Comparative study of subgrade strength of soil using Bio-Enzyme

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Abstract. Environmental concerns have significantly influenced the construction industry regarding the identification and use of environmentally sustainable construction materials. Bio-Enzymes (organic materials) have been introduced recently for ground improvement projects such as pavements and embankments. The present experimental study was carried out in order to evaluate the subgrade strength of two different clayey soil treated with two different types of enzyme namely, TerraZyme and EarthZyme as assessed through California Bearing Ratio (CBR) Test and Standard Proctor Test. Soil specimens to be tested are prepared using different dosages of Bio-Enzyme (1ml, 2ml, 3ml and 4ml) mixed with water at optimum moisture content and then it is sprayed over soil and compacted. Bio-Enzyme reduces the voids between the particles of soil and minimizes the amount of absorbed water in the soil so that the compaction caused by the enzymes can be maximum. It is seen that with the addition of Bio-Enzyme, OMC first decreases and then increases while MDD increases and then decreases. In case of CBR test, CBR value increases and then decreases.

Keywords: TerraZyme, EarthZyme, California Bearing Ratio test, Compaction

1 Introduction

The demand for new construction materials, which maintain a balance between cost and performance while at the same time satisfying environmental problems is one of the main challenges, construction firms face nowadays. Another difficulty faced by the engineers is the unavailability of sufficient land for construction. Hence, construction on available land becomes necessary even if it is weak in strength. Suitable stabilizing material is adopted considering the type of soil, cost effectiveness and availability of materials. These challenges have led to the introduction of new ground improvement methods. Recently, an effective ground improvement method was introduced, that is stabilization using Bio-Enzyme. Bio- Enzyme is an organic, natural, inflammable and non-corrosive liquid which are the products of fermentation of organic matter. They are mainly used in highway projects. Bio-Enzyme improves the properties of soil and gives higher soil strength. They can easily get breakdown and dissolve with time as they are extracted by the fermentation of vegetables and sugar canes, hence they are bio-degradable. As they are in liquid form, it is easily soluble in water which saves time and cost of mixing. There are many Bio-Enzymes available in market like TerraZyme, PermaZyme, EarthZyme etc. In this study two types of Bio-Enzymes namely TerraZyme and EarthZyme were used. Most of the informations about the enzymes are provided by the suppliers, and hence independent testing information is not available.

The clay content plays a vital role in Bio-Enzyme stabilization. When the amount of clay content in the soil increases, the improvement in the soil properties by the addition of Bio-Enzyme also increases. Here, two types of soil with varying clay content are used. Enzyme accelerates reaction between clay and organic cations and cation exchange process take place which reduce the adsorbed water layer thickness. The use of Bio-Enzyme as a stabilizing material is accepted worldwide due to its effectiveness.

2 Experimental program

The California Bearing Ratio (CBR) test and Standard Proctor test were conducted to evaluate the effect of TerraZyme and EarthZyme on geotechnical properties of soils.

2.1 Materials used

Soil. Two types of soil with varying clay content were used in this study. The first soil was collected from Poochinnipadam, Mukundapuram Taluk, Thrissur and the next soil was collected from Thejus Engineering College campus of Thrissur District, Kerala. The geotechnical properties of soil sample 1 and soil sample 2 are given in table 1. The soil sample 1 and soil sample 2 were classified as high plasticity clay (CH) and intermediate plasticity clay (CI) respectively by IS Plasticity chart.

