RESEARCH ARTICLE OPEN ACCESS

Improving the Properties of Black Cotton Soil Using Terrazyme as a Admixture

Suresh.T[1], Balakrishna.Y[2], Nitesh.k3

[1]Department of Civil Engineering, Arjun College of Technology and Science, Hyderabad, 501512.

[2] Department of civil engineering, CMR Technical campus, Hyderabad, 501401.

[3]Department of Civil Engineering, Arjun College of Technology and Science, Hyderabad, 501512.

Abstract:

Bio-enzyme is a natural, non toxic, non flammable, non-corrosive liquid enzyme formulation fermented from vegetable extracts that improves the engineering qualities of soil, facilitates higher soil compaction densities and increases stability. Enzyme catalyze the reactions between the clay and the organic cat-ions and accelerate the cat-ionic exchange process to reduce adsorbed layer thickness. For other types of chemical stabilization, chemicals are mixed with soil, which is difficult to mix thoroughly, but bio-enzyme is easy to use as it can be mixed with water at optimum moisture content and then it is sprayed over soil and compacted. Recently many Bio-enzymes have emerged as cost effective stabilizers for soil stabilization. One such bio-enzyme, Terrazyme, has been used in the present work to study its effect on the CBR value of the Black Cotton soil. The tests conducted in this project are specific gravity, plastic limit, liquid limit, CBR and standard proctor test. In this project, local soil was mixed with Terrazyme with different dosages i.e. 0.25 ml per 100 ml of water, 0.50 ml per 100 ml of water, 0.75 ml per 100 ml of water, and 1 ml per 100 ml of water was mixed subjected to various tests as mentioned. All the testing programs have given optimum value at 0.5 ml terrazyme per 100ml of water. The pavement thickness values reduced by improving the sub grade strength (CBR value).The cost analysis done for this project by using CBR values of the experiments with the reference of pavement design catalogue MORD specification table. The pavement construction value is reduced 30% of the total cost with the help of my laboratory testing results.

Keywords — **Bio-Enzyme Stabilization, Black Cotton Soil, California Bearing Ratio, Terrazyme**.

I. INTRODUCTION

The growth of the population has created a need for better and economical vehicular operation which requires good highways having proper geometric design, pavement condition and maintenance. Many areas of India consist of soils with high silt contents, low strengths and minimal bearing capacity [1]. The long-term performance of any construction project depends on the soundness of the underlying soils. Unstable soils are always a trencher and can create significant problems for pavements or structures. With proper design and construction techniques, lime and cement treatment chemically transforms unstable soils into usable materials. Indeed, the structural strength of stabilized soils can be factored into pavement designs. Stabilizers can be used to treat soils to varying degrees, depending upon the objective. The least amount of treatment is used to dry and temporarily modify soils. Such treatment produces a working platform for construction or temporary roads. A greater degree of treatment supported by testing, design, and proper construction techniques produces permanent structural stabilization of soils. Before beginning any construction project, project plans and specifications must be developed. For highway pavements, the design must accommodate expected traffic volumes along with environmental, site, and material conditions. All structural designs should be based upon laboratory tests and mix designs that fit the demands of the particular project and provide the most economical alternative for the planned use. A highway is a public road, especially a major road connecting two or more destinations. Any interconnected set of highways can be variously referred to as a "highway system", a "highway network", or a "highway transportation system". The history of highway engineering gives us an idea about the roads of ancient times. Roads in Rome were constructed in a large scale and it radiated in many directions helping them in military operations. Thus they are considered to be pioneers in road construction. The modern roads by and large follow Macadam's construction method, use of bituminous concrete and cement concrete are the most important developments. Various advanced and cost-effective construction technologies are used. Developments of new equipment help in the faster construction of roads. Many easily and locally available materials are tested in the laboratories and then implemented on roads for making economical and durable pavements. Scope of transportation system has developed very largely. Population of the country is increasing day by day. The need for travel to various places at faster speeds also increased. This increasing demand led to the emergence of other modes of transportation like railways and travel by air. While the above development in public transport sector was taking place, the development in private transport was at a much faster rate mainly because of its advantages like accessibility, privacy, flexibility, convenience and comfort. This led to the increase in vehicular traffic especially in private transport network. Thus road space available was becoming insufficient to meet the growing demand of traffic and congestion started. In addition, chances for accidents also increased. This has led to the increased attention towards control of vehicles so that the transport infrastructure was optimally used. Various control measures like traffic signals, providing Roundabouts and medians, limiting the speed of vehicle at specific zones etc. were implemented.

