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Comparative Study of Strength Characteristics (CBR) of Bio - Enzymatically Treated Expansive Soil for Subgrade Stabilization

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Abstract: The subgrade stabilization using bio – enzymes becomes a revolutionary and most useful technique among all the available methods of soil stabilization. The previous research work shows that, the use of bio – enzymes in field is soil specific and depends upon various factors such as clay content, type and dosages of bio – enzymes and curing period. Thus, present work aims to study the effect on both soaked and unsoaked CBR of expansive soil treated with varying dosages of different bio - enzymes (Terrazyme and DZ – 2X) for curing period of 1, 7, 14, 21 and 28 days. The result shows that significant improvement in CBR values for all dosages of bio – enzymatic treatment. The maximum strength gain was achieved after 21 days of curing and further increase in curing period shows marginal improvement. The precipitation formed on the surface of sealed soil samples results in improvement in CBR values. The comparative study helps in finding the maximum percentage increase in CBR values (Soaked and Unsoaked) for individual bio – enzymes and its optimum for the treatment of expansive soil. The treated soil can be effectively use as subgrade material for the construction of road pavement.

Keywords: CBR, bio – enzymes, subgrade stabilization, expansive soil, curing period

1 Introduction

The expansive soils are mostly found to be unsuitable for the construction of road pavement considering its low bearing capacity and swelling potential. Therefore, it is necessary to improve the properties of subgrade soil so as to make it suitable for the construction of road pavement [1, 2]. However, conventional methods of soil stabilization (lime and cement stabilization) are energy and time consuming which has hazardous effect on the environment [3]. In this regards, several eco-friendly approach i.e. use of bio-enzymes in soil to improve its strength properties becomes popular among all geotechnical engineers. The bio-enzymes are organic liquid formed brown colored materials prepared from fermentation of plants and vegetables. The main advantage of bio-enzyme is its solubility in water which makes it more convenient in improving the properties of subgrade and subbase layers in pavement. The use of bio-enzyme in field is soil specific and improvement depends upon the type of bio-enzyme treatment. Thus,

it found difficult to apply the specific bio-enzyme in field without having standardized data [9]. The present work focuses on finding the optimum dosages of different bio-enzymes and its effect on CBR values of expansive soil as improved CBR will reduce the thickness of pavement layers which ultimately reduce cost of construction and can be considered as sustainable green initiative towards soil stabilization when compared to conventional methods.

1.1 Mechanism of Bio - Enzyme Stabilization

The bio-enzymes when introduced in soil mass increases the cationic exchange and also binds soil particles by reducing layer of adsorbed water which makes it more stiff to carry higher loads [6]. From the experimental investigation, it was also observed that improvement in properties of bio-enzyme stabilized expansive soil is due to precipitation formed on the surface of soil samples with different curing period under sealed conditions. The basic mechanism of soil bio-enzyme stabilization is as shown in Fig. 1 (Renjith et al. 2020)

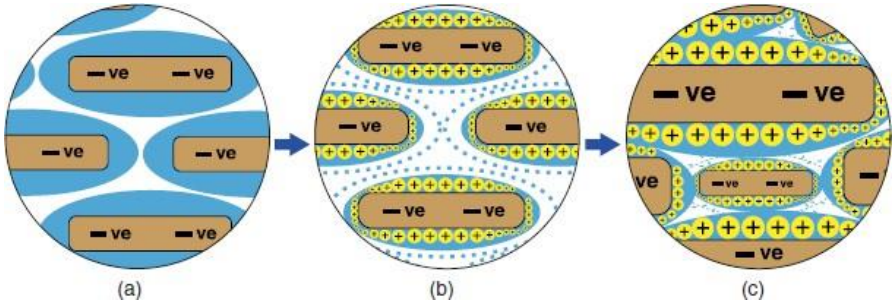

Fig. 1. Soil Bio-Enzyme Mechanism

The bio-enzymes can also effectively use with other conventional stabilizing agents such as lime, cement and micro silica. The bio-enzymes when treated with hydraulic lime and micro silica results in formation of primary and secondary gels which helps to improve the properties of soil [5, 10].

