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STABALIZATION OF SOIL USING TERRAZYME FOR ROAD CONSTRUCTION

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Abstract - *In developing countries like India the most important requirement of any project after performance criteria is its economical, feasibility and serviceability criteria. The traditional methods are not economically feasible also time consuming. Hence, it has created a need to discover the other possible ways to satisfy the performance as well as economical criteria. The present paper describes a study carried out to check the improvements in the properties of black cotton soil (BCS) and red soil (RS) with a bio-enzyme, named Terrazyme. Bio-enzyme improves the engineering qualities of soil, facilitates higher soil compaction densities and increases stability. Bio-enzyme helps in easy mixing with water at optimum moisture content (OMC) and then it is sprayed over soil and compacted. Soil with varying index properties have been tested for virgin as well as stabilized soil with different dosages. The test results indicate that stabilization improves the soil strength up to great extent, which implies that the bearing capacity and the resistance to deformation increases in stabilized soil. The locally available material can be used, and in case of scarcity of granular material, only bio-enzyme stabilized thin bituminous surfacing can fulfill the pavement design requirement. Adopting the IRC method based on soil CBR, the pavement design thickness on stabilized soil also reduces 25 to 40 percent. The use of bio-enzyme in soil stabilization is not very popular due to lack of awareness between engineers and non-availability of standardized data.*

***Key Words*: Black Cotton Soil (BCS), Red Soil (RS), Bio-Enzyme- Terrazyme, Soil Stabilization, OMC, IRC.**

1.INTRODUCTION

As we all know that population of India is increasing day by day which has created a need for better and economical vehicular operation which requires good highways/roads having proper geometric design, pavement condition and maintenance. In many parts of India soil consist of high silt contents, low strengths and minimal bearing capacity. When poor quality soil is available at the construction site, the best option is to modify the properties of the soil so that it meets the pavement design requirements. This has led to the development of soil stabilization techniques which improve the strength and durability of soil. 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 pavement.

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. Recently Bio-Enzymes have emerged as a new chemical for stabilization. Bio-Enzymes are chemicals, organic and liquid concentrated substances which are used to improve the stability of soil sub base of pavement structures. Bio-enzyme is convenient to use, safe, effective and dramatically improves road quality. In reality and practice, addition of bio-enzyme gives better performance in the field and ultimately ensures durable and maintenance free pavement.

1.2 OBJECTIVES

- To study the geotechnical properties of the soil.
- To study change in the properties by stabilizing with enzyme and to conduct parametric study.
- To optimize the use of locally available materials in the design and construction of roads by improving their engineering properties.
- To optimize the quantity of Terrazyme to be used as a stabilizing agent.
- To increase the durability, strength, stiffness of soil and improve workability.

1.3 SIGNIFICANCE OF THE STUDY

- Output of this research will enhance development of India economies, particularly rural economies.
- Useful to policy makers in decision making and to economists in budgeting purposes.

2. LITERATURE REVIEW

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. [2]

Bergmann (2000) concluded from his study on bio enzyme that for imparting strength to the soil, bio enzyme requires some clay content. He stated that for successful stabilization of soil minimum 2% clay content is required and 10 to 15 % of clay content gives good results. Compared to 28 % of untreated soil CBR after 1, 2, 3, 14 weeks was found as 37, 62, 66 and 100 respectively. [3]

Sharma (2006) has conducted laboratory studies on use of bio-enzyme stabilization of three types of soils namely clay of high plasticity (CH), clay of low plasticity (CL) and silt of low plasticity (ML). It was found that the CH soil had an increase in CBR value with reduction in saturation moisture from 40 to 21% after 4 weeks of stabilization. Also, it was found that there was 100% increase in unconfined compression strength. [2]

Shankar et al. (2009) conducted tests on lateritic soil of Dakshina Kannad (district of India). The initial liquid limit and plastic limit of soil were 25 % and 6% respectively. The lateritic soil of the district was not satisfying the sub base requirement. For satisfying the sub base course requirements sand is mixed with soil in different proportions until specified values were attained. Study was done on the effect of enzyme, on soil properties like CBR, UCS and permeability for a period of 4 weeks. CBR value increased by 300% with about 10 % sand and 200ml/m3 of enzyme mixed with soil after 4 weeks of curing. It was concluded from the CBR results of treated and untreated soil that addition of enzyme in non-cohesive soil has no effect on the cohesion less soil. [3]