II. LITERATURE REVIEW

Hitam et al (1998) of palm oil research institute of Malaysia conducted field studies on improvement of plantation roads. The road was unpaved road and it affects badly due to adverse weather conditions. Terrazyme was treated to 27.2 km of the road and the sections were then monitored on the surface erosion for two monsoon seasons. No damage was noticed and there searches have concluded that Terrazyme stabilization can convert the road to all weather roads that has minimum destruction in hot and wet seasons. **Yusuf et al** (1998) conducted a Laboratory experiments with two types of enzymes Studied for variation in strength and maintenance cost [2]. **Lacuoture and Gonzalez** (1995) conducted a comprehensive study of the Terrazyme soil stabilizer product and its effectiveness on sub-base and sub-grade soils. The reactions of the soils treated with the enzyme was observed and recorded and compared to the untreated control samples, the variation in properties was observed over a short period only and it was found that in cohesive soils there was no major variation in properties during the early days but the soil showed improved performance progressively [3]. **Highway Department of Thailand** (1996) and they found that after one week, two week, three week, and14 week periods CBR was found as 37, 62, 66 and 100+ respectively as compared to 28% of untreated soil, investigators also reported reduction in gravel loss, road roughness, dust levels on the Terrazyme treated road sections[4]. **Mohamed. Ali** (2001) as per laboratory test to establish the deformation modulus of sub-graded soil as well as inter relationship between CBR and modulus of elasticity for the structural design of highways in Sudan. He proposed an equation between modulus of elasticity and California Bearing Ratio [5]. **Sharma** (2001) has conducted laboratory studies on use of Bio-Enzyme stabilization of three types of soils namely, clay of high plasticity, clay of low plasticity and silt of low plasticity. It was found that soil shows a marginal improvement in CBR value and substantiates reduction in saturation moisture after four weeks of stabilization. The soil shows a marginal improvement in unconfined compressive strength, direct tensile strength and fatigue strength [6]. **Isaac et al** (2003) have done experimental studies in the area of Bioenzymatic soil stabilization in the laboratory for different types of soils from Kerala. The soil samples were laterite, clay and sand. These samples were tested for grain size analysis and Atterbergs limit. The optimum moisture content of the soil was determined from modified compaction test. The soil was treated with different dosage of enzyme. CBR test were conducted on each soil samples at different curing period under soaked condition. From the study they found that Terrazyme treatment is very effective, economical and environment friendly technique for the stabilization of fine grain soil [7]. **Sridhar anand Nagaraj** (2005) have made a compaction study with 5 different types of soils; the correlation is made between OMC and Plastic limit, maximum dry density and plastic limit. A mineralogical analysis was performed using an X-ray Diffract Meter [8]. **Mihai et al** 2005 have done experiments on two types of soils with two enzyme products. The main objective is to investigate the stabilization mechanism of some of the commercially available enzyme based products to understand their potential value for road construction [9]. **Roger Bergmann** (2006) has studied on soil stabilizers on trail surface and concluded that Bioenzymes requires some clay content in the aggregate material in order to create the reaction that will strengthen the material. Also reports showed that successful stabilization with as little as 2%clay in the aggregate material but best result seem to be achieved with 10 to 15% clay, upon completion of construction the trail looked very good but like the other trail sections it did not hold up over the first winter [10]. **Saad Aiban** (2006) studied the compressibility and swelling characteristics of eastern Saudi Arabian expansive soil. Odometer free swell test were conducted on undisturbed and re-molded play gorsite expansive soil. The mineralogical composition and fabric of soil was analyzed. This welling to re-molded samples was higher than undisturbed samples. It was found that Pre-wetting of undisturbed samples this swell potential [11]. **Shankar et al** (2009) have done experimental work on lateritic soil collected from Dakshina Kannada and Udupi districts. The lateritic soil and blended lateritic soil are tested for Engineering properties, CBR and UCC. Then these soils are treated with different dosages of Enzyme, Again these soils are tested for Engineering properties, CBR and UCC over different curing periods, By comparing CBR, UCC values the soil treated with Enzyme shows a margin a improvement [12].**TewodrosAlene** (2010) has done Extensive study in Ethiopia on expansive soils. The construction of test sections is carried out on a road with Expansive sub grade along the Chancho Ginchi road. Different types of soil stabilization techniques have been used (Mechanical, lime and chemical stabilization). The expansive sub grade is mechanically stabilized by mixing it with on – plastic gravel with a proportion of 50% by volume and compacted to the required density. The expansive soil is treated with semi processed lime with an application rate of 10% by weight further the expansive sub grade was treated with a combination of hydra ted lime and aTerrazyme. Nine trial sections were formed by using different materials. A comparative study on different trial sections reveals that Terrazyme stabilization gives fruitful results [13]. **Patel and Desai** (2010) proposed a method for correlating CBR values with the liquid limit, plastic limit, and plasticity index, optimum moisture content and maximum dry density of cohesive soil of various zone of Surat City of Gujarat state[14] .**Kyle Marlins** (2010) has done experimental investigation on 3 types of soils (coarse medium, fine) using Terrazyme. Tests were performed on samples which were allowed to cure for 1, 4 and14 weeks after compaction. The results from these tests were compared with untreated samples the CBR values for all 3 Terrazyme treated gradation, (coarse, medium, and fine) increased significantly at 4 weeks and 14 weeks over the untreated soil samples [15].

