

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

Stabilization of Black Cotton Soil using Bio-Enzyme for a Highway Material

Joydeep Sen¹, Jitendra Prasad Singh²

P.G. Student, Department of Geotechnical Engineering, Birsa Institute of Technology, Sindri, Jharkhand, India¹

Associate Professor, Department of Civil Engineering, Birsa Institute of Technology, Sindri, Jharkhand, India²

ABSTRACT: Bio-enzyme is a natural, non toxic, non flammable, non-corrosive liquid enzyme formulation fermented from vegetable extracts that improves the engineering qualities of soil, facilitates higher soil compaction densities and increases stability. Enzyme 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 study Black cotton soil with varying index properties have been tested for stabilization process and strength of the stabilized soil were evaluated after curing period of 0 days, 14days, 21 days and 28 days for various enzyme dosages 200ml/3m³, 200ml/2.5m³, 200ml/2m³, 200ml/1.5m³. The tests which were carried out are the California Bearing Ratio (CBR) test and Unconfined Compressive strength (UCS) test of the soil specimen. The test results indicate that bio-enzyme stabilization improves the strength of BC soil up to great extent, which indicate the bearing capacity and the resistance to deformation increases in stabilized soil.

An attempt has been made to study the properties of soil modified with the bio-enzyme, in order to use this technology for low volume roads. Based on laboratory findings, field trials were carried out using bioenzyme in some of roads in India. Moreover, in case of scarcity of granular material, only bio-enzyme stabilized surface with thin bituminous surfacing also can fulfil the pavement design requirement. Adopting the IRC method based on soil CBR, the pavement design thickness on stabilized soil also reduces 25 to 40 percent.

KEYWORDS: Bio-Enzyme, Terrazyme, Soil Stabilization, Black Cotton Soil, CBR and UCS.

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. Many areas of India consist of soils with high silt contents, low strengths and minimal bearing capacity. 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. The objective of any stabilization technique used are to increase the strength and stiffness of soil, improve workability and constructability of the soil and reduce the plasticity index.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

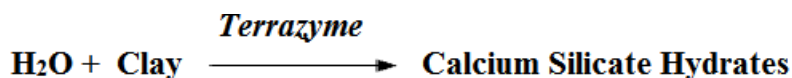
Vol. 4, Issue 12, December 2015

1.2 Mechanism of Soil Stabilization by Bio-Enzyme:

In clay water mixture positively charged ions (cat-ions) are present around the clay particles, creating a film of water around the clay particles that remains attached or adsorbed on the clay surface. The adsorbed water or double layer gives clay particles their plasticity. In some cases the clay can swell and the size of double layer increases, but it can be reduced by drying. Therefore, to truly improve the soil properties, it is necessary to permanently reduce the thickness of double layer. Cat-ion exchange processes can accomplish this. By utilizing fermentation processes specific micro organisms can produce stabilizing enzyme in large quantity. The soil stabilizing enzymes catalyse the reactions between the clay and the organic cat-ions that accelerate the cat-ionic exchange without becoming part of the end product.



Bio-Enzyme(Terrazyme) replaces adsorbed water with organic cat-ions, thus neutralizing the negative charge on a clay particle.



I. RELATED WORK

This chapter details the various tests conducted in the laboratory in order to study the characteristics of sub-base material. In the present study, samples were collected to assess the suitability of Bioenzyme (Terrazyme) as soil stabilizer in black cotton soil.

2.1 MATERIALS:

The soil used in this study is black cotton soil (dark grey in colour) which is collected from Baliapur are of Dhanbad district, Jharkhand. Liquid stabilizer Bio-Enzyme (Terrazyme) is used as a admixture to stabilize the investigating soil. The manufacturer's information is available for this product in table no. 1.

Table No. 2.1 Enzyme Properties

Physical/Chemical Characteristics	
Boiling Point	212° 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/3.5m³ to 200 ml/1.5m³ of the soil, and it depends upon soil properties. In this experimental investigation the Enzyme Dosages assumed for Expansive Clayey soil was 200 ml for bulk volume 3.5 m³ to 1.5 m³ of soil.