Venkatasubramanian & Dhinakaran (2011) 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%. [2]

Vijay Rajorial, Suneet Kaur (2014) carried out a theoretical evaluation of enzyme. Reduction of about 18 to 26 % is seen in cost of construction of roads by using Terrazyme as a soil stabilizer, constructed by public work department in Maharashtra. Structures made of bio enzyme are economical and have greater strength. [1]

Venika Saini et al (2015) In this work, the performance of Bio-Enzymatic soil has been scrutinized. From the results obtained by the tests conducted on the soil, the following observations were made. Bio Enzymes are organic, non-toxic and biodegradable in nature. The end products obtained by usage of Terrazyme are biodegradable in nature and their effect is perpetual. The initial cost for the application of Terrazyme maybe high as compared to other traditional proposals but the benefit of using Terrazyme such as the zero-maintenance cost and long durability makes this approach economically cost-effective. [6]

Priyanka Shaka et al (2016): Based on IS classification, red soil is classified as Clayey sand and the black cotton soil as highly compressible clay. Laboratory testing showed that decrease in liquid limit and plasticity index was observed with the increase in dosages of Terrazyme. Also, the Terrazyme dosage of 200ml/0.75m3 of dry soil garnered the best result. Further increase in the dosage does not alter the plasticity characteristics of soils substantially. CBR Value of the soil sample was increased by 2.75%. 3.345%. 3.47% and 3.56% by application of the bio-enzyme with a dosage of 200ml/0.75m3. With further increase in the dosage of the enzyme, no substantial increase was recorded. [6]

Sandeep Panchal et al (2017): In this study different type of geotechnical tests were performed on the soil sample under study with and without enzyme. The duration of treating bio-enzyme on the local soil played an important role in the improvement of strength. The CBR value with the third dosage having two week curing period showed great outcome and percentage increase as compared to local soil sample without Terrazyme is 131.49%. [6]

3. MATERIALS

3.1 Terrazyme

Terrazyme is a liquid enzyme which is organic in nature and is formulated from the vegetable and fruit extract. It is brown in color with smell of molasses and can be easily used without the need of masks or gloves. It is easily mixed with water and for optimal results should be diluted with optimum moisture content of that soil. This decreases the swelling capacity of the soil particles and reduces permeability. **The required quantity of Terrazyme was supplied by Avijeet Agencies, Chennai. [1-2-3-4-5]**

Table 1- Properties of Terrazyme Supplied by Manufacturer (Source- Avijeet Agencies)

Identify (As it appears on label)	**N-Zyme**
Hazardous components	None
Boiling Point	100 Degree Celsius
Specific Gravity	1.05
Melting Point	Liquid
pH value	4.4
Evaporating Rate	Same as water
Solubility in water	Complete
Appearance/Odour	Brown Liquid, Non obnoxious

3.1.1. Mechanism of Terrazyme

In clay water mixture positively charged ions (cat-ions) are present around the clay particles, creating a film of water around the clay particle that remains attached or adsorbed on the clay surface. The adsorbed water or double layer gives clay particles their plasticity. Terrazyme replaces adsorbed water with organic cations, thus neutralizing the negative charge on a clay particle. The organic cations also reduce the thickness of the electrical double layer. This allows Terrazyme treated soils to be compacted more tightly together. Terrazyme resists being replaced by water, thus reducing the tendency of some clay to swell. Terrazyme promotes the development of cementitious compounds using the following, general reaction:

$$H_2O + \text{Clay} \xrightarrow{\text{Terrazyme}} \text{Calcium Silicate Hydrates}$$

[1-2-4-5-7]

3.1.2 Calculation of Terrazyme dosage

- Determine quantity of soil to be treated with 1 liter of Terrazyme in cubic meters, based on plasticity and gradation.
- Read 0.01 ml of TZ Concentrate per Kg of soil mix.
- Lab Preparation = 0.01 ml of TZ Concentrate + 100 ml water (1:100 dilution).
- Withdraw from the Lab Preparation that ml as required and add to the water required to bring sample to within 2 % below Optimum Moisture Content.
- Mix water required + mls of Lab Application Mixture uniformly with soil sample.