III. OBJECTIVE OF STUDY

- To study Black Cotton Soil.

- To study the admixtures like terrazyme.
- To study the behavior of improving the properties and strength of BC soil using terrazyme.

IV. MATERIALS

Black cotton soil: Black cotton soil (BC soil) is a highly clayey soil. The black colour in Black cotton soil (BC soil) is due to the presence of titanium oxide in small concentration. The Black cotton soil (BC soil) has a high percentage of clay, which is predominantly montmorillonite in structure and black or blackish grey in colour. Expansive soils are the soils which expand when the moisture content of the soils is increased. The clay mineral montmorillonite is mainly responsible for expansive characteristics of the soil. The expansive soils are also called swelling soils or black cotton soils.

Fig.1: Black Cotton Soil with Terrazyme

Terrazyme: Bio-enzyme from Australia is a natural, non-toxic bio-degradable liquid concentrate that mixes easily in water for application with standard water spraying equipment. Bio-Enzyme is a low cost additive with long lasting effects.

By altering the physical and chemical characteristics of soil, materials treated with Bio-Enzyme retain higher performance levels and extended life span. Bio-Enzyme may be used to increase the Maximum Dry Density and Unconfirmed Compressive Strength (UCS) values of a marginal material to achieve specified standards for a base course

Fig.2 Bottle of Terrazyme

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TABLE 1. PROPERTIES OF TERRAZYME

Properties	Values
Specific gravity	1.05
pH value	3.50
Appearance / odour	Dark brown Non-obnoxious
Total dissolved solids	19.7ppm
Cation exchange capacity	3.87%
Hazardous content	None
Boiling point	212˚F
Evaporation Rate	Same as water
Solubility in water	Complete
Melting point	Liquid
Reactivity data	Stable

V. EXPERIMENTAL RESULTS

TABLE 2: SPECIFIC GRAVITY OF BLACK COTTON SOIL USING 0ML, 0.25ML, 0.5ML, 0.75ML AND 1ML OF TERRAZYME 0 ML OF TERRAZYME

CALCULATIONS	0ml			0.25ml			0.5ml			0.75			1ml		
	Trail 1	Trail2	Trail3	Trail 1	Trail2	Trail3	Trail 1	Trail2	Trail3	Trail 1	Trail2	Trail3	Trail 1	Trail2	Trail3
M_1	28.28	28.55	28.54	28.27	28.48	28.296	28.3	28.39	28.49	28.56	28.34	28.64	28.53	28.84	28.686
M_2	50.15	50.07	50.149	50.93	50.46	50.48	50.94	50.79	50.65	50.61	50.2	50.296	50.37	50.53	50.696
M_3	93.73	93.56	93.632	92.83	93.51	95.855	95.22	95.54	96.019	90.71	91.04	97.689	91.2	92.5	95.563
M_4	80.91	80.39	80.605	80.51	80.79	80.206	81.52	80.49	80.56	80.4	80.41	81.64	80.47	80.41	81.426
G= (M2-M1)/(M2-M1)-(M3-M4)	2.4165	2.564	2.517	2.191	2.373	3.395	2.532	3.047	3.307	1.871	1.946	3.863	1.965	2.259	2.795

