Study on Physical and Chemical Change Behavior of Stabilized Black Cotton Soil for Pavement Subgrade

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Abstract. The soil in the highway material as sub grade plays an important role in the pavement component, which is an integral part of Pavement. It is desirable to have the pavement with the good sub grade soil. But this is challenging in the case when the sub grade soil is expansive in nature. In order to obtain the better performance, various Soil stabilizers are used to improve the sub grade soil properties. In the present study Black Cotton soil is used which is expansive in nature and is treated with conventional additive Lime with the dosage of (2%, 4%, 6%, 8%, 10% by weight of soil) and Non conventional additive Terrazyme with (50 to 250ml/m^3 of soil) with the increment of 50ml and chemical based additive Terrasil with (0.2 to 1.0 kg/m^3) with the increment of 0.2ml. Study aimed to identify the chemical change behaviour of soil when it is stabilized with different additives. Chemical modification in the soil due to additives plays the important role in physical modification of soil. Laboratory test program aimed at evaluating the potential chemical parameters such as: pH, Silica, Aluminium oxide, Ferrous oxide, Chlorides, Sulphates, Calcium oxide and Magnesium oxide that are responsible to increase the strength and volumetric change behaviour of modified soil treated with various additives.

Keywords: Expansive soil, Terrasil, Terrazyme.

1 Introduction

A large part of Central India and portion of South India is covered with Black Cotton Soil. These soils are residual deposits formed from basalt or trap rocks. They are clays of high plasticity. They contain clay mineral called Montmorillinite, which is the most unstable clay mineral, thus the soils have high shrinkage and swelling characteristics.

The shearing strength of the soil is extremely low, it is highly compressible and has very low bearing capacity. It is very difficult to work with this soil, as it do not possess sufficient strength to support the loads imposed upon them, either during construction or during the service life of the structure. For the better performance of structures built on such soils, the performance characteristics of such soils need to be improved.

There are various methods that could be used to improve the performance of poor quality soils. These methods range from replacing it with a good quality soil and methods that involve complex chemical process. The process of improving the strength and durability of soil is known as Soil stabilization. The main aim of stabilization is cost reduction and to efficiently use the locally available material. Geotechnical properties of poor sub grade soil can be improved by various methods and it can be replaced by good quality of sub grade material, but this method may be expensive and hence overall economy cannot be achieved.

The objectives of the present study is to study the improvement of geotechnical and engineering properties of stabilized black cotton soil and also to study the volumetric change behaviour and chemical change behaviour of stabilized black cotton soil by laboratory method.

2 Materials and Methodology

The soil collected is black cotton soil from Nargund, located in Gadag district of Karnataka. The soil is problematic due to its high shrinkage and swell properties and high liquid limit. The soil is air dried for a week later it is used for various laboratory tests. All preliminary tests are performed on the virgin soil and is characterized according to its particle size and other engineering properties.The figure 1 shows the methodology of the present work, the collection of sample and stabilizer are discussed in the following sections.

2.1 Material Used

Black cotton soil: The natural soil existing at the site is taken, the soil is collected at the depth of 1.5m below ground level. Table 1 shows the Engineering and geotechnical properties of the Black cotton soil used for the study. All the tests were conducted as per the IS codes. Figure 2 shows the soil that is being used for the present study.

Lime: Lime is traditional stabilizer and it is easily available. Stabilization using lime is an effective way to modify soil and improves the workability and load bearing characteristics. The results are reduction in plasticity, swelling properties and moisture holding capacity of soils and improves the stability.

Terrasil: Terrasil is a nano technology-based material. It is made of 100% organosilane molecules. Terrasil is highly water soluble, UV stable, heat stable and active soil stabilizer which is used for subgrade stabilization. Terrasil is a user-friendly product. It improves the cohesion and adhesive value of the soil layer.

Terrazyme: Terrazyme is a bio enzyme which is bio degradable, non-toxic, non-inflammable liquid. It is in brownish colour with the smell of molasses. It improves the engineering qualities of the soil facilitating higher compaction and increasing the soil stability. Before using as stabilizer, it must be diluted with calculated amount of water.