The dosage used in the experiments are 0.01 ml, 0.02 ml & 0.03 ml on trial and error basis.

3.2 Soils

3.2.1 Black Cotton Soil (BCS)

Table 2- Properties of Black Cotton Soil (BCS)

Sr. No.	Property	Value
1	Specific Gravity	2.5
2	Atterberg's limit	
	Liquid Limit (%)	53.33
	Plastic Limit (%)	29.20
	Plasticity Index	24.13
3	Grain Size Distribution	
	a) Gravel (%)	52.50
	b) Coarse Sand (%)	28.50
	c) Fine Sand (%)	13.75
	d) Silt & Clay (%)	03.25
4	IS Soil Classification	GC
5	Free Swell Index %	02.00
6	Engineering Properties	
	a) M.D.D. (KN/m3)	18.25
	b) O.M.C. (%)	22.50
7	Co-efficient of Permeability	8.0*10^-8cm/sec

The black soil is very retentive of moisture. The black cotton soil is found to contain montmorillonite clay mineral that has high expansive characteristics and these are mainly found in Maharashtra, Madhya Pradesh, parts of Karnataka, Andhra Pradesh, Gujarat and Tamil Nadu. [8]

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The black cotton soil in this experimental work was brought from the Dhule district of Maharashtra.

3.2.2 Red Soil (RS)

Table 3- Properties of Red Soil (RS)

Sr. No.	Property	Value
1	Specific Gravity	2.36
2	Atterberg's limit	
	Liquid Limit (%) Plastic Limit (%) Plasticity Index	60.90 31.40 29.50
3	Grain Size Distribution	
	a) Gravel (%) b) Coarse Sand (%) c) Fine Sand (%) d) Silt & Clay (%)	0.00 12.12 25.85 61.02
4	IS Soil Classification	CH
5	Free Swell Index %	60.80
6	Engineering Properties	
	a) M.D.D. (KN/m3) b) O.M.C. (%)	15.20 28.00
7	Co-efficient of Permeability	1.6*10^-9cm/sec

Red soils are usually poor growing soils, low in nutrients and humus and difficult to cultivate because of its low water holding capacity. These soils can be found around in large tracts of western Tamil Nadu, Karnataka, southern Maharashtra and many part of India. [9]

The red soil used in this experimental work is from Mumbai district of Maharashtra.

4. Problem Statement:

The various problems faced due to poor quality of soil are subgrade failure, freeze and thaw action and many more. In this project we will examine roads against traffic and try to minimize the problems faced by road users which are generally attributed to **poor subgrade conditions** [Fig. 1]. We will reduce or eliminate the thickness of the different layers of road by treating the subgrade layer with the Terrazyme [Fig. 2] as per the design requirement. The purpose is to explain about the material used i.e. Terrazyme, mechanism and its advantages by solving these consequences. **Our main focus is to develop the infrastructure of the country by providing better quality of subgrade layer.**

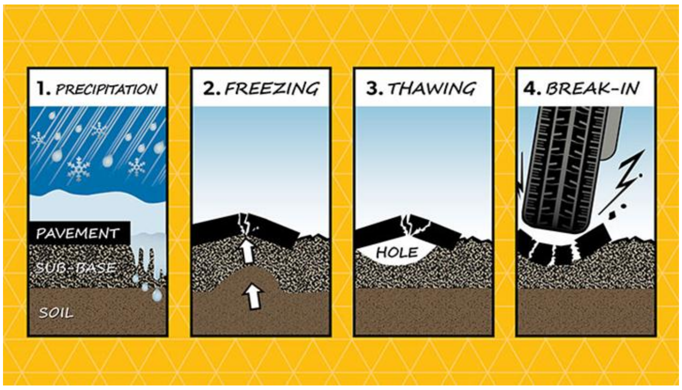

Fig. 1- Potholes (Source- Pothole Wikipedia)

