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An Experimental Study of Soil Stabilization using Bio Enzyme

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ABSTRACT: The idea of using enzyme for stabilization in pavement construction was developed from the application of enzyme products used to treat soil in order to improve horticultural applications. A modification to the process produced a material, which was suitable for stabilization of poor ground or road traffic. When added to a soil, the enzymes increased the wetting and bonding capacity of the soil particles. In the present study various geotechnical experiments were performed on virgin soil and enzymatic soil. Bio-Enzymatic soil showed significant improvement in Consistency limits, Standard Proctor test, Unconfined Compressive Strength and California bearing ratio of local soil with different dosages. Duration of treatment of Bio-Enzymatic soil played a vital role in improvement of strength. As the percentage of Enzyme dosage increases from 0 to 200ml/2m^3 of soil there is decrease in the liquid limit from 37.25% to 29.46% and slight decrease in the plastic limit from 26.20% to 22.10%.

I. INTRODUCTION

An enzyme is by definition an organic catalyst that speeds up a chemical reaction, that otherwise would happen at much slower rate, without becoming a part of the end product. Since the enzymes do not become the part of end product and are not consumed by the reaction, a very small amount of bio-enzyme is required for soil stabilization. (Saini *et al.* 2015) They are organic molecules that catalyze very specific chemical reactions if conditions are conducive to the reaction they facilitate. (Patel, R.S *et al.* 2010).“For an enzyme to be active in a soil, it must have mobility to reach at the reaction site. The pore fluid available in the soil mass provides means for mobility of the molecules of bio-enzyme, the specific soil chemistry provides the reaction site, and time is needed for the enzyme to diffuse to the reaction site. (Joy deep *et al.* 2015)” An enzyme would stay active in a soil until there are no more reactions to catalyze. “Enzymes would be expected to be very soil specific. “Each enzyme is specifically tailored to promote a chemical reaction within or between other molecules. The enzymes themselves are unchanged by these reactions. They serve as a host for the other molecules, greatly accelerating the rate of normal chemical and physical reactions. The enzyme allows soil materials to become more easily wet and more densely compacted. They also improve the chemical bonding between soil particles and creating a more permanent structure that is more resistant to weathering, water penetration and wear and tear. (Anjali *et. al.,* 2017, Manoj Shukla *et al* 2003).”

“Extensive research has been conducted studying the application of traditional stabilization additives such as lime; cement and fly ash (A. Sharma, 2001). However, engineering research studying non-traditional stabilization additives such as enzymes are less documented. Santoni *et. al*., (2002) conducted a laboratory experiment to evaluate the stabilization of silty-sand (SM) materials with traditional and nontraditional chemical or liquid stabilizers. Their research focused on the load bearing capacity as the basis of performance characterization. They tested four types of enzymes and found that none of the enzymes tested improved the unconfined compressive strength of the soil under the dry or wet conditions. Eujine *et. al.* (2015) studied the stabilization performance of two types of enzyme stabilizers in addition to the performance of an asphalt emulsion and lime additive product. The stabilizers were tested on a highly plastic fat clay material and were based on the unconfined compressive strength test. Their results indicated that the undrained shear strengths of the enzyme products were 21% higher than the control specimens this suggested that the products in the concentrations used, added a stabilizing quality to the relatively dry specimens. When the specimens were immersed in distilled water, the enzyme products nearly or completely disintegrated by slaking. This indicated that the products tested may not offer waterproofing qualities, using the recommended dilutions.

Experimental investigation carried out on local soil available from Fatehabad. Since the roads are not properly designed the premature failure of pavement are taking place very often. This is mainly because of sub base failure in almost all the cases. An attempt is made in this study to improve the strength of the sub base by stabilizing the soil by Bio-enzyme. To assess the suitability of Bio-Enzyme as soil stabilizer, laboratory tests were conducted to determine the engineering properties and strength characteristics of local soil with and without Bio-Enzyme.

