EFFECT OF BIOENZYME AND GEOTEXTILE ON STRENGTH CHARACTERISTICS OF SUBGRADE SOIL

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Abstract – *The most important aspect of any project is its cost, performance, durability and time. Since the conventional methods are very uneconomical and time consuming, there is an urgent need for the development of new techniques which greatly improves the geotechnical properties of soil. The Bio-enzyme, emerged as an organic stabilizer which drastically improves the strength of soil, is environment friendly and economical in long run. In the present study, an attempt is made to determine whether the soil treated with Terrazyme or the soil reinforced with geotextile has developed greater strength over time. The strength characteristics are compared by conducting California Bearing Ratio (CBR) test. The CBR tests are conducted after curing periods of 7, 14, 21 and 28 days from the application of Terrazyme. The CBR tests are also conducted on soil reinforced with a single layer of geotextile placed at different depths. The test results indicate that bio-enzyme improves the strength of soil up to a great extent. Paper also presents microstructure analysis by X-Ray diffraction (XRD) and Scanning Electron Microscope (SEM) techniques.*

***Key Words*: Bio-enzyme, Terrazyme, geotextile, CBR, microstructure analysis, XRD, SEM.**

1. INTRODUCTION

Soil is an important construction material and an overriding factor in many of the civil engineering projects. The performance of buildings, dams and roads greatly depends on the stability of soil upon which it is built. A sub-grade that can transfer huge loads without excessive deformation is considered good and stronger subgrade demands thinner pavement layers. One of the major problems which civil engineers confront during a project is the poor quality of in-situ soil. It may be possible to replace the poor subgrade soil with suitable fill. But the declining availability and increasing cost of high quality soil poses a major challenge.

The use of Bioenzymes in soil has emerged as one of the renewable technologies for improving soil characteristics. When added to a soil, enzymes increased the wetting and bonding capacity of the soil particles. As demonstrated by the termites and white Ants the shelter built by ant saliva is rock hard and not gets washed away in heavy rains. In order to stabilize soils for improving strength and durability, a number of chemical additives, both inorganic and organic, have also been used.

2. LITERATURE REVIEW

Lacuoture and Gonzalez (1995) conducted a comprehensive study on the effects of Terrazyme on sub-base and sub-grade soils. The properties of soil treated with Terrazyme were observed, recorded and compared with that of untreated soil. It was found that soil showed improvement in short period of time but the cohesive soils showed improved performance successively. Bergmann (2000) conducted a study on the effect of bio-enzyme on soils with varying clay content. He concluded that bio-enzyme requires some clay content for imparting strength to the soil. Bergmann conducted a field study to examine the effects of seven different soil stabilizers in The Wood River accessible fishing site and day use area on the Winema National Forest. It was observed that enzyme stabilized section had shown a significant improvement in strength and its surface finish was retained for a long period. Brazetti and S.R. Murphy (2000) explained the benefits of using bioenzyme stabilizer in improving the function and structure of roads, in reducing the incidence of defects on the travel surface that affects the comfort of road users and in increasing the CBR of base layer. Isaac et al (2003) conducted a study to determine the effectiveness of Terrazyme on lateritic soil and clayey soil. An increase in the California Bearing Ratio (CBR) was observed by the addition of Terrazyme. He stated that Terrazyme is suitable for clayey soil and sand but is less useful for silty soils. Manoj Shukla et al (2003) carried out tests on five different types of soils having low clay content to very high clay content. Ravi Shankar et al (2009) conducted tests on lateritic soil to determine the effects of bio-enzyme on soil properties like CBR, Unconfined Compressive Strength (UCS) and permeability for a curing period of 28 days. The test results showed that CBR value increased by 300 % for the blended soil containing 10 % sand and 200 ml/2m^3 of enzyme after 28 days of curing from the application of enzyme. Field studies were also conducted on National Highway which showed that CBR of enzyme treated soil is higher than that of ordinary soil. Venkatasubramanian and Dhinakaran (2011) performed tests to determine the variations in Unconfined Compressive Strength, CBR and plasticity index of soil treated with different dosages of enzyme. Three different soils were selected for study. Enzyme treated soil showed significant improvement in CBR and UCS. M.V. Sravan and H.B. Nagaraj (2015) conducted a study on the use of Terrazyme as a biostabilizer along with cement and lime in Compressed Stabilized Earth Blocks (CSEB). CSEBs prepared with optimum dosages of Terrazyme along with conventional stabilizers were found to have higher wet compressive strength and lesser water absorption values than CSEBs prepared with conventional stabilizers only.

