ISSN: 0976-3031

Available Online at http://www.recentscientific.com

CODEN: IJRSFP (USA)

International Journal of Recent Scientific Research
Vol. 8, Issue, 8, pp. 19029-19034, August, 2017

International Journal of Recent Scientific Research

DOI: 10.24327/IJRSR

Research Article

AN INVESTIGATION ON "BEHAVIOUR OF BIO ENZYME STABILIZED EXPANSIVE SOIL"

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DOI: http://dx.doi.org/10.24327/ijrsr.2017.0808.0615

ARTICLE INFO

Article History:

Received 05th May, 2017
Received in revised form 08th June, 2017
Accepted 10th July, 2017
Published online 28st August, 2017

Key Words:

Terrazyme, Enzyme dosages, Consistency limits, Compaction properties, UCS, Triaxial test, CBR

ABSTRACT

In this present study, the effectiveness of bio enzyme in stabilizing the expansive soils of Puri districts is studied through laboratory experiments. Bio-Enzyme namely Terrazyme has been used as stabilizer in this work. The locally available expansive soil was accumulated from field to study the geotechnical properties. The plasticity index is much more due to the high percentage of clay content in this type of soil. Various tests were carried out for the virgin soil and bio enzyme treated soils with variable dosages. The tests carried out were the consistency limits, compaction properties, unconfined compressive strength, triaxial test and California bearing ratio. The laboratory tests results showed a lot of improvement and desirable results in terms of strength of the stabilized soil.

INTRODUCTION

Engineers are often faced with the complication of constructing facilities on or with soils, which do not possess adequate strength to bear the loads imposed upon during construction or during the service life of the structure. Many areas of India composed of soils with high silt contents, low strengths and minimum bearing capacity. For effective performance of structures constructed on such soils, the performance characteristics of such soils require to be improved. The poor engineering performance of such soils has forced Engineers to strive to improve the engineering properties of poor quality soils. There are several methods that could be applied to refine the performance of poor quality soils. These methods extend from replacing with a good quality soil to methods that include complex chemical process. The choice of a specific method depends generally on the type of soil to be improved, its properties and the type and extent of improvement required in a particular application. Lately bio-enzymes have emerged as a new chemical for soil stabilization. Bio-enzymes are chemical, organic, and liquid concentrated substances which are utilized to enhance the stability of soil sub-grade for pavement structures. Bio-Enzyme is advantageous to use, safe, effectual and dramatically upgrades road quality. Stabilization of soils is an efficacious process for enhancing the properties of soil and pavement system performance. The aims of any stabilization technique used are to increase the strength and stiffness of soil, enhance workability and constructability of the soil and decrease the Plasticity Index. For any given soil numerous stabilization methods, using different stabilizing agents, may be effectual to enhance the soil properties in-place rather than removing and replacing the material. Availability or economic considerations may be the determining factor on which a stabilizing agent is chosen. In India the expansive soils cover almost 20 percent of the total land area. These expansive soils are known by many local names such as Black cotton soils or Regur. There is no regular occurrence of expansive soil in the state. These soils occur occasionally in the districts of Puri, Ganjam, Malkangiri, Kalahandi, Nuapada, Bolangir, Sonepur, Boudh, Sambalpur, Bargarh and Angul covering an area of 0.96 m. ha of lands. Delanga is a village located in the Puri district of Orissa state, India. The latitude 19.8129875 and longitude 85.8311766 are the geocoordinate of the Delanga.