II. MATERIALS USED

Bio-Enzyme stabilizer Terrazyme and local soil collected from the specified sources were used as main materials for conducting the study.

Terrazyme. It is a natural, non-toxic liquid, non-flammable, non-corrosive formulation, fermented from vegetable extracts. Literature confirms that Terrazyme improves the engineering qualities of the soil like CBR values and UCS values. This in turn also decreases the OMC and plasticity index of soil.

Considering research studies done with bio enzyme the dosage depending upon types of the soil and it is per/m3 of soil. Most of the research studies have been done based on the dosage recommended by the suppliers. In this experimental investigation local soil was mixed with TerraZyme with different dosages as given in table 1.

Table 1: Dosage rates applied to soil sample.

No	Dose	ml/m^3 of soil	ml/kg of soil
1	Dosage 1	100	0.061
2	Dosage 2	150	0.092
3	Dosage 3	200	0.122

III. TESTING PROGRAMME

Tests were conducted to determine the Atterberg limits, compaction characteristics and the UCC strength of virgin and stabilized soils.

Table 2: Testing Programme for Basic Properties.

S.No	Laboratory Tests	Complying Standards	Varying Parameters		Resulting Parameters
			Dosage of Terrazyme	Curing Period	
1	Grain Size Analysis	IS:2720 (Part IV) 1985	Untreated soil	0 Days	Coefficient of Uniformity and Coefficient of Curvature
2	Specific Gravity Test	IS:2720 (Part III/Sec 1) 1980	Untreated soil	0 Days	Specific Gravity
3	Atterberg's Limit Test	IS:2720 (Part V) 1985	Untreated Soil Dosage 1 Dosage 2 Dosage 3	0 Days	Liquid Limit, Plastic Limit and Plasticity Index
4	Standard Proctor Test	IS:2720 (Part VII) 1980	Untreated Soil Dosage 1 Dosage 2 Dosage 3	0 Days	Optimum Moisture Content and Maximum Dry Density
5	California Bearing Ratio Test	IS:2720 (Part XVI) 1979	Untreated Soil Dosage 1 Dosage 2 Dosage 3	0 Days 4 Days	CBR Value (Unsoaked) (Soaked)
6	Unconfined Compression Test	IS:2720 (Part X) 1973	Untreated Soil Dosage 1 Dosage 2 Dosage 3	7 Days 14 Days 21 Days 28 Days	UCS Value

IV. TESTS ON UNTREATED SOIL

Specific Gravity Test. For knowing the specific gravity, Specific gravity test was done with the reference of IS: 2720 (Part III/Sec I) 1980) by using pycnometer. Specific gravity of local soil was obtained to be 2.42.

Grain Size Analysis. The sieve analysis was done to determine the relative proportions of different grain sizes which make up a given soil mass. The test was conducted as per IS: 2720 (Part IV) 1985.

About 500 gm of dry soil was subjected to a sieve analysis. From the sieve analysis it was found that gravel was 3.8%, sand was 48 % and fines (silt and clay fraction) were 48.2%.

Atterberg's Limit Test. This test was performed in the laboratory to determine the liquid limit, plastic limit and plasticity index of the local soil as per IS: 2720 (Part V) 1985.

Liquid Limit. The water content corresponding to 25 number of blows is termed as Liquid limit. The Liquid Limit (LL) was found to be 37.25%.

Plastic Limit. The Plastic limit (PI) was found to be 26.20%.

Standard Proctor Test. Standard proctor test was conducted to determine the relationship between moisture content and dry density of the soil sample for a specified compactive effort. The test was conducted as per IS: 2720 (Part VII) 1980 ("Determination of water content – Dry density Relation using Light compaction").

The Optimum Moisture Content and Maximum Dry Density of untreated soil were found to be 13.80% and 1.890 g/cc respectively.