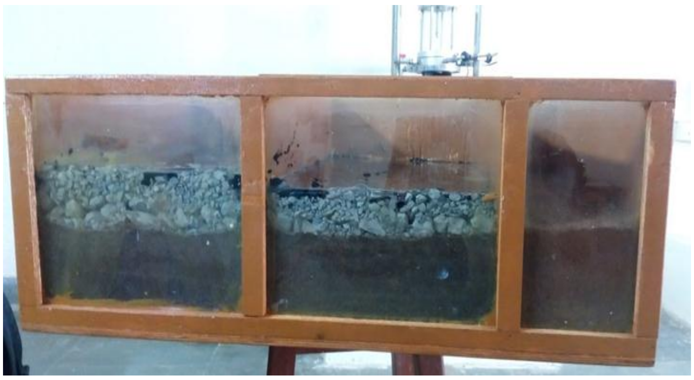

Fig. 2- Proposed Model

5. Concept

We are using Terrazyme in sub grade layer of road. The Terrazyme is mixed with water and is spread over sub grade soil which makes the sub grade layer of road almost impermeable. As the surface become impermeable it will not absorb water which percolates from upper layer of road. It increases the durability of the road and prevent the formation of rut, pot holes, etc.

6. Methodology

It is necessary for both consultants and contractors, as executors involved in a production process that is making use of Terrazyme, to understand that significant cost savings that can be achieved through the relatively fast speed of construction with Terrazyme.

6.1 Pre-construction Phase

- For companies or organizations without prior experience with Terrazyme, it is advisable to contact a certified consultant or the manufacturer for advice on the dilution ratio and the crust thickness of the sub-base and base layers of the road structure. The certified consultants or the manufacture can provide design assistance to determine the need for pavement on the stabilized soil layers and the type of pavement that can be selected.
- It is imperative to properly study the characteristics of the selected soil to insure its suitability for treatment. Depending on characteristics of the soil information on the plasticity and load bearing capacity, it is necessary and prudent in some cases to submit the soil prior to the initiation of the project to laboratory or field trials to ensure its suitability.

6.2 Construction Phase

Step 1: After the embankment or the box cutting has been made according to the conventional construction methods, the construction team puts a layer of scarified soil on top of the sub-grade soil and remove all the large stones, roots and trash from the loosened soil. Road grader or farm tractor with teeth is used.

Step 2: Pulverize the scarified soil, so that the mass is separated from particles rather than breaking down of individual particles with the help of either road grader or farm tractor with roto-tiller, or any other mixing equipment.

Step 3: The engineer then starts with the Terrazyme application by spraying water containing diluted Terrazyme on the road surface. After a sufficient quantity of water has been sprayed to bring the soil to OMC, the spraying of the water is stopped, which is carried out with water truck with distributor bar nozzle mounted at front or back. The soil has to be mixed thoroughly to make sure that the enzymes diluted in water are mixed through the soil and initiate the process of cat-ion exchange with road grader or farm tractor with any mixing equipment.

Step 4: Once the soil containing the Terrazyme is properly mixed, the engineer can start with the formation of the camber, to meet design requirements with the help of road grader with blade adjustment for pitch, angle and side to side elevation. As soon as the camber formation is completed, the compaction of the soil can take place for finishing the surface. This can be done with smooth drum rollers, vibrating compactors or sheep-foot rollers depending upon the composition of the soil.

Step 5: After compaction, a spray of water containing a light concentration of Terrazyme can be used under extremely dry and hot conditions to enhance the curing. The constructed road can be opened for traffic within two to three days after construction under dry conditions. It will also be ready for the application of pavement layers. Items being used for directing the traffic are barriers, signs, cones, tapes, etc.

6.3. Quality Control

- The quality control of structures constructed making use of the bio-enzymatic soil stabilizer, Terrazyme has to be done by engineers who have a proper understanding of soil mechanics and road construction. Attention can be given to the fact that the proper soil that was selected is also actually used during the construction of the road structures.
- After the construction of Terrazyme layers, density test such as the Proctor density test can provide information on the quality of compaction while load bearing test such as CBR or DCP test can provide information on the strength increase of the soil during its curing period.