Hitam and Yusof *et al* (1998) [1]conducted field studies on improvement of plantation roads by treating Terrazyme to 27.2 km of the road, which was having serious problems during monsoon. After two monsoon seasons the road was found to be in very good condition in spite of immense exposure to heavy rainfall. No surface damage was observed, thus demanding no repair works to the road section. Brazetti and Murphy *et al* (2000)[2] conducted field experiments in Brazil to study the use of Terrazyme for road construction. The selected soils were sandy clay, silty clay, sandy silt, plastic and non-plastic clay,

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sandy loam, loam mixed with clay, soil mixtures with pieces of recycled pavement. The field stretches were periodically tested with Dynamic Cone Penetrometer. They reached the conclusion that enzyme stabilization is an effective and economic solution for pavement construction. Bergmann *et al* (2000) [3] conducted field study on effects of seven different soil stabilizers in Wood River accessible fishing site and day use area on Winema National Forest. The temperature varied from -9°C to 38°C. Among the other stabilizers, enzyme stabilized section showed significant improvement in soil strength and its surface finish was retained for long. Isaac *et al* (2003) [4] studied effectiveness of Terrazyme on lateritic and clay type soil collected from Kerala. The reactions of the soils treated with enzyme were recoded for 8 weeks. The CBR value increased in all soil typein the range of 136 to 1800 percent that of the original value by addition of Terrazyme, which proved its suitability as a stabilizing agent. Terrazyme is useful for clay soil and sand but is less significant to silty soils; clayey and sandy soils had increase in CBR by 700 percent. Manoj *et al* (2003) [5] conducted a study to assess the suitability of Bio-Enzyme as soil stabilizer on five types of soils with low clay content to very high clay content. Laboratory tests were conducted to determine the engineering properties and strength characteristics of soil with and without Bio-Enzyme. The Bio-Enzyme stabilization has shown little to very high improvement in physical properties of soil. This little improvement may be due to chemical and constituent of the soil, which has low reactivity with Bio-Enzyme. In the cases of highly clay moderate soil, like silty soil to sandy soil, the effect of stabilization has improved the CBR and unconfined compressive strength. Andrew R. Tolleson *et al* (2003) [6] in their research conducted a laboratory bench scale testing program to evaluate the effectiveness of enzyme treatment on subgrade soil. Their objective was to study the potential applicability of tested enzyme for unpaved road in-situ stabilization. The effectiveness of enzyme treatment was evaluated on the basis of statistical measurement of change in CBR strength, soil stiffness and soil modulus. It was concluded that the CBR test appears to be a relatively poor indicator of direct soil strength for testing conditions. Not withstanding, the test results showed CBR strength gain and to a lesser degree strength gain measured by the means of the SSG equipment resulting from the application of the enzyme solution on most soils tested, indicating a promising potential for subgrade stabilization using the enzyme solution. Ravi Shankar *et al* (2009) [7] studied the effect of enzyme on lateritic soil and blended lateritic soil in terms of unconfined compressive strength, CBR, compaction and permeability. Their study found that Bio-Enzyme stabilization showed medium improvement in physical properties of lateritic soil. Enzyme was found to be ineffective for improving the consistency limits of lateritic soil. CBR value showed 300% increment while unconfined compressive strength increased by 450% and permeability decreases by 42%. Sureka *et al* (2010) [8] conducted oedometer consolidation tests on expansive soil on both untreated and bioenzyme treated soil specimens. The dosage of bioenzyme was varied from 0.25% to 2%. The swelling potential and swelling pressure were measured in the one dimensional consolidation load cell using swell and load procedure, scanning electron microscope studies and cation exchange capacity tests were conducted to observe the structural and CEC modifications. They observed that bioenzyme treated expansive soil exhibit lesser percent of swell and swell pressures. Curing period beyond 30days did not yield any further significant reduction in swell properties. The structure of the soil changed from flocculated to dispersed structure. No significant changes were observed in cation exchange capacity values of bio-enzyme treated soil specimen. Venkatasubramanian & Dhinakaran *et al* (2011) [9] 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%. Agarwal, P and Kaur, S (2014) [10] conducted a comprehensive study on the effect of bio-enzyme on unconfined compressive strength of Black cotton soil .The UCC strength was evaluated by stabilization with variable dosages of enzyme (0.0, 0.25ml, 0.5ml, 0.75ml, 1.0ml, 2.0ml, 3.0ml and 4.0ml/ 5kg of soil) for one and seven days of curing. The UCC strength of black cotton soil increased effectively. Duration treatment of soil with enzyme played a vital role in improvement of strength and soil treated with enzyme for 7 days gives higher strength. Puneet and Suneet *et al* (2014)[11] studied the effect of terrazyme on the UCS strength of Black Cotton soil. Stabilization of the soil using Terrazyme resulted in significant increase in the Unconfined Compressive Strength of the Black Cotton Soil up to 200%. Duration of treatment of soil with Terrazyme played a vital role in improvement of strength and soil treated with Terrazyme for 7 days gives higher strength. The optimum dosage of Terrazyme for improvement of UCS of Black Cotton soil was 1ml/per 5kg of soil. Ramesh and Sagar *et al* (2015) [12]studied the effect of air dry curing and desiccator curing on the index properties , compressibility and strength properties of Terrazyme treated black cotton soil and red earth for the curing periods from 7days to 60days. UCS Strength of both black cotton soil and red earth showed tremendous increment with drying than curing in a laboratory desiccator after treating it with Terrazyme. Atterberg Limits for both black cotton soil and red earth did not exhibit any difference in drying and desiccator curing. Both black cotton soil and red earth attained hydrophobic nature with drying after treatment. The properties of Black cotton soil showed much improvement by stabilizing with Terrazyme dosage of 200ml/2.0m3 of soil and for red earth by 200ml/3.0m3 of soil. Hence this dosage was considered as the optimum one. Even Unsoaked CBR of both black cotton soil and red earth showed better improvement with treatment in drying than in desiccator curing. Compaction characteristics were not affected immediately after treatment with Terrazyme. Compressibility behaviour of black cotton soil was improved well with treatment from Terrazyme. Black cotton soil showed more structural stability during oedometer test. Free Swell Index of black cotton soil showed drastic reduction with treatment from Terrazyme especially with drying. Air-dry curing (or drying) condition proved more efficient in treating both the soils than desiccator curing condition. Swathy M Muraleedharan1, Niranjana (2015) [13] conducted laboratory tests on clay of high plasticity treated with Terrazyme. The effect of enzyme on soil in terms of Plasticity Index, Compaction, Unconfined Compressive Strength (UCC), and California Bearing Ratio (CBR) were studied. The dosage of bio-enzyme added to the soil was 0ml, 0.1ml, 0.2ml, 0.3ml and 0.4ml per kg soil on bio-enzyme stabilized soil .The soil properties showed improvement in stabilizing with enzyme dosage of 0.2ml/kg. The treated soil was observed to be having lesser plasticity index values. For the optimum dosage of 0.ml/kg, the MDD of the soil increases up to 6% and OMC decreases up to 19%. At the optimum dosage, there was an increase of 351%in the UCC strength and 352% in CBR value of soil.

