An Experimental Study of Bio-Enzyme on Black Cotton Soil as a Highway Material

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***Abstract* — Bio-enzyme is a natural, non-toxic, non-flammable, non-corrosive liquid enzyme formulation fermented from vegetable, fruit and sugarcane extracts that improves the engineering qualities of soil, facilitates higher soil compaction densities and increases stability. A bio-enzyme called Ecozyme is used to stabilize the expansive soil. Enzymes catalyze the reactions between the clay and the organic cat-ions and accelerate the cat-ionic exchange process to reduce adsorbed layer thickness. For other types of chemical stabilization, chemicals are mixed with soil, which is difficult to mix thoroughly, but bio-enzyme is easy to use as it can be mixed with water at optimum moisture content and then it is sprayed over soil and compacted.**

In this experimental study, a step is taken to stabilize the black cotton soil for the construction of roads and buildings. In this study, strength of the Untreated black cotton soil and Enzymatic soil (Ecozyme + black cotton soil) are tested after the curing period of 0days, 7days, 14days, 21days and 28days for various Ecozyme dosages 200ml/3m^3, 200ml/2.5m^3, 200ml/2m^3, 200ml/1.5m^3. The various tests such as Preliminary test, Compaction test, Unconfined Compression Test (UCC), Soaked and Unsoaked California Bearing Ratio (CBR) test are performed for Untreated soil and Enzymatic soil and also test results are tabulated. The experimental results are shows that Bio-enzyme (Ecozyme) stabilization improves the strength of the black cotton soil up to great extent, which signifies the bearing capacity and the resistance to deformation increased in the stabilized soil.

Keywords*— *Bio-Enzyme, Ecozyme, Black Cotton Soil, Enzymatic Soil, UCC, CBR test.

I. INTRODUCTION

The growth of the population has created a need for better and economical vehicular operation which requires good highways having proper geometric design, pavement condition and maintenance. Black cotton soil mostly present in the districts of Tamil nadu like Ramanathapuram, thirunelveli, Salem, Coimbatore etc. Black cotton soil is good for agriculture because it is highly fertile. But it is not suitable for the construction of roads and foundation due to its instability. Black cotton soil is highly potential for shrinkage and swelling. These negative soil performance characteristics are generally attributed to the nature and quality of the fines present in the material. When poor quality soil is available at the construction site, the best option is to modify the properties of the soil so that it meets the pavement design requirements. This has led to the development of soil stabilization techniques. Since the nature and properties of natural soil vary widely, a suitable stabilization technique has to be adopted for a particular situation after considering the soil properties. Soil improvement by mechanical or chemical mean is widely used. Recently Bio-Enzymes have emerged as a new chemical for stabilization. Bio-Enzymes are chemicals, organic and liquid concentrated substances which are used to improve the stability of soil of soil sub base of pavement structures. Bio-enzyme is convenient to use, safe, effective and dramatically improves road quality.