Bulk Density of BC soil = 1.56 g/cc

Bulk Density = Weight / Volume

Weight = Bulk Density x Volume

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

For Dosage 1

200 ml for 3.0 m³ of soil = 1.56 x 3.0 x 1000 = 4680 kg of soil

For 1 kg = 0.042 ml of Enzyme

For Dosage 2

200 ml for 2.5 m³ of soil = 1.56 x 2.5 x 1000 = 3900 kg of soil

For 1 kg = 0.051 ml of Enzyme

For Dosage 3

200 ml for 2.0 m³ of soil = 1.56 x 2.0 x 1000 = 3120 kg of soil

For 1 kg = 0.064 ml of Enzyme

For Dosage 4

200 ml for 1.5 m³ of soil = 1.56 x 1.5 x 1000 = 2340 kg of soil

For 1 kg = 0.085 ml of Enzyme.

Table 2.2 Enzyme Dosages

Dosage	200ml/m ³ of soil	ml/kg of soil
1	3.0	0.042
2	2.5	0.051
3	2.0	0.064
4	1.5	0.085

III. EXPERIMENTAL RESULTS

3.1 BASIC PROPERTIES OF INVESTIGATING SOIL:

Table 3.1 Properties of black cotton soil.

Sl. No	Property	Value	I S Codes
1	Specific Gravity	2.48	IS 2720 (part III)
2	Atterberg limits	61.40	IS 2720 (part V)
	Liquid limit (%)	34.00	
	Plastic limit (%)	27.40	
	Plasticity index	16.60	
3	Grain size distribution		IS 2720 (part IV)
	a) Gravel (%)	0.00	
	b) Coarse Sand (%)	10.17	
	c) Fine sand (%)	20.87	
	d) Silt & Clay (%)	68.70	
4	USCS Soil Classification	CH	
5	Free swell index %	72.80	IS 2720(part XL)
6	Engineering Properties		IS 2720 (part VII) IS 2720 (part II)
	Light Compaction		
	a) Max dry density, (kN/m ³)	14.80	
	b) O.M.C %	23.00	
7	CBR Value (%)		
	IS Standard Compaction a) Un-soaked condition	2.86	

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

	b) Soaked condition	1.19	IS 2720 (part XVI)
8	Swelling Pressure (kN/m ²)	48.00	IS 2720(part XLI)
9	Unconfined compression test (kg/cm ²)	3.53	IS 2720 (part X)
10	Co-efficient of Permeability	1.5x10 ⁻⁸ cm/sec	IS: 2720 (part XVII)

3.2 Atterberg limits:

The effect of Terrazyme at different dosage on index properties (Liquid limit, Plastic limit and Plasticity index) of Black Cotton (BC) soil have been presented in table no. 3.1. The enzyme treated soil sample's consistency limits were tested immediately after the mixing. The mix becomes very stiff after weeks of curing.

Table 3.2 Consistency limits of stabilized black cotton soil

Dosage number	Enzyme dosage	Black Cotton soil		
		Liquid limit (%)	Plastic limit (%)	Plasticity index
0	Un treated	61.40	34.00	27.40
1	200 ml/3.0 m ³	60.22	33.50	26.72
2	200 ml/2.5 m ³	59.00	32.79	26.21
3	200 ml/2.0 m ³	57.75	32.23	25.52
4	200 ml/1.5 m ³	56.49	31.70	24.79

3.3 Compaction Test:

Black cotton (BC) soil with different dosage of Terrazyme, StandarD Proctor's Test was conducted. Test results are presented in table 3.2.

Table 3.3 OMC and MDD of stabilized Black Cotton soil

Dosage No.	Enzyme Dosages	Standard Compaction (Light Compaction)	
		OMC (%)	MDD (gm/cm ³)
0	Untreated	23.00	1.486
1	200ml/3m ³	22.40	1.521
2	200ml/2.5m ³	22.10	1.564
3	200ml/2m ³	21.00	1.590
4	200ml/1.5m ³	20.4	1.633

The increase in MDD with different dosages of Terrazyme is uniform till the final dosage 200ml/1.5m³. This trend happens due to the formation of transitional compounds that had higher densities in the range of 3rd -4th enzyme dosage.

