

Effect of Bio-Enzyme (Terrazyme) on the Properties of Sub Grade Soil

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Abstract - Improvement and soil stabilization are widely used as an alternative to substitute the lacking of suitable material on site. There is an urgent need for the development of new technique, which improves the Geo technical properties of the subsoil. Sub-base is main part of structure, which act as stress transmitting medium and spread the load over large area. Vast areas of India consist of black cotton soil which has high clay content, low strength and minimum bearing ratio. Recently many Bio-enzymes (Terrazyme) have been used in the present work to study its effect on the unconfined compressive strength of black cotton soil. It has been found that Bio-enzymes (Terrazyme) treated Black cotton soil shows significant increase in unconfined compressive strength with longer curing period. Bio-enzyme has significant impact on improving unconfined compressive strength. Bio-enzyme is natural, non toxic, non flammable, non corrosive, liquid enzyme formulation fermented from vegetable extracts that improves the engineering qualities of soil. In this study a laboratory experiments are conducted to find engineering properties of soil, to evaluate the effects of Bio-enzyme (Terrazyme) with different dosage and curing time for finding consistency by Atterbergs limit test and modified proctor test, swelling index, Unconfined compression test, California bearing ratio, and compression strength and durability for Black cotton soil.

Key words: Atterbergs limit test, modified proctor test, swelling index, unconfined compression test, California bearing ratio, unconfined compression test, Bio-enzyme (Terrazyme), Black cotton soil etc.

1. INTRODUCTION

The process of improving the strength and durability of soil is known as soil stabilization. Soil improvement by mechanical or chemical means is widely adopted. In order to stabilize soils for improving strength and durability, a number of chemical additives, both inorganic and organic, have also been used. The main aim of stabilization is cost reduction and to efficiently use the locally available material. Most common application of stabilization of soil is seen in construction of roads and airfields road pavement.

Recently Bio-Enzymes have emerged as a new chemical for soil stabilization. Bio-Enzymes are chemical, organic, and liquid concentrated substances which are used to improve the stability of soil sub-base of pavement structures. Chemical stabilization is done by adding chemical additives to the soil that physically combines with soil particles and alter the geotechnical properties of soil. Enzymes enhance

the soil properties and provide higher soil compaction and strength. TerraZyme is non toxic, non corrosive and inflammable liquid which can be easily mixed with water at the optimum moisture content. TerraZyme improves the properties of soil and strength of soil significantly. Life of a structure increases as CBR value is increased and consistency limits are decreased. The chemical bonding of the soil particles is increased by the use of TerraZyme and a permanent structure is formed which is resistant to wear and tear, weathering and infiltration of water in soil. Apart from improving strength of soil this bio enzyme replaces the need of granular base and sub base.

1.1 Objectives of the Investigation

1. The main objective is to investigate the stabilization mechanism of some of the commercially available enzyme-based products to better understand their potential value for road construction.
2. Limited laboratory experiments are performed to determine if these products improve the material properties of sub grade soils and if they offer superior mechanical properties compared to other types of stabilization for which comprehensive laboratory and field performance already exists.
3. To determine the physical & engineering properties of natural soil by conducting laboratory tests and also to evaluate the improvement in properties by the addition of stabilizers (Bioenzyme) to be used in pavement design for economy.

2. MATERIAL AND METHODOLOGY

2.1. Material

2.1.1 Terrazyme

Terrazyme is a natural, non-toxic liquid, 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, it emphasizes on strength, performance and higher resistance towards deformation. Terrazyme is specially formulated to modify the engineering properties of soil. They require dilution in water before application. The use of Terrazyme enhances weather resistance and also increases load bearing capacity of soils. These features are particularly

evident in fine-grained soils such as clay in which the formulation affects the swelling and shrinking behavior.

This formulation has the ability to change the matrix of the soil so that after compaction the soil loses its ability to reabsorb water and the mechanical benefits of compaction are not lost even after water is reapplied to the compacted soil. Once the enzyme reacts with the soil, the change is permanent and the product is bio-degradable.



