IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 12, Issue 2 Ver. III (Mar - Apr. 2015), PP 01-08
www.iosrjournals.org

Effect of Addition of Lime on the Properties of RBI-81 Treated Expansive Soil Subgrade

Pallavi H N[1], Sureka Naagesh[2]
1*(PG student, Department of Civil Engineering, BMS College of Engineering Bangalore, India)*
2*(Professor, Department of Civil Engineering, BMS College of Engineering Bangalore, India)*

Abstract: *This paper presents the laboratory investigation of an Expansive soil treated with an ecofriendly stabilizer RBI-81 both with and without lime. The soil mixes were tested for Unconfined Compressive Strength, California Bearing Ratio and Indirect Tensile Strength. The RBI-81 stabilizer was added in various percentages (2%, 4%, & 6%) to the soil and tested after curing for different periods (7days, 14days, & 28days). Results indicate optimum percentage of RBI-81 as 4%. However the soil-RBI mixtures had low CBR strength and zero tensile strength. Conventionally, lime is used to improve the strength and reduce swell shrink of an expansive soil. Lime was added to soil treated with 4% RBI after determining Initial consumption of lime (ICL) as 6%. The results indicate that addition of lime to soil–RBI-81 mixtures significantly increased the compressive strength, indirect tensile strength and CBR value. Further, longer curing period resulted in improvised strength.*
Keywords: *Curing, Expansive soil, Hydrated Lime, RBI-81, Stabilizers.*

I. Introduction

The Flexible pavements depend more on the subgrade soil for transmitting the traffic loads. Problems associated to the design of pavements are the effect of repetitive loading, swelling and shrinkage of sub-soil and frost action. Expansive Clays are considered as the problematic deposits for civil engineering constructions since they are susceptible for volume change due to seasonal moisture variation and temperature. The drastic changes in characteristics of expansive clays upon exposure to moisture and temperature changes are the main cause for damage of facilities built in them. Therefore stabilization of expansive clay is essential for supporting the foundation of the structure. Stabilization technique may be mechanical or chemical, or both.

In present work, the possibility of stabilizing an expansive soil with chemical stabilizers RBI-81 and lime are investigated. Lime is considered to be the most suitable stabilizing agent particularly for clays. The lime content required for stabilization depends on role of lime. Short term function affects the plasticity whereas the long term function affects the strength.

II. Literature Review

There are various techniques adopted to stabilize expansive soil for road construction such as chemical modification, mechanical modification, use of geosynthetics, etc. Lime is the commonly used additive for expansive soil wherein Pozzolonic action, Flocculation, cation exchange results in the modification of properties of the soil. However, other non traditional additives are also being used as stabilizers like bioenzymes, polymers, emulsions, and waste materials from industry, etc. Each of the stabilizers needs to be investigated thoroughly before using it in the field.

An inorganic additive RBI-81 stabilizer is finding an application presently for pavement construction on non expansive soils. However, studies on the effect of RBI on expansive soil subgrade are scanty. Hence, an attempt is made to investigate the effect of RBI-81 and lime on compressive and tensile strength of expansive soil.

Earlier Studies:

Patil, et.al (2013), carried out the investigation on Moorum and RBI-81 to improve the properties of subgrade soil. They concluded that the soaked CBR value of soil is improved from 2.56% to 14.76% by stabilizing the soil with 20% moorum and 4% RBI Grade 81.

Few researchers have worked on stabilization of Black Cotton soil using RBI.

Nazia, et.al (2014) studied the effect of RBI on Black Cotton soil. Swell pressure tests were also conducted. The results indicated that 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 and swell pressure of 6% RBI treated black cotton soil was zero.

Haricharan, et.al, (2013) carried out investigation on Expansive soil stabilized with RBI-81. Black cotton soil with varying percentages of RBI-81 (0.5 to 2.5 %) was studied for moisture density relationships and strength of soils. The results obtained show an increase in soil strength with increasing percentage of RBI-81 suggesting its potential applications in soil stabilization.

Lekha, et.al (2014) carried out the laboratory performance of RBI stabilized soil for pavements. The Soaked CBR test results indicate that the stabilizer used works well with cohesive soils. Fatigue life test results indicate a high fatigue life for all treated soils when subjected to repeated loading as compared to the untreated soils. Sushant Bhuyan, 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 and concluded 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.