$$H_2O + CaO = Ca(OH)_2\ (Primary\ Gel) \quad (1)$$

$$Ca(OH)_2 + SiO_2 + Enzyme = Calicium\ Silicate\ Hydroxyl\ (CSH)Gel \quad (2)$$

2 Literature Review

In the recent past some of the researchers had carried out stabilization of soils using various bio-enzymes to study the effect on its properties. Divya et al. (2021) has carried out evaluation of two different soils treated with varying dosages of Terrazyme and found that maximum percentage increase in CBR values was 75 % and 222 % in case of laterite and black cotton soil respectively. Eujine et al. (2020) has studied the behavior of soft soils treated with enzymatic lime with dosages of bio – enzyme as 80 ml/m^3 for individual enzyme and 70 ml/m^3 for enzymatic lime treatment. The CBR values increased upto 5 times, 3 times and 6 times in case of treated with lime alone, enzyme alone and enzymatic lime under unsoaked conditions respectively. Venkatesh and

Reddy (2018) has carried out experimental investigation of Terrazyme treated clay of high compressibility (CH) by preforming series of laboratory CBR test with varying dosages of Terrazyme as (1, 2, 3 and 4 %) by weight of dry soil. It was observed that maximum percentage increase in unsoaked CBR was around 104 % and soaked CBR was around 138 % for 4 % of TerraZyme treated soil. Thomas and Rangaswamy (2021) investigated the strength behavior of cement and Terrazyme treated soil by conducting a series of UCS tests in laboratory with varying percentages of cement and Terrazyme. For curing periods of 1 and 7 days, the maximum increase in UCS of cement treated soil (4% by weight of dry soil) was around 457.34 % and 623.51 % respectively. For a dosage of 200 ml/2.0 m^3, the maximum increase in UCS of Terrazyme treated soil was around 272 %. Aboukhadra et al. (2018) studied behaviour of fine and coarse grained soils treated with Terrazyme and Permazyme and found improvement in CBR values from 12 to 35 %. The behavior of treated soil was also affected by clay fraction present in the soil. Pooni et al. (2019) checked the durability of enzyme treated soil in case of road pavement which is subjected to moisture degradation and found increased in CBR values by 48 % and 58 %, respectively in unsoaked and soaked cases. Renjith et al. (2020) has carried out optimization of soil enzyme stabilization using brown coloured Eko soil solution with varying dilution and application mass ratios. The CBR of treated soil was checked for DMR of 1:100, 1:300, 1:500 and 1:900 with AMR of 1, 3, 5 and 7 %. The results shows enzyme stabilized soil can significantly improve CBR values more than 500 % when treated at reference OMC under controlled conditions. Muguda and Nagaraj (2019) conducted an experimental programme to investigate the impact of Terrazyme on soil characteristics and found that plasticity properties of treated soil were improved for the optimum dosages of 133.33 ml/ m^3 with curing period of 60 days. The addition of enzyme may cause the soil to become more flocculated. The most of studies were related to particular type of enzyme and improvement in properties of treated soil is varying with respect to clay content. Moghal et al. (2020) has studied the effect on geotechnical properties of cohesive soil using EICP techniques. The enzyme solutions were prepared with the use of urease enzyme, urea and calcium chloride. The results shows, remarkable reduction in swell characteristics and permeability of soil for 21 days of curing period. In view of this limitations, the proposed work is carried out to study the effect of DZ-2X and Terrazyme on CBR of locally available soil.