Ayyar and Dipu (1997) studied the effects of coir composites on bearing capacity of sand. It was shown that coir fabrics increases the bearing capacity of sand subgrade significantly. Rajagopal and Ramakrishna (1998) performed a study on coir reinforcement for stabilizing soft soil subgrade. Test results showed that coir geotextiles can be used for improving stiffness and bearing capacity of soft subgrade. Rao and Balan (2000) conducted a comprehensive study on the production, properties and applications of coir geotextiles. Shaheem S. and Tomy Cyriac (2013) conducted a study to assess the performance of coir geotextiles in subgrade reinforcement. It was found that use of coir geotextiles in subgrade reinforcement and soil structure protection was very effective in soft soils.

3. MATERIALS USED

The materials used for the tests include Kuttanad clay, Terrazyme (bioenzyme) and Coir geotextile. The details of the materials used in this study are given below:

3.1 Kuttanad Clay

Soil used in this study was collected from the place Chambakulam, a part of Kuttanad region in Alappuzha District, Kerala. The basic engineering properties of the soil were determined by conducting various laboratory tests such as Unconfined Compressive Strength test, Liquid limit test and plastic limit test, Hydrometer analysis, Standard Proctor Test, California Bearing Ratio Test (CBR) etc. The results obtained were presented in table 1. All the tests were conducted as per SP 36-1(1987).

Table -1: Properties of Kuttanad clay

Properties	Kuttanad clay
Color	ash
Natural Moisture Content (%)	150
Specific Gravity	2.35
Grain Size Distribution	
Clay	60%
Silt	36%
IS Soil Classification	Silty Clay (CH-MH)
Atterberg's Limit (fresh sample)	
Liquid Limit (%)	157
Plastic Limit (%)	33
Plasticity Index (%)	124
Compaction Characteristics	
Maximum Dry Density (g/cc)	1.26
Optimum Moisture Content (%)	36
Unconfined Compressive Strength (kPa)	35
Cohesion (kN/m^2)	18
CBR (Untreated)	1.49%

3.2 Bioenzyme

Bioenzyme used in this study is Terrazyme. Terrazyme is obtained from Avijeeth Agencies, Anna Nagar Chennai, India. Terrazyme is a natural, non-toxic organic stabilizer formulated using vegetable extracts and accepted all over the world as a sound and resourceful road building practice, which completely replaces the conventional granular base and the granular sub base layer of pavement. The properties of Terrazyme are shown in table 2.

Table -2: Properties of Terrazyme

Identity	N-zyme
Hazardous Components	None
Boiling Point	212⁰F
Melting Point	Liquid
Specific Gravity	1.05
Evaporation Rate	Same as water
Solubility in Water	Complete
Appearance/Colour	Brown
Odour	Non-obnoxious
Explosion Hazard	None

Mechanism of Stabilization

The surface of a clay particle, being negatively charged, attracts positive ions. This region of attracted positive ions in solution and the negatively charged surface of the clay is termed as 'diffuse double layer'. The diffuse double layer occurs at the interface between the clay surface and the soil solution. The innermost layer of double layer water, which is held very strongly by clay, is known as adsorbed water. The orientation of water around the clay particles gives clay their plastic properties. In order to improve the soil properties, it is necessary to permanently reduce the thickness of diffused double layer. This can be accomplished by cation exchange process.

Terrazyme catalyzes the reactions between clay and organic cations and accelerates the cation exchange process without becoming a part of the end product. TerraZyme replaces adsorbed water layer of clay particle with organic cations and reduces the thickness of double layer due to which voids between the soil particles reduces and the soil particle gets closer orientation with lower compactive effort. Three different dosages of Terrazyme selected for the study are shown in Table 3.

Table -3: Enzyme dosage

Dosage No:	Dose
1	200ml/3m^3
2	200ml/2m^3
3	200ml/2.5m^3

3.3 Coir geotextile

The Coir geotextile (H_2M_6) used in this study was obtained from Coir Board, Alleppey, Kerala. The Coir geo-textiles find use to reinforce the soils that are poor in tension thereby reducing applied stress on the sub grade and preventing rutting caused by sub grade overstress. Properties of coir geotextile are shown in Table 4.

Table -4: Properties of Coir geotextile

Type		H_2M_6
Mass/unit area (gm/m^2)		454.48
Thickness at 20 kPa (mm)		6.55
Peak load Dry (kN/m)	Warp	8.89
	Weft	6.02
Peak load Wet (kN/m)	Warp	4.44
	Weft	3.50

4. EXPERIMENTAL INVESTIGATION

California Bearing Ratio (CBR) test, Atterberg's limit test and Unconfined Compressive strength test were conducted on the soil sample treated with Terrazyme.