Enzyme Properties

Table- 1: Physical/Chemical Characteristics
Physical/Chemical Characteristics

Boiling point	212°F
Specific Gravity	1.05
Evaporation Rate	Same as water
Solubility in water	Complete
Appearance/Odor	Brown liquid, Non-obnoxious

According to the literature, when mixed with water and applied, the enzyme solution combines the inorganic and organic material in the soil through a catalytic bonding process, producing a “cementation” action. Soil stabilization using enzymes is a relatively new approach to soil improvement. Enzyme promotes the development of cementations compounds using the following, general reaction.

- To minimize the problems faced, we introduce TerraZyme an alternate tool for building roads
- TerraZyme, manufactured by Nature Plus Inc – U.S, (under ISO – 9002 procedures) is an excellent replacement for metalling and soling.
- TerraZyme is a liquid extract from sugar molasses that improves the engineering qualities of the soil like CBR values and density and decreases the OMC, plasticity index of soil.

Benefits of using Terrazyme

1. Cuts construction cost by 10%-20%
2. Higher CBR value / higher road strength: TerraZyme base Structures have a much higher CBR value.
3. Lowers the maintenance cost by 30-50%.
4. Saves construction time by 50%
5. Pavement thickness is reduced by 5-10% in phase of trials
6. Environment friendly and bio-degradable product.
7. The product has been accredited by IRC

2.1.2 Soil

Black cotton soil, silty soil, red soil which is abundantly available in India is used for the investigation. Soil sample is

collected from the various region of country like as Surgana, Chandwad, sangamner, Maharashtra.

The soil used in the work was monmorillitic clay obtained from Nasik and Nagar District of Maharashtra. Samples were air dried for a week, broken down into smaller pieces and stored in desiccators. Various tests were performed to establish the engineering properties of the untreated sample.

Collected sample from

- Black cotton soil –Sangamner, Dist- A. Nagar.
- Black cotton soil –Chandwad, Dist – Nasik.
- Red soil- surgana, Dist- Nasik.

2.2 Methodology

Various laboratory and experimental work have been carried out in the present investigation. The work includes two black cotton soils from sangamner, dist-Nagar and chandwad, Dist-Nasik, one red soil from surgana dist-Nasik and one additive to treat all taken soil respectively. Specimens were prepared at three different dosages of the additive and cured up to 28 days. Tests were conducted at 7 day intervals. All experiments were carried out as per the standard procedures described in the Bureau of Indian Standards.

2.2.1 Material Characterization

The soil used in the work was black cotton soil, black cotton soil and red soil obtained from Sangamner, Chandwad and surgana, Maharashtra respectively. Samples were dried in oven for a 2days, and stored in regular temperature. Various tests were performed to establish the engineering properties of the untreated sample and are given below.

Table -2: Engineering properties of soil

Sr	Properties	Black cotton soil (Sangamner)	Black cotton soil (Chandwad)	Red soil (Surgana)	IS Classification
1	Specific gravity	2.49	2.49	2.44	IS 2720 (part III)
2	Liquid limit	51.13	51.13	42.14	IS 2720 (part V)
3	Plastic limit	29.53	51.13	28.69	IS 2720 (part V)
4	Plasticity index	21.6	21.5	13.45	IS 2720 (part V)
5	IS Soil	CI	CI	CI	
6	Compaction Characteristics Maximum Dry Density.kN/m ³ Optimum Moisture Content. %	1.80 11.50	1.80 12.56	1.63 16.92	
7	Unconfined	2.28	2.68	2.30	IS 2720

	Compressive Strength (kPa)				(part II, VII)
8	Free swell index	43	19	25	IS 2720 (part XL)

2.2.3 Bio-Enzyme (Terrazyme)

TerraZyme liquid stabilizer is specifically formulated to modify the engineering properties of soil and aggregate mixtures by catalyzing natural chemical reactions in the soil, converting poor materials into more water and load resistant forms to improve the structural properties of cohesive soils. One bottle of Terrazyme was purchased from Avineet Agencies, Chennai. Also referred to as TZ, it is a natural, non-toxic liquid, formulated from sugar molasses. Literature confirms that TZ improves the engineering qualities of the soil like CBR values and dry density. This in turn also decreases the OMC and plasticity index of soil.

