INVESTIGATION OF STRENGTH CHARACTERISTICS OF BLACK COTTON SOIL (BC) STABILIZED WITH TERRAZYME

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Abstract: The present research work is carried out to examine the characteristics of Black Cotton (BC) soil using the soil stabilizer namely Terrazyme. Terrazyme is non-toxic and harmless to humans, animals, marine life, and the environment. It is non-irritating, non-flammable, and non-corrosive. Terrazyme contains no combustible or corrosive materials and can be safely used near an open flame or in poorly ventilated areas. It contains neither bacteria nor known allergens. Terrazyme is an eco-friendly chemical soil stabilizer. Terrazyme soil catalyzes the reaction between the clay of the soil and the organic cat ions and accelerates the cation exchange process to decrease the adsorbed layer thickness. Stabilizer replaces adsorbed water with organic ions, thus neutralizing the negative charge on a clay particle. In the present work, black cotton soil with varying index properties has been tested for the stabilization process, and the strength of the stabilized soil was evaluated after a curing period of 7 days, 14 days, 21 days, and 28 days to find the optimum dosage of stabilizer. Different dosages, such as 200 ml/3.0 m3, 200 ml/2.5 m3, 200 ml/2.0 m3, and 200 ml/1.5 m3, were adopted. An attempt has been made to study the properties of soil modified with Terrazyme soil stabilizer to use this technology for low-volume roads. Based on laboratory results, there is observed that that there is a significant improvement in dry density and CBR values and resulting in an overall reduction in pavement thickness, increased stability of the soil, and a reduction in the cost of construction.

Index Terms: Black Cotton Soil ,Terrazyme, Low-volume roads, Stability, Pavement thickness, Cost of construction.

I. INTRODUCTION

Soil stabilization means the improvement of the stability or strength (bearing power) of the soil by the use of controlled compaction processes and the addition of suitable additives or stabilizers by altering the geotechnical properties of the soil. In developing countries like India, the major problem is limited financial resources to build a complete road network system using conventional methods. Hence, there is an urgent need to find out the most suitable methods of low-budget road construction while ensuring good quality and performance. Apart from affecting the economy in the initial construction costs of lower layers of the road, such as sub-base courses, it should be possible to upgrade the low-cost roads to higher specifications and standards. The cost of road construction can be reduced by using proper locally available soils for the construction of the pavement layers, like subgrade or base courses. If the stability of the locally available soil is not adequate for supporting wheel loads, the geotechnical properties of the soil are improved by an effective soil stabilization process.

Figure 1: Typical Cracks in Black Cotton Soil

1.1 The Purpose of Soil Stabilization is

- To increase the shearing strength of pavement subgrade, sub-base courses, and base courses.
- To decrease the cost of road construction and hence bring the economy to the project.
- To encourage the best use of locally available subgrade material like soil and other industrial waste materials.
- To counteract the undesirable properties of soil, such as swelling and high plasticity
- To facilitate compaction and increase load-bearing capacity.
- To reduce the permeability of soil.

1.2 The different types of soil stabilization techniques are:

- **Proportioning Method:** Locally available, different types of soils and aggregates are selected and mixed in suitable proportions to achieve maximum density by compaction. The stability of fine-grained soil can be improved by the addition of a suitable proportion of gravel and sand. Likewise, the stability of cohesion-less sand increases with the addition of cohesive soil.
- **Cementing materials**: Cementing materials like Portland cement, lime or lime-fly ash, and bituminous materials increase the strength of the stabilized soil and also impart effective binding character.
- **Modifying materials:** Materials like lime and port-land cement can be added in small amounts and modify the properties of soils, reducing their high plasticity and swelling character and making them more useful as road construction materials. These types of materials are called modifying agents. Lime is one of the most commonly used modifiers in the case of high-plasticity soils.
- **Water-proofing agents**: due to the ingress of water into the subgrade, the compacted soil mass may become weaker or softer. If the imbibing of moisture content can be stopped or retarted by means of some water-proofing materials, we can avoid subgrade failure in pavements. Bituminous materials are more commonly used for waterproofing.
- **Water repelling agents:** Vinsol resin and other resinous materials are used as water repelling agents. These materials function almost the same as water-proofing agents.
- **Water retaining agents:** calcium chloride has good deliquescent properties and is used as a water retaining agent. When the compacted layer has some moisture content, non-cohesive soils have good stability, but when the soil is completely dried, the compacted layer becomes loose and less stable. To avoid this phenomenon, water-retaining agents are likely to be used.
- **Heat treatment:** It has various advantages in clayey soils. There are desirable effects, such as a reduction in the swelling characteristics of the soil. Preheated soft aggregate is used in the mechanical soil stabilization technique, and pozzolanic material is used in soil-lime stabilization.
- **Chemical stabilization:** today's different types of chemical soil stabilizers are used to improve the soil's strength. They are non-toxic and eco-friendly in nature. Some chemical stabilizers are also used with cement and lime to get better results. Some examples are Terrazyme and condor soil stabilizer.