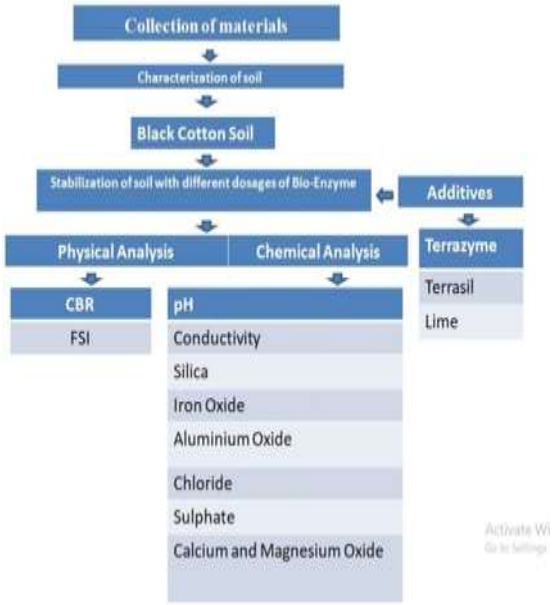


Fig.1. Methodology of present work

Fig.2. Soil used for the study

Table 1. Geotechnical Properties of the Soil

S.R. No.	Property	Soil
1	Specific Gravity	2.67
2	Grain Size Distribution	
	A Gravel	0.0
	B Sand	12.0
	C Silty & Clay	88.0
3	Soil Classification	
	A I.S. Soil Classification	CH
	B HRB Soil Classification	A-7-5
4	Atterbergs Limit (%)	
	A Liquid Limit	68.0
	B Plastic Limit	38.0
	C Plasticity Index	30.0
5	Compaction Characteristics (Standard Proctor Test)	
	A OMC (%)	25.60
	B Maximum Dry unit weight (kN/m^3)	15.40
6	California Bearing Ratio Test (CBR) Test (%)	
	Soaked condition	1.20

2.2 Experimental Work

The experimental study involves studying the effect of lime, Terrasil and Terrazyme on the various properties of expansive soil. In addition, the effect of these stabilizers in the strength parameters such as CBR is studied. Chemical analysis is carried out to study the chemical parameters responsible for gain in the strength of the soil.

Soil Samples: The Experimental work is carried out for the Virgin Soil and soil treated with Lime with the varying dosages such as 2%, 4%, 6%, 8% & 10% and Terrasil with varying dosages of 0.2,0.4,0.6,0.8 and $1.0kg/m^3$ and Terrazyme with dosages of 50, 100, 150, 200, and $250ml/m^3$.

3 Results and Analysis

3.1 CBR of Lime Stabilized Soil

The CBR moulds were prepared for soil treated with Lime with varying dosages and each moulds were prepared at their optimum moisture content and compacted to the maximum dry density and soaked for the period of 96 hours, the sample preparation and testing are done as per the IS standards. From the figure it is observed that CBR value is maximum for 8% of Lime and the CBR value increased with increase in the lime content, as this is because lime acts as soft clay.

3.2 CBR of Terrasil Stabilized Soil

The CBR tests were carried out for the soil treated with Terrasil and each of the soil samples prepared at their respective moisture content and maximum dry density and is observed for the Terrasil treated soil the CBR showed the maximum value for the dosage of 0.6kg/m^3.

3.3 CBR of Terrazyme Stabilized Soil

The CBR tests were carried out for the soil treated with Terrazyme and each of the soil samples prepared at their respective moisture content and maximum dry density. It is observed that the maximum value of CBR is obtained for the dosage of 250ml/m^3. Results are represented in Fig 3.