Table -3: Properties of Terrazyme

Property	Value
Specific Gravity	1.05
PH value	3.50
Appearance/ odour	Dark brown, Non obnoxious
Total dissolved solids	19.7 ppm
Cation exchange capacity	3.87
Hazardous content	None
Boiling point	212°F
Evaporation rate	Same as water
Solubility in water	Same as water
Melting point	Liquid
Reactivity data	Stable
Materials to avoid	Caustics and strong bases

3. RESULTS AND DISCUSSIONS

This section expressed the experimental results of the Atterbergs limits tests, modified compaction tests, unconfined compressive strength tests, free swell index test which are used as defining parameters for the optimization of the dosage of TerraZyme required to treat the soils. The differential free swell tests were conducted for the soils treated with optimized dosage of TerraZyme.

3.1 Atterbergs limits: IS 2720 Part V- 1985, IS 2720 Part VI- 1972

These tests are performed to determine liquid limit, plastic limit and the plasticity of cohesive soil in order to characterize its condition by water content. The effect of Bioenzyme at different dosage on index properties (LL, P.L. and P.I.) of Black Cotton soil from sangamner, from chandwad respectively and red soil from Surgana have been presented in table no. 3.1. The enzyme treated soil sample's consistency limits were tested immediately after the mixing.

Table -4: Consistency limits of stabilized black cotton soil

Dosage no	Enzyme dosage	B.C. soil (Sangamner)			B.C. soil (Chandwad)			Red soil (Surgana)		
		LL (%)	PL (%)	PI (%)	LL (%)	PL (%)	PI (%)	LL (%)	PL (%)	PI (%)
0	Untreated	51.13	29.53	21.6	55.70	29.54	26.16	42.14	18.69	23.45
1	100ml /1.5m ²	49.81	28.92	20.89	55.10	28.70	26.4	41.47	18.05	23.43
2	200ml /1.5m ²	48.26	28.31	19.95	53.83	28.15	25.68	40.20	17.89	22.31
3	300ml /1.5m ²	47.96	28.00	19.96	53.10	28.10	25	39.87	17.63	22.24

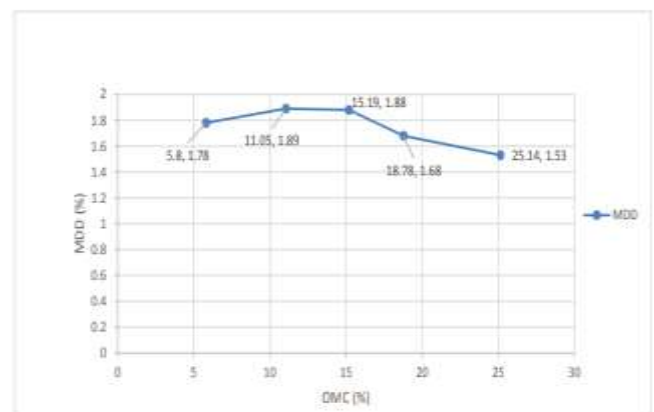
3.2 Compaction Test / Modified proctor test: IS 2720 Part VII- 1965

To obtain relation between moisture content and dry density of soil using heavy compaction and hence to find out MDD and OMC. Above mentioned two Black cotton (BC) soil with different dosage of Terrazyme, and Red with different dosage of Terrazyme, Modified Proctor's Test was conducted. Test results are presented in table 5

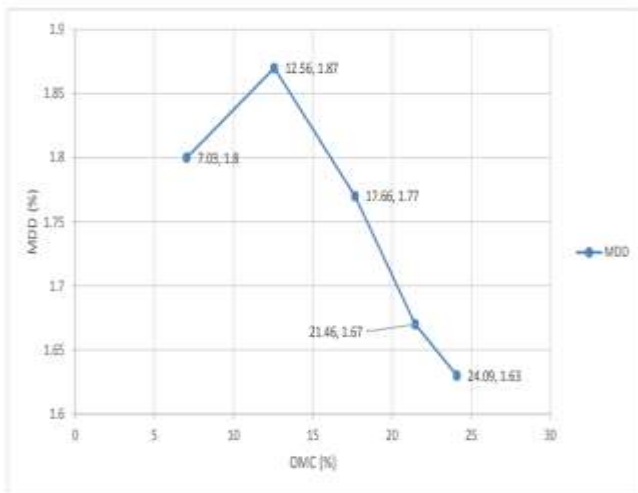
Table -5: OMC and MDD of stabilized two Black Cotton soil and one red soil