3.4 Unconfined Compression Strength (UCS) Test:

Unconfined compression strength of black cotton soil was evaluated by stabilization with variable dosages of enzyme for 0, 7, 14, 21 and 28 days curing. The specimens were prepared and kept in desiccators to retain the moisture

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

of the sample so that reaction between soil particle and enzyme may be continued. Number of samples were tested with different dosage of enzyme i.e 200ml for 3, 2.5, 2, 1.5m³ of soil. The test results are summarized in table 3.3.

Table 3.4 UCS value of BC soil with varying enzyme dosage & curing time

Dosage No.	Dosages	UCS of soil in (KPa) for period of treatment				
		0 day curing	7 days curing	14days curing	21days curing	28days curing
0	Untreated	3.53	3.78	4.05	4.21	4.63
1	200ml/3m ³	4.00	5.10	5.75	6.17	6.92
2	200ml/2.5m ³	4.64	5.55	6.37	7.10	7.74
3	200ml/2m ³	5.20	6.41	7.00	7.82	8.63
4	200ml/1.5m ³	5.57	6.64	7.27	7.95	8.86

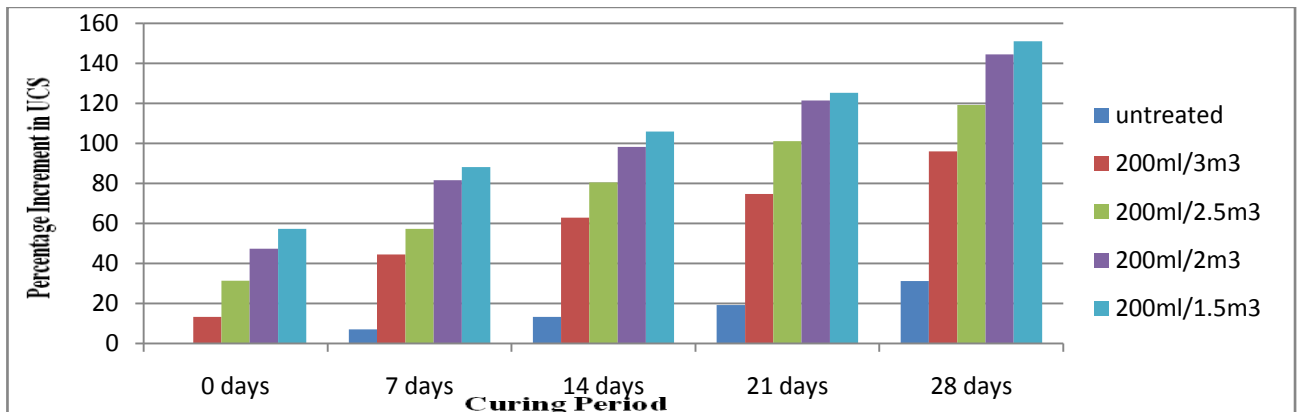


Fig 3.1 Percentage Increment in UCS

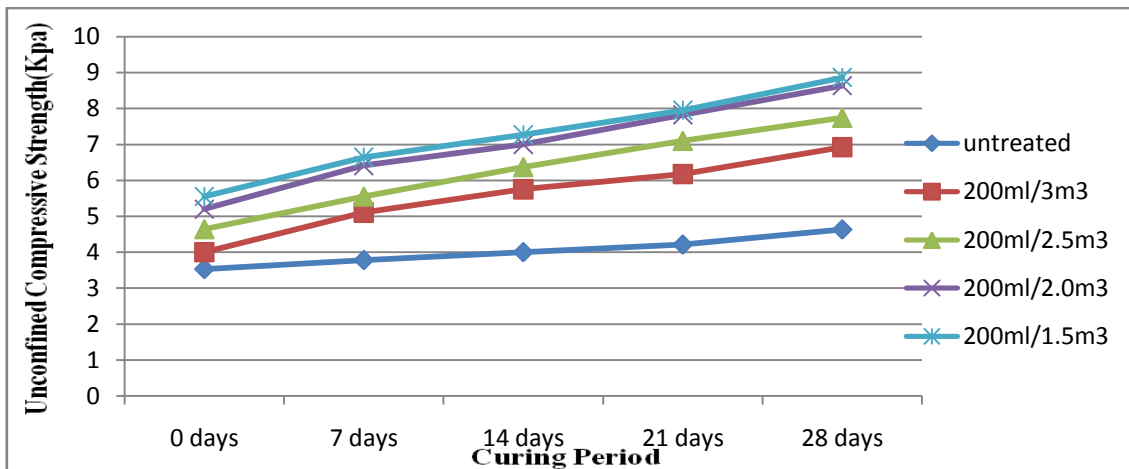


Fig 3.2 Variation of UCS for different curing period on expansive clayey soil

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

3.5 California Bearing Ratio (CBR) Test:

Black cotton soil was treated with 4 dosage of enzyme (Terrazyme) at optimum moisture content 23%. CBR moulds were prepared with different dosages by standard proctor method and kept by covering plastic bags for testing on different days. Later for soaked conditions moulds were kept in water condition for 4 days and then tested for CBR.

The soaked CBR values of black cotton soil with different enzyme dosages in various curing days are given in table 3.5.

Table 3.5 CBR test of BC soil with varying enzyme dosage and curing time

Dosage No.	Soil Enzyme Dosage	Curing Period				
		0 day	7 days	14 days	21 days	28 days
0	Untreated	1.19%				
1	200ml/3m ³	1.20	1.32	2.40	3.70	5.21
2	200ml/2.5m ³	1.22	1.67	2.59	3.83	5.40
3	200ml/2m ³	1.23	1.93	2.91	3.97	5.63
4	200ml/1.5m ³	1.25	2.00	3.12	4.21	5.80