7. Tests Performed & Results

As per BIS, Indian Standard Methods of Test for soils- IS: 2720. [10]

7.1 Liquid Limit

Table No. 4 – Liquid Limit Determination for RS

Sr. No.	Particulars	Red Soil		
1	Container No.	1	2	3
2	No. Of Blows	56	34	27
3	Mass of empty container in gm	20	15	20
4	Mass of container + wet soil in gm	35	30	40
5	Mass of container + dry soil in gm	30	25	32.5
6	Mass of water in gm	5	5	7.5
7	Mass of dry soil in gm	10	10	12.5
8	Water content (%)	50	50	60
9		Average =53.33%		

Table No. 5 – Liquid Limit Determination for RS

Sr. No.	Particulars	Black Cotton Soil		
1	Container No.	1	2	3
2	No. Of Blows	68	72	70
3	Mass of empty container in gm	35	35	35
4	Mass of container + wet soil in gm	60	68	65
5	Mass of container + dry soil in gm	50	57	53
6	Mass of water in gm	10	11	12
7	Mass of dry soil in gm	15	22	18
8	Water content (%)	66.66	50	66.66
9		Average =61.1%		

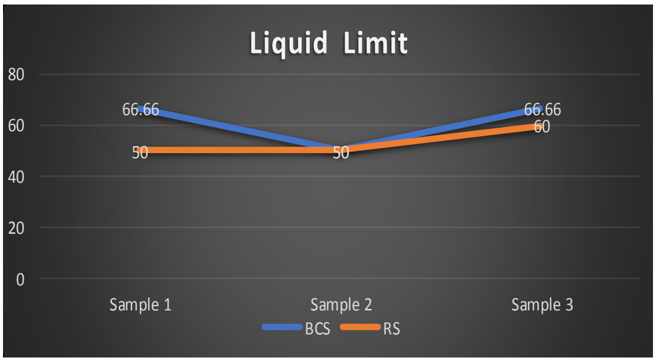

Chart No. 1 –Liquid Limit Determination

7.2 Plastic Limit

Table No. 6 –Plastic Limit Determination for RS

Sr. No.	Particulars	Red Soil		
1	Container No.	1	2	3
2	Mass of empty container in gm	19.62	20.45	19.47
3	Mass of container + wet soil in gm	20.63	24.67	22.4
4	Mass of container + dry soil in gm	20.4	23.6	21.5
5	Mass of water in gm	0.23	1.07	0.9
6	Mass of dry soil in gm	0.78	3.15	2.03
7	Water content (w)	29.4	34	30
8		Average Wp =31.2%		
9		Plasticity Index =22.13%		

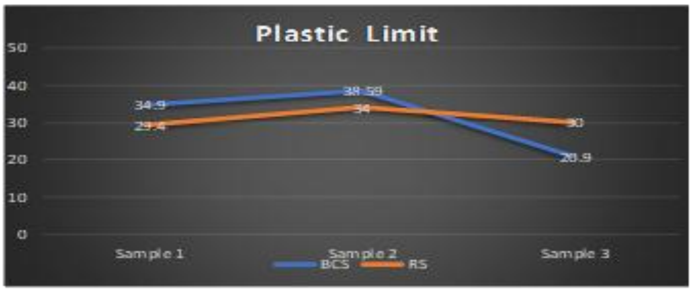

Chart No. 2 –Plastic Limit Determination

Table No. 7 –Plastic Limit Determination for BCS

Sr. No.	Particulars	Black Cotton Soil		
1	Container No.	1	2	3
2	Mass of empty container in gm	20	20	20
3	Mass of container + wet soil in gm	38.54	59.50	71.30
4	Mass of container + dry soil in gm	33.52	48.50	62.43
5	Mass of water in gm	4.72	11	9.07
6	Mass of dry soil in gm	13.34	28.5	42.43
7	Water content (w)	34.9	38.59	20.90
8		Average Wp =31.46%		
9		Plasticity Index =29.64%		

7.3 Unconfined Compression Test

Table No. 8 – UCS Determination for BCS

Curing Period In Days	Unconfined Compressive Strength (KPa)			
	BCS Alone	BCS+TZ (1)	BCS+TZ (2)	BCS+TZ (3)
0	147	163	184	174
7	-	180	234	218
15	-	240	309	276
30	-	283	352	305