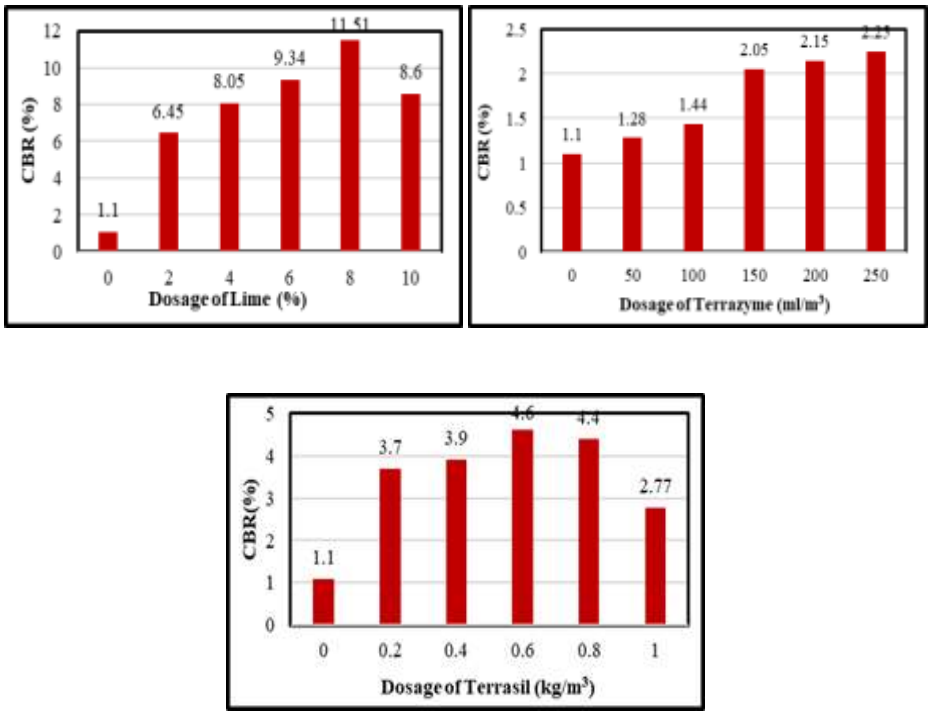


Fig 3. Variation of CBR value of soil after stabilizing

3.4 Free swell index of the stabilized soil

This test was carried out to know the volumetric change behavior of stabilized black cotton soil. It is seen that as the dosage of stabilizers increased, the swell index decreased. Which clearly proves that the stabilizers reduces the volumetric change behavior of the soil and increases the stability of the soil. Fig 4 gives the variation of FSI with varying dosage of additives.