Nasrizar A.A, et.al, (2010) examined the role of lime content on strength of black cotton soil from Chennai. After knowing the Initial Consumption of Lime (ICL) required for the soil selected four percentages of lime (i.e.; 3%, 5%, 7% and 9%) were added with the soil and UCC specimens were prepared to study the effect of lime on the strength. The results showed that increase in in lime content increase the strength up to certain lime content and beyond that the strength reduces.

Lasledj, et.al, (2008) studied the effect of hydrated lime on the engineering behaviour of highly plastic French clay soil. Tests were performed with different percentages of hydrated lime. The experimental results indicated that increasing the percentage of lime decreases the plasticity index, specific surface and swell properties. Moreover the addition of 8% lime reduced both the swelling pressure and potential to zero after 3 days, whereas there was no significant effect of lime addition (above 6%) and time of curing on plasticity index.

III. Experimental Investigation

3.1 Materials

Black Cotton Soil: The black cotton soil procured from Kukkatnoor, Gadag Road, Hubli is used as sub-grade in the present study. This soil was collected from an open excavation, at a depth of 1m below the natural ground surface. The Soil is classified as clayey soil of high plasticity (CH) and as A-7-6 as per AASHTO classification .The properties of the soil are indicated in Table 1.

RBI Grade 81: RBI Grade 81 is an ecofriendly, chemically stable, grayish commercially available additive with a bulk density of 700 kg/m^3. It was procured from the chemical industry Al-Chemist. It consists of oxides of calcium, alumina, silica, sulphur, etc. along with additives and fibers. In this paper, the word stabilizer is used synonymously with RBI-81.

Hydrated Lime: Commercially available hydrated lime is used in the present study.

3.2 Methodology

The untreated soil was tested for Index properties, compaction characteristics, CBR, UCC and Indirect Tensile Strength as per relevant IS code 2720. Similarly, tests were conducted on soil treated with different percentages of RBI-81 after curing for 7, 14, and 28 days. The optimum dosage of RBI stabilizer was determined based on CBR Strength and UCC strength. In order to further improve the strength characteristics, conventionally used stabilizer lime was mixed after determining the initial consumption of lime (ICL) (by Eades and Grim method). Various tests were performed to evaluate the strength and compaction characteristics of composite mix of expansive soil with RBI and lime.

Table 1: Properties of Expansive soil

Sl. No	Properties	Result	Relevant IS Code
1	Specific Gravity	2.67	IS 2720 Part 3
2	Water Content, w	14.4 %	IS 2720 Part 2
3	Grain size % sand % silt % clay	 12 28 60	IS 2720 Part 4
4	Liquid Limit (%)	90.8	IS 2720 Part 5
5	Plastic Limit (%)	54.6	IS 2720 Part 5
6	Plasticity Index	36.2	IS 2720 Part 5
7	Shrinkage Limit (%)	15.2	IS 2720 Part 6
8	Free Swell Index (%)	70	IS 2720 Part 11
9	Modified proctor Compaction Optimum Moisture Content (%) Maximum Dry Density (g/cc)	 19.46 1.56	IS 2720 Part 8
10	California Bearing Ratio (%)	1.09	IS 2720 Part 16

11	Unconfined Compressive Strength, (kN/m^2)	34	IS 2720 Part 10
12.	IS Classification	CH	
13.	HRB Classification	A-7-6 (20)	

IV. Results And Discussions

The results are discussed under three categories: **a)** Addition of RBI-81 to soil **b)** Addition of lime to soil and
c) Addition of optimum dosage of RBI-81 and lime to soil

4.1 ADDITION OF RBI-81

Expansive soil was treated with 2%, 4% and 6% RBI-81 and cured for 7 days, 14 days and 28 days to study its effect on compaction characteristics, CBR, unconfined compressive strength and tensile strength of the treated samples.

4.1.1 Effect on Compaction characteristics

Modified proctor compaction tests were performed on the treated soil samples. Fig 1 shows the effect of RBI-81 stabilizer on compaction characteristics of the expansive soil. As the dosage of RBI increased from 0% to 6%, the optimum moisture content increased gradually from 19.4% to 27.9% and maximum dry density decreased marginally from 1.56g/cc to 1.50g/cc. This trend is similar to the trend obtained when lime is added to an expansive soil. The reason for increase in water content may be attributed to flocculation of particles requiring more water to coat the particles. The results of modified proctor test are indicated in Table 2.