3 Materials and Methodology

The untreated black cotton soil (Fig. 2) was collected from Amravati district of Maharashtra at depth of 0.6 to 1.0 m from ground surface. The laboratory tests such as consistency limits, compaction characteristics (OMC and MDD) were performed to classify the soil as per IS classification system and classified as CH i.e. clay of high compressibility having clay content of around 58 %. The soil enzyme stabilization was achieved with the use of different bio – enzymes such as Terrazyme and DZ-2X (Fig. 3) with varying dosages as shown in Table 1 and curing period as 1, 7, 14, 21 and 28 days. The soaked and unsoaked CBR test soil samples were prepared in laboratory for each enzyme concentration with properly sealed in plastic bags and kept in air tight containers (Fig. 4). The detailed testing program for proposed study is as shown in

Table 2. The results of treated soil samples were compared with untreated soil to identify the improvement in CBR of enzyme stabilized soil. The same results will be useful to find optimum dosages for both the enzymes.

Fig. 2. Black Cotton Soil used in Experimental Testing Programme

Fig. 3. Brown Colored Bio-Enzyme used in Experimental Testing Programme

Fig. 4. Sealed Bio-Enzyme Stabilized CBR Soil Samples

Table 1: Details of bio – enzymes selected for soil enzyme stabilization

Sr. No.	Type of Enzyme	Details of Enzyme	Dosages of Enzyme
1	Terrazyme	• Dark Brown • Boiling Point of 212 ^{0}F • Specific Gravity – 1.00 to 1.09 • 200 ml packaging from A. V. Agencies, Chennai	1000 ml per 15, 12.5, 10, 7.5 and 5.0 m^3
2	DZ - 2X	• Light Brown • Boiling Point of 121 ^{0}F • PH – 4.30 to 4.60 • 1000 ml packaging from Dhara Bio. Gujarat	1000 ml per 9.0, 8.0, 7.0, 6.0 and 5.0 m^3

Table 2: Testing programme for soil enzyme stabilization

Sr. No.	Soil Condition	Bio - Enzyme	Test Performed
1	Untreated Soil	---	Atterberg's limits, Compaction test, Particle Size Analysis, California Bearing Ratio (CBR) test
2	Treated Soil	DZ - 2X TerraZyme	Compaction test, CBR test for each enzyme concentration with curing period of 1, 7, 14, 21 and 28 days

4 Results and Discussions

Fig. 5 shows compaction curve for unstabilized soil with an OMC of 23.5 % and MDD of 1.46 gm/cc. The unsoaked and soaked CBR for unstabilized soil was found to be 4.76 % and 1.76 % respectively. The results of various test such as consistency limits, specific gravity, compaction test and CBR test etc. performed on untreated soil are as shown in Table 3.

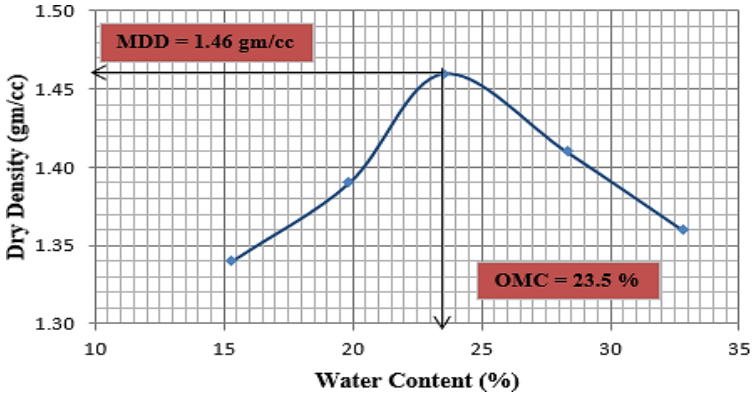

Fig. 5. Compaction Curve for Unstabilized Soil

Table 3: Test Results for Unstabilized Expansive Soil

Sr. No.	Test	Value
1	Consistency Limits Liquid Limit Plastic Limit Shrinkage Limit	 62.80 % 28.50 % 34.30 %
2	Specific Gravity	2.68
3	Optimum Water Content (OMC)	23.5 %
4	Maximum Dry Density (MDD)	1.46 gm/cc
5	Unsoaked CBR	4.76 %
6	Soaked CBR	1.79 %
7	Soil Classification (ISC)	CH