Dosage No.	Enzyme Dosages	Heavy compaction B.C. soil (sangamner)		Heavy compaction B.C. soil (chandwad)		Heavy compaction Red soil (surgana)	
		OMC (%)	MDD (kg/cm ³)	OMC (%)	MDD (kg/cm ³)	OMC (%)	MDD (kg/cm ³)
1	Untreated	11.05	1.89	12.56	1.867	16.92	1.629
2	100ml /1.5m ²	10.97	1.88	13.13	1.98	17.64	1.68
3	200ml /1.5m ²	12.73	1.91	11.732	2.13	20.40	1.73
4	300ml /1.5m ²	11.26	1.897	12.73	1.912	16.07	1.73

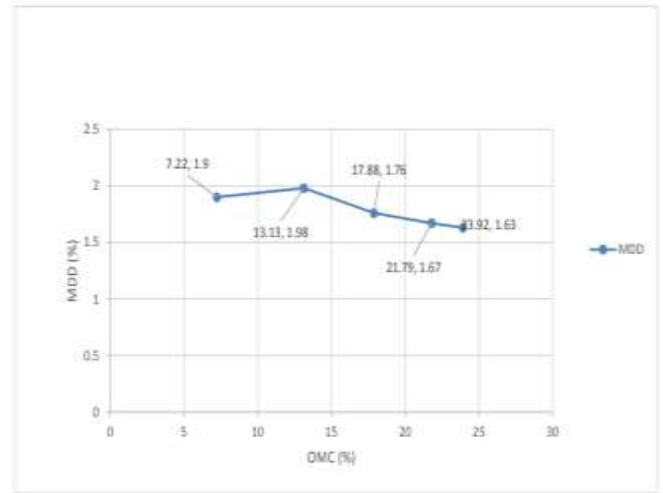
The increase in MDD with different dosages of Terrazyme is uniform till the final dosage 200ml/1.5m³. This trend happens due to the formation of transitional compounds that had higher densities in the range of 3rd enzyme dosage.



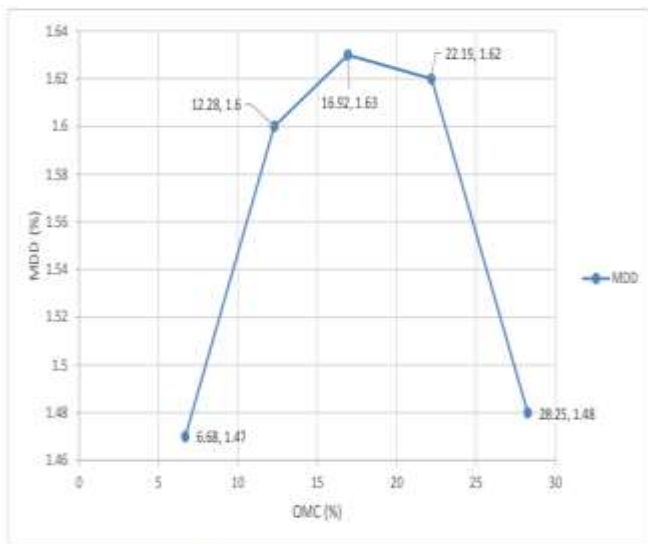
Graph -1: Black Cotton soil-Sangamner without Terrazyme



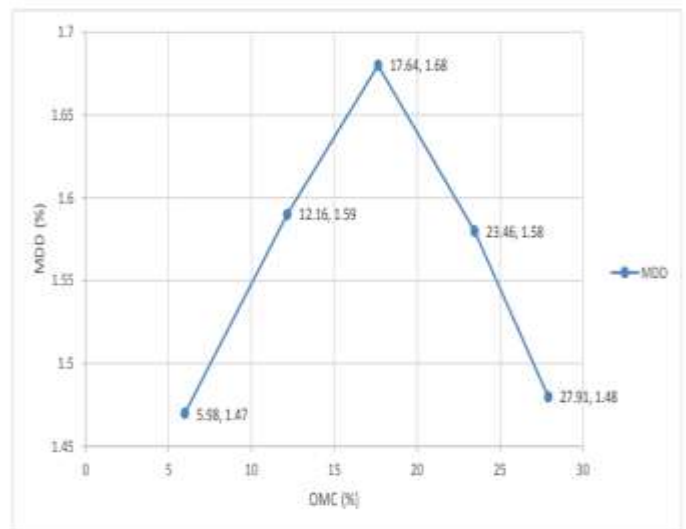
Graph -2: Black cotton soil-Chandwad without Terrazyme