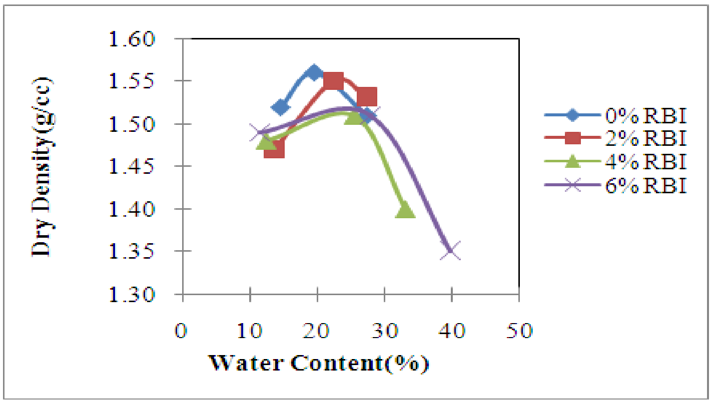

Fig.1 Compaction curve for soil treated with different percentages of RBI-81

Table 2: Variation of compaction characteristics of treated soil

Percentage of RBI-81 added	Optimum Moisture Content (%)	Maximum Dry Density (g/cc)
0%	19.46	1.56
2%	22.3	1.55
4%	25.36	1.51
6%	27.91	1.50

4.1.2 Effect of RBI-81 on CBR

Two identical specimens were prepared as per IS 2720-PART XVI for each curing period (7 days, 14 days, 28 days) , soaked for 4 days and tested for CBR. The results are tabulated in Table 3.

Table 3: Effect of addition of RBI on CBR for different curing periods.

Soil mix	California Bearing Ratio (%)		
	7 days	14 days	28 days
2% RBI	2.19	2.43	2.92
4% RBI	3.28	3.40	3.65
6% RBI	3.35	3.59	3.83

From Table 3, it is observed that untreated soil exhibits CBR of 1.09%. Upon treatment with RBI-81, there is an increase in CBR value. As the dosage of RBI increased from 2% to 6%, for specimens cured for 7days, CBR increased from 2.19% to 3.35%. Upon further curing up to 28days, an overall increase ranging from 11% to 14% in CBR was observed.

This indicates that increase in percentage of RBI and curing period results in improvements in CBR Value of the treated specimens. However, marginal increase of 2% to 5% in CBR value was observed when percentage of RBI was increased from 4% to 6% irrespective of the curing periods.

The increase in strength may be attributed to bonding effect between particles because of formation of cementing agents. However, IRC 37-2012 recommends the minimum value of CBR as 10% for soil subgrade. Hence, it is inferred that the addition of RBI-81 alone will not meet the requirements.

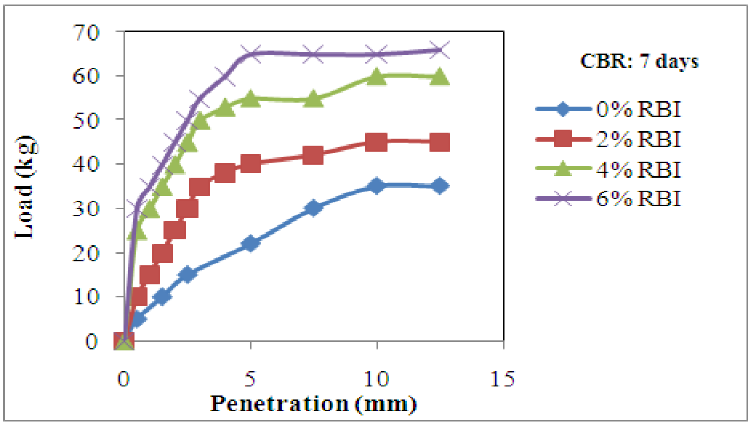

Fig.2 Effect of RBI-81 on CBR for soil specimens cured for 7 days.

4.1.3 Effect on Unconfined compressive strength

Three identical soil specimens treated with different percentages of RBI-81 were tested for unconfined compression strength after 7 days, 14 days, and 28 days of curing. The average value was calculated for each curing period and is shown in Table 4.

