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LABORATORY INVESTIGATION ON BLACK COTTON SOIL STABILIZED WITH NON TRADITIONAL STABILIZER

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ABSTRACT: *The present paper describes a study carried out to check the improvements in the properties of Black Cotton (BC) soil with a non traditional stabilizer. The collected soil samples were treated with a commercially available bio enzyme and the treated soil samples were cured for different curing periods as 0, 7 and 28 days. The engineering properties obtained for different mix proportions of soil and the stabilizer are studied. The results of Consistency limits, Compaction test, Free swell index (FSI), Unconfined Compressive Strength (UCS), California Bearing Ratio (CBR), Durability tests such as Wet Dry (WD) and Freeze Thaw (FT) and Permeability test obtained for different curing periods under soaked and unsoaked conditions have been studied and discussed. Tests were also conducted to determine the chemical composition of untreated and treated soils to understand the mechanism of stabilization. Test results indicate that properties of BC soil, which are important for pavement construction, get enhanced by bio enzyme stabilization.*
Keywords – *Bio enzyme, CBR, Durability test, Free swell index, Permeability, UCS.*

I. INTRODUCTION

The BC soil covers considerably large area, nearly one - third, of Indian land. This BC soil occurs mostly in the central and western parts of India. In North Karnataka region the land under cultivation is mostly of BC soil. It is inorganic clay of medium to high compressibility. It is characterized by high shrinkage and swelling properties and hence the BC soil has been a challenge to the highway engineers. This soil is very hard in dry state, but loses its strength completely when it is in wet condition. Recently many researchers have been trying to use commercial chemicals, enzymes etc. to enhance the soil performance [1, 2]. Enzymes may provide some additional shear strength for some soils and hence the soil stabilization with enzymes should be considered for various applications but only on a case-by-case basis [1]. Brazetti et al. [3] conducted on field experiments in Brazil to study the use of bio-enzyme stabilizer for road construction. The selected soil were sandy clay, silty clay, sandy silt, plastic and non-plastic clay, sandy loam, loam mixed with clay, soil mixtures with pieces of recycled pavement. The field stretches were periodically tested with Dynamic Cone Penetrometer equipment. After their evaluation they reached the conclusion that enzyme stabilization is a good technique for the effective and economic solution for pavement construction.

A laboratory bench scale testing program was conducted by Andrew et al. [4] to evaluate the effectiveness of enzyme treatment on subgrade soil. The objective was to study the potential applicability of tested enzyme for unpaved road in-situ stabilization. The effectiveness of enzyme treatment was evaluated on the basis of statistical measurement of change in CBR strength, soil stiffness and soil modulus. It was concluded that the CBR test appears to be a relatively a good indicator of direct soil strength for testing conditions. Ravi Shankar et al. [5] studied effect of enzyme on lateritic soil and soil blended with sand in terms of UCS, CBR, Compaction and permeability characteristics. It has been observed that the enzyme treated soil showed significant improvement in UCS, CBR for longer curing period. The lateritic soil properties have been much improved by stabilizing with enzyme dosage of 200 ml/ 2 m^3 of soil. By comparing the CBR values of the unblended and blended soil after enzyme treatment, enzyme was found to be not effective for soil containing higher per cent of cohesion less soil. The UCS tests are more realistic than CBR and therefore, for enzyme stabilized soils CBR tests are not recommended. According to Venkatasubramanian et al. [6] bio-enzymatic stabilization resulted significant increase in UCS and CBR of all the three soil tested with varying parameters. Duration of treatment of soil with bio-enzyme played a vital role in improvement of strength. Soil treated with bio-enzyme for 4 weeks duration gives higher strength for all the soil tested maximum rate of increase in UCS was observed to be 200, 160 and 152% for clayey, silty and sandy soils respectively, maximum rate of increase in CBR was observed to be 157, 613 and 673% for clayey, silty and sandy soils respectively. In reality and practice, addition of bio-enzyme gives better performance in the field and ultimately ensures durable and maintenance free pavement.