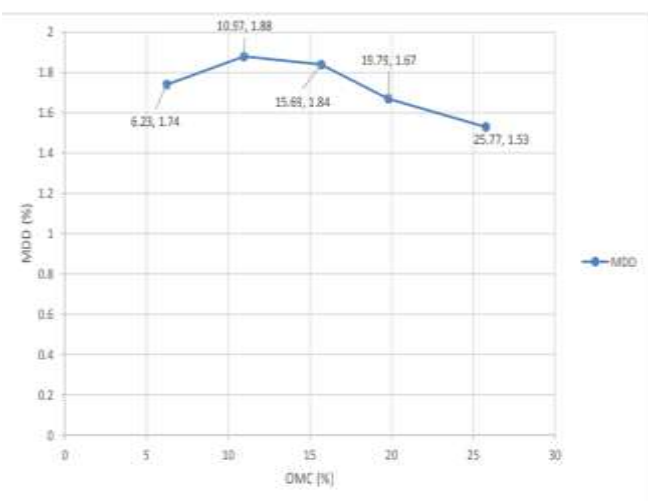
Graph -5: Black cotton soil-Chandwad with Terrazyme 100ml/1.5m³



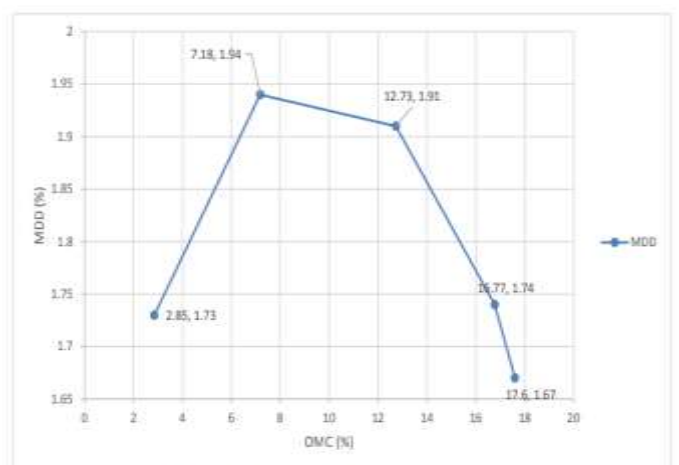
Graph -3: Red Soil-Surgana without Terrazyme



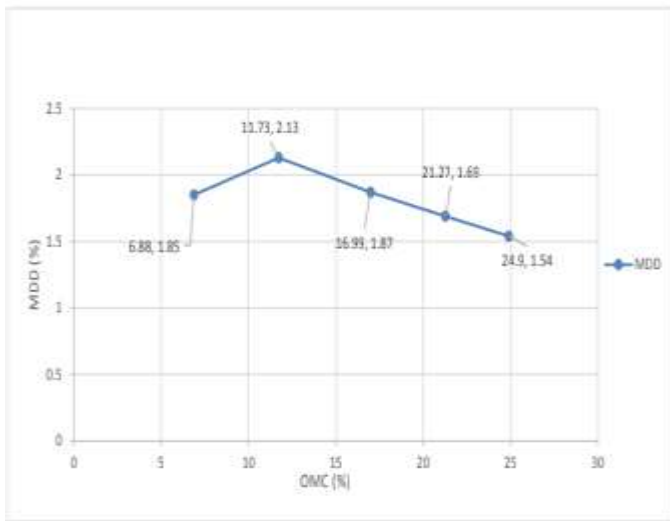
Graph-6: Red Soil-Surgana with Terrazyme 100ml/1.5m³