Table 4: Variation of UCC value with different percentages of RBI-81 for different curing period

Type of Soil	Unconfined compressive strength (UCC) (kN/m^2)		
Untreated soil	34		
Treated soil	**7 days**	**14 days**	**28 days**
2% RBI	71.6	87.3	96.1
4% RBI	141.2	215.8	257.0
6% RBI	193.2	225.1	269.2

From Table 4, it is observed that untreated soil exhibits compressive strength of 34 kN/m^2. Upon treatment with RBI-81, there is an increase in UCC value. As the dosage of RBI increased from 2% to 6%, for specimens cured for 7 days, compressive strength increased from 71.6 kN/m^2 to 193.2 kN/m^2. Specimens treated with 6% RBI and cured for 28 days, exhibits compressive strength of 269 kN/m^2.

This indicates that increase in percentage of RBI and curing period results in improvements in UCC Value of the treated specimens. Upon further curing up to 28 days, increase in UCC was observed as shown in Table 4. It is also observed that the maximum increase in compressive strength of 82% was observed when curing period increased from 7 days to 28 days for specimens treated with 4% RBI-81 Stabilizer.

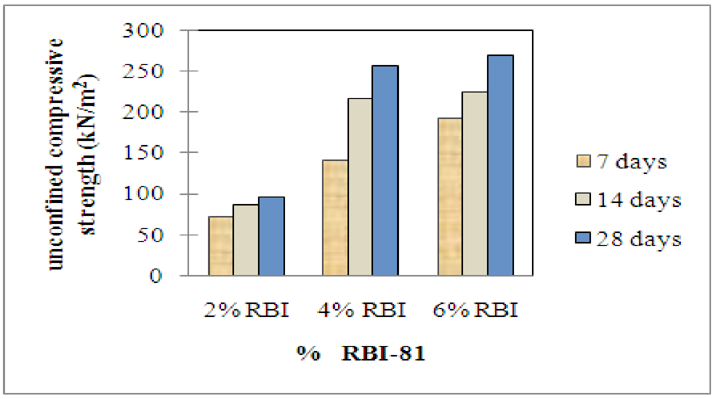

Fig.3 Unconfined compressive strength for soil treated with RBI-81 at different curing periods

The Fig 3 shows an increasing trend of unconfined compressive strength values for various percentages of RBI-81 for different curing periods. It is observed that there is marginal rise in UCC strength when RBI -81 content was increased from 4% to 6%.

4.1.4 Effect on Indirect Tensile Strength

Indirect tensile tests were conducted as per ASTM D4123-1995 on soil specimens treated with 4% RBI. Three identical specimens were prepared for each curing period and average of three trials is reported as the value. The diameter of specimen was 100mm and height 80mm. The specimens treated with 4% and 6% RBI and cured for different periods (7, 14, and 28 days) exhibited zero tensile strength.

Based on the CBR and UCC strength, the optimum percentage of RBI-81 was taken as 4%. However, the minimum required unconfined compressive strength for subgrade is 700 kN/m^2. Hence addition of RBI-81 alone will not meet the requirements. Therefore further strength improvement was investigated by the addition of lime to soil.

4.2. ADDITION OF LIME TO SOIL

The percentage of lime to be added to soil is determined by Initial consumption of lime (ICL) value. The ICL value is the minimum amount of lime to be added to a soil to enhance the pH value to 12.4. This was determined by pH method and by liquid limit method. Both the methods indicated the ICL value as 6%.

4.2.1 pH test:

In order to determine the ICL value, pH method (Eades and Grim method) was adopted. Test was conducted to fix the minimum consumption of Lime required for soil stabilization. The ICL value was found to be 6%.

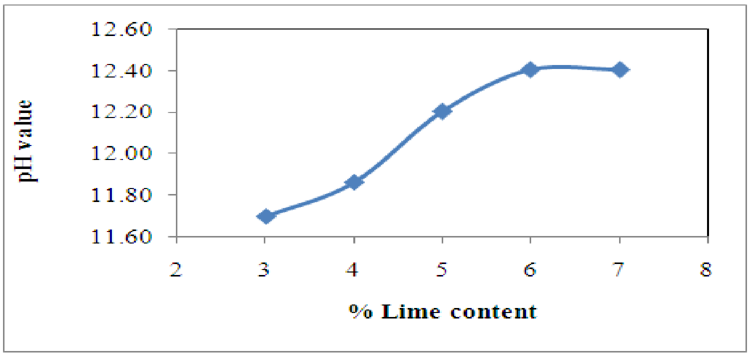

Fig.4 Initial Consumption of Lime

4.2.2 Tests performed with addition of lime:

The properties of expansive soil such as compaction characteristics, CBR and UCS tests were performed for soil treated with 6% lime and results are as shown in Table 5 below.