TABLE 3: PLASTIC LIMIT OF BLACK COTTON SOIL USING 0ML, 0.25ML, 0.5ML, 0.75ML, 1ML AND1.25ML OF TERRAZYME

CALCULATIONS	0ml			0.25ml			0.5ml			0.75			1ml			1.25ml		
	Trail 1	Trail2	Trail3	Trail 1	Trail2	Trail3	Trail 1	Trail2	Trail3	Trail 1	Trail2	Trail3	Trail 1	Trail2	Trail3	Trail 1	Trail2	Trail3
M_1	23.5	25	19.4	25.92	25.658	24.26	27.61	26.12	27.45	31.99	33.64	34.15	26.36	27.79	28.48	24.825	23.69	24.99
M_2	28.5	29.8	28.9	28.96	28.2	26.89	29.98	29.16	29.25	34.23	36.9	37.82	29.5	30.54	31.14	27.69	26.925	27.869
M_3	27.5	28.7	26.8	28.283	27.642	26.29	29.42	28.439	28.827	33.68	36.106	36.522	28.78	29.902	30.526	27.076	26.218	27.244
(WP)=(M2-M3)/(M3-M1)*100	25	29.729	28.378	28.623	28.12	29.04	30.932	31.04	30.69	32.544	32.164	31.96	29.752	30.16	29.96	27.24	27.94	27.68

TABLE 4: LIQUID LIMIT OF BLACK COTTON SOIL USING TERRAZYME AS STABILIZER

CALCULATIONS	0ml			0.25ml			0.5ml			0.75			1ml		
	Trail 1	Trail2	Trail3	Trail 1	Trail2	Trail3	Trail 1	Trail2	Trail3	Trail 1	Trail2	Trail3	Trail 1	Trail2	Trail3
M_1	29.5	26.5	29	29.5	277.29	28.628	25.84	27.05	27.45	30.28	29.53	26.82	29.68	29.85	27.86
M_2	3.9	31.5	35.5	32.5	30.5	31.568	31.31	32.48	32.1	34.22	33.38	30.04	32.29	33.014	29.98
M_3	33.2	30	33.5	31.509	29.43	30.602	29.42	30610	30.52	32.99	32.14	28.99	31.457	32	29.302
(wl) = ((M2-M3))/((M3-M1))×100	45.945	42.857	44.44	49.286	49.868	48.926	52.793	52.528	51.465	45.387	47.509	48.387	46.84	47.04	46.96
N	35	28	25	42	35	26	35	29	25	44	36	26	35	30	26

TABLE 5: PROCTOR TEST OF BLACK COTTON SOIL USING 0ML, 0.25ML, 0.5ML, 0.75ML AND 1ML OF TERRAZYME

CALCULATIONS	0ml			0.25ml			0.5ml			0.75			1ml		
	Trail 1	Trail2	Trail3	Trail 1	Trail2	Trail3	Trail 1	Trail2	Trail3	Trail 1	Trail2	Trail3	Trail 1	Trail2	Trail3
M_1	31.5	27.5	27.5	32.5	32.5	27	26.39	27.21	26.76	34.15	35.04	32.04	35.05	34.15	26.39
M_2	2.5	41	40	48.5	39	34	31.64	35.53	31.9	39.71	40.21	37.78	40.256	39.986	31.986
M_3	41	39	38.5	45.5	37.5	32.5	30.54	31.33	30.75	38.58	39.1	36.41	39.263	38.862	30.869
(wl) = ((M2-M3))/((M3-M1))×100	15.789	17.391	13.636	23.076	30	27.27	26.506	29.506	28.822	25.507	27.339	31.35	23.569	23.853	24.938
Water content added	15%	20%	25%	30%	23%	26%	24%	27%	29%	23%	25%	27%	20%	22%	24%