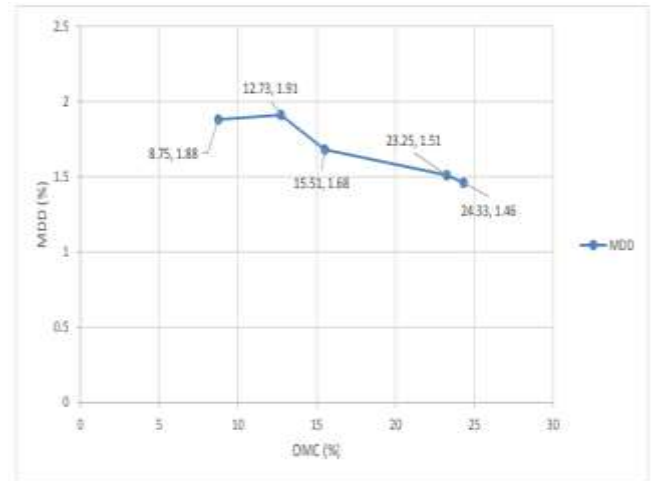
Graph -4: Black Cotton soil-Sangamner with Terrazyme 100ml/1.5m³



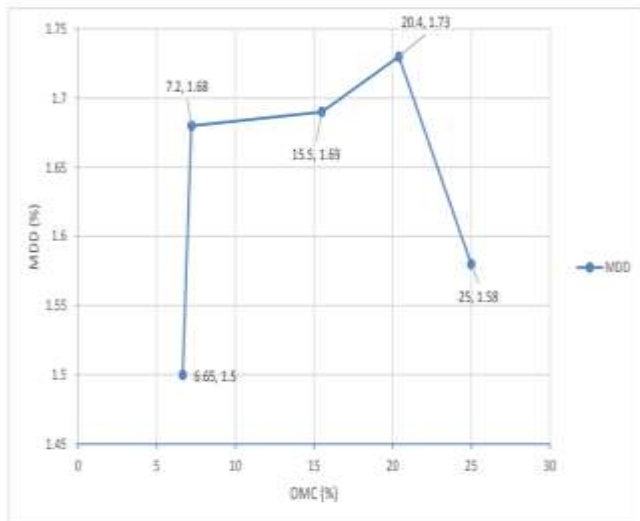
Graph -7: Black Cotton soil-Sangamner with Terrazyme 200ml/1.5m³



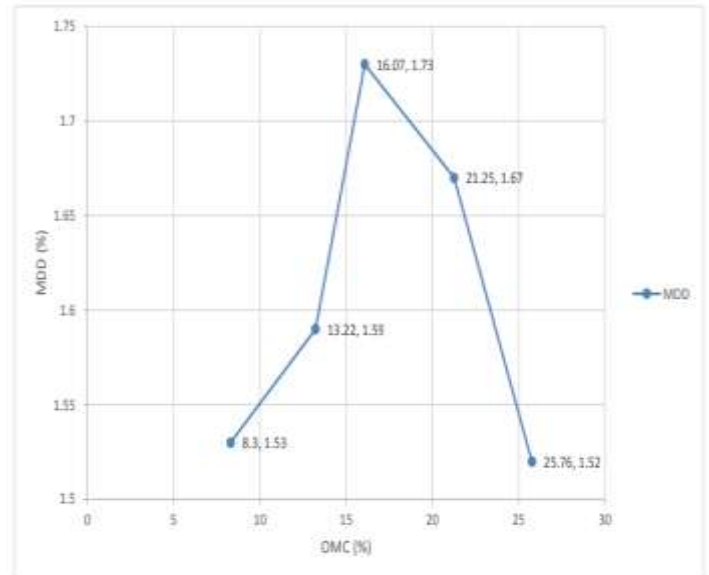
Graph -8: Black cotton soil-Chandwad with Terrazyme 200ml/1.5m³



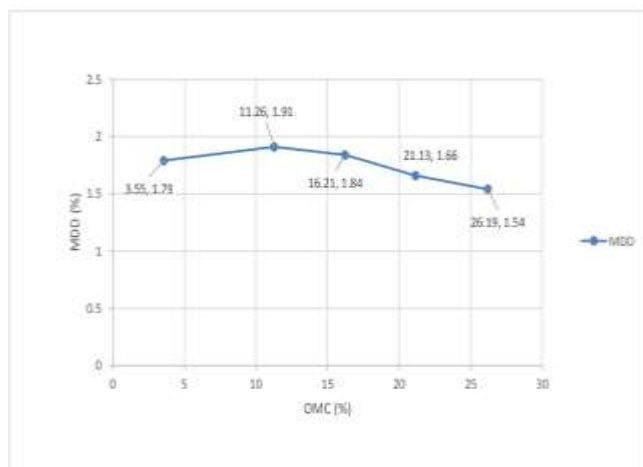
Graph -11: Black cotton soil-Chandwad with Terrazyme 300ml/1.5m³