The series of compaction tests were performed on treated soil samples to find the compaction characteristics of each enzyme dosage. It was observed that optimum moisture content decreases and maximum dry density increases for both types of bio-enzymes. In case of DZ-2X, maximum percentage decrease and increase in OMC and MDD values was found to be 16.33 % and 8.90 % respectively. However, in case of Terrazyme, maximum percentage decrease and increase in OMC and MDD values was found to be 15.19 % and 10.95 % respectively. The variation in OMC and MDD of enzyme stabilized soil is as shown in Table 4 and Table 5.

Table 4: Compaction Characteristics of DZ – 2X Treated soil

Sr. No.	Dosage of DZ - 2X	OMC (%)	MDD (gm/cc)
1	D1DZ (1000 ml for 9 m^3)	23.2	1.49
2	D2DZ (1000 ml for 8 m^3)	22.5	1.48
3	D3DZ (1000 ml for 7 m^3)	21.8	1.53
4	D4DZ (1000 ml for 6 m^3)	20.5	1.56
5	D5DZ (1000 ml for 5 m^3)	20.2	1.59

Table 5: Compaction Characteristics of Terrazyme Treated soil

Sr. No.	Dosage of Terrazyme	OMC (%)	MDD (gm/cc)
1	D1T (1000 ml for 15 m^3)	24.2	1.43
2	D2T (1000 ml for 12.5 m^3)	22.8	1.51
3	D3T (1000 ml for 10 m^3)	21.2	1.56
4	D4T (1000 ml for 7.5 m^3)	20	1.63
5	D5T (1000 ml for 5 m^3)	20.4	1.62

The results of series of soaked and unsoaked CBR tests performed on bio-enzyme stabilized soil samples were determined for each bio-enzyme concentration. The test results shows improvement in CBR values for each enzyme dosage with increase in curing period.

Tables 6 and 7 shows the CBR values of soil treated with DZ - 2X at various dosages and curing period. For optimum dosage of 6 m^3 and curing period of 28 days, the maximum percentage increase for unsoaked CBR was around 203 %, while for soaked CBR it was 238 %. The variation in unsoaked and soaked CBR values of DZ-2X treated soil with respect to varying dosages and curing period is as shown in Fig. 6 and 7 respectively.

Table 6: Unsoaked CBR Test Results for DZ – 2X Treated Soil

Sr. No.	Dosage of DZ - 2X	Curing Period in Days				
		1	7	14	21	28
		Unsoaked CBR Values (%)				
1	D1DZ (1000 ml for 9 m^3)	5.05	5.85	7.84	8.32	10.33
2	D2DZ (1000 ml for 8 m^3)	5.85	6.73	8.34	10.65	11.5
3	D3DZ (1000 ml for 7 m^3)	6.22	8.77	10.93	11.78	13.7
4	D4DZ (1000 ml for 6 m^3)	8.25	9.89	11.89	12.86	14.45
5	D5DZ (1000 ml for 5 m^3)	8.45	9.29	12.05	12.33	13.75

Table 7: Soaked CBR Test Results for DZ – 2X Treated Soil

Sr. No.	Dosage of DZ - 2X	Curing Period in Days				
		1	7	14	21	28
		Soaked CBR Values (%)				
1	D1DZ (1000 ml for 9 m^3)	1.81	1.89	2.58	3.14	4.33
2	D2DZ (1000 ml for 8 m^3)	1.92	2.01	2.85	3.55	4.68
3	D3DZ (1000 ml for 7 m^3)	2.01	2.85	3.68	4.35	5.16
4	D4DZ (1000 ml for 6 m^3)	2.45	3.95	4.82	5.62	6.05
5	D5DZ (1000 ml for 5 m^3)	2.32	3.45	4.93	5.37	5.64

The CBR values for soil treated with Terrazyme with varying dosages and curing period is as shown in Table 8 and Table 9. It was observed that, both soaked and unsoaked CBR values are improved for each concentration of Terrazyme with varying curing period. The maximum percentage increase in case of unsoaked CBR was around 149 % where as in case soaked CBR it is 160 % for optimum dosage of 7.5 m^3 with curing period of 28 days. The variation in unsoaked and soaked CBR values of Terrazyme treated soil with respect to varying dosages and curing period is as shown in Fig. 8 and 9 respectively.