Based on the detailed literature review, the objectives of the present work is to evaluate the various geotechnical engineering properties of Bio-enzyme stabilized soil and to judge the suitability as a better engineering / construction material.

METHODOLOGY

Dosage of Enzyme

The majority of the research studies have been done based on the dosage proposed by the suppliers. In this experimental investigation dosage of 200 ml per 3.5 m^3, 3 m^3, 2.5 m^3, 2 m^3, 0.5 m^3, 0.25 m^3, 0.15 m^3 and 0.075 $m^3$is compared.

Testing Programme for Basic Properties

Tests are conducted to determine the consistency limits, compaction properties, unconfined compressive strength, cohesion and angle of internal friction by triaxial test and California bearing ratio. The details of testing programme

Table 1 Testing Programme for basic properties of soil

Soil Type	Enzyme	Enzyme Dosages	Enzyme Percentage	Tests Performed
Expansive soil	Terrazyme	200 ml per 3.5 m^3 of soil	0.006	1. Consistency limit
		200 ml per 3 m^3 of soil	0.007	2. Compaction Test
		200 ml per 2.5 m^3 of soil	0.008	3. UCS
		200 ml per 2 m^3 of soil	0.01	4. Triaxial Test
		200 ml per 0.5 m^3 of soil	0.04	5. CBR
		200 ml per 0.25 m^3 of soil	0.08	
		200 ml per 0.15 m^3 of soil	0.15	
		200 ml per 0.075 m^3 of soil	0.3	