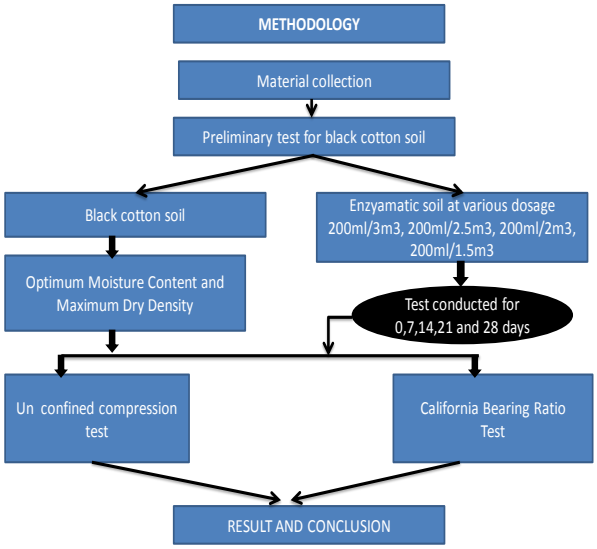

Figure 1. Experiments Performed on Soil

II. LITERATURE REVIEW

Bergmann (2000) concluded through studies that Bio-Enzymes need some clay content to strengthen the soils. It was observed that at least 2% clay is needed for successful stabilization whereas 10 to 15% clay gave very good results. Shukla et al. (2003) used Bio-Enzymes to stabilize five different types of soil ranging from low clay content to very high clay content, engineering properties and strength characteristics were determined and it was found that there is little to high improvement in physical properties. Little improvement could be due to soil constituent, which has low reactivity with Bio-Enzymes. There was improvement in CBR and unconfined compression strength of soils like silty soil to sandy soil. An increase of 65 to 252% in UCS value was observed after 4 weeks of curing. Pavement design

thickness also reduces to 25 to 40 percent. Moreover, in case of scarcity of granular material, only stabilized surface with thin bituminous surfacing can fulfill the pavement design requirement. Shankar et al. (2009) studied the effect of different dosages of Bio-Enzymes on Lateritic soil of Dakshina Kannada (district of India), having liquid limit and Plasticity Index more than 25% and 6% respectively. Tests were conducted on lateritic soil by adding different percentages of sand as well. They concluded that there is medium improvement in physical properties of lateritic soil. Therefore it was suggested that effect of Bio-Enzyme on soil should be examined in laboratory before actual field application. Higher dosage (200ml/2m3 of soil) produced 300% increase in CBR, 450% in unconfined compressive strength and permeability was reduced by 42% after four weeks of curing. It was also observed that enzyme is not effective for cohesion less soil. Lacuoture and Gonzalez (1995) conducted a comprehensive study of the TerraZyme soil stabilizer product and its effectiveness on sub-base and sub-grade soils. The reactions of the soils treated with the enzyme was observed and recorded and compared to the untreated control samples. The variation in properties was observed over a short period only and it was found that in cohesive soils there was no major variation in properties during the early days but the soil showed improved performance progressively. Sharma (2006) has conducted laboratory studies on use of bio-enzyme stabilization of three types of soils namely clay of high plasticity (CH), clay of low plasticity (CL) and silt of low plasticity (ML). It was found that the CH soil had an increase in CBR value with reduction in saturation moisture from 40 to 21% after 4 weeks of stabilization. Also it was found that there was 100% increase in unconfined compression strength. Venkatasubramanian & Dhinakaran (2011) conducted tests on three soils with varied properties and different dosages of Bio-Enzyme. Three soils had liquid limits of 28, 30 and 46% and plasticity index of 6, 5 and 6%. Increase in unconfined compressive strength after 4 weeks of curing was reported as 246 to 404%.

III. MATERIALS

A. Black Cotton Soil

The black cotton soil which was used for this experiment was collected from Kovilpatti which is located in the district of Thirunelveli, Tamilnadu.

Table 1. Properties of Black Cotton Soil

S.No.	Property	Value
1	Specific gravity	2.63
2	Grain size distribution	
	Clay(%)	20.2
	Gravel(%)	0.0
	Sand(%)	11.8
	Silt(%)	68.0
3	Atterberg's limits	
	Plastic limit(%)	35.71
	Liquid limit(%)	54
	Plasticity index(%)	18.29
4	Maximum dry density (Kn/m^3)	14.32
5	Optimum moisture content(%)	24
6	C.B.R(%)	
	Unsoaked	5.3
	Soaked	1.10
7	Unconfined compressive strength (Kn/m^3)	40

B. Eco-zyme

Eco-zyme is a non-toxic formulation of enzyme rich materials that is manufactured through a natural fermentation process using only sugars. Eco-zyme is also blended with a biodegradable surfactant that reduces the surface tension, bringing the enzymes in closer contact with the soil materials, further promoting enzymatic reactions. When mixed with water and applied during compaction, eco-zyme acts upon the soil's organic fines through a catalytic bonding process producing a strong cementation effect. The result is a durable and water-resistant mix that can be used in any climatic environment as a sub-base or as primary surface natural, organic compounds. The enzymes have been tailored to provide the "lock" for numerous soil materials and promote the desired alteration of their properties, causing a rapid cementation process to occur.