Table 1. Geotechnical properties of soils

Properties	Results	
	Sample 1	Sample 2
Specific gravity	2.68	2.71
Percentage of gravel (%)	5	0
Percentage of sand (%)	9	41
Percentage of fines (%)	86	59
Liquid limit (%)	52	48
Plastic limit (%)	25	22
Shrinkage limit (%)	16	18
Plasticity index (%)	27	26
Soil classification system	CH	CI

Optimum moisture content (%)	18	16
Maximum dry density (kN/m^3)	16.1	16.8
Unsoaked CBR value (%)	2.3	3.3
Soaked CBR value (%)	1.7	2.3

Bio-Enzyme. Two types of Bio-Enzyme namely, TerraZyme and EarthZyme were selected for this study. TerraZyme was purchased from Avijeet Agencies Pvt Ltd, Chennai and EarthZyme was collected from Neha Infra Services, Mumbai. The main ingredients of two enzyme are nonionic surfactant and carbohydrates. EarthZyme contained Carbohydrates and TerraZyme consisted of fermented vegetable extract. The chemical and physical properties of TerraZyme and EarthZyme are shown in Table 2.

Table 2. Chemical and Physical properties of Bio-Enzymes

Properties	TerraZyme	EarthZyme
Water	21.06%	>50%
Alcohols, C12-C16, ethoxylated	NA	<30%
Fermented vegetable extract	NA	<20%
Non-ionic surfactants	55%	NA
Polysaccharides	2%	NA
Oligosaccharides	3%	NA
Disaccharides	5%	NA
Monosaccharide	8%	NA
Lactic acid	3.5%	NA
Potassium as the chloride	1.2%	NA
Aluminium as the sulphate	0.04%	NA
Magnesium as the sulphate	1.2%	NA
Specific gravity	1.0-1.1	1.0-1.1
pH	3 to 6	2.8 to 3.5
Boiling point	>100°C	>100°C
Ultimate biodegradability	Dissolved organic content reduction>90% after 28days	NA

(a) Soil sample 1

(b) Soil sample 2

(c) EarthZyme

(d) TerraZyme

Fig. 1. Materials used for the study

2.2 Sample preparation

Standard Proctor Test. The collected natural soils were in the form of wet condition and placed in the oven for 24hours and crushed into dry powder form in a mortar. The light compaction test of both plain soils was conducted in order to determine the optimum moisture content and dry density. The measured quantity of plain soil and water for compaction test was taken. Bio-Enzyme with different dosages that is 1ml, 2ml, 3ml and 4ml were diluted with the water taken and mixed with the soil and compaction test is done. Same procedure was repeated using other soil sample. From the compaction test, the optimum moisture content (OMC) and maximum dry density (MDD) of treated soil samples were obtained. The optimum value of OMC and MDD were also obtained.

California Bearing Ratio Test. For the sample preparation of CBR test, Modified Proctor test should be done in order to obtain the optimum moisture content of the plain soil. With this optimum moisture content, CBR test was done. The measured quantity of plain soil sample and water for CBR test was taken. Bio-Enzyme with different dosages, 1ml, 2ml, 3ml, and 4ml mixed with water at optimum moisture content of plain soil sample. This is then mixed with the soil sample taken and tied in a polyethylene cover and placed in a desiccator for two days for the reaction to take place. This sample is then taken and CBR test is conducted. The CBR value for each dosage of Bio-Enzyme is obtained and also the optimum CBR value is obtained. In the same way, Soaked CBR value is also founded. The same procedure was repeated for the other soil sample. The results obtained from the above tests for two different soil sample were compared with the untreated soil samples results

2.3 Testing program

Standard Proctor Test. Compaction characteristics of both soil (untreated) were determined using standard compaction effort, and the same procedure was used to identify any change in compaction characteristics due to enzymes. Three important factors that affect the compaction are moisture content, type of soil and compaction effort. Compaction test is conducted in a compaction mould of diameter 100mm, height 123mm and weighs 4.5kg. Bio-Enzyme of different dosages are added to the measured water and mixed with the soil. During the preparation of untreated and treated soil samples, an increment of 2% moisture content was chosen so that precise compaction characteristics could be determined. The mixed soil is placed into the mould in three layers, where each layer is compacted giving 25blows using 2.5kg hammer. The mould is filled with soil and the collar is removed. The excess soil is trimmed off using a trowel. The weight of the mould with base plate and soil is taken.