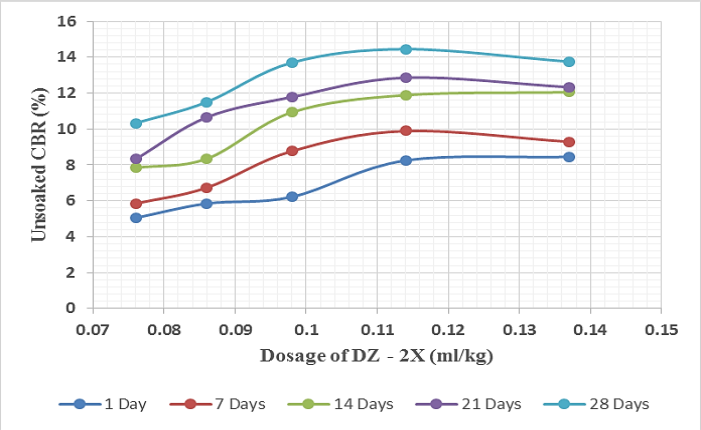

Fig. 6. Unsoaked CBR of DZ-2X Treated Soil with Varying Dosage

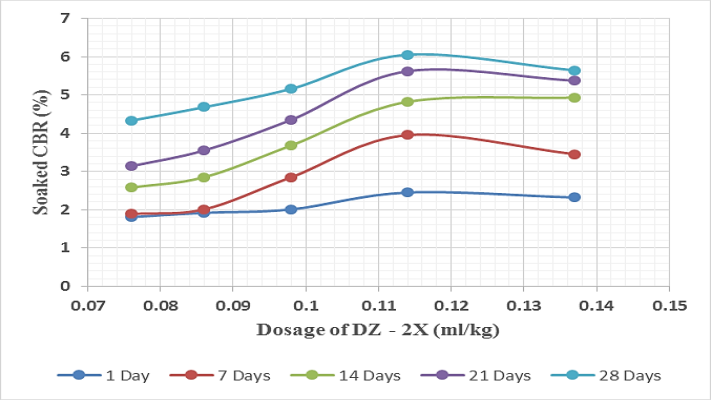

Fig. 7. Soaked CBR of DZ-2X Treated Soil with Varying Dosage

Table 8: Unsoaked CBR Test Results for Terrazyme Treated Soil

Sr. No.	Dosage of Terrazyme	Curing Period in Days				
		1	7	14	21	28
		Unsoaked CBR Values (%)				
1	D1T (1000 ml for 15 m^3)	4.85	5.05	5.98	6.78	8.05
2	D2T (1000 ml for 12.5 m^3)	5.37	6.15	7.43	8.25	8.74
3	D3T (1000 ml for 10 m^3)	5.85	6.84	8.93	9.82	10.45
4	D4T (1000 ml for 7.5 m^3)	6.76	7.85	9.85	11.05	11.88
5	D5T (1000 ml for 5 m^3)	7.15	7.76	9.68	10.58	11.96

Table 9: Soaked CBR Test Results for Terrazyme Treated Soil

Sr. No.	Dosage of Terrazyme	Curing Period in Days				
		1	7	14	21	28
		Soaked CBR Values (%)				
1	D1T (1000 ml for 15 m^3)	1.76	1.85	2.16	2.85	3.14
2	D2T (1000 ml for 12.5 m^3)	1.81	2.01	2.48	3.05	3.82
3	D3T (1000 ml for 10 m^3)	1.92	2.36	2.68	3.87	4.26
4	D4T (1000 ml for 7.5 m^3)	2.07	2.87	3.48	4.62	5.08
5	D5T (1000 ml for 5 m^3)	2.15	2.45	3.93	4.48	4.89