TABLE 6: CBR TEST OF BLACK COTTON SOIL USING 0ML, 0.25ML, 0.5ML, 0.75ML AND 1ML OF TERRAZYME

0ml				0.25ml				0.5ml				0.75				1ml			
Dis G(MM)	P GUAGE (KN)	CONSTANT VALUE	CBR VALUE	Dis G(MM)	P GUAGE (KN)	CONSTANT VALUE	CBR VALUE	Dis G(MM)	P GUAGE (KN)	CONSTANT VALUE	CBR VALUE	Dis G(MM)	P GUAGE (KN)	CONSTANT VALUE	CBR VALUE	Dis G(MM)	P GUAGE (KN)	CONSTANT VALUE	CBR VALUE
0.5	8	0.0592	48.277	0.5	8	0.0592	48.28	0.5	8	0.0592	48.277	0.5	6	0.0592	36.207	0.5	4	0.059	24.138
1	10	0.0592	60.346	1	10	0.0592	60.35	1	10	0.0592	60.346	1	8	0.0592	48.277	1	6	0.059	36.207
1.5	12	0.0592	72.415	1.5	14	0.0592	84.49	1.5	15	0.0592	90.519	1.5	10	0.0592	60.346	1.5	8	0.059	48.277
2	14	0.0592	84.485	2	16	0.0592	96.55	2	18	0.0592	108.62	2	14	0.0592	84.485	2	10	0.059	60.346
2.5	14	0.0592	84.485	2.5	18	0.0592	108.6	2.5	20	0.0592	120.69	2.5	16	0.0592	96.554	2.5	14	0.059	84.485
3	14	0.0592	84.485	3	20	0.0592	120.7	3	22	0.0592	132.76	3	18	0.0592	108.62	3	16	0.059	96.554
4	16	0.0592	96.554	4	24	0.0592	144.8	4	26	0.0592	156.9	4	20	0.0592	120.69	4	18	0.059	108.62
5	18	0.0592	108.623	5	26	0.0592	156.9	5	28	0.0592	168.97	5	22	0.0592	132.76	5	20	0.059	120.69
7.5	20	0.0592	120.693	7.5	28	0.0592	169	7.5	32	0.0592	193.11	7.5	24	0.0592	144.83	7.5	22	0.059	132.76
10	22	0.0592	132.762	10	30	0.0592	181	10	38	0.0592	229.32	10	26	0.0592	156.9	10	24	0.059	144.83
12.5	22	0.0592	132.762	12.5	30	0.0592	181	12.5	38	0.0592	229.32	12.5	26	0.0592	156.9	12.5	24	0.059	144.83
15	24	0.0592	144.834	15	30	0.0592	181	15	38	0.0592	229.32	15	26	0.0592	156.9	15	24	0.059	144.83