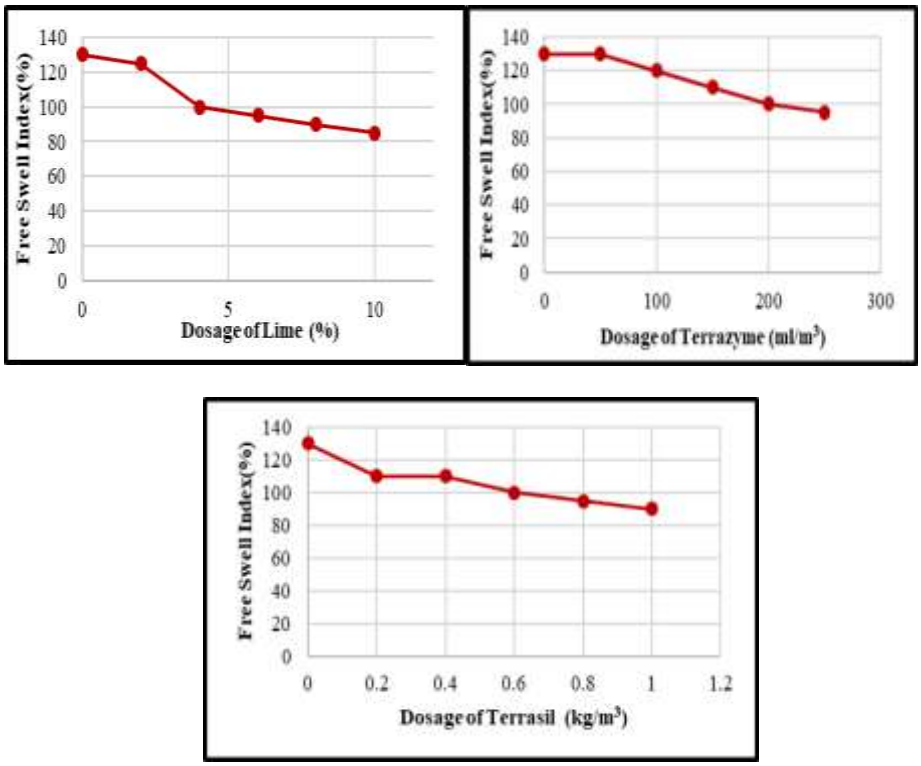


Fig. 4. Variation of FSI value of soil after stabilizing

3.5 pH of the stabilized soil

As the dosage of lime increased the pH value of the soil increased as it is alkaline in nature (presence of Calcium oxide).the percentage increase in the pH is 35.14%, where as Terrasil is acidic in nature the pH of the soil reduced from 9.93 to 7.55 for the soil treated with Terrasil and the percentage decrease in pH is 23.96%, and similarly Terrazyme is acidic in nature and the percentage decrease in the pH for the soil treated with Terrazyme is 24.16%.

3.6 Silica content in the stabilized soil

As the lime is hydraulic lime it contains few amount of silica or alumina and similarly Terrazyme and Terrasil are silica compounds therefore, the silica content increased for increased dosage. Silica plays an important role in the contribution of gain in strength of the soil. Silica is a pozzolanic material; presence of silica in black cotton soil increases maximum dry density and reduces the swelling capacity of the soil. Excess of Silica makes the Soil Sandy. Variation of silica is shown in Fig 6

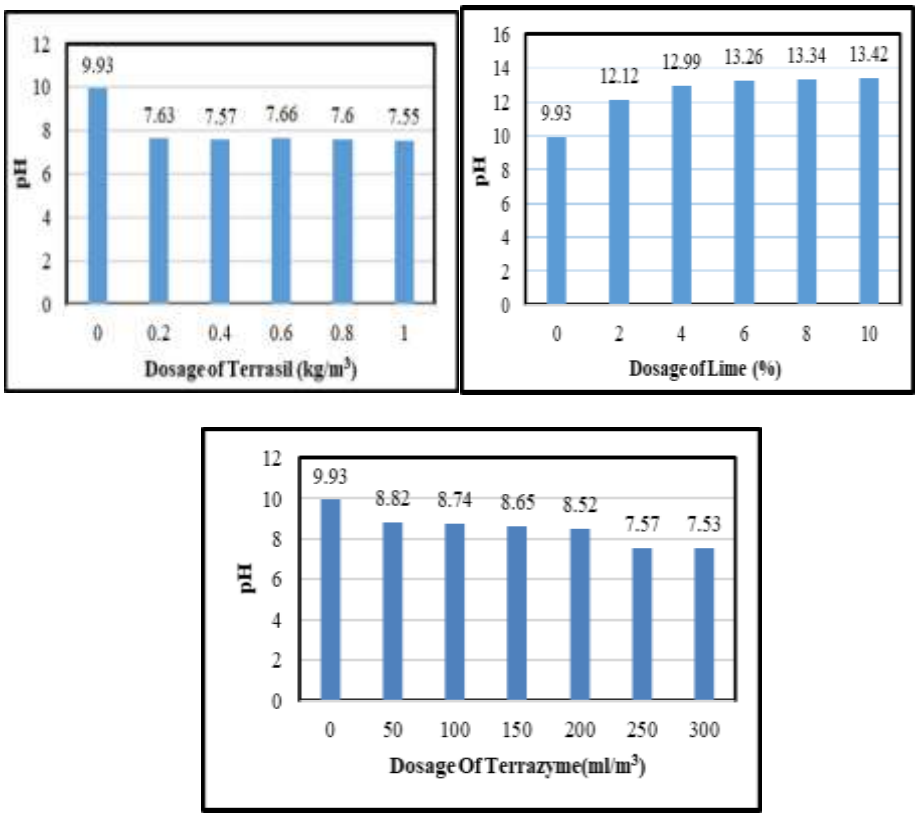


Fig. 5. Variation of pH value of soil after stabilizing

3.7 Combination of aluminum oxide and iron oxide (R_2O_3) in the stabilized soil

Aluminium and iron oxide plays a very important role in Stabilization. Increase the aggregate Stability of Soil, increase the permeability and porosity. Excess of R_2O_3 decreases the swelling Capacity and modulus of rupture. Reduces the Swelling of Montmorillonite. Increase in the dosage of stabilizers increased the R_2O_3 content of the soil.