4.1 California Bearing Ratio (CBR) Test

The soil was treated with different dosages of enzyme i.e 200ml for 3, 2.5,2 m^3 of soil at optimum moisture condition and kept for curing. Soaked CBR tests were conducted after a curing period of 7, 14, 21 and 28 days from the application of Terrazyme. The variation of CBR value for untreated soil and soil treated with different dosages of Terrazyme is shown in Fig. 1.

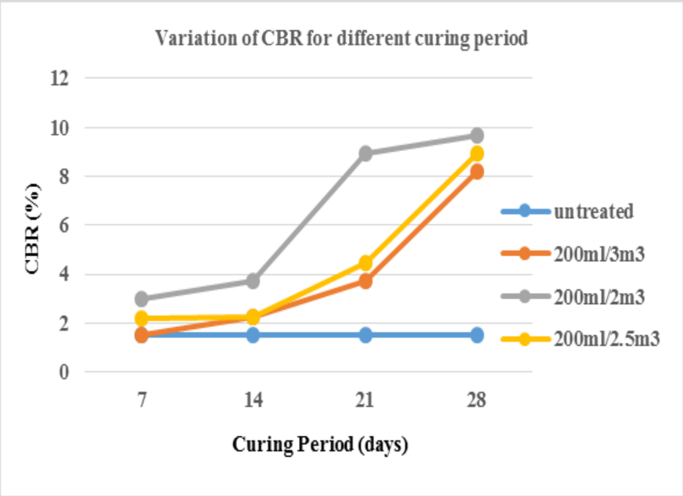


Fig -1: Variation of CBR of Terrazyme treated soil.

CBR test was also conducted on the soil reinforced with a single layer of Coir geotextile placed at different depths. The test was carried out by placing a single layer of coir geotextile at depths of 2.5cm, 5cm, 7.5 cm and 10 cm from top of the CBR mould. CBR test results are shown in Table 5. Fig 2 shows the load Vs Settlement graph of soil reinforced with geotextile.

Table -5: CBR values of soil reinforced with coir geotextile

Depth of embedment of geotextile (cm)	Soaked CBR (%)
2.5	2.23%
5	2.98%
7.5	5.21%
10	4.46%

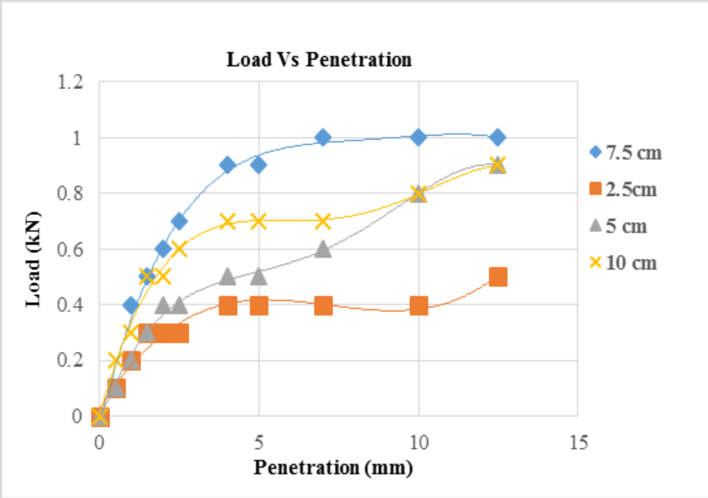


Fig -2: Load Vs Penetration graph of soil reinforced with geotextile.

It can be seen that CBR value of soil treated with Terrazyme has shown a greater increase than that of soil reinforced with coir geotextile. Table 6 shows the comparison of CBR test results.

Table -6: Comparison of CBR test results.

Dose	CBR (%)			
	7days	14days	21days	28days
Untreated	1.49			
200ml/3m3	1.5	2.23	3.72	8.18
200ml/2 m3	2.98	3.72	8.93	9.67
200ml/2.5m³	2.2	2.23	4.46	8.93
Soil with geotextile	5.21			

CBR value is increased from 1.49% to 9.67% for the soil treated with bioenzyme whereas for the soil reinforced with geotextile, CBR value increases from 1.49% to 5.21%. The rate of increase of CBR of Terrazyme treated soil after a curing period of 28 days is up to 550%. But the percentage increment in CBR of soil reinforced with geotextile is only 250% for a depth of embedment of 7.5 cm from top of the mould. Fig. 3. shows the percentage increase in CBR for different enzyme dosages and curing period.