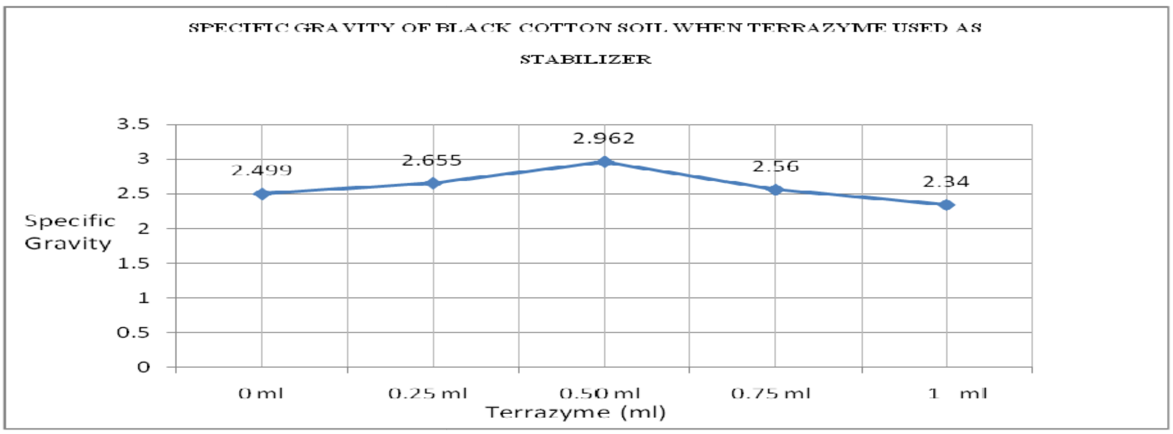

Fig. 3: Specific Gravity of Black Cotton Soil Using Terrazyme as Stabilizer

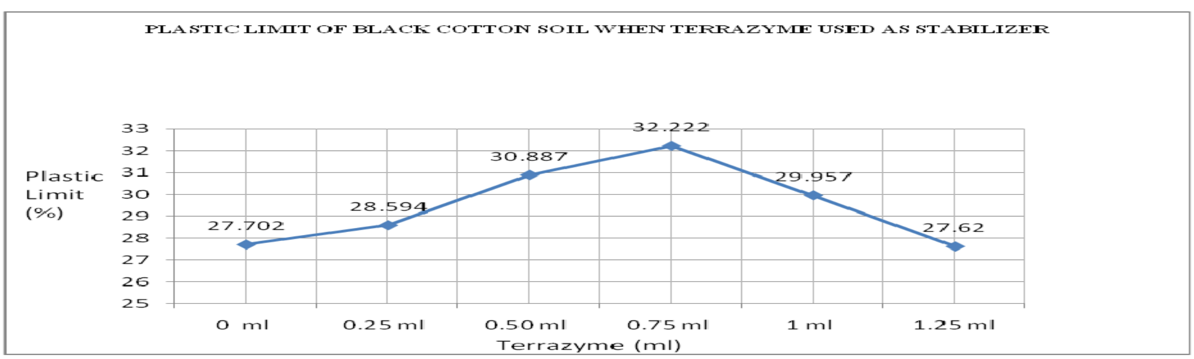

Fig. 4: Plastic Limit of Black Cotton Soil using Terrazyme as Stabilizer

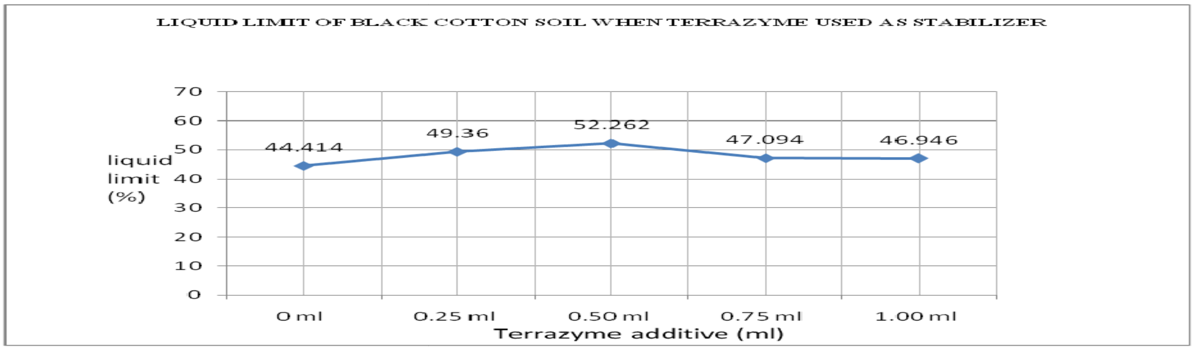

Fig. 5: Liquid Limit of Black Cotton Soil using Terrazyme as Stabilizer

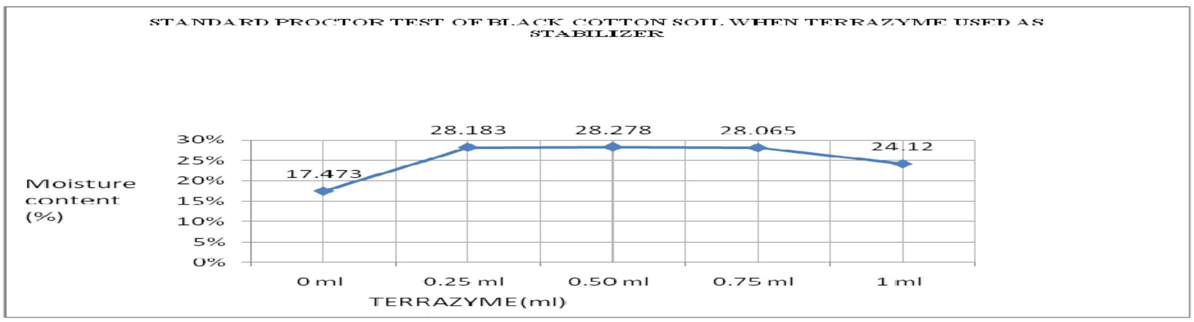

Fig. 6: Standard Proctor Test of Black Cotton Soil when Terrazyme using as Stabilizer