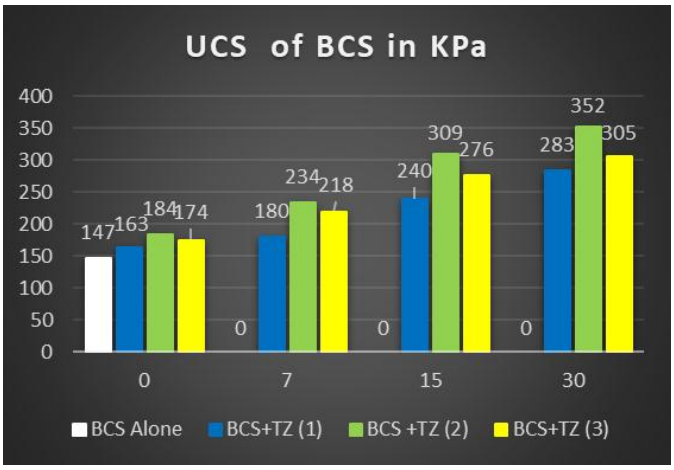

Chart No. 3 –UCS Determination for BCS

Table No. 9 – UCS Determination for RS

Curing Period In Days	Unconfined Compressive Strength (KPa)			
	RS Alone	RS+TZ (1)	RS+TZ (2)	RS+TZ (3)
0	160	177	195	182
7	175	192	258	239
15	-	250	316	291
30	-	298	369	324

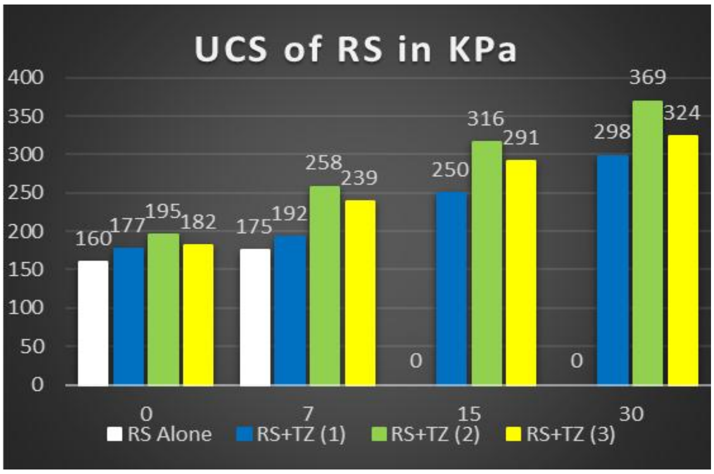

Chart No. 4 –UCS Determination for RS

7.4 California Bearing Ratio Test

Table No. 9 – CBR Determination for BCS

Penetration (mm)	CBR (%)			
	BCS Alone	BCS+TZ (1)	BCS+TZ (2)	BCS+TZ (3)
2.5	2	3	3.5	2.98
5	3	4	5	4.24
7.5	-	8	9	5.02

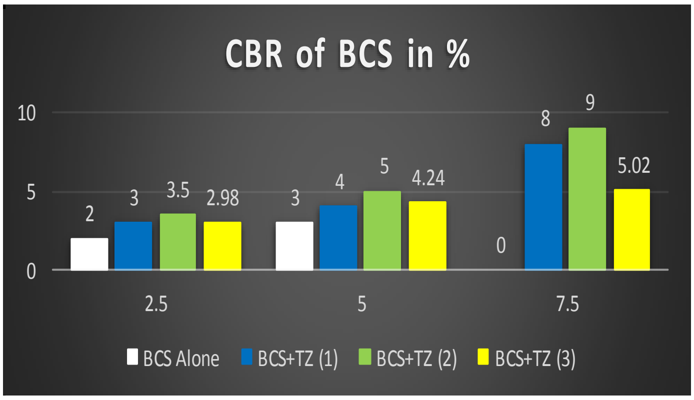

Chart No. 5 –CBR Determination for BCS

Table No. 10 – CBR Determination for RS

Penetration (mm)	CBR (%)			
	RS Alone	RS+TZ (1)	RS+TZ (2)	RS+TZ (3)
2.5	2.62	3.02	4	3.72
5	3.5	6.2	5.5	4.74
7.5	4	7.4	9.7	7.4