1.3 Terrazyme Soil Stabilizer:

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, and improving the structural properties of cohesive soils. Terrazyme is non-toxic and harmless to humans, animals, marine life, and the environment. It is non-irritating, non-flammable, and non-corrosive. Terrazyme contains no combustible or corrosive materials and can be safely used near an open flame or in poorly ventilated areas. It contains neither bacteria nor known allergens. Terrazyme has been tested for safety by both independent and government scientific agencies.

1.4 Benefits of Terrazyme:

- Minimizes material loss of surface gravel on soil roadways due to erosion or abrasion by traffic.
- Reduces the ongoing cost and environmental impact of the purchase, transport, and spreading of replacement gravel.
- Reduces health and cleanliness concerns by impeding the occurrence of dust from loose, fine material on road surfaces. Dust reductions of at least 75% occurred in our Canadian program.
- Minimizes the harmful production and use of crushed rock and historical mineral stabilizers in road construction and maintenance.
- Reduces fuel usage associated with frequent, short-interval road repairs
- Lessens the impact of open gravel mines and pits. Terrazyme allows maximum leveraging of existing sources.

1.5 Working Mechanism of Terrazyme:

Terrazyme is a surfactant (an ionic surface active agent), which changes the hydrophilic nature of clay and lime materials to hydrophobic. Its application not only assists in the expulsion of water from soils but also aids in the lubrication of soil particles and increases the compatibility of many soils. The reaction of Terrazyme on these materials is particularly effective because of the ion-exchange capacity of clay minerals and the property that clay minerals have of absorbing certain ions, such as the Terrazyme molecule, thereby changing their physical properties. Of special importance is that Terrazyme changes the plastic characteristics of these materials due to a reduction in their water-absorbing capacity. Unlike most other soil stabilizers, the effect of Terrazyme on these materials is permanent. Terrazyme was developed to assist engineers with the removal of adsorbed water from materials in order to achieve maximum density with less mechanical effort and to prevent the absorption of water that results in permanently stabilized construction materials.

Most materials are made up of stacks of silica and alumina sheets. The arrangements of these result in different clay minerals such as kaolinite, smectite, illite, etc. A simplified explanation is that these clay minerals have a predominately positive electrical or ionic charge. This causes clay minerals to have a strong attraction for any cations present. Cations, or negative molecules, are therefore attracted to the positive clay minerals, like iron filings, like a magnet. In close proximity to the clay molecule or particle, the electrostatic forces are larger, and thereby the ions are held very firmly. Nominal temperatures will not remove them. This layer of water is known as the electrostatic diffused double layer. This water is known as adsorbed water. Moving further away from the clay particle, the water molecules are no longer in an attracted or oriented state, and this water is known as random water and is also called absorbed water. Certain materials, like Smectite, have spaces between the plates or layers that can adsorb water, causing them to expand. These are known as expansive or swelling materials and are the cause of many failures in foundations or road works. The solution, therefore, is to obviously expel or prevent the adsorption of water. If some powerful positive molecules can be supplied, the negative charge of the clay minerals can be satisfied and balanced out. At the same time, any weaker cations, such as water, can be disassociated and replaced, and/or occupation of the vacated sites on the surface of the clay can take place. Large cations, such as sodium or water, cannot easily fit into these sites and are disassociated or replaced. Small cat ions, on the other hand, fit firmly into these vacated sites and cannot be removed. We therefore have the situation that the clay's negative charge is in balance and positive ions cannot be removed, thereby rendering the clay inert to water. The soil mass is now a permanently stable, water-repellent road surface similar to rigid pavement.

Terrazyme is a catalyzed ion-reactive synthetic compound that forms a protective coating on oily clay layers on the surfaces of soil and clay particles. It reduces ion mobility and ion exchange and simultaneously makes the material hydrophobic by eliminating the absorption of water. The result is a soil material that is much less sensitive to moisture, more workable, and can be compacted to a better particle-interlock state by equipment and traffic forces. Better particle interlock means higher internal friction and improved bearing capacity. It also means greater density and less penetration of water. The active reagent is permanently bonded to the material particles, and should any excess reagent be present, additional water will facilitate deeper penetration into the soil horizon until the entire reagent has been adsorbed.

