage along with the increase in curing period. The rate of increase in the UCS value was found higher during the initial stage.
- SEM, EDS and XRD analyses justified the experimental observations of UCC test. SEM micrographs reveal the change in microstructure of the treated soil and reduction in pore spaces which explains the increase in strength.
- The changes in elemental composition of RBI 81 treated soil is found favourable, compared to untreated soil as depicted in EDS spectra which confirms the chemical reaction between soil and additive. Formation of hydration products is confirmed by SEM and EDS results. Change in peak intensity gives an indication for the change in morphology of the soil sample up on treatment with RBI grade 81 stabilizer.

Acknowledgement

The authors wish to thank Department of Physics and Nanotechnology Research Centre, SRM University, Kattankulathur for the help in Micro level study.

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