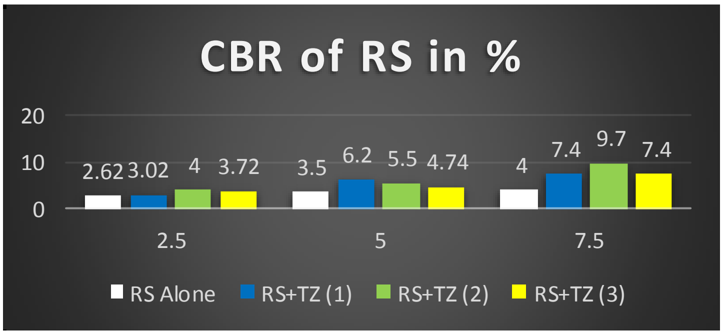

Chart No. 6 –CBR Determination for RS

8. Advantages

- It increases the durability, shear strength, and makes the sub grade layer of the soil almost impermeable.
- It reduces quantity of materials required in construction, reduction in cost of overall construction of road.
- It does not have an adverse effect on soil or on environment, hence it is an eco-friendly technique.
- This technique can save a lot of money of government required for the maintenance of road.

9. Disadvantages

- It requires skilled labor and expertise supervision.
- Proper dilution ratio should be taken to get the optimum strength.
- Excess amount may lead to formation of cracks.
- It is unsuitable for small construction work.

10. **Cost Comparison**- Estimated Cost for 1000 m length, 2-way 2 lane - 8m wide road.