3.8 Calcium oxide in the stabilized soil

Presence of Calcium oxide increases the Strength, Durability, Workability and reduces the swelling Capacity. As the lime is rich in calcium the calcium content increases with increase in the dosage. It is seen that as the dosage of stabilizers increases the calcium content got increased in the soil.

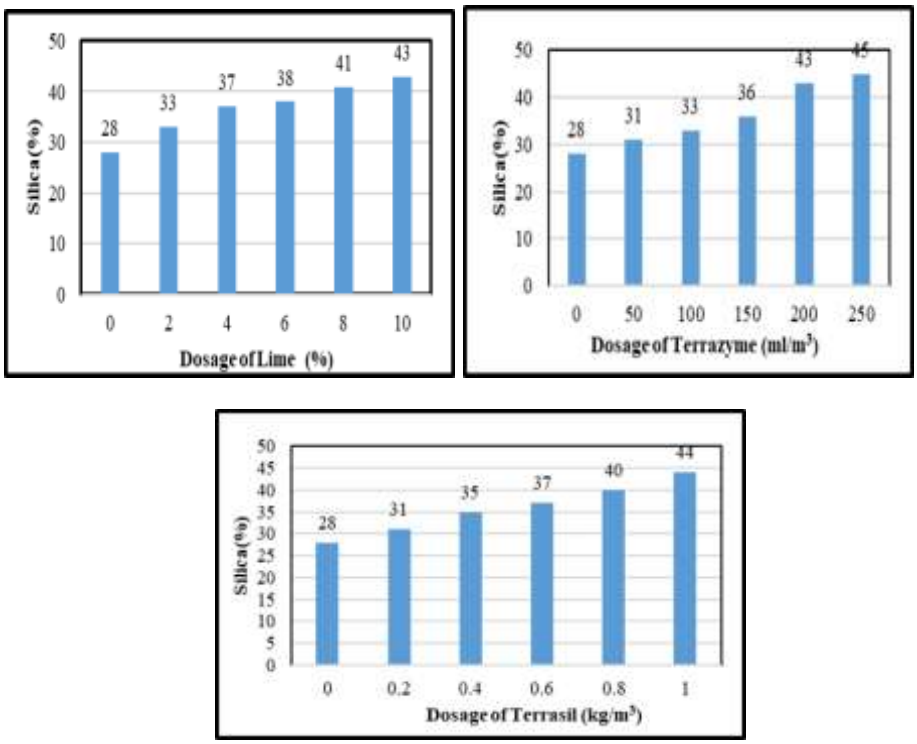


Fig. 6. Variation of silica content of soil after stabilizing

3.9 Chloride content in the stabilized soil

Plasticity of soil decreases with increase in the concentration of chloride. Maximum dry density also increases with increase in concentration of Chloride thus the strength also increases. Excess of Chloride leads to increase in acidity which leads to the corrosion of reinforcement of Structure. Ferric Chloride and Aluminium Chloride reduce the Swelling capacity of Soil. Shrinkage limit, dry density and UCS increases and Moisture Content decreases on addition of Potassium Chloride. Calcium Chloride increases the water hardness. As the dosage of the stabilizers increased the chloride content of the soil incresed.

3.10 Sulphate content in the stabilized soil

Presence of Sulphate alters physical and Chemical behaviour of the soil. It leads to the abnormal increase in the Liquid Limit and Volumetric Change behaviour and it also increases the acidic nature of soil and it results in the rusting of reinforcement of structure. Reduction of shear strength occurs due to reduction in effective Cohession. It decreases the Strength of soil.The sulphate content of the soil got decreased due to increase in the dosage of the stabilizers.