Table 5: Properties of Expansive soil with 6% lime addition

Soil mix	Modified proctor compaction		Soaked CBR, %			UCC, kN/m2		
			Curing, days			Curing, days		
	OMC, %	MDD, g/cc	0	7	28	0	7	28
Untreated Soil	19.46	1.56	1.09	-	-	34	-	-
Soil + 6% lime	28.1	1.45	-	5.4	9.63	-	467	672

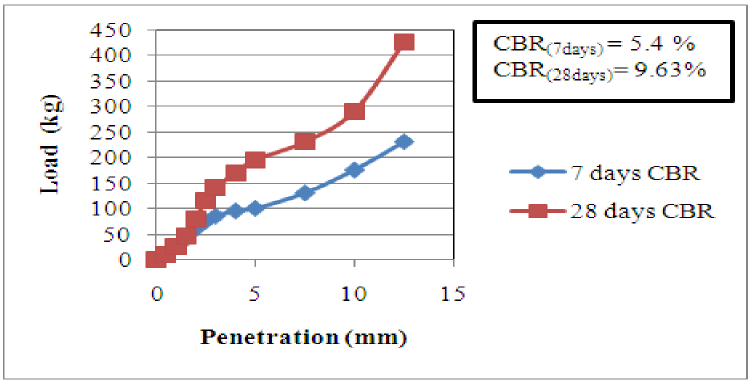

Fig.5 CBR curves for Soil treated with 6% Lime

It is seen from Table 5, upon addition of lime to soil, the optimum moisture content increases and maximum dry density reduces**.** This is attributed to flocculation occurring when lime is added. The CBR value increases from 1.09% to about 9.63% for specimens cured for 28 days. Soil treated with 6% Lime exhibited a CBR of 9.63% which is little short of the required subgrade strength. The unconfined compressive strength increased from 34 kN/m^2 to 672 kN/m^2 upon curing for 28days.

The indirect tensile strength test was conducted on 6% lime treated soil for three identical specimens cured for different periods and the results are shown in Table 6.

Table 6: Indirect tensile strength of soil treated with 6% Lime for different curing periods

Mix Designation	Indirect tensile strength (MPa)		
	7 days	14 days	28 days
Soil + 6% lime	0	0	0.0095

Specimens cured for 28 days exhibit a low tensile strength of 0.0095MPa. However, for specimens cured for 7 days and 14 days tensile strength was zero. Hence, an attempt has been made to combine both RBI-81 and Lime with their optimum dosages for economy so as to achieve the minimum required CBR strength and Unconfined Compressive Strength of subgrade.

4.3 Addition of 4% RBI and 6% lime to soil: Composite mix

The optimum dosage of RBI -81 was found to be 4% and ICL for the soil was found to be 6% as discussed in earlier sections. Further tests were conducted on soil mix with 4% RBI and 6% lime. The results are tabulated in Table 7.

Table 7: Properties of Expansive soil treated with Lime and RBI-81

Soil Mix	OMC %	MDD T /m^3	CBR %	CBR , %		UCC kN/m^2	UCC kN/m^2	
				7days	28days		7days	28days
Untreated Soil	19.46	1.56	1.09	-	-	34	-	-
Soil+ 4%RBI + 6% Lime	26.03	1.61		9.12	15.3		703	800