Table 2 Geotechnical properties of soil

Sl. No	Property	Expansive soil
1.	Specific Gravity	2.7
2.	Free Swell Index	100%
3.	Grain size distribution Sand (%) Silt (%) Clay (%)	 10 48 42
4.	Consistency limits Liquid limit (%) Plastic limit (%) Plasticity Index (%)	 66.4 29.382 37.018
5.	IS Soil Classification	CH
6.	Engineering Properties IS Light Compaction Max dry density (KN/m^3) OMC (%)	 15.5 23
7.	CBR Value [OMC condition](%)	 0.479
8.	Unconfined Compressive Strength- [IS Light Compaction](KN/ m^2)	 52.9
9.	Triaxial Shear strength parameters øC (KN/ m^2)	6 20

for the basic properties of soil and geotechnical properties of soil are tabulated in Table 1 and Table 2 respectively.

Grain Size Analysis Test [IS: 2720 (Part 4) - 1985]

The grain size analysis test results for the expansive soil are tabulated in Table 3. The soil carries Sand 10 %, Silt 42 % and Clay 48%. Hence the soil is classified as CH.

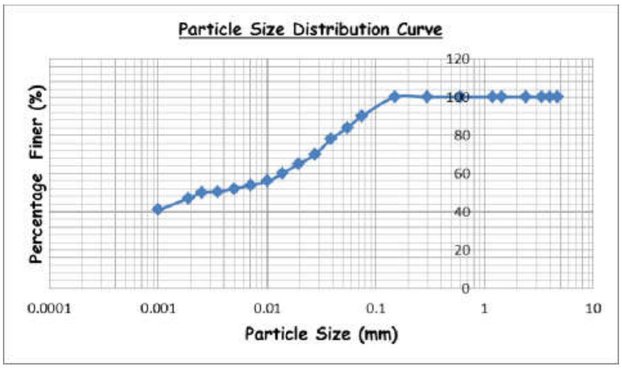

Figure 1 Particle size distribution curve

Experimental investigations, analysis and discussion of test results

Effect of consistency limit on enzyme treated soil

The enzyme treated soil consistency limits test results are tabulated in Table 3 and the variation of liquid limit, plastic limit and plasticity index values with different dosages of enzyme are graphically presented in Figure 4, 5 and 6 respectively. As the percentage of enzyme dosage increases from 0% to 0.3% there is decrease in the liquid limit from 66.4 % to 45.35 %, plastic limit from 31.5% to 21.28%. The plasticity index decreased from 37.01 % to 24.07 %. Terrazyme reduces the plasticity index of the expansive soil.

Table 3 Consistency limits values for different dosages of enzymes

Sl.No	Enzyme Dosages	Enzyme Percentage	Liquid Limit	Plastic Limit	Plasticity Index
1	200 ml per 3.5 m^3 of soil	0.006	61.20	26.25	34.95
2	200 ml per 3 m^3 of soil	0.007	60.20	25.61	34.59
3	200 ml per 2.5 m^3 of soil	0.008	55.34	24.90	30.44
4	200 ml per 2 m^3 of soil	0.01	55.82	24.76	31.06
5	200 ml per 0.5 m^3 of soil	0.04	55.20	24.35	30.85
6	200 ml per 0.25 m^3 of soil	0.08	54.20	22.26	31.94
7	200 ml per 0.15 m^3 of soil	0.15	48.20	21.70	26.50
8	200 ml per 0.075 m^3 of soil	0.3	45.35	21.28	24.07