California Bearing Ratio Test. This test was conducted to determine the soaked and unsoaked CBR values of soil. The standard procedure for the 'California bearing ratio test' as explained in Indian Standard Code IS: 2720 (Part XVI) 1979 was adopted for the study.

Unsoaked CBR Test

Table 3: Unsoaked CBR Test.

UNSOAKED CBR	**Deflection in mm**	**Load in divisions**	**Deflection in inches**	**Load in Tonnes**	**Load in KGs**
	0.50	0.00	0.000000	0.0008	0.79
	1.00	1.00	0.000100	0.0082	8.31
	1.50	1.50	0.000150	0.0119	12.07
	2.00	2.00	0.000200	0.0156	15.83
	2.50	3.50	0.000350	0.0267	27.10
	3.00	5.00	0.000500	0.0378	38.36
	4.00	7.00	0.000700	0.0525	53.37
	5.00	8.50	0.000850	0.0636	64.62
	7.50	18.00	0.001800	0.1336	135.75
	10.00	29.00	0.002900	0.2144	217.83
	12.50	42.00	0.004200	0.3095	314.49
	Load in KGs	**Standard Load**	**CBR in %**		
Corrected to 2.5 mm	27.1	1370	1.98		
Corrected to 5.0 mm	64.62	2055	3.14		
Result, CBR			**3.14**		

Soaked CBR Test

The unsoaked and soaked CBR value of soil was observed to be 3.14% and 1.7% respectively as shown in Table 3 & 4.

Unconfined Compression Test. The test was conducted to determine the unconfined compressive strength of the soil. The standard procedure for "Unconfined Compression Test" as explained in IS: 2720 (Part X) 1973 was adopted for the study.

Observation Table

Table 4: Soaked CBR Test.

Soaked CBR	Deflection in mm	Load in divisions	Deflection in inches	Load in Tonnes	Load in KGs
	0.50	0.00	0.000000	0.0008	0.79
	1.00	0.50	0.000050	0.0045	4.55
	1.50	1.00	0.000100	0.0082	8.31
	2.00	2.00	0.000200	0.0156	15.83
	2.50	3.00	0.000300	0.0230	23.34
	3.00	3.00	0.000300	0.0230	23.34
	4.00	3.50	0.000350	0.0267	27.10
	5.00	4.50	0.000450	0.0341	34.61
	7.50	9.00	0.000900	0.0673	68.37
	10.00	14.00	0.001400	0.1042	105.83
	12.50	21.00	0.002100	0.1557	158.16
	Load in KGs	**Standard Load**	**CBR in %**		
Corrected to 2.5 mm	23.34	1370	1.70		
Corrected to 5.0 mm	34.61	2055	1.68		
Result, CBR			**1.70**		

Table 5: Unconfined Compression Test.

Sample	Compression Dial Reading (L) (mm)	Strain (ε =L/L0)	Area(mm^2) ($A=A_0/(1-\varepsilon)$)	Load at Failure (N)	Compressive Stress (kN/m^2)
1	12	0.158	1347	320	237.56
2	13	0.171	1368	290	211.99
3	11.5	0.151	1335.7	275	205.88

The Average of the three samples was taken as Compressive strength of the soil. The Compressive strength of the soil was found to be 213.58 kN/m^2.

V. TESTS ON ENZYME TREATED SOIL

Atterberg's Limit Test. The liquid limit, plastic limit and plasticity index of enzyme treated soil with different dosage is tabulated in table.

Standard Proctor Test. The optimum moisture content and maximum dry density of enzyme treated soil with different dosage is tabulated in table.

California Bearing Ratio Test. The unsoaked and soaked CBR values of enzyme treated soil with different dosage are tabulated in table.

Unconfined Compression Test. The unconfined compressive strength value of enzyme treated soil with different dosage and varying curing period is tabulated in table.

Table 6: Liquid limit, Plastic limit and Plasticity index.