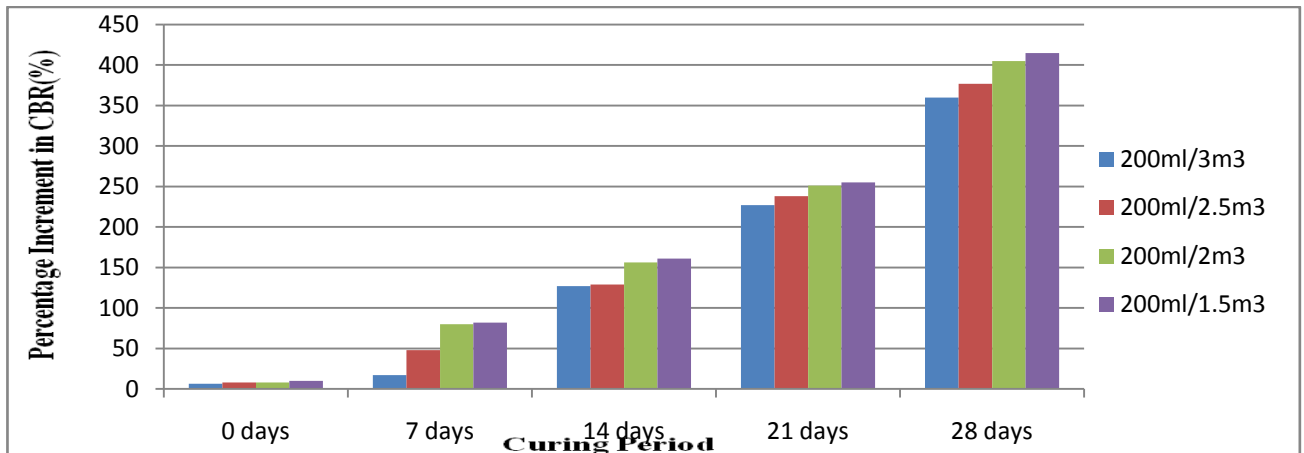


Fig 3.3 Percentage Increment in CBR

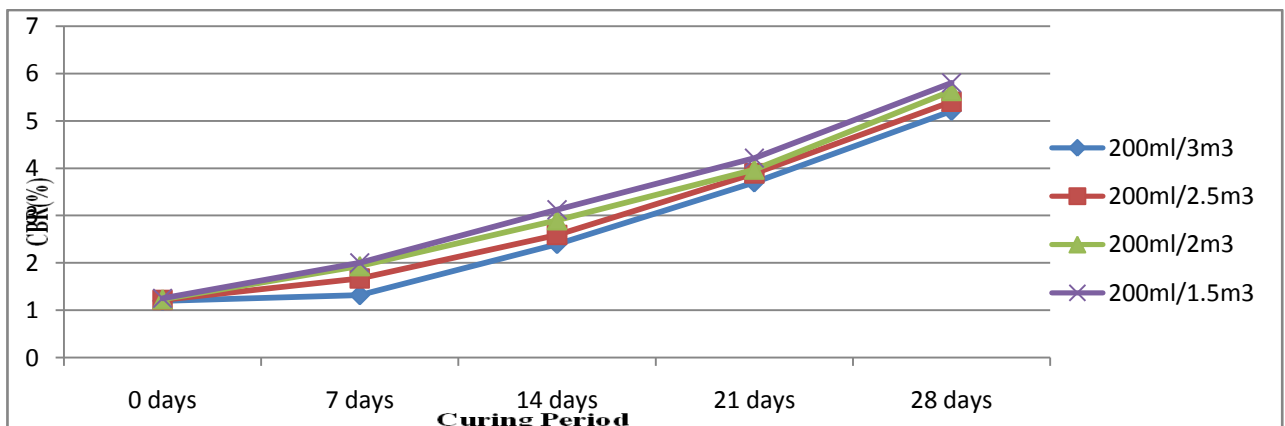


Fig 3.4 Variation of CBR for different dosage & curing period

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

IV. 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:

- Amount of clay content plays a major role in the variation of consistency limits. It is found that liquid limit decreases from 61.40% to 56.49% while the plastic limit reduces from 34.00% to 31.70% at the dosage no.4
- Changes are marginal for MDD of enzyme treated soil which is from 1.486 gm/cm³ to 1.633 gm/cm³ where as decrease in OMC is observed to be 23.00% to 20.40%. The decrease is due to effective cat ion exchange process which generally takes longer period in the absence of such stabilizers.
- The UCS value increases from 3.53 KN/m² to 8.86 KN/m² when compared to the original soil after 4 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 4 weeks (150.99% increase from original soil) is greater than that at 1 week (88.10% from the original soil).
- 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. Initially for the local soil the soaked CBR value was 1.19% but with stabilization after 4 weeks of curing the soaked CBR value was 5.80% which shows an increase of 387% from the original soil.

REFERENCES

1. Bajpai, P. (2014), "Non-conventional Soil Stabilization Techniques The Way Forward to an Aggregate Free Pavement and a Cost Effective Method of Road Construction", International Journal of Scientific and Engineering Research, Vol.05, 1063-1066.
2. Faisal Ali "Stabilization of Residual Soils Using Liquid Chemical"(2012)Civil Engineering Department, Faculty of Engineering, National Defense University of Malaysia, Kuala Lumpur, Malaysia.