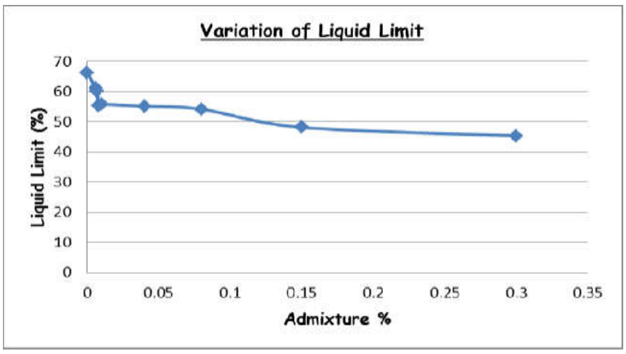

Figure 2 Variation graph of liquid limit value for different dosages of enzymes

A reduction in plasticity is usually accompanied by reduced potential for swelling of an expansive soil. Terrazymecan reduce the expansion of the soil. Soil becomes more workable and non expansive.

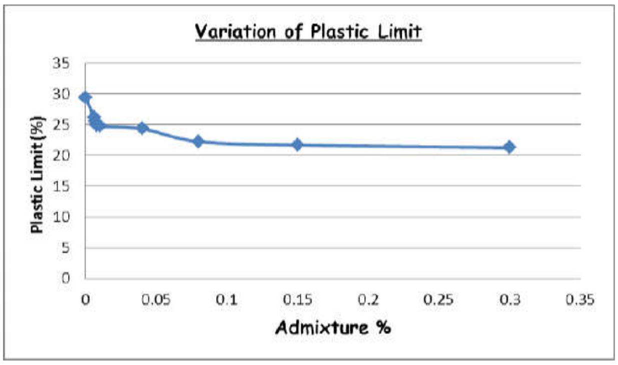

Figure 3 Variation graph of plastic limit value for different dosages of enzymes

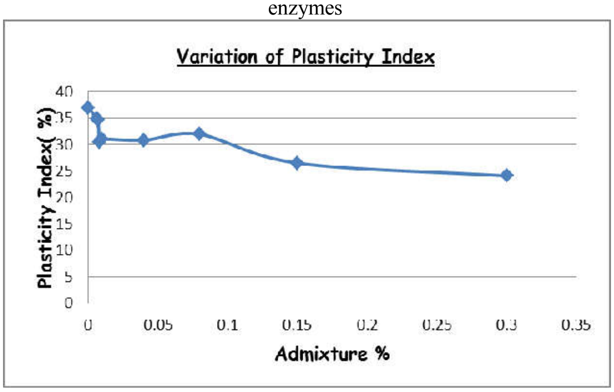

Figure 4 Variation graph of plasticity index for different dosages of enzymes

Effect of Compaction on Enzyme Treated Soil

The IS Light compaction test results for enzyme treated soil samples are tabulated in Table 4 and the variation of OMC and MDD values with different dosages of enzyme are graphically presented in Figure 7 and 8 respectively. There is a decrease in OMC till 0.08% dosage. This may be due to the water reduction capacity of the terrazyme. For enzyme treated samples there is an increase in MDD and the values remain nearly same at all dosages. From the test results it can be concluded that the optimum dosage to get maximum MDD is 0.08%.With terrazyme a high dry density is gained with lesser compaction.

Table 4 OMC and MDD values for different dosages of enzymes

Sl.No	Enzyme Dosages	Enzyme Percentage	OMC (%)	MDD(KN /m^3)
1	200 ml per 3.5m ^{3} of soil	0.006	23	15.5
2	200 ml per 3 m ^{3}of soil	0.007	23	16.5
3	200 ml per 2.5m ^{3} of soil	0.008	20	15.9
4	200 ml per 2 m^{3}of soil	0.01	20.5	16.5
5	200 ml per 0.5m ^{3}of soil	0.04	19	16.2
6	200 ml per 0.25m ^{3}of soil	0.08	19	16.4
7	200 ml per 0.15m ^{3}of soil	0.15	20.5	16.2
8	200 ml per0.075 m ^{3}of soil	0.3	22	16.0

Effect of Unconfined Compression Strength Test Results on Enzyme Treated Soil

Based on the test results which are tabulated in Table 5 it is obtained that the unconfined compression strength increases with enzyme dosages when compared to the original soil.