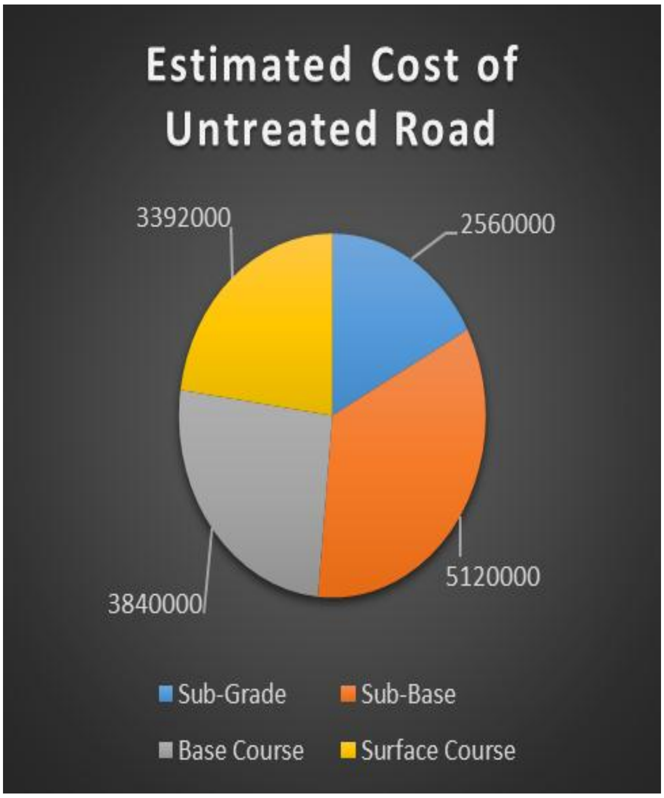

Chart No. 7 –Estimated Cost of Untreated Road

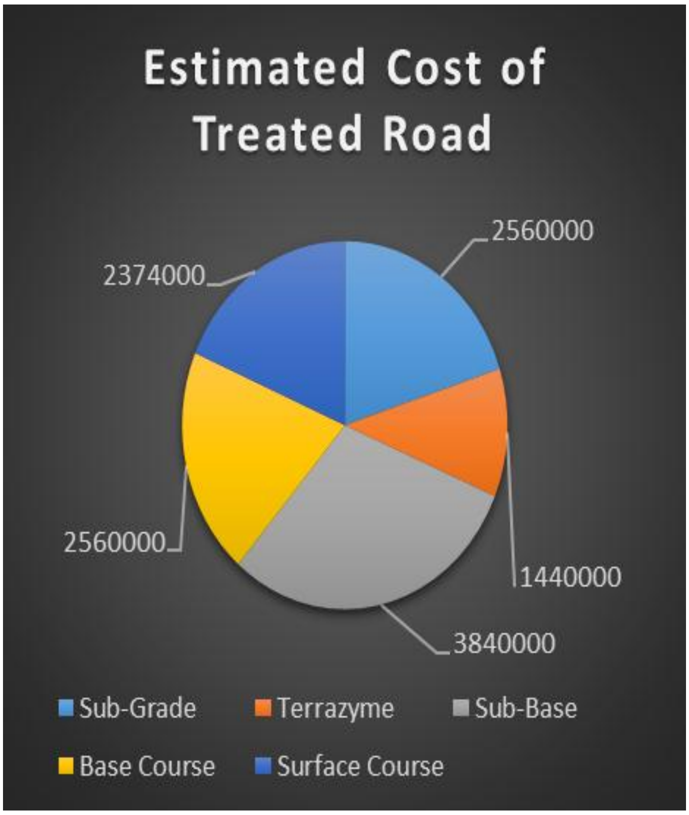

Chart No. 8 –Estimated Cost of Treated Road

Table No. 11 – Estimated Cost

Sr. No.	Layer of Road	Estimated Cost			
		Without treatment		With Treatment	
		Depth (m)	Cost in K (Rs.)	Dept h(m)	Cost in K (Rs.)
1	Sub-Grade	0.1	2560	0.1	2560
2	Terrazy me				1440
3	Sub-Base	0.2	5120	0.15	3840
4	Base Course	0.15	3840	0.1	2560
5	Surface Course	0.1	3392	0.07	2374
Total Cost		1,49,12,000		1,27,74,000	
Cost Saving		21,37,600			

11. Conclusion:

- In reality and practice, addition of bio-enzyme gives better performance in the field and ultimately ensures durable and maintenance free pavement.
- As we proceed in our research, we came to the conclusion that there is not any improvement in properties of red soil due to addition of Terrazyme since red soil is a non-cohesive soil. Hence, it concludes that Terrazyme improves the property of cohesive soil only.
- It could play a pivotal role in this upcoming revolution if their remarkable properties are been exploited.
- The material to be used is eco-friendly and saves a lot of resources. Thus, the product so formed after the application of Terrazyme is biodegradable in nature and the affect is permanent.
- Terrazyme eliminates the use of granular sub-base, base course and surface course also in case of low traffic. The benefits of using Terrazyme is that the maintenance cost is almost zero, making this approach economically cost effective.
- Terrazyme are proved not only smarter material but also eco-friendly in coming years and are most feasible in construction work as we have discussed.

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References

1. Vijay Rajoria, Suneet Kaur –A Review on Stabilization of Soil Using Bio-Enzyme, IJRET, Volume: 03 Issue: 01, Jan-2014. http://www.ijret.org
2. Puneet Agarwal, Suneet Kaur - Effect of Bio-enzyme Stabilization on Unconfined Compressive Strength of Expansive Soil, IJRET, Volume: 03 Issue: 05, May-2014. http://www.ijret.org
3. Venika Saini, Priyanka Vaishnava – Soil Stabilization by Using Terrazyme, IJAET, Vol. 8, Issue 4, Aug. 2015. www.ijaet.com
4. Joydeep Sen, Jitendra Prasad Singh - Stabilization of Black Cotton Soil using Bio-Enzyme for a Highway Material, IJIRSET, Vol. 4, Issue 12, December 2015. www.ijirset.com
5. Anjali Gupta, Vishal Saxena, Ayush Saxena, Mohd. Salman, Shamshul Aarfin, Avinash Kumar - Review

Paper on Soil Stabilization by Terrazyme, IJERA, Vol. 7, Issue 4, (Part -6) April 2017. www.ijera.com

6. Pradeep Singh Sodhi, Ocean, Yogesh Kumar – Stabilization of Soil Using Acidic Bio-Enzyme (Terrazyme), IJIRSET, Vol. 7, Issue 8, August 2018. www.ijirset.com
7. Lekha B. M, Goutham Sarang, Chaitali N, Ravi Shankar A. U. – Laboratory Investigation on Black Cotton Soil Stabilized with Non-Traditional Stabilizer, IOSR-JMCE. www.iosrjournals.org
8. BCS:https://www.indiaagronet.com/indiaagronet/soil_management/CONTENTS/Management%20of%20black.htm.
9. RS-https://en.wikipedia.org/wiki/Red_soil
10. Bureau of Indian Standards, Indian Standard Methods of Test for soils-IS:2720