The procedure is repeated until the weight of the mould and soil is reduced by increasing the moisture content. From each soil sample made, small amount of soil is taken in a container and wet weight is taken and kept in the oven for 24hours. After 24hours the soil sample is taken and dry weight is taken. From the calculation of compaction, the values of dry density and water content is obtained. The graphs were plotted showing the variation in optimum moisture content and maximum dry density of soil sample 1 and soil sample 2 for different dosages of Bio-Enzymes.

California Bearing Ratio Test. The procedure according to IS 2720 Part XVI (1987) was followed for the sample preparation and testing. Modified proctor test was carried out first in order to obtain the optimum moisture content (OMC) of plain soil. All specimen (untreated and treated) of CBR test were prepared using this OMC. The amount of soil taken was more than that of standard proctor test that is 5kg of soil. The different dosages of Bio-Enzyme were added to this OMC, and then mixed with the soil. This mixture is placed in a polyethylene cover tied and placed in a desiccator for two days so that reaction can take place and adsorbed water can be removed.

The CBR mould is taken and a weight is kept at the bottom of the mould. On the top of the weight, a filter paper is kept. The soil is taken out and placed in a CBR mould on the top of the filter paper in five layers where each layer is compacted giving 56 blows using hammer which weighs 4.5kg. The soil is filled and the collar is taken out. The excess soil is trimmed off and the mould is kept upside down and the weight and filter paper which was kept at the bottom was taken out. This mould filled with soil is kept in the CBR testing machine by placing two weights inside the mould. Testing is done by noting the load against the corresponding penetration. From the reading load against 2.5mm penetration and 5mm penetration is noted. The graphs were plotted showing the variation in unsoaked and soaked CBR value of soil sample 1 and soil sample 2 for different dosages of Bio-Enzymes.

3 Results and discussions

3.1 Effect of Bio-Enzyme on Geotechnical properties of soils

Standard Proctor Test. EarthZyme and TerraZyme of varying dosages were added to the soil and compaction test were carried out. The optimum moisture content (OMC) and maximum dry density (MDD) were found to be varying with the addition of EarthZyme and TerraZyme. Table 3 and Table 4 shows the variation in OMC and MDD of soil sample 1 and soil sample 2 with the addition of TerraZyme and EarthZyme respectively.

Table 3. Variation in OMC of soil sample 1 and 2 with the addition of Bio-Enzyme.

Dosage(ml)	Optimum Moisture Content (%)			
	Soil Sample 1		Soil Sample 2	
	EarthZyme	TerraZyme	EarthZyme	TerraZyme
0	18	18	16	16
1	16.8	16.4	15.2	15
2	14.6	14.3	13.9	13.6
3	16.5	16.2	12.3	12.1
4	17.6	17.1	14.7	14.1