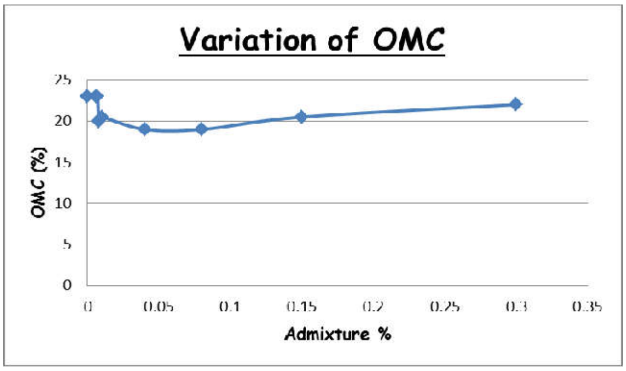

Figure 5 Variation graph of OMC values with different dosages of enzyme

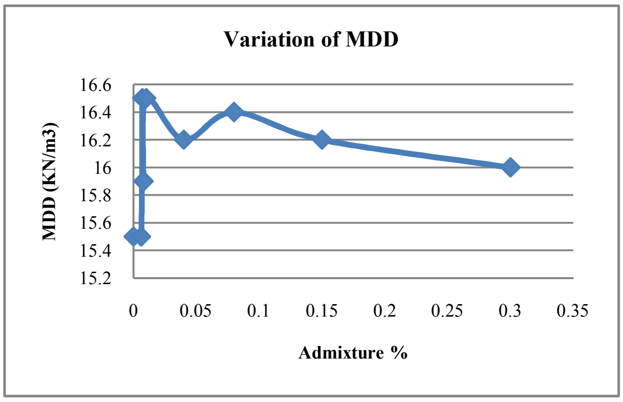

Figure 6 Variation graph of MDD values with different dosages of enzyme

This may be due to the reaction of enzyme with clay which results in cementation effect. The maximum unconfined compressive strength is 125.7 KN/m^2 with 0.08% of Enzyme dosage.

Table 5 UCS and Shear strength values for different dosages of enzymes

Sl.No	Enzyme Dosages	Enzyme Percentage	UCS Value,KN/m^2	Shear Strength of Soil KN/m^2
1	200 ml per 3.5 m ^{3} of soil	0.006	77.2	38.6
2	200 ml per 3 m ^{3} of soil	0.007	81.7	40.8
3	200 ml per 2.5 m ^{3} of soil	0.008	84.8	42.4
4	200 ml per 2 m ^{3}of soil	0.01	94.8	47.4
5	200 ml per 0.5 m^{3}of soil	0.04	121.3	60.6
6	200 ml per 0.25 m ^{3}of soil	0.08	125.7	62.8
7	200 ml per 0.15 m ^{3}of soil	0.15	87.3	43.6
8	200 ml per 0.075 m^{3}of soil	0.3	85.0	42.5