Graph -9: Red Soil-Surgana with Terrazyme 200ml/1.5m³



Graph -12: Red Soil-Surgana with Terrazyme 300ml/1.5m³



Graph -10: Black Cotton soil-Sangamner with Terrazyme 300ml/1.5m³

3.3. Free Swell Index:

Swelling is the system of entry of water into the pores which causes swelling of the soil volume. The measure of swelling is the extent between stature changes after submersion of the primary unique soil example is by and large shown as percent. Free swell file bears a remarkable relationship both with liquid limit and percent swell.

Table -6: shows the swelling property of untreated and BC soil.

Sr	Sample	BC soil (sangamner)	BC soil (chandwad)	Red soil (Surgana)
1	Mass of Dry Soil	10	10	10
2	Volume of Soil in Water	14.3	11.9	12.5
3	Volume of Soil in Kerosene	10	10	10
4	Free Swell Index (%)	43	19	25

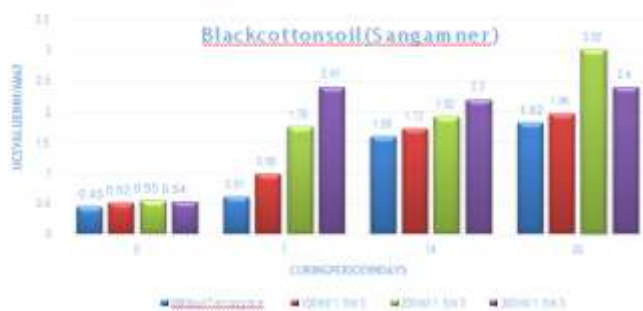
3.4 Unconfined Compression Strength (UCS) Test:

Unconfined compression strength of two black cotton soil and one red soil have evaluated by stabilization with variable dosages of enzyme for 0 and 7 curing day. For 14, 21 and 28 days curing UCS calculation will be determined after completion of mention curing period. The test results are summarized in table 7

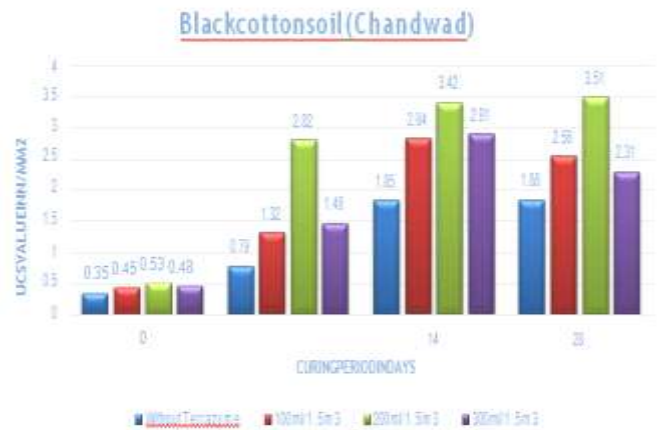
Table -7: UCS value (N/mm²) of two BC soil and one Red soil with varying enzyme dosage & curing time

Dosage No.	Enzyme dosage	B.C. soil(sangamner)				B.C. soil(chandwad)				Red soil(surgana)			
		Curing Period in days											
		0	7	14	28	0	7	14	28	0	7	14	28
1	Untreated	0.45	0.61	1.59	1.82	0.43	0.79	1.85	1.86	1.14	2.23	1.77	2.41
2	100ml /1.5m ³	0.52	0.98	1.72	1.96	0.32	1.32	2.84	2.56	0.53	1.86	2.68	2.73
3	200ml /1.5m ³	0.55	1.76	1.92	3.02	0.53	2.82	3.42	3.51	0.67	1.85	2.92	3.00
4	300ml /1.5m ³	0.54	2.41	2.20	2.40	0.28	1.48	2.19	2.31	1.05	2.42	2.55	2.31