Table2. Property of Eco-zyme

S.No.	Properties	Value
1	Boiling Point	212º F
2	Specific Gravity	1.04-1.06@ 25ºC
3	Evaporation Rate	Same as water
4	Solubility in water	Complete
5	Appearance/ Odor	Brown Liquid/ odorless
6	PH	Neutral

C. Amount of Eco-zyme

The amount of eco-zyme varies from 200ml/3m^3 to 200ml/1.5m^3

For specimen 1
200ml for 3.0 m^3 of soil = 1.43 * 3.0 *1000
= 4290 kg of soil
For 1 kg = 0.0466 ml of enzyme

For specimen 2
200ml for 2.5 m^3 of soil = 1.43 * 2.5 *1000
= 3575 kg of soil
For 1 kg = 0.0559 ml of enzyme

For specimen 3
200ml for 2.0 m^3 of soil = 1.43 * 2.0 *1000
= 2860 kg of soil
For 1 kg = 0.0699 ml of enzyme

For specimen 4
200ml for 1.5 m^3 of soil = 1.43 * 1.5 *1000
= 2145 kg of soil
For 1 kg = 0.0932 ml of enzyme

IV. EXPERIMENTAL WORK

A. California Bearing RatioTest(CBR)

Black cotton soil was treated with 4 dosage of enzyme (eco-zyme) at optimum moisture content 24%.California Bearing Ratio test was conducted for different proportions of black cotton soil with eco-zyme. 4days soaked CBR values of black cotton soil with different enzyme dosages in various curing days are given below,

Table 3. Soaked CBR test results (%)

Soil enzyme Dosage	Curing period				
	0days	7days	14days	21days	28days
Untreated soil	1.10				
200ml/3m^3	1.31	1.43	1.72	2.2	4.9
200ml/2.5m^3	1.39	1.48	1.81	2.31	5.15
200ml/2m^3	1.44	1..58	1.87	2.46	5.36
200ml/1.5m^3	1.49	1.64	1.90	2.70	5.5

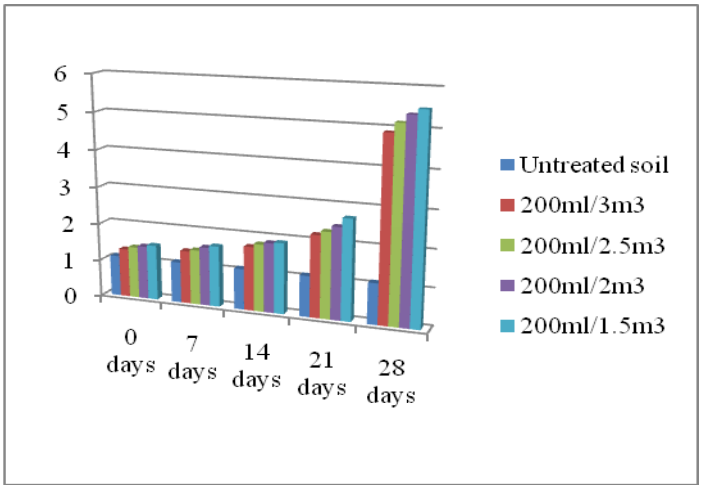

Figure 2. Soaked CBR test

Table 4.Unsoaked CBR Test Results (%)

Soil enzyme Dosage	Curing period				
	0days	7days	14days	21days	28days
Untreated soil	5.3				
200ml/3m^3	5.45	6.1	7.09	7.8	7.92
200ml/2.5m^3	5.60	6.3	7.12	7.82	7.99
200ml/2m^3	5.82	6.7	7.3	7.89	8.10
200ml/1.5m^3	5.94	6.9	7.6	8.0	8.3