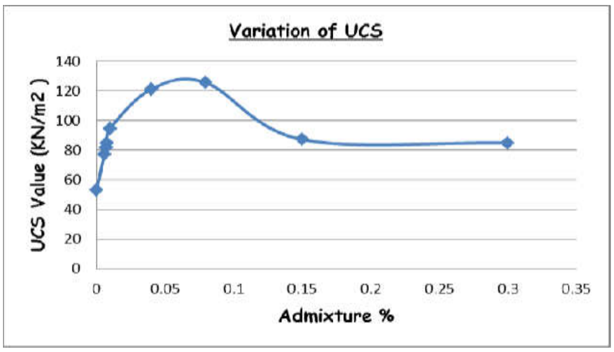

Figure 7 Variation graph of UCS values for different dosages of enzymes

Effect of Triaxial Test Results on Enzyme Treated Soil

The unconsolidated undrained tests were conducted on treated soil with enzyme dosage of 0.006% , 0.007% , 0.008 % , 0.01% , 0.04% , 0.08% , 0.15% and 0.3%.The cell pressure considered were 200 KN/m^2 , 250 KN/cm^2 and 300KN/m^2 .The triaxial test results for the enzyme dosages are tabulated in the Table 6. Figure 10 and 11 plot the variation of cohesion and angle of internal friction obtained for soil for different dosages respectively. It is noticed that cohesion increases with increase in enzyme %. Rate of increase in cohesion for dosages 0.006%, 0.007%, 0.008 %, 0.01%, 0.04% and 0.08% are higher than that for increase in dosages 0.15% and 0.3%. The angle of internal friction determined from triaxial test increases for all enzyme percentage and it is normally 1^0- 4^0 higher than for that soil. For dosage 0.007% it increased by 4^0 and for dosages 0.008 %, 0.01%, 0.04%, 0.08% and 0.15% it remained constant and increased by 2^0. Further for enzyme dosage 0.3% it started decreasing.

The vital parameters which control the shear strength of soil are cohesion and angle of internal friction. By increasing cohesion and angle of internal friction of the soil, the shear strength is increased.

Table 6 Cohesion and Angle of internal friction values for different dosages of enzymes

Sl.No	Enzyme Dosages	Enzyme Percentage	Cohesion (KN/m^2)	Angle of internal friction (ø)
1	200 ml per 3.5 m ^{3} of soil	0.006	40	7
2	200 ml per 3 m ^{3} of soil	0.007	30	10
3	200 ml per 2.5 m ^{3} of soil	0.008	42	8
4	200 ml per 2 m ^{3} of soil	0.01	35	8
5	200 ml per 0.5 m ^{3}of soil	0.04	40	8
6	200 ml per 0.25 m ^{3} of soil	0.08	40	8
7	200 ml per 0.15 m ^{3} of soil	0.15	29	8
8	200 ml per 0.075 m ^{3} of soil	0.3	30	7

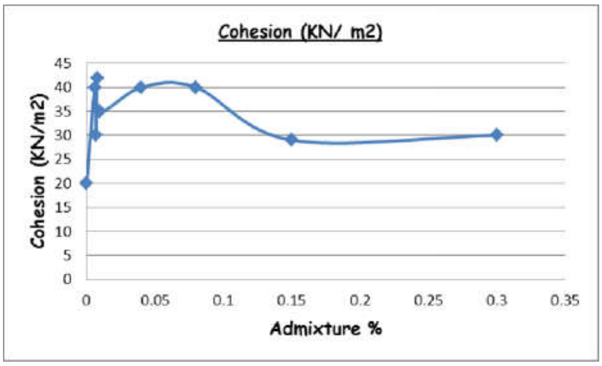

Figure 8 Variation graph of Cohesion values for different dosages of enzymes

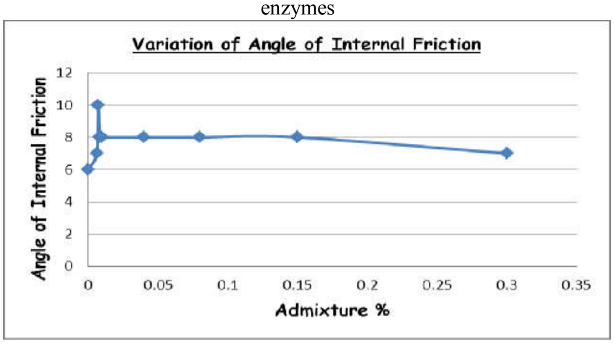

Figure 9 Variation graph of Angle of internal friction values for different dosages of enzymes

Effect of California Bearing Ratio Test Results on Enzyme treated soil

The CBR test is conducted with 0.006%, 0.007%, 0.008 %, 0.01%, 0.04%, 0.08%, 0.15% and 0.3% Enzyme dosage. The CBR test results for the enzyme dosage are tabulated in Table 7 and the variation of CBR results are graphically presented in Figure 12. CBR-value is used as an index of soil strength and bearing capacity. There is a substantial improvement in CBR value with the increase in enzyme percentage. This may be because soil treated with enzyme shows improved density by reducing the void ratios**.** The maximum CBR value is 1.474 % with 0.08 % of enzyme dosage.