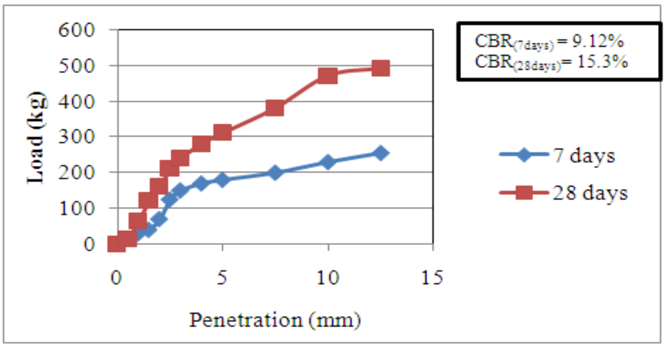

Fig.6 CBR curves for BC Soil treated with 4% RBI and 6% Lime

The CBR of 7 days cured specimens was found to be 9.12% which increased to 15.3% upon curing for 28days. The unconfined compressive strength of 7 days cured specimens is 703kN/m^2 which increased to 800kN/m^2 upon further curing of specimens of the composite mix. However, the required unconfined compressive strength for lime stabilized soils for subgrade layer of pavement is 700kN/m^2. Therefore the expansive soil can be used as a subgrade after treatment with 4% RBI and 6% lime.

The indirect tensile strength tests were conducted on three identical composite mix specimens for different curing periods 7, 14, and 28 days and the results are shown in Table 8. The composite mixture of soil with RBI and lime exhibited tensile strength of 0.0117MPa just after 7days of curing. Specimens cured for 28 days of exhibited a tensile strength of 0.024Mpa. However, it is known that higher tensile strength corresponds to stronger cracking resistance.

Table 8: Split Cylinder test results for soil treated with 4% RBI and 6% Lime at different curing periods

Mix Designation	Indirect tensile strength (MPa)		
	7 days	14 days	28 days
Soil + 4% RBI + 6% Lime	0.0117	0.0158	0.024

4.4 Comparison

The Fig 7, Fig 8 and Fig 9 shows CBR, UCC and Indirect Tensile Strength values compared for untreated soil and treated soil cured for 7 days and 28days.

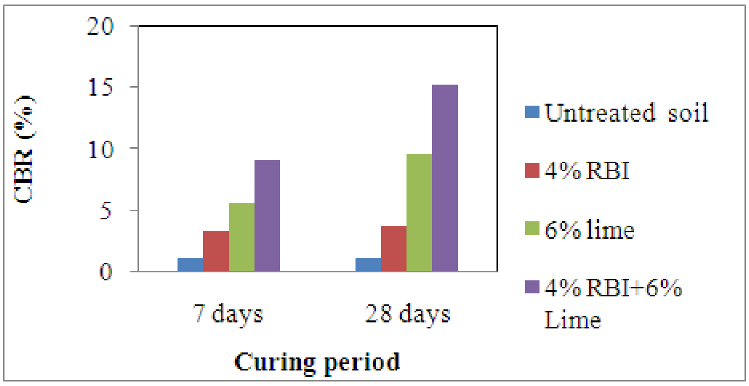

Fig.7 CBR for specimens cured for 7days and 28days

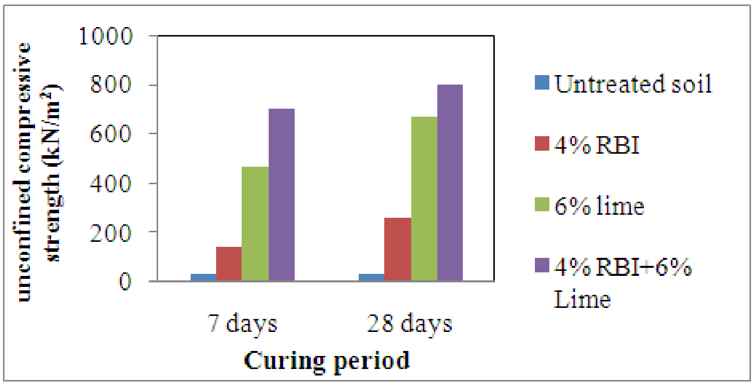

Fig.8 Unconfined compressive strength for specimens cured for 7days and 28days

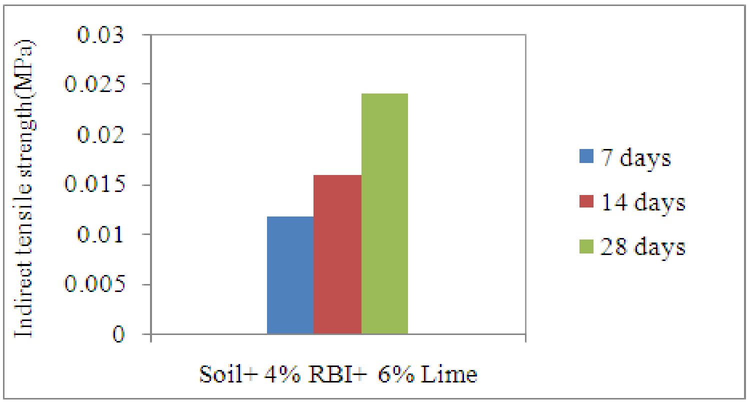

Fig.9 Tensile strength of soil-Lime-RBI-81 mix for different curing periods.