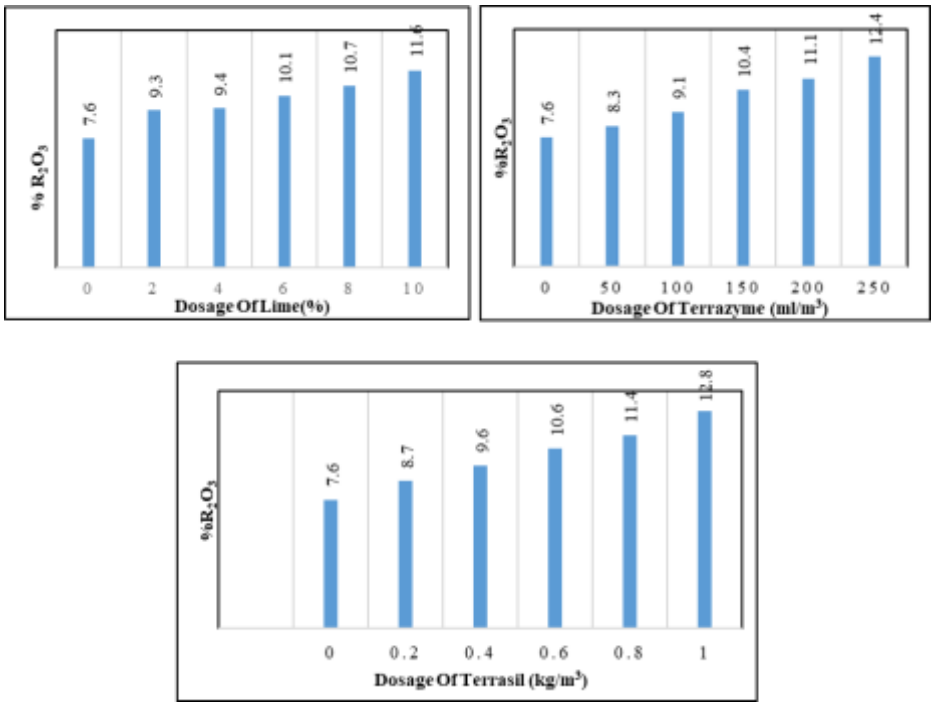


Fig. 7. Variation of R_2O_3 of soil after stabilizing

3.11 Comparison of the results

After the stabilization of the soil with the different dosage of stabilizers, comparison of the results is done for the optimum dosage of the stabilizers. The optimum dosage for lime is seen to be 8% of the weight of the soil, for terrasil it is 0.6kg/m^3 and for terrazyme it is 250ml/m^3. For the above dosages the results of physical and chemical analysis are compared in the table no.2.

4 Results of chemical analysis

pH value increased for lime and decreased for Terrasil and Terrazyme. It can be observed that there is an increase in SiO_2 and R_2O_3 content for all the additives. Chloride content increased on addition of additives but the concentration lies within the permissible limit. As the dosage of additives increased the sulphate concentration in the soil got decreased. Calcium and magnesium content increased with increase in the dosage of additives.