Table 7 Variation of CBR values for different dosages of enzymes

Sl.No	Enzyme Dosages	Enzyme Percentage	CBR Value (%)
1	200 ml per 3.5 m^3 of soil	0.006	0.766
2	200 ml per 3 m ^{3} of soil	0.007	0.810
3	200 ml per 2.5 m^3 of soil	0.008	0.884
4	200 ml per 2 m ^{3}of soil	0.01	1.167
5	200 ml per 0.5 m^{3}of soil	0.04	1.215
6	200 ml per 0.25 m ^{3} of soil	0.08	1.474
7	200 ml per 0.15 m^3 of soil	0.15	1.253
8	200 ml per 0.075 m ^{3} of soil	0.3	1.142

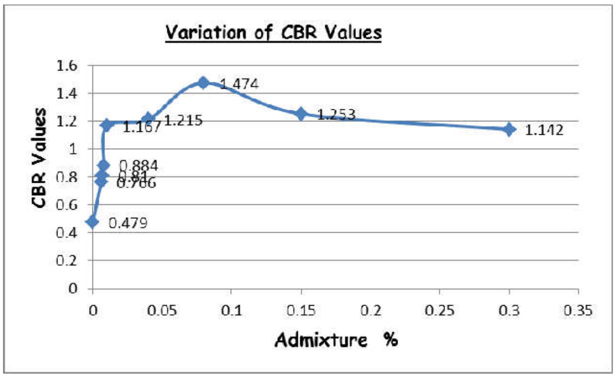

Figure 10 Variation graph of CBR values for different dosages of enzymes

CONCLUSIONS

Based on the tests conducted in laboratory the following conclusions have been drawn.

1. **Consistency Limits**: The Liquid limit, plastic limit and plasticity index decreased by 47%, 28% and 54% respectively for the higher dosage of 0.3 %. Thus terrazyme can reduce the expansion of the soil.
2. **Compaction**: The MDD and OMC of expansive soil, after treating with optimal 0.08 % enzyme, is found to be 16.4 KN/m^3 and 19 % respectively. With Terrazyme which has water reduction capacity, a high dry density can be obtained with minor compaction.
3. **Unconfined Compression Test**: From the test results it is observed that for expansive soil treated with optimal 0.08% enzyme the Unconfined Compressive Strength increases more than 138% when compared to virgin soil. This indicates reaction of enzyme with clay results in cementation effect.
4. **Triaxial Test:** A comparison of UU triaxial test results conducted on various enzyme dosages of soil showed increase in cohesion and friction angle. The cohesion

value increased 100% when compared to virgin soil and friction angle is normally about 1^{o}- 4^{o} higher that of virgin soil. Higher the values higher are the shear strength.

5. **California Bearing Ratio Test**: The test results indicate that there is a continuous improvement in the CBR values with increase in enzyme dosages. After 96 hours of curing increase in CBR value for the expansive soil treated with optimal 0.08% enzyme is around 208%.

- The properties of expansive soil have been improved by stabilizing with enzyme dosage of 0.008 %.
- Bio-Enzyme stabilization has shown high improvement in physical properties of expansive soil. This improvement may be due to chemical constituent of the soil, which has high reactivity with Bio-Enzyme. So it is always advisable to first examine the effect of Bio-Enzyme on soil in the laboratory before trying in the field.

Future Scope

1. The effect of enzyme on soil for higher weeks of curing period can be studied.
2. The effects of other types of enzymes are to be investigated.
3. The effect of enzyme on other type of soil can be studied.
4. Shear strength parameters for CU and CD triaxial test can be studied.

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How to cite this article:

Sweta Das and Maheswar Maharana.2017, An Investigation on "Behaviour of Bio Enzyme Stabilized Expansive Soil''. *Int J Recent Sci Res.* 8(8), pp. 19029-19034. DOI: http://dx.doi.org/10.24327/ijrsr.2017.0808.0615

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