V. Conclusions

Based on the experimental investigation on effect of lime and RBI-81 on expansive soil, the following conclusions are drawn:

1. Expansive soil, characterized as highly plastic, with LL=90% exhibited a low CBR value of 1% and UCS of 34 kN/m^2.
2. Addition of 2% to 6% RBI-81 to the soil resulted in reduction of plasticity index. However, the reduction in plasticity characteristics was marginal between 4% and 6% of RBI.
3. Upon addition of RBI (0% to 6%), the CBR increased from 1% to 3.8% , Unconfined compressive strength increased from 34kN/m^2 to 193kN/m^2 for specimens cured for 7days and to 269kN/m^2 for specimens cured for 28days .The strength increase was marginal between 4% and 6% RBI addition. Hence 4% RBI is considered for further tests with lime.

4. The ICL value of lime was found to be 6% for the soil. Addition of 6% lime to soil resulted in CBR of 9.6% and UCC of 672kN/m^2.
5. Addition of 6% lime to soil treated with 4% RBI -81, resulted in unconfined compressive strength of 703 kN/m^2.
6. The soil specimens treated with RBI-81 did not exhibit tensile strength. The indirect tensile strength value for composite mix was found to be 0.024 MPa for samples cured for 28 days. This value observed was higher than that of the corresponding values obtained either with addition of RBI-81 or lime alone to the soil.
7. Thus, the study shows that the addition of RBI-81 alone is not sufficient for highly plastic soils irrespective of the curing period. Lime can be added with RBI-81 to achieve the desired strength.

Acknowledgement

The authors extend their sincere thanks to Dr. R. Satya Muthy, Dr. H. S. Jagadeesh, Professors of Civil Engineering Department, BMSCE, Faculty and staff of Civil Engineering Department, BMSCE for their encouragement and support to carry out this work.

References

[1] Lekha B.M. and A.U. Ravi Shankar, International Journal of Civil Engineering Research ISSN 2278-3652 Volume 5, Number 2 (2014): "Laboratory Performance of RBI 81 Stabilized Soil for Pavements".

[2] Manisha Gunturi, P.T.Ravichandran, R.Annadurai, Divya Krishnan.K IJRET: International Journal of Research in Engineering and Technology ISSN: 2319-1163 | pISSN: 2321-7308 " Study on strength characteristics of soil using soil stabilizer RBI-81"

[3] B.M.Patil and K.A.Patil International Journal of Scientific & Engineering Research, Volume 4, Issue 5, May 2013 ISSN 2229-5518 "Improvement in Properties of Subgrade Soil by Using Moorum and RBI Grade 81"

[4] LASLEDJ Abdelmadjid, AL-MUKHTAR Muzahim (2008) "Effect of Hydrated Lime on the Engineering Behaviour and the Microstructure of Highly Expansive Clay".

[5] Nazia Nouf , Sureka Naagesh , Dept of Civil Engineering, BMSCE, Bangalore, International Journal of Research Development in Engineering and Technology, 2014 , ISSN 2347-6435 "Effect of RBI-81 on properties of Black Cotton soil".

[6] Sushanta Bhuyan, Department of civil engineering, NIT, Rourkela, thesis "Stabilization of blast furnace slag and fly ash using lime and RBI Grade 81".

[7] Nadgouda K.A.,Hegde R.A., Indian Geotechnical Conference – 2010, GEO trendz, IGS-2010 , "The Effect of Lime Stabilization on Properties of Black Cotton Soil".

[8] Bandyopadhyay K. And Bhattacharjee S., Dept. of Construction Engg., Jadavpur University, Kolkata. "Indirect Tensile Strength Test of Stabilized Fly ash".

[9] ASTM D6276-99a Standard Test Method for using pH to Estimate the Soil-Lime Proportion Requirement for Soil Stabilization.