II. OBJECTIVES OF THE STUDY

The present research study focuses on laboratory studies on strength characteristics of Black Cotton (BC) Soil stabilized with Terrazyme at different dosages. The study evaluates the soil properties such as Specific Gravity, Atterberg limits, Maximum Dry Density (MDD) and California Bearing Ratio (CBR) values.

III. 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 were observed, 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.

Hitam and Yusof of the Palm Oil Research Institute of Malaysia (1998) conducted field studies on improvements to plantation roads. The road was a soil road that became impassable and poor due to adverse weather conditions. Terrazyme was treated to 27.2 km of road, which was having serious problems during the monsoon season or after heavy downpours. The sections were then monitored for surface erosion due to rainwater and wear due to usage. After two monsoon seasons, the road was found to be in very good condition in spite of its large exposure to heavy rainfall. No surface damage was observed, thus requiring no repair work to the road section. The researchers have concluded that Terrazyme stabilization can convert the road to an all-weather road that has minimum destruction in hot and wet seasons.

Brazetti and Murphy (2000) conducted field experiments in Brazil to study the use of Terrazyme as a bio-enzyme stabilizer for road construction. The selected soils were sandy clay, silty clay, sandy silt, plastic and non-plastic clay, sandy loam, loam mixed with clay, and soil mixtures with pieces of recycled pavement. The field stretches were periodically tested with DCP (Dynamic Cone Penetrometer) equipment. Following their evaluation, they concluded that enzyme stabilization is an effective and cost-effective solution for pavement construction.

Andrew R. Tolleson et al. (2003), in their research on “An Evaluation of Strength Change on Subgrade Soils Stabilized with an Enzyme Catalyst Solution Using CBR and SSG Comparisons," 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 the tested enzyme for unpaved road in-situ stabilization. The effectiveness of enzyme treatment was evaluated on the basis of statistical measurements of changes 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. Notwithstanding, 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.

Isaac K.P. et al. (2003) conducted a comprehensive study of the Terrazyme soil stabilizer product and its effectiveness on laterite soil and clay-type soil collected from Kerala. The reactions of the soils treated with the enzyme were observed, recorded, and compared to the untreated control samples for a period of 8 weeks. It was found that in all soil types, the CBR value increased with the addition of

Terrazyme, which proved its suitability as a stabilizing agent. The increase in CBR was in the range of 136 to 1800 times that of the original value. Finally, they concluded that the use of Terrazyme is useful for clay soil and sand but is less significant compared to silty soils.

Manoj Shukla et al. (2003) conducted a study to assess the suitability of bioenzymes as soil stabilizers, and five types of soils were considered for the study, ranging from low clay content to very high clay content. Laboratory tests were conducted to determine the engineering properties of soil and the strength characteristics of soil with and without stabilization with bioenzymes. They concluded that bioenzyme stabilization has shown little to very high improvement in the physical properties of soil. This little improvement may be due to the chemical constituents of the soil, which have low reactivity with bioenzymes. Therefore, it is advisable to first examine the effect of bioenzymes on soil stabilization in the laboratory before actually conducting a field trial.

Roger Bergmann (2006), in his technical note on “Soil Stabilizers on Universally Accessible Trails,” used an EMC squared enzyme for the stabilization of trail surfaces. Conclusions were drawn that bio-enzymes require some clay content in the aggregate material in order to create the reaction that will strengthen the material. Also, reports showed successful stabilization with as little as 2% clay in the aggregate material, but the best results 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.

Sharma (2001) has conducted laboratory studies on the use of bio-enzyme stabilization in three types of soils: clay of high plasticity (CH), clay of low plasticity (CL), and silt of low plasticity (ML). It was found that the CH soil had a 260% increase in CBR value with a reduction in saturation moisture from 40 to 21% after 4 weeks of stabilization. Also, it was found that there was a 100% increase in unconfined compression strength, a 10-fold increase in direct tensile strength at room temperature, and a 4-fold increase in fatigue cycles of failure. There was no increase in CBR for soil of CL type, but the reduction in saturation moisture was from 43 to 34%. ML-type soil had its CBR increase by 210% with a reduction in saturation moisture from 13 to 10% after 4 weeks of stabilization.