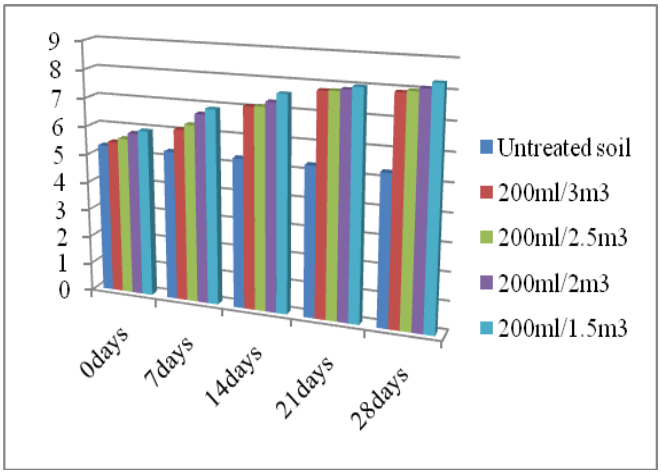

Figure 3. Unsoaked CBR test

B. Unconfined Compression Test

The materials used for the tests include the Black cotton soil and eco-zyme (Bio-Enzyme). The Black cotton soil obtained from the field was tested in the laboratory for Unconfined Compressive Strength. The Unconfined Compressive Strength was evaluated by stabilization with variable dosages of enzyme(200ml/3m^3, 200ml/2.5m^3,200ml/2m^3 and 200ml/1.5m^3) for 28days (0 days,7 days,14 days,21 days,28 days) of curing. The test results have been given in table.

Table 5. Unconfined compression test (N/cm^2)

Soil enzyme Dosage	Curing period				
	0days	7days	14days	21days	**28days**
Untreated soil	40				
200ml/3m^3	44	45	49	50	58
200ml/2.5m^3	47	49	54	57	64
200ml/2m^3	54	56	59	66	68
200ml/1.5m^3	57	58	62	68	71

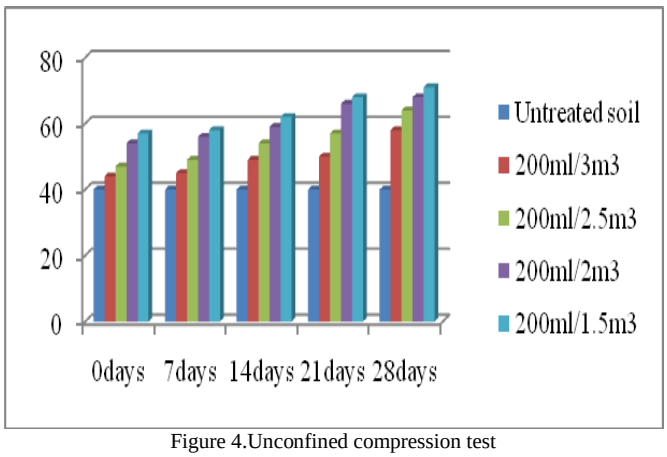

Figure 4.Unconfined compression test

V. CONCLUSION

Performance of Bio-Enzyme stabilized soil has been investigated in this work. Based on the tests conducted in the laboratory, the following conclusions were drawn:

- Best result for unsoaked CBR value was observed with dosage 200ml per 1.5m^3 the percentage increase for soil sample *S1, S2, S3 and S4*, 7.92%, 7.99%, 8.10% and 8.3% respectively.
- After 28 Days of stabilization with eco-zyme dosage of 200ml per 1.5m^3 the soaked CBR value for the soil Samples S1, S2, S3 and S4 was 4.9%, 5.15%, 5.36% and 5.5%.
- With the application of eco-zyme best result for ucc values was observed with the dosage 200ml/1.55m^3 of eco-zyme at curing period of 28 days.

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