The main objective of this paper is to study the geotechnical properties of the BC soil

- To study change in these properties by stabilizing with enzyme and to conduct parametric study.
- To evaluate the influence of various parameters such as curing period on stabilized soil.
- To study the chemical composition of untreated and enzyme treated BC soil.
- To study the durability of untreated and enzyme treated BC soil by subjecting the samples to freeze and thaw cycles.

II. EXPERIMENTAL INVESTIGATIONS

2.1 Materials used

Soil: Black cotton soil which is abundantly available in North Karnataka is used for the investigation. Soil sample is collected from the Naragund Taluk of Gadag district of Karnataka.

Enzyme: One commercially available enzyme (Terrazyme) has been used in the present investigation. It is available as a concentrated liquid and is to be diluted with water in specified proportion before mixing with the soil. The manufacturer's information available for this product is presented in Table 1.

According to the literature, when mixed with water and applied, the enzyme solution combines the inorganic and organic material in the soil through a catalytic bonding process, producing a "cementation" action. Soil stabilization using enzymes is a relatively new approach to soil improvement. Enzyme promotes the development of cementitious compounds using the following, general reaction.

$$\mathbf{H_2O + Clay \xrightarrow{Enzyme} Calcium\ Silicate\ Hydrates}$$

Table 1. Enzyme Properties

Physical/Chemical Characteristics	
Boiling Point	212^{o}F
Specific Gravity	1.05
Evaporation Rate	Same as water
Solubility in Water	Complete
Appearance/Odor	Brown liquid, Non-obnoxious

2.2 Enzyme Dosage

The enzyme dosage varies from 200 ml/3m^3 to 200 ml/1m^3 of the soil, and it depends upon soil properties. In this experimental investigation enzyme dosage of 200ml for 1m^3 of soil is considered to study the variation in geotechnical properties of the selected soil. The amount of enzyme required per kg of the soil is calculated below.

Dosage : 200 ml of enzyme for 1.0 m^3 of soil

Weight = Bulk density x Volume

Bulk Density of BC Soil= 1.77g/cc

Volume of soil for 200ml dosage= 1m^3= 1 x 10^6 cc

Therefore weight of soil required for 200ml of dosage = 1.77 x 1.0 x 1000 = 1770 kg

For 1 kg of soil, dosage required = 0.113 ml. For 1ml of dosage, amount of soil required= 8.85kg.

III. RESULTS AND DISCUSSIONS

3.1 Basic tests on BC soil

The test procedures have been performed as per the Indian Standards and the results are depicted in Table 2.

Table 2. Basic properties of BC soil

Sl. No.	Property	BC soil
1	Specific gravity	2.5
2	Grain size distribution (%) a) Gravel b) Sand c) Silt d) Clay	 5 25 54 16
3	Consistency limits (%) Liquid limit Plastic limit Plasticity index	 64 31 33
4	IS Soil Classification	CH
5	Engineering Properties IS standard Compaction a) MDD (g/cc) b) OMC (%) IS modified Compaction a) MDD (g/cc) b) OMC (%)	 1.62 20.45 1.77 16.31
6	CBR Value (%) IS Standard Compaction a) Unsoaked condition b) Soaked condition IS Modified Compaction a) Unsoaked condition b) Soaked condition	 19.45 1.12 28.17 1.04
7	Unconfined compression test IS Standard Compaction (kN/m^2) IS Modified Compaction (kN/m^2)	 152 267
8	Co-efficient of permeability IS standard Compaction (cm/sec) IS modified Compaction (cm/sec)	 0.99×10^{-7} 0.94×10^{-7}
9	Free Swell Index (%)	50

3.1 Atterberg limits

Consistency limits of enzyme treated soil samples for different curing period are presented in Table 3. The enzyme treated soil samples consistency limits were tested immediately after the mixing. It shows the variation of consistency limit with different curing period. The decrease in liquid limit is 12%, plastic limit is

9% and plasticity index is 15% after 8 weeks of curing period. Thus it is observed from table that, there is marginal reduction in Atterbergs limits. Amount of clay content plays a major role in the variation of consistency limits. The mix becomes very stiff after weeks of curing.