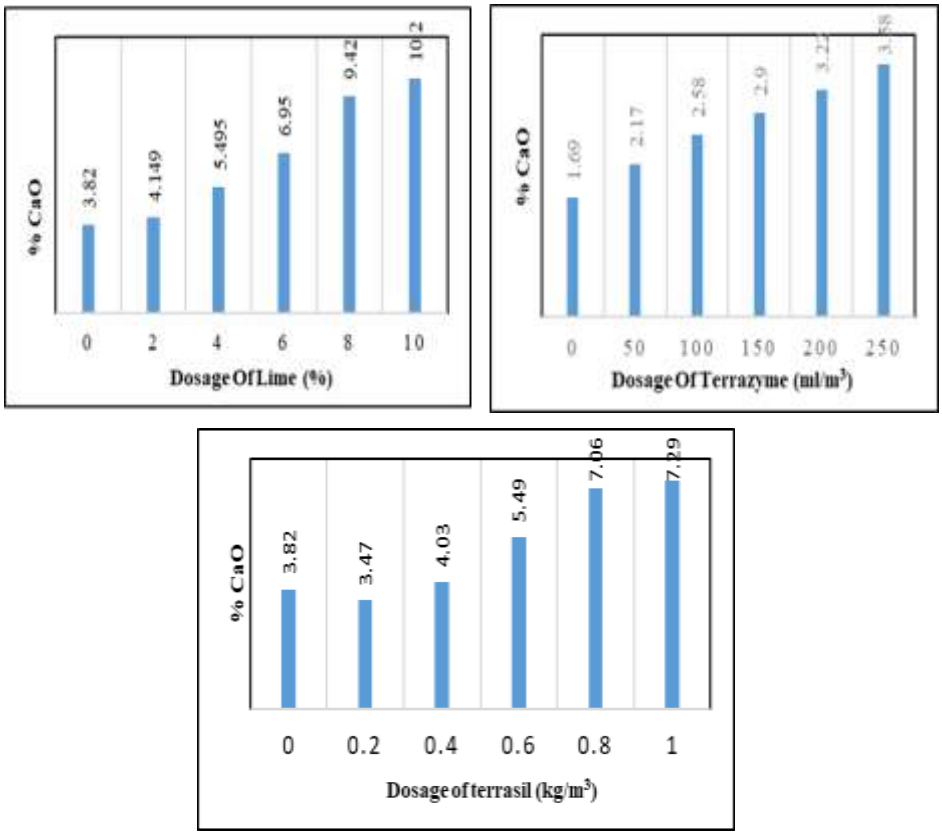
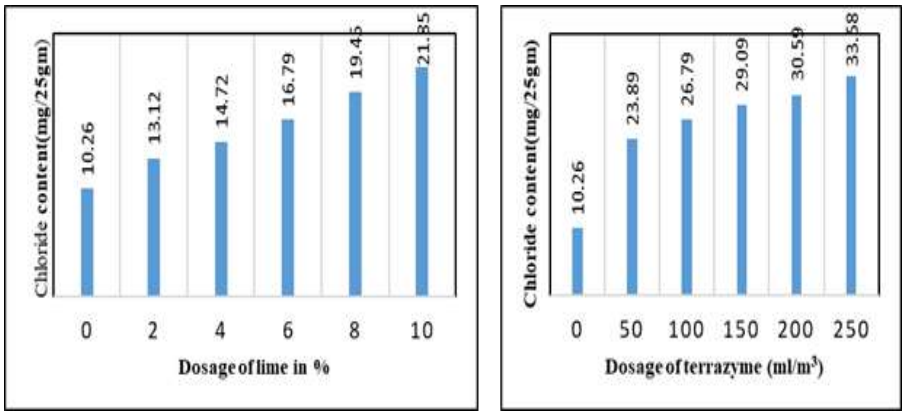


Fig. 8. Variation of Calcium oxide of soil after stabilizing



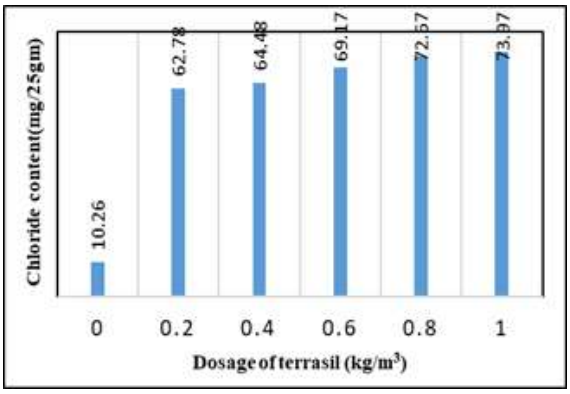
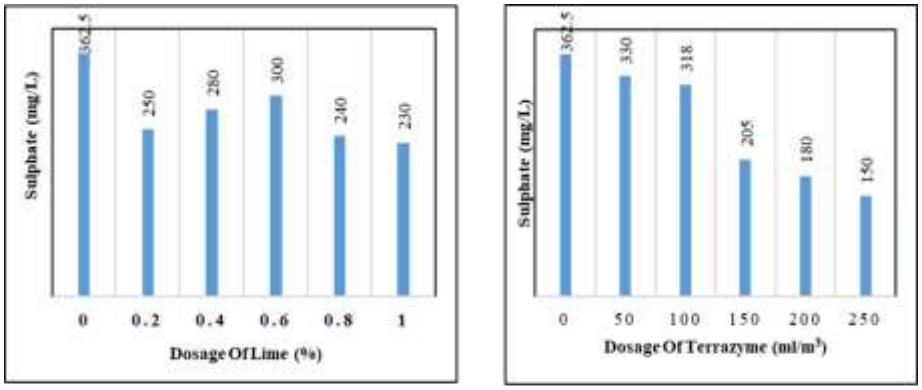