IV. METHODOLOGY

In the present investigation, the black cotton soil was brought from a place namely Davangere in Karnataka where the black cotton soil is available in abundant. The soil is subjected to various tests such as specific gravity, grain size distribution, liquid limit and plastic limit. Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) and California Bearing Ratio (CBR) were performed on the different soil samples containing varying percentages of Terrazyme used as a stabilizer.
The methodology adopted in the present research is as follows;

- The black cotton soil is brought from the place namely Davanagere, Karnataka
- The basic tests such as specific gravity, grain size distribution and liquid and plastic limit of the soil found in the laboratory.
- The optimum moisture content (OMC) and maximum dry density (MDD) of the soil sample is found out by proctor density tests.
- The California Bearing Ratio (CBR) of the soil sample is found by mixing the Terrazyme at different dosages, added as a stabilizer to find the optimum dosage of stabilizer
- The specimens were casted for different curing period namely, 7 days, 14 days, 21 days and 28 days.
- Finally, the comparison of the results were made.

4.1 Dosages adopted in the present research are as shown below:

Dosage-1 (200ml/3.0m3)
200 ml for 3.0m3 of soil = 1.49*3*1000=4470kg
For one kg of soil = 200/4470 = 0.0447 ml of stabilizer
Dosage-2 (200ml/2.5m3)
200 ml for 2.5m3 of soil = 1.49*2.5*1000=3725kg
For one kg of soil = 200/3725 = 0.0536ml of stabilizer
Dosage-3 (200ml/2.0m3)
200 ml for 2.0m3 of soil = 1.49*2.0*1000=2980kg
For one kg of soil = 200/2980 = 0.067 ml of stabilizer.
Dosage-4 (200ml/1.5m3)
200 ml for 1.5m3 of soil = 1.49*1.5*1000=2235kg
For one kg of soil = 200/2235 = 0.0894ml of stabilizer.

V. RESULTS AND DISCUSSIONS

5.1 The basic properties of the soil sample is shown in Table 1

Table 1: The Basic Properties of Soil Sample

Sr No	Properties of Soil Sample	Obtained Results
1	Specific gravity	2.51
2	**Grain size distribution**	
	Gravel (%)	0
	Sand (%)	10.51
	Silt (%)	39.40
	Clay (%)	50.45
3	**Consistency limits**	
	Liquid limit (%)	65
	Plastic limit (%)	36
	Plasticity index (%)	29
	Shrinkage limit (%)	12.75
4	IS soil classification	MH & OH
5	**Engineering properties**	
	Max. dry density g/cm^3	1.46
	OMC (%)	30
6	CBR value (%)	
	Un soaked CBR value	4.0
	Soaked CBR value	2.4

5.2 The results and graph of Specific Gravity tests are shown in Table 2 and Figure 2 respectively.

Table 2: Results of Specific gravity test of soil sample at different dosages.

Dosages	Curing Period			
	07days	14days	21days	28days
200ml/3.0m3	2.51	2.60	2.65	2.70
200ml/2.5m3	2.52	2.61	2.65	2.76
200ml/2.0m3	2.52	2.62	2.65	2.80
200ml/1.5m3	2.51	2.61	2.60	2.70