Dose	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
Dosage 1	32.13	23.05	9.08
Dosage 2	27.8	22.30	5.5
Dosage 3	29.46	22.10	7.36

Table 7: OMC and MDD of Terrazyme Treated Soil.

Dose	Optimum Moisture Content (%)	Maximum Dry Density (g/cc)
Dosage 1	12.0	1.875
Dosage 2	12.4	1.868
Dosage 3	12.9	1.891

Table 8: CBR Values of Terrazyme Treated Soil.

Dose	Unsoaked (%)	Soaked (%)
Dosage 1	11.15	14.90
Dosage 2	13.22	20.83
Dosage 3	8.12	5.33

Table 9: Variation of UCS on Curing (All values are in kN/m^2).

Dose	0 Days	7 Days	14 Days	28 Days
Dosage 1	261	315	422	495
Dosage 2	275	358	450	511
Dosage 3	237	305	431	481

VI. SUMMARY AND CONCLUSIONS

The results obtained from the laboratory study are summarized in Table 10 and Table 11 below. Local soil was tested in the laboratory to find out the geotechnical properties like specific gravity, grain size distribution, consistency limits, compaction test, UCS and CBR.

Table 10: Geotechnical Properties of Untreated Soil.

S.No	Property	Value
1.	Specific Gravity	2.42
2.	Grain Size Distribution Gravel (%) Sand (%) Fines (%) (Clay & Silt)	3.8 48 48.2
3.	Atterberg's Limit Liquid Limit (%) Plastic Limit (%) Plasticity Index (%)	37.25 26.20 11.05
4.	IS Soil Classification	OI
5	Standard Proctor Test OMC (%) MDD (g/cc)	13.1 1.883
6.	California Bearing Ratio Unsoaked (%) Soaked (%)	3.14 1.70
7.	Unconfined Compressive Strength (kN/m^2)	205.88

Table 11: Geotechnical Properties of Enzyme Treated Soil.

S.No	Property	Dosage 1	Dosage 2	Dosage 3
1.	Atterberg's Limit Liquid Limit (%) Plastic Limit (%) Plasticity Index (%)	32.13 23.05 9.08	27.8 22.30 5.5	29.46 22.10 7.36
2.	Standard Proctor Test OMC (%) MDD (g/cc)	12.0 1.875	12.4 1.868	12.9 1.891
3	California Bearing Ratio Unsoaked (%) Soaked (%)	11.15 14.90	13.22 20.83	8.12 5.33
4.	Unconfined Compressive Strength (kN/m^2) 0 Days 7 Days 14 Days 28 Days	261 315 422 495	275 358 450 511	237 305 431 481

VII. CONCLUSIONS

In the present study various geotechnical experiments were performed on virgin soil and enzymatic soil. Bio-Enzymatic soil showed significant improvement in Consistency limits, Standard Proctor test, Unconfined Compressive Strength and California bearing ratio of local soil with different dosages. Duration of treatment of Bio-Enzymatic soil played a vital role in improvement of strength.

1. Consistency Limits. As the percentage of Enzyme dosage increases from 0 to 200ml/2m^3 of soil there is decrease in the liquid limit from 37.25% to 29.46% and slight decrease in the plastic limit from 26.20% to 22.10%.

2. Compaction. Initially the MDD of local soil without the enzyme was 1.883 gm/cm^3 and OMC to be 13.1%. After treating the soil with enzyme the OMC decreased from 13.1% to 12.4%. Best results for OMC and MDD were observed with second dosage and the values of OMC and MDD were 12.4 % and 1.868 kg/cm^3.

3. California Bearing Ratio. Initially for the local soil the soaked CBR value was 1.7% and unsoaked CBR was 3.14%. After stabilization the soaked value for the local soil was increased around 1260% and for the unsoaked CBR increment was around 455%. Best result for unsoaked and soaked CBR was observed with second dosage and the value of unsoaked and soaked CBR for the second was observed to be 14.22% and 21.43% respectively.

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