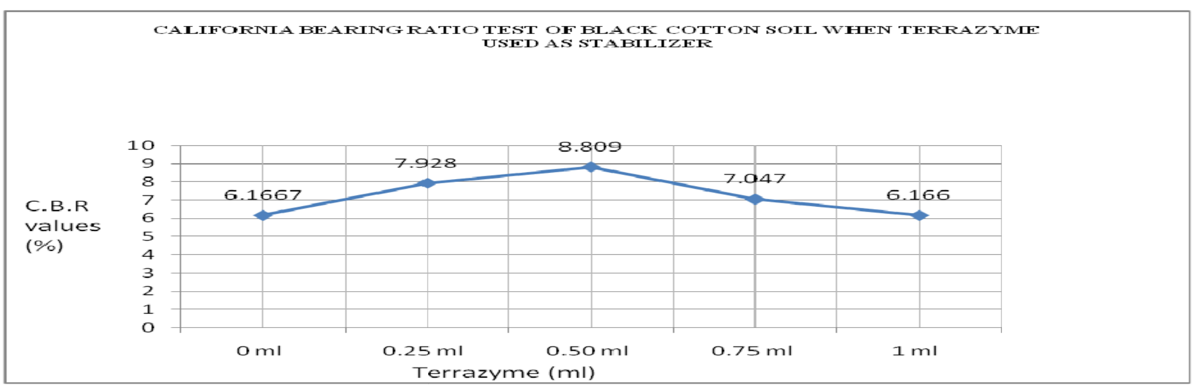

Fig. 7: CBR Test of Black Cotton Soil when Terrazyme used as Stabilizer

1) Specific Gravity

The addition of Terrazyme, increases specific gravity consistently from 2.499 to 2.962, the maximum specific gravity value is obtained at 0.5 ml is high with a value as 2.962[15]

2) Plastic Limit

The addition of Terrazyme, increases plastic limit consistently from 27.702 to 32.222, the Maximum plastic limit value is obtained at 0.75ml is high with a value as 32.222 [16]

3) Liquid Limit

The addition of Terrazyme, increases Liquid limit consistently from 44.414 to 52.262, the maximum Liquid limit value is obtained at 0.5 ml is high with a value as 52.262[17].

4) Plastic Index

The value of plastic limit has increases consistently from 16.712 to 21.375, the maximum value is obtained at 0.5 ml is high with a value as 21.375[18].

5) Proctor test

The addition of Terrazyme, increases proctor test consistently from 25 % to 27 %, the maximum proctor test value is obtained at 0.5 ml is high with a value as 27 %.

6) C.B.R Test

The addition of Terrazyme, increases C.B.R Test consistently from 6.1667 % to 8.809 %, the maximum C.B.R Test value is obtained at 0.5 ml is high with a value as 8.809 %.

The cost of the pavement is reduced by using terrazyme as a admixture. The pavement construction value is reduced 30% of the total cost with the help of my laboratory testing results.

VI CONCLUSIONS

The addition of Terrazyme, increases C.B.R Test consistently from 6.1667 % to 8.809 %, the maximum C.B.R Test value is obtained at 0.5 ml is high with a value as 8.809 %.

The cost of the pavement is reduced by using terrazyme as a admixture. The pavement construction value is reduced 30% of the total cost with the help of my laboratory testing results.

As a result of soil stabilization, the bearing capacity of the foundation of the structure is increased and its strength, water tightness, resistance to washout, and other properties are improved. Soil stabilization is widely used in the construction on sagging soils of industrial and civil buildings

Terrazyme stabilization has shown little to very high improvement in physical properties of soils. This little improvement may be due to chemical constituent of the soil, which has low reactivity with Bio-enzyme. Therefore, it is advisable to first examine the effect of Bio-enzyme on soil stabilization in the laboratory before actual field trials. In some cases where the soil is very weak like highly clay to moderate soil, like silty soil to sandy soil, the effect of stabilization has improved the CBR and unconfined compression strength. Pavement design thickness also reduces to 25 to 40 percent. Moreover, in case of scarcity of granular material, only stabilized surface with thin bituminous surfacing can fulfill the pavement design requirement with more than 10 percent saving in cost component.

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.

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