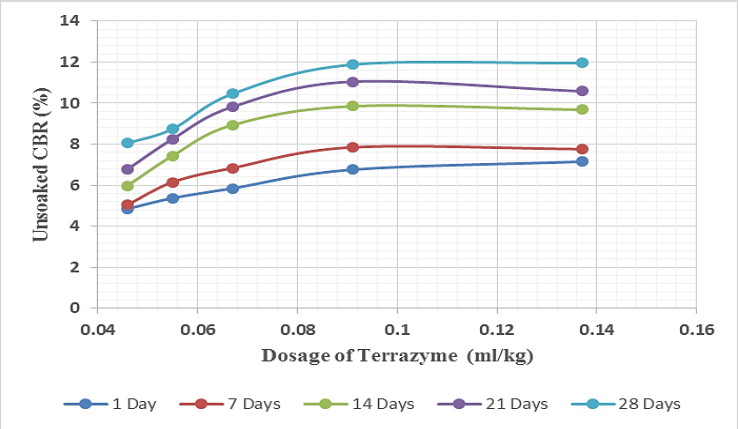

Fig. 8. Unsoaked CBR of Terrazyme Treated Soil with Varying Dosage

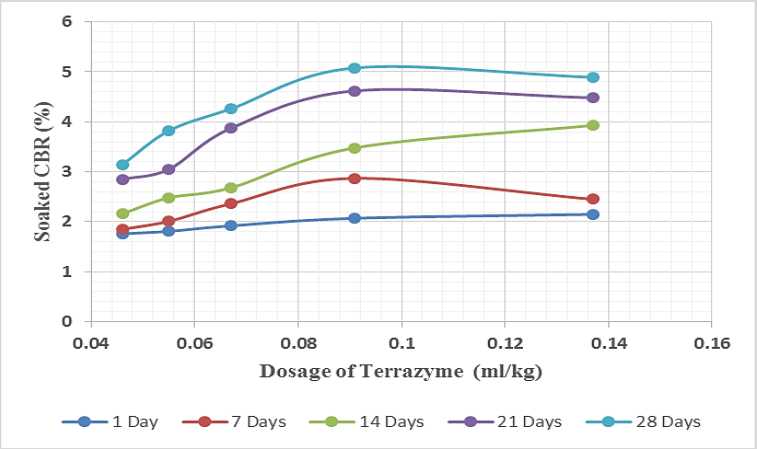

Fig. 9. Soaked CBR of Terrazyme Treated Soil with Varying Dosage

5. Conclusions

- The bio-enzyme soil stabilization was proven to be effective in all cases to improve both compaction and strength behavior when compared to untreated soil.
- The CBR values of expansive soil increases with increase in dosages and curing period for both DZ-2X and Terrazyme and thus can be effectively used in case road pavement.
- The curing period supports in improving the CBR values of soil as precipitation was formed on surface of sealed soil samples which results in strength gain.
- The maximum percentage increase in CBR values for DZ - 2X treated soil was found to be 203 % and 238 % for unsoaked and soaked CBR respectively for enzyme dosage of 1000 ml/6 m^3 with 28 days of curing period.
- The maximum percentage increase in CBR values for Terrazyme treated soil was found to be 149 % and 184 % for unsoaked and soaked CBR respectively for enzyme dosage of 1000 ml/7.5 m^3 with 28 days of curing period.
- The optimum dosages for DZ – 2X and TerraZyme for treating soil of (CH) category were found to be 0.1141 ml/kg and 0.091 ml/kg respectively.
- The use of bio-enzymes for soil stabilization was proven to be most effective and environmental friendly alternative to all available methods.

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