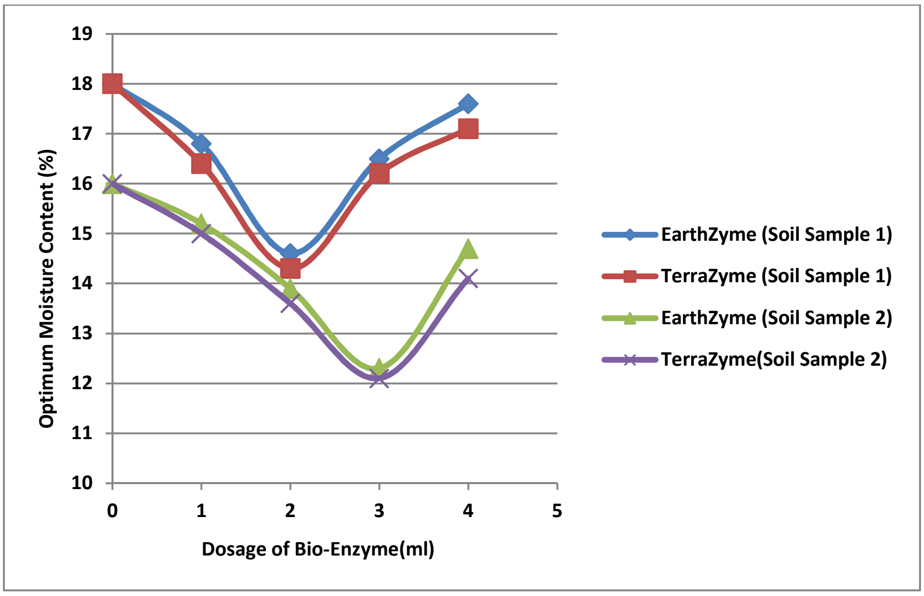

Fig. 2. Variation in Optimum Moisture content by the addition of Bio-Enzyme

Table 4. Variation in MDD of soil sample 2 with the addition of Bio-Enzyme

Dosage (ml)	Maximum Dry Density (kN/m^3)			
	Soil Sample 1		Soil Sample 2	
	EarthZyme	TerraZyme	EarthZyme	TerraZyme
0	16.1	16.1	16.8	16.8
1	16.7	16.9	17	17.1
2	17.4	17.7	17.3	17.5
3	17.1	17.4	17.6	17.8
4	16.9	17.2	17.4	17.7

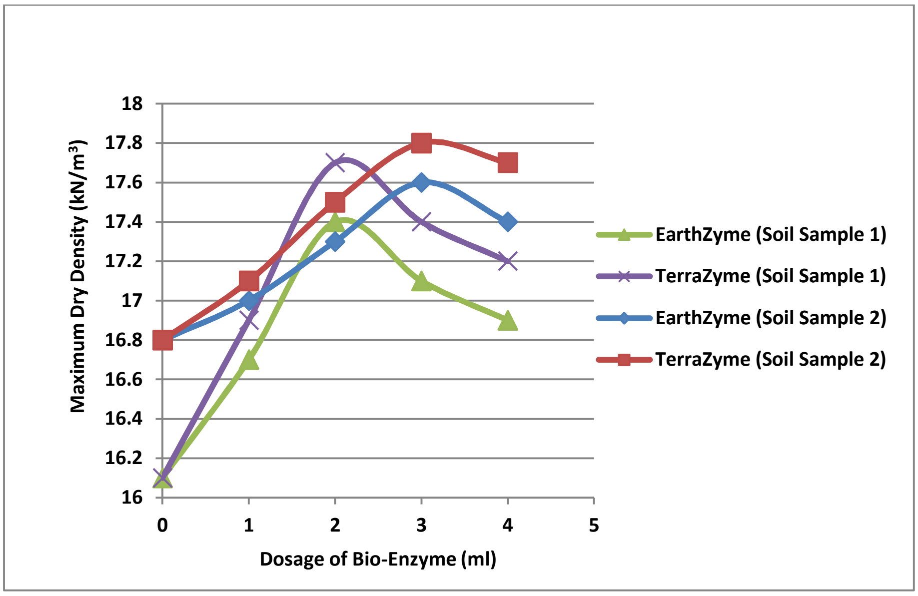

Fig. 3. Variation in Maximum Dry Density with the addition of Bio-Enzyme

The compaction characteristics of the soil samples improved when treated with Bio-Enzyme. From the above graphs it is clear that the OMC goes on decreasing and the MDD goes on increasing first with the increase in Bio-Enzyme. This improvement is mainly due to the reduction in the void ratio of the soil samples when treated with Bio-Enzyme (Shankar A.U.R, et.al.; 2009). When comparing both the soil samples, soil sample 1 has got more MDD value than soil sample 2. And when comparing both the Bio-Enzymes used, TerraZyme has got more MDD value than EarthZyme. The MDD of soil sample 1 and soil sample 2 increases up to 2ml and 3ml dosage of Bio-Enzyme respectively and decreases thereafter. The OMC of soil sample 1 and soil sample 2 decreases up to 2ml and 3ml dosage of Bio-Enzyme respectively and increases thereafter. Hence the optimum value is obtained at 2ml and 3ml dosage of Bio-Enzyme for soil sample 1 and soil sample 2 respectively.