3. Agarwal, P., and Kaur, S. (2014), "Effect of Bio Enzyme Stabilization on Unconfined Compressive Strength of Expansive.
4. Shukla, M., Bose, S. & Sikdar, P. 2010."Enzyme for stabilization of soil in road construction a cost effective approach". IRC Seminar "Integrated development of rural and arterial road networks for socio-economic development", New Delhi.
5. Venkatasubramanian, C & Dhinakaran, G. 2011. "Effect of bio-enzymatic soil stabilization on unconfined compressive strength and california bearing ratio". Journal of Engineering and Applied Sciences: 6(5):295-298.
6. Brazetti, R. and Murphy, S.R. (2000): "General usage of Bio-Enzyme stabilizers in Road Construction in Brazil", 32nd annual meeting on paving Brazil, October 2000.
7. M B Mgangira 2010"evaluation of the effects of enzyme-based liquid chemical stabilizers on sub-grade soils" CSIR, Built Environment, Pretoria.
8. Marasteanu, M. O., Hozalski, R., Clyne, T. R. & Velasquez, R. 2005. "Preliminary laboratory investigation of enzyme solutions as a soil stabilizer". Minnesota Department of Transportation, Research Services.
9. Manoj Shukla, Sunil Bose and Sikdar, P.K. (2003): "Bio-Enzyme for stabilization of soil in Road construction a cost effective approach", Presented at the IRC Seminar: Integrated Development of Rural and Arterial Road Networks for Socio-Economic development, New Delhi, December 2003.
10. Sharma, A., "Laboratory Study to Use of TerraZyme for Soil Stabilisation", Research Report (unpublished) Central Road Research Institute, New Delhi 2001.
11. 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.