Table 3. Atterberg Limits

Curing period (Weeks)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
0	63	31	32
2	62	31	31
4	58	30	28
6	56	28	28
8	56	28	28

3.2 Unconfined Compression Strength

The variation of UCS values with zero, two, four, six and eight weeks curing period are tabulated in Table 4. It is observed from the table that UCS values increase with the increase in curing period. This may be due to the reaction of enzyme with clay which results in cementation effect.

Table 4. Variation of UCS for treated Soil

Curing Period (Weeks)	UCS (kN/m^2)
0	268
2	549
4	631
6	747
8	859

3.3 Compaction test

The modified compaction test results for enzyme treated soil samples are shown in Table 5. From table it is clear that there is no much change in MDD of treated soil, but OMC is observed to be decreasing with increase in curing period.

Table 5. IS Modified Compaction result

Curing Period (Weeks)	MDD (g/cc)	OMC (%)
0	1.77	17.08
2	1.75	17.53
4	1.77	13.64
6	1.80	14.45
8	1.76	13.46

3.4 California Bearing Ratio (CBR) test

Unsoaked and soaked CBR test results for the soil samples are tabulated in Table 6. It is observed that, both unsoaked and soaked CBR values increase with the increase in curing period. This is because soil treated with enzyme renders improved density values by reducing the void ratios. This tendency may be due to effective cation exchange process which generally takes longer period in the absence of such stabilizers.

Table 6. Unsoaked and Soaked CBR test result

Curing Period (Weeks)	Unsoaked CBR (%)	Soaked CBR (%)

0	17.44	1.19
2	44.27	1.34
4	55.45	2.55
6	77.36	3.28
8	79.60	6.84

3.5 Free Swell Index

Free Swell Index test results for enzyme treated soil samples are presented in Table 7. Film of adsorbed water is greatly reduced for treated soil and these soil particles acquire a tendency to agglomerate. As a result of relative movement, the surface area get reduced which in turn reduces the swelling capacity. This causes decrease of FSI values with increase in curing period, as shown in table.

Table 7. FSI test results

Curing Period (Weeks)	FSI (%)
0	18.1
2	18.1
4	8.33
6	8.33
8	8.33

3.6 Permeability Test

The permeability tests are conducted as per standard procedure IS: 2720 (part 17)-1986, Laboratory determination of permeability for treated and untreated soil samples and the test results are given in Table 8.

Table 8. Co-efficient of Permeability results

Curing Period (Weeks)	Permeability (cm/sec)
0	0.94E-07
2	0.88E-07
4	0.78E-07
6	0.73E-07
8	0.70E-07

3.7 Durability Test

The soil samples, both untreated and treated, could not withstand wet and dry cycles. They collapsed as soon as placed in water bath. During FT cycles the entire samples passed 12 cycles and the weight loss was within 14%, hence satisfied the ASTM criteria.

Plot of percentage weight loss versus number of Freeze Thaw cycles for untreated and treated samples shown in Fig. 1. It is observed that loss in weight of soil samples is less for treated soil when compared to untreated soil samples.

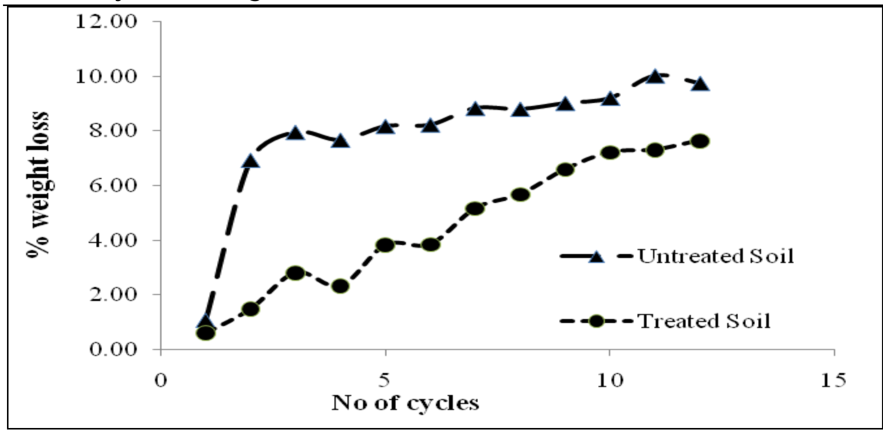

Figure. 1 Percentage weight loss verses no of cycles for untreated and treated FT samples