California Bearing Ratio Test. EarthZyme and TerraZyme of varying dosages mixed with the OMC of both soil samples were added to the soil and CBR test was carried out. Table 5 and Table 6 shows the variation in unsoaked and soaked CBR value of soil sample 1 and soil sample 2 on addition of EarthZyme and TerraZyme respectively.

Table 5. Variation in Unsoaked CBR value on addition of Bio-Enzyme

Dosage(ml)	Un Soaked CBR value (%)			
	Soil Sample 1		Soil Sample 2	
	EarthZyme	TerraZyme	EarthZyme	TerraZyme
0	2.3	2.3	3.4	3.4
1	8.9	9.4	8.18	8.9
2	13.6	14.9	10.8	11.6
3	11.6	12.2	14.1	15.1
4	9.4	10.7	11.8	12.9

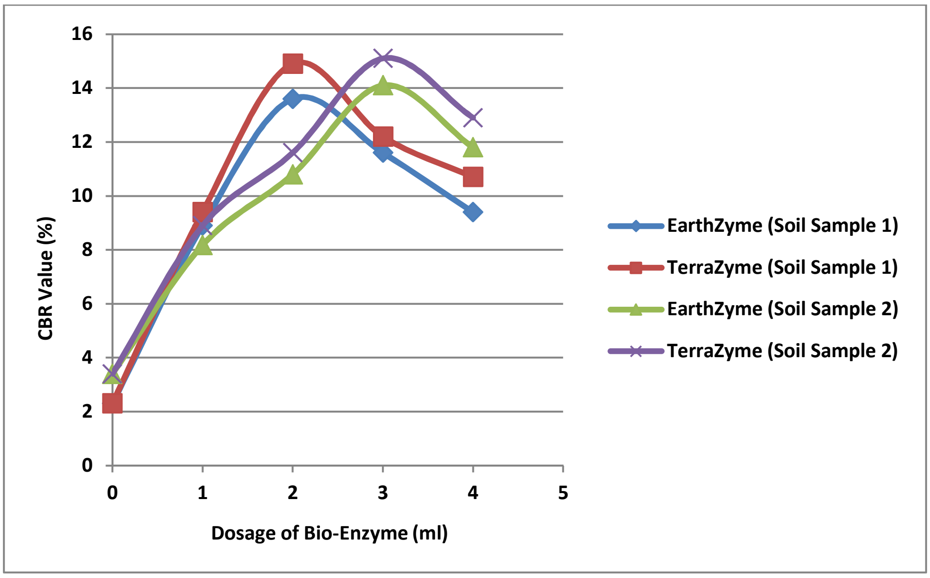

Fig. 4. Variation in Un Soaked CBR value on addition of Bio-Enzyme

Table 6. Variation in Soaked CBR value on addition of Bio-Enzyme

Dosage(ml)	Soaked CBR value (%)			
	Soil Sample 1		Soil Sample 2	
	EarthZyme	TerraZyme	EarthZyme	TerraZyme
0	1.7	1.7	2.4	2.4
1	7.1	8.2	6.7	7.4
2	11.8	12	9.5	9.9
3	9.9	10.5	13.5	13.6
4	8.4	8.9	10.4	10.7