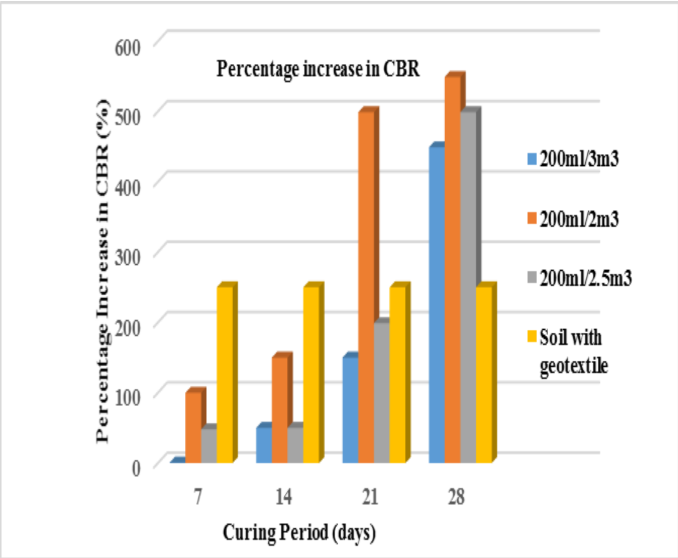


Fig -3: Percentage increase in CBR for different curing period.

4.2 Unconfined Compressive Strength Test

Unconfined Compressive Strength (UCS) test was conducted on the Terrazyme treated soil to evaluate the effect of enzyme dosages and curing period on strength development. Table 7 shows the variation of UCS of soil treated with Terrazyme for different curing period. Percentage increase in Unconfined Compressive Strength is shown in Fig4.

Table -7: Unconfined Compressive Strength of soil treated with Terrazyme.

Dosage No.	Dosages	UCS of soil in kPa			
		0 day	7 days	14 days	28 days
0	Untreated	36			
1	200ml/3m³	36.15	38.05	43.17	49.47
2	200ml/2m³	38.05	45.66	60.88	98.93
3	200ml/2.5m³	36.15	41.86	64.25	96.37

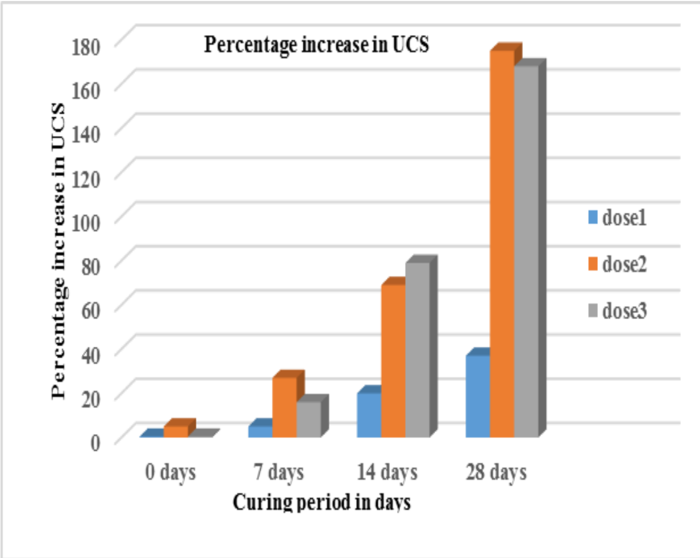


Fig -4: Percentage increase in Unconfined Compressive Strength.

Unconfined Compressive strength of soil treated with bioenzyme has increased from 36 kN/m² to 98.93 kN/m² for the dosage of 200ml/2m³. This shows an increase of 200% from the untreated soil.

4.3 Microstructure Analysis

Microstructure analysis was done by using X-ray Diffraction technique (XRD) and Scanning Electron Microscope (SEM). The results are shown in Fig 5-7. Soil samples were tested after a curing period of 28 days.