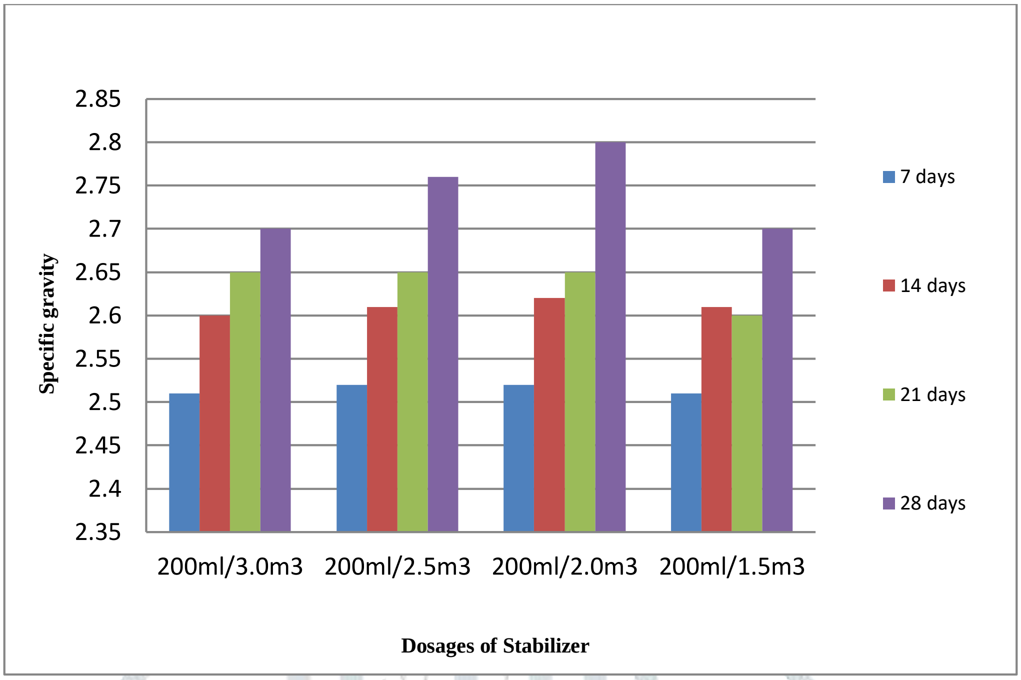

Figure 2: Graph of Specific Gravity Values v/s Dosage of Stabilizers

5.3 The results and graph of Maximum Dry Density (MDD) v/s different dosages of stabilizers are shown in Table 3 and Figure 3 respectively.

Table 3: Results Maximum Dry Density of soil sample at different dosages.

Curing period	**7days**	**14days**	**21days**	**28days**
Dosages	**Maximum dry density (MDD) in g/cm3**			
200ml/3.0m3	1.46	1.49	1.52	1.57
200ml/2.5m3	1.47	1.50	1.51	1.60
200ml/2.0m3	1.47	1.51	1.53	1.60
200ml/1.5m3	1.46	1.48	1.53	1.55

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Figure 3: Graph of MDD Values v/s Dosage of Stabilizers

5.4 The results and graph of California Bearing Ratio (CBR) v/s different dosages of stabilizers are shown in Table 4 and Figure 4 respectively

Table 4: Results of CBR Value of soil sample at different dosages.

Curing period	**7days**	**14days**	**21days**	**28days**
Dosages	**CBR values (%)**			
200ml/3.0m3	4.0	4.5	5.5	6.2
200ml/2.5m3	5.3	5.5	6.5	7.0
200ml/2.0m3	4.5	5.9	6.9	7.5
200ml/1.5m3	4.5	5.0	6.0	7.1

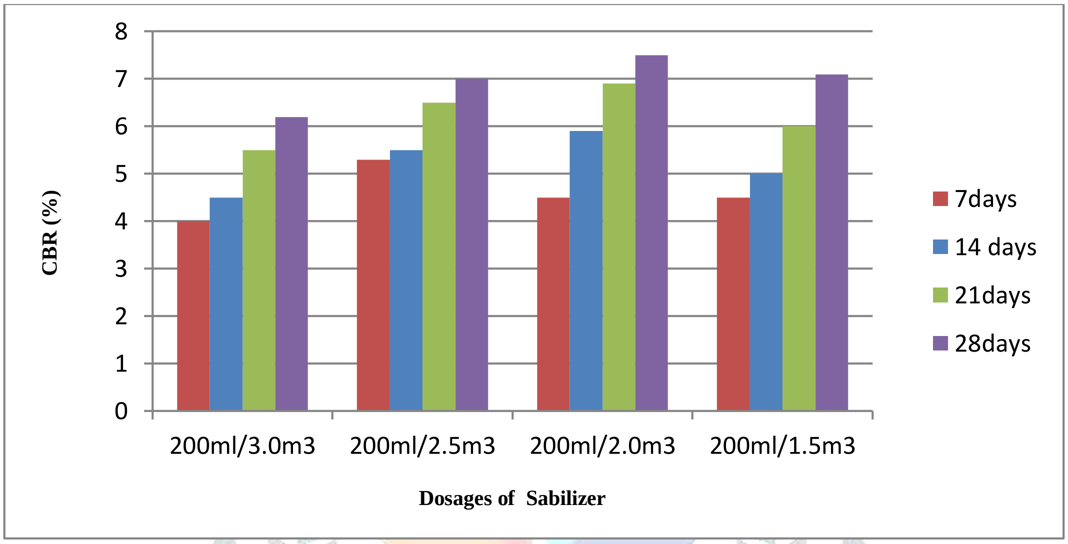

Figure 4: Graph of CBR Values v/s Dosage of Stabilizers

VI. CONCLUSIONS

From the present research, it can be concluded that:

- By treating the soil with Terrazyme, the liquid limit decreases from 65% to 57%, and the liquid limit decreases from 36% to 32%. Hence, the plasticity index decreases from 30% to 25%. Also, the plastic index decreases as the curing period increases.
- In the compaction test, the result shows that MDD increases from 1.46 g/cm3 to 1.57 g/cm3. There is an improvement in MDD. Where the OMC decreases from 30% to 26.5%.
- The strength of expansive soil is measured in terms of CBR values. CBR values improved upon the addition of stabilizer Terrazyme, and it is observed that CBR values increase with the curing period.
- CBR values increase from 3.4% to 7.5%, mainly due to the reaction of enzymes with clay particles, which finally reduces the voids and increases the density values. The reaction time is also significant, as the CBR value at the end of 28 days is 7.5% compared to 4% at 7 days.
- The final value of CBR after 28 days has increased by 170% compared to the initial value of CBR, and the increase in CBR value has led to an overall reduction in pavement thickness.
- The above results show that for road construction in expansive soil, stabilizer Terrazyme improves the subgrade strength.

REFERENCES

[1].Lacuoture, A. and Gonzalez, H. (1995): “Usage of Organic Enzymes for the stabilization of Natural base soils and sub bases in Bagota”, Pontificia Universidad Jevariana, Faculty of Engineering.

[2]. Hitam, A. and Yusof, A. (1998): “Soil stabilizers for plantation road”, National seminar on Mechanisation in Oil Palm Plantation, 30 June 1998, Selangor, Malaysia.

[3]. Brazetti, R. and Murphy, S.R. (2000): “General usage of Bio-Enzyme stabilizers in Road Construction in Brazil”, 32nd annual meeting on paving Brazil, October 2000.

[4]. Andrew, R.T., Fadi, M.S., Nicholos, E.H. and Elahe, M. (2003): “An Evaluation of Strength change on Subgrade soils stabilized with an Enzyme Catalyst solution using CBR and SSG comparisons”, Geomatrics, Inc. Columbia, Sc 29210, USA, July 2003.

[5]. Isaac, K.P., Biju, P.B. and Veerararagavan, A. (2003): "Soil stabilization using Bio-Enzyme for Rural Roads" presented at the IRC Seminar: integrated Development of Rural an Arterial Road Networks for Socio- Economic development, New Delhi, December 2003.

[6].Manoj Shukla, Sunil Bose and Sikdar, P.K. (2003): "Bio-Enzyme for stabilization of soil in Road construction a cost effective approach", Presented at the IRC Seminar: Integrated Development of Rural and Arterial Road Networks for Socio-Economic development, New Delhi, December 2003.

[7]. Roger, B. (2006): "Soil stabilizers on universally accessible trails", Technical Report 0023-1202-SDTDC, San Dimas, Ca: U.S.Department of Agriculture, Forest Service, San Dimas Technology and Development Center, 10 p.

[8]. Sharma, A., "Laboratory Study to Use of Terrazyme for Soil Stabilisation", Research Report (unpublished) Central Road Research Institute, New Delhi 2001.

[9]. IRC: SP: 20 -2002 "Rural roads Manual", The Indian Roads Congress, New Delhi.

[10].IS 2720 (Part III) (1980) "Determination of Specific gravity" Bureau of Indian Standards, Manak Bhavan New Delhi.

[11].IS 2720 (Part IV) (1975) "Determination of Grain Size" Bureau of Indian Standards, Manak Bhavan, New Delhi.

[12]. IS 2720 (Part V) (1985) "Determination of Liquid and Plastic limit" Bureau of Indian Standards, Manak Bhavan, New Delhi.

[13].IS 2720 (Part VII) (1980) "Determination of Moisture content and dry density" Bureau of Indian Standards, Manak Bhavan, New Delhi.

[14].IS 2720 (Part X) (1973) "Determination of Unconfined Compressive Strength" Bureau of Indian Standards, Manak Bhavan, New Delhi.

[15].IS 2720 (Part XVI) (1979) "Determination of California Bearing Ratio" Bureau of Indian Standards, Manak Bhavan, New Delhi.

[16]. IS 2720 (Part XVII) (1986) "Determination of Permeability" Bureau of Indian Standards, Manak Bhavan, New Delhi.

[17].Highway Materials and Pavement Testing, S.K. Khanna, C.E.G. Justo, A. Veeraragavan, (Fifth edition) 2013.