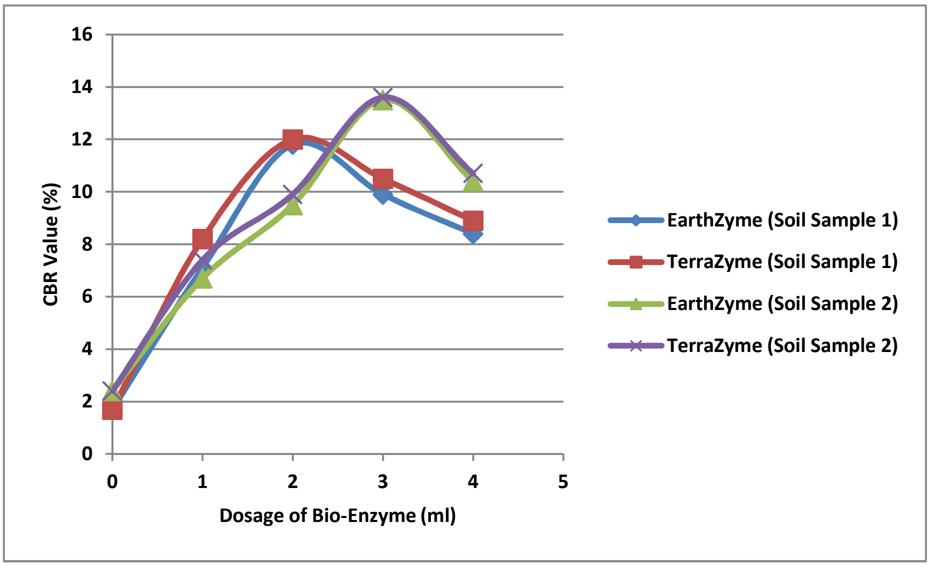

Fig. 5. Variation in Soaked CBR value on addition of Bio-Enzyme

It can be inferred from the above graphs that the CBR value has increased on addition of Bio-Enzyme and decreased after the optimum value. This is because the soil treated with Bio-Enzyme renders improved density values by reducing the void ratio.

This may be due to effective cation exchange process which generally takes longer period in the absence of such stabilizers (Venkataraman, et.al.; 2011). When comparing both the soil sample, soil sample 1 has got more CBR value than soil sample 2 in both unsoaked and soaked condition. This is because when the clay content in the soil increases, the improvement in the soil properties by the addition of Bio-Enzyme also increases. And on comparing both the Bio-Enzymes used, TerraZyme has got more CBR value of 547%. The unsoaked and soaked CBR value of soil sample 1 increases up to 2ml dosage of Bio-Enzyme and decreases thereafter whereas for soil sample 2, the value increases up to 3ml dosage of Bio-Enzyme and decreases. Therefore the optimum value is obtained at 2ml and 3ml dosage of Bio-Enzyme for soil sample 1 and soil sample 2 respectively.

4 Conclusions

It has been found that mixing of both type of Bio-Enzymes, namely TerraZyme and EarthZyme have sufficiently improved the geotechnical properties of soil. The results showed that there is a significant effect on compaction characteristics of soil with the addition of Bio-Enzyme. At the same time, CBR value of the soil also increased with the increase in dosage of Bio-Enzyme.

- The variation in OMC of both soil sample goes on decreasing up to an optimum value and increases thereafter with the increase in dosage of EarthZyme and TerraZyme
- The variation in MDD of both soil sample goes on increasing up to an optimum value and decreases thereafter with the increase in dosage of EarthZyme and TerraZyme
- Maximum Dry Density was obtained at 2ml dosage of Bio-Enzymes for soil sample 1 and at 3ml dosage of Bio-Enzymes for soil sample 2.
- The unsoaked and soaked CBR value of both soil sample goes on increasing up to an optimum value and decreases with the increase in dosage of EarthZyme and TerraZyme.
- Maximum CBR value was obtained at 2ml dosage of Bio-Enzymes for soil sample 1 and at 3ml dosage of Bio-Enzymes for soil sample 2.
- Better result was obtained for soil sample 1 that is CH soil due to the presence of more clay content in the soil when comparing with soil sample 2 that is CI soil. When the clay content in the soil increases, the improvement in the soil properties by the addition of Bio-Enzymes also increases.
- When comparing both TerraZyme and EarthZyme, soil treated with TerraZyme showed better results than the soil treated with EarthZyme.

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