Fig. 9. Variation of Chloride content of soil after stabilizing



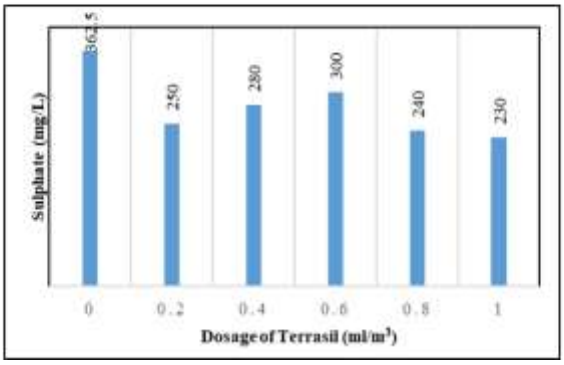


Fig. 10. Variation of Sulphate content of soil after stabilizing

Table 2. Comparison of test results

Additives	Normal Soil	Lime	Terrazyme	Terrsil
Optimum Dosage	-	8%	250ml/m^3	0.6kg/m^3
CBR (%)	1.1	11.51	2.25	4.7
FSI (%)	130	90	95	90
pH	9.3	13.34	7.53	7.55
Conductivity (mS)	1.1	7.3	2.7	2.9
Silica Content (%)	28	41	45	44
R_20_3 Content (%)	7.6	10.7	12.4	12.8
Iron Content (mg/L)	0.9	0.87	-	0.9
Chloride Content (mg/25gm)	10.26	19.45	33.58	73.97
Sulphate Content (mg/L)	362.5	180	150	230
Calcium (%)	3.82	8.4	9.75	7.29
Magnesium (%)	1.69	3.14	3.38	3.71

5 Conclusions

From the above investigations the following conclusions drawn:

- According to HRB classification the sample is A-7 type which is clayey soil. General rating for subgrade as fair to poor for the construction of highway pavement.
- When the soil treated with different dosages of Lime, Terrazyme and Terrasil it is found that CBR value was found to be maximum for 8% lime, 250ml/m3 and 0.6 kg/ m^3.
- Conventional additive Lime was used as stabilizer and it is found that CBR increased from 1.10% to 11.5% for 8% of lime.
- FSI reduced from 130% to 90% for 8% of lime.
- For the dosage of 8%of lime the silica, R_2O_3, iron, chloride, sulphate, calcium and magnesium was found to be 41%, 10.7%, 0.87mg/l, 19.45mg/25gm, 180mg/l, 8.4% and 3.14% respectively.
- When soil was stabilized with Bioenzyme Terrazyme it is found that CBR increased from 1.10% to 2.25% for 250ml/m^3 of terrazyme.
- FSI reduced from 130% to 95% for 250ml/m3 of terrazyme.

- For the dosage of 250ml/m^3 of terrazyme the silica, R_2O_3, , chloride, sulphate, calcium and magnesium was found to be 45%, 12.4%, 33.58mg/25gm, 150mg/l, 9.75% and 3.38% respectively.
- When the stabilization was done using Nano material terrasil it is found that CBR increased from 1.10% to 4.7% for 0.6 kg/ m^3 of terrasil.
- FSI reduced from 130% to 90% for 0.6 kg/ m^3 terrasil.
- When stabilized with 0.6 kg/ m3 terrasil. .the silica, R_2O_3, iron, chloride, sulphate, calcium and magnesium was found to be 44%, 12.8%, 0.9mg/l, 73.97mg/25gm, 230mg/l, 7.29% and 3.71% respectively.
- After analysis the results it is seen that the performance soil stabilized with lime is better (based on the CBR value) compared to other two stabilizers. Lime is traditional stabilizer. It is available in abundant quantity and is cheap compared to Terrasil and Terrazyme.
- Thus, it's concluded that Lime is suitable stabilizer for black cotton soil, which gives better performance compared to Terrasil and Terrazyme.

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