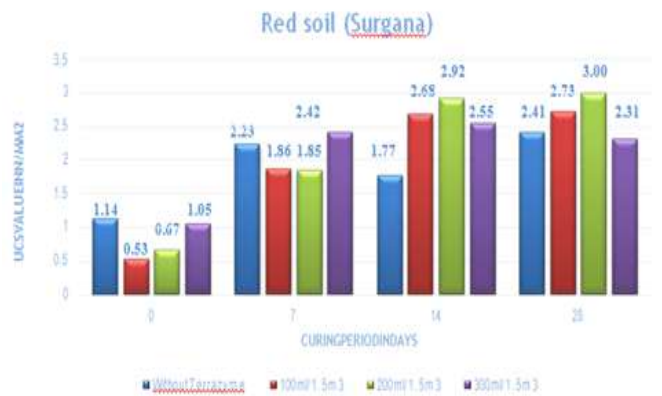
From above result unconfined compressive strength of black cotton soil and red earth was evaluated by stabilization with variable dosages of TerraZyme and subjected to air-dry curing conditions up to 28 days of curing. Above table presents the unconfined compressive strength for treated black cotton soil and red earth. The unconfined compressive strength of TerraZyme treated black cotton soil and red earth has shown tremendous improvement. With increase in curing periods, UCS has increased and also with increase in dosage amount.



Graph 13: Result Of UCS Test On Black Cotton Soil (Sangamner)



Graph 14: Result of UCS Test on Black Cotton Soil (Chandwad)



Graph -15: Result of UCS Test on Red Soil (Surgana)

3.5 California bearing ratio:

Two black cotton soil and red earth were treated with dosage 2 of TerraZyme and subjected to curing up to 14 days. Dosage 2 has been considered as the optimum dosage of TerraZyme for all three soils based on Index properties tests and UCS tests. The treated specimens were tested in unsoaked condition. The test results are presented in Table below for two black cotton soils and one red soil respectively.

Table 8: Unsoaked CBR of Two Black cotton soil and one red soil treated with TerraZyme

Dosage No.	Enzyme dosage	B.C. soil (sangamner)				B.C. soil (chandwad)				Red soil (surgana)			
		Curing Period in days											
		0	7	14	0	7	14	0	7	14			
1	Untreated CBR (%)	3	-	-	3	-	-	7	-	-			
2	200ml/1.5m ³ CBR (%)	3	6	15	3	5	11	7	9	22			

A tremendous increment in Unsoaked CBR has been observed in the TerraZyme treated both black cotton soil and red soil. Even in the case of CBR, air-dry curing has proved the best method of curing in curing methods for treating the expansive and non-expansive soils using TerraZyme.

4. CONCLUSIONS

The suitability of TerraZyme for the modification of Geotechnical properties of expansive and non-expansive soils is concluded by studying the effect of TerraZyme on the index and engineering properties of black cotton soil and red earth. Air-dry curing condition was adopted along with regular controlled laboratory desiccators curing condition to study the suitability of TerraZyme for field conditions during treatment of soils. Based on the test results, the following conclusions have been drawn.

1. Bioenzyme (TerraZyme) stabilization has shown good improvements in engineering properties of both black cotton soil and red soil
2. Unconfined compressive strength of both black cotton soil and red soil has shown tremendous increment with drying than curing in laboratory desiccators after treating it with TerraZyme.
3. Atterbergs limits for both black cotton soil and red soil did not exhibit any difference in drying and desiccators curing.
4. Black cotton soil and red soil attained hydrophobic nature with drying after treatment from TerraZyme as observed during Atterbergs limits test.
5. The properties of black cotton soil have been much improved by stabilizing with TerraZyme dosage of 200ml/1.5m³ of soil and for red earth by 200ml/1.5m³ of soil. Hence this dosage is considered as the optimum one.
6. Even Unsoaked CBR of both black cotton soil and red soil has shown better improvement with treatment in drying or normal room temperature.
7. Compaction characteristics are not affected immediately after treatment with Terrazyme.
8. Free Swell Index of black cotton soil showed drastic reduction with treatment from TerraZyme especially with drying.
9. Air-dry curing (or drying) condition proved more efficient in treating both the black cotton soils and one red soil.

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