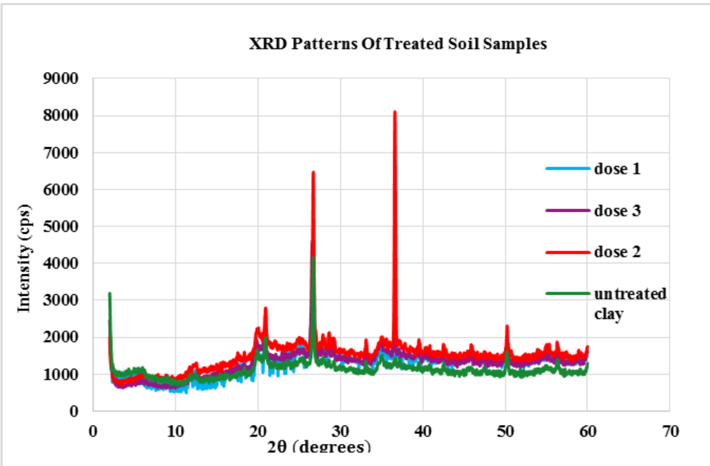
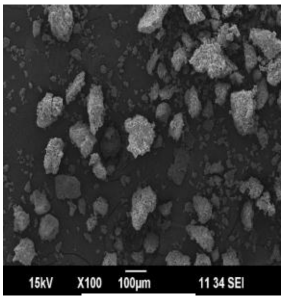
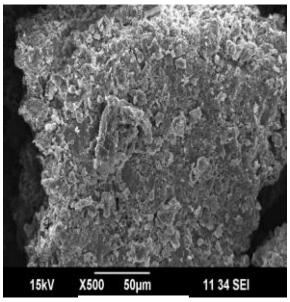


Fig -5: Graph obtained by X-Ray Diffraction



a) 100x



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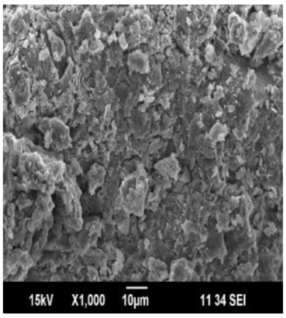
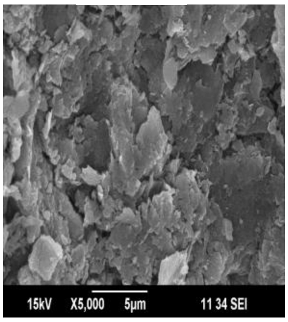
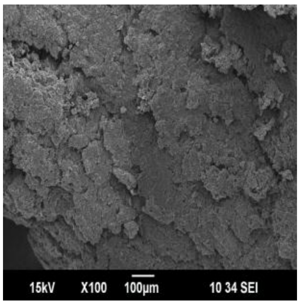


c) 1,000x



d) 5,000x

Fig -6: SEM images of untreated clay in order of increasing magnification



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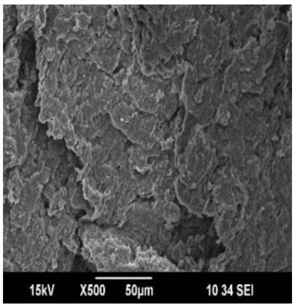

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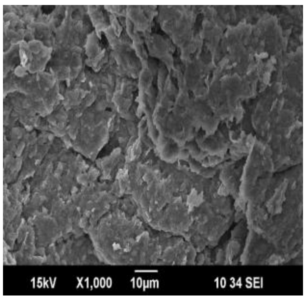
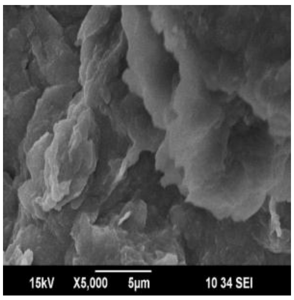


c) 1000x



d) 5,000x

Fig -7: SEM images of clay treated with Terrazyme dosage of 200 ml/2m^3

Fig. 7 shows some morphological changes occurred on the clay particles with the addition of enzyme. New reaction products joined the soil particles together making the voids in the soil less distinct. From the SEM images, it can be clearly seen that clay particles having a flaky-like structure initially are transformed into a dense form with the addition of Terrazyme.

5. CONCLUSIONS

In the present study, effect of bio-enzyme and geotextile on the strength characteristics of sub-grade soil has been investigated and the following conclusions are drawn:

1) Soaked CBR and Unconfined Compressive Strength of soil treated with bio-enzyme have shown greater increase than that of soil reinforced with geotextile.
2) 200ml/2m^3 is the optimum dosage of Terrazyme. Strength characteristics have greatly improved at this dosage.
3) CBR and Unconfined Compressive Strength have increased with increase in curing period.
4) Optimum position of coir geotextile is 7.5 cm from top of the mould.
5) Pavement thickness can be reduced if the subgrade soil is treated with bio-enzyme. Stabilization of subgrade with bio-enzyme offers a durable and aggregate free pavement.
6) Microstructure analysis shows that treatment of soil with Terrazyme results in reduction of voids in the soil structure with a closer orientation of soil particles.

6. FUTURE SCOPE OF STUDY

The study can be extended by conducting a comparative study on the effect of different bioenzymes on different types of soil.

ACKNOWLEDGEMENT

We thank our colleagues who provided insight and expertise that greatly assisted this research.

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