3.8 Chemical Analysis

Soil samples analyzed for pH, metal concentrations (e.g., Ca, Fe, Al), and inorganic anion concentrations (e.g., Cl^-, NO_3^-, $SO_4^{\ 2-}$) are described in Table 9. The pH values of untreated and treated soil solution are 8.22 and 8.17 respectively. The conductivity of the untreated and treated soil solutions are 1.17 and 1.37 ms/cm. The total dissolved solids in untreated and treated soil solution are 188 and 190 ppm.

Table 9. Metal Concentrations in the untreated and treated soil

Metal	**Concentration (%)**	
	Untreated Soil	**Treated Soil**
SiO_2	57.12	56.6
R_2O_3	14.13	11.77
Fe_2O_3	6.08	2.74
Al_2O_3	8.05	9.022
Cl	0.085	0.115
SO_3	0.091	0.065
CaO	0.0045	0.011
MgO	0.013	0.0073

IV. CONCLUSIONS

Performance of bio-enzyme stabilized soil has been investigated in this work. Based on the tests conducted in the laboratory, the following conclusions have been drawn:

- Amount of clay content plays a major role in the variation of consistency limits. Treated soil was observed to be having lesser plasticity index values.
- Changes are marginal for MDD of enzyme treated soil whereas decrease in OMC is observed to be 13.46% from 17.08% after 8 weeks of curing. This decrease is due to effective cation exchange process which generally takes longer period in the absence of such stabilizers.
- The UCS value increases from 268 kN/m^2 to 859 kN/m^2 when compared to the original soil after 8 weeks of curing period. This is due to the reaction of enzyme with clay which results in cementation effect. The reaction time is significant as the strength at 8 weeks is greater than that at 2 weeks.
- It is observed that the treated soaked CBR values are increased as the curing periods increase which is because soil treated with enzyme renders improved density values by reducing the void ratios.
- FSI value of treated soil reduces to 8.33% from 50% of untreated soil sample after 8 weeks of curing period. This is because the film of adsorbed water is greatly reduced for treated soil and the surface area reduces, resulting in decreased swelling capacity.
- The percentage loss in weight of soil samples is reduced by 22% for treated soil in comparison with untreated soil samples for freeze and thaw cycles, whereas the soil samples could not withstand for wet and dry cycles.

REFERENCES

[1] R Wright Fox, J. G. Macfarlane, and R. F. Bibbens, Alternate Chemical Soil Stabilizers, Minor Research Report. CalTrans. 1993.
[2] B.M. Lekha, A.U. Ravi Shankar, and S. Goutham, Fatigue and Engineering Properties of Chemically Stabilized Soil for Pavements, *Indian Geotechnical Journal, Volume 43, Issue 1*, 2013, 96-104
[3] R. Brazetti, and S. R. Murphy, General usage of Bio-Enzyme stabilizers in Road Construction in Brazil, 32ndAnnual Meeting on Paving Brazil, October 2000.
[4] R. Andrew, S. M. Fadi, E. Nicholos, and M. Elahe. An Evaluation of Strength change on Subgrade soils stabilized with an Enzyme Catalyst solution using CBR and SSG comparisons, Report submitted to University Transportation Centre South Carolina State University Orangeburg, SC, USA, 2003.
[5] A. U. Ravi Shankar, H. K. Rai, and I. R. Mithanthaya, Bio-Enzyme Stabilized Lateritic Soil as a Highway Material, *Journal of the Indian Roads Congress, Paper No. 553*, 2009, 143-151.
[6] C. Venkatasubramanian, and G. Dhinakaran, Bio-Enzymatic Stabilization on Unconfined Compressive Strength and California Bearing Ratio, *Journal of Engineering and Applied Sciences, 6(5)*, 2011, 295-298.