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Bio-enzyme stabilized soil as Pavement Subgrade

Serin Issac[1]
[1]Civil Engineering, New Horizon College of Engineering, Bangalore, serin.issac@gmail.com

Abstract— ***The pavements are subjected to premature failures in the form of rutting and fatigue failure. These are mainly attributed to increasing traffic. Also, cost effective roads are very vital for the economic growth of a country. There is an urgent need to identify new materials to improve the road structure and to expand the road network without involving much cost. When poor quality soil such as expansive 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 economically. This has led to the development of soil stabilization techniques. This study was conducted to stabilize Black Cotton (BC) soil which is highly expansive and undergo significant volume change i.e. swelling and shrinkage due to changes in water content. Stabilizing agent used in the study is Bio-enzyme, which is a natural, nontoxic, non-flammable, non-corrosive liquid enzyme formulated and fermented from vegetable extract, which improves the engineering properties of soil, facilitates higher soil compaction densities and increases stability. The dosage of Bioenzyme are taken as 200ml/m^3 , 400ml/m^3 , 600ml/m^3 , 800ml/m^3 and 1000ml/m^3 in the soil sample and result are analysed from the laboratory tests after a curing period of 7 days. Optimum dosage of Bioenzyme is found out from laboratory tests. The tests which were carried out are the Atterberg's limits, California Bearing Ratio (CBR) test, Unconfined Compressive strength (UCS) test and compaction test. The test results indicate that bio-enzyme stabilization improves the strength of BC soil up to great extent, which indicate the bearing capacity and the resistance to deformation increases in stabilized soil.***

Keywords— Bioenzyme, Black cotton soil, Atterberg's limits, California Bearing Ratio.

INTRODUCTION

Evolving new construction materials to suit various traffic and site conditions for economic and safe design is a challenging task in road construction. Effective utilization of local weak soils by imparting additional strength using stabilization materials enable reduction in construction cost and improved performance for roads. Exploring the feasibility of such materials for subgrade and embankment stabilization will help the road building sector to evolve a stronger, durable and economic design.

If highways are constructed on Black cotton soil it become problematic due to its expansive characteristics. Black cotton soil has tremendous strength when it is dry but after getting wet it loses its strength of subgrade. This project is an attempt to improve the properties of black cotton soil obtained from Hubli-Dharwar region, Karnataka, using various dosages of a natural organic fluid called as Bioenzyme.

Bioenzyme catalyze the reactions between the clay and the organic cat-ions and accelerate the cat-ionic exchange process to reduce adsorbed layer thickness. 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. Also, bio enzyme will impart the results quickly when compared to other stabilization materials. An attempt has been made to study the properties of soil modified with the bioenzyme, in order to use this technology for low volume roads. Based on laboratory findings, field trials were carried out using bioenzyme in some of roads in India. Moreover, in case of scarcity of granular material, only bioenzyme stabilized surface with thin bituminous surfacing also can fulfil 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.

MATERIALS USED

A. BLACK COTTON SOIL

The soil used in the investigation is highly expansive Black Cotton soil, shown in Fig 1, obtained from Hubli – Dharward municipal corporation area, Karnataka, India. The soil was collected at a depth of 1.5 m from the ground level after removing all the vegetation matter. The soil was air dried and pulverized to break all the lumps present. It was oven dried and later cooled in room temperature before use.

B. BIOENZYME

The Bioenzyme used is Terrazyme, shown in Fig 2, which is collected from Avigeet agencies, Chennai. Terrazyme is a good alternative to the conventional stabilizers like fly ash, lime etc., to be used as a soil stabilizer in the construction of roads. The effect of Terrazyme on soil is permanent and the soil becomes bio degradable in nature. The reason behind the improvement of soil properties is the cat ion- ion exchange capacity of the clay. Terrazyme reacts with absorbed water layer of clay particle and causes reduction in the thickness around particle of soil, this result in the reduction of voids between the particles of soil, thereby giving soil particle a closer orientation with low compaction. This ultimately results in the decrease in swelling capacity of soil and it also reduces permeability of soil. As the strength and stiffness of the soil is increased by adding Terrazyme to soil maintenance cost gets reduced by 30 to 50 %.It decreases the plastic characteristic of soil. Pavement thickness is reduced by 30 to 50%. Construction time is reduced by 50 %. Terrazyme improves load bearing capacity of soil.

Fig .1 Black cotton soil

Fig .2 Bioenzyme – Terrazyme

EXPERIMENTAL INVESTIGATION

The properties of the Black cotton soil used in this study are shown in Table 1.

TABLE I - PROPERTIES OF BLACK COTTON SOIL

Sl No:	Soil Properties	Values
1	Specific gravity	2.68
2	Liquid limit (%)	67.62
3	Plastic limit (%)	37
4	Plasticity Index (%)	40.62
5	Shrinkage limit (%)	16
6	Unconfined compressive strength (kg/cm^2)	0.1065
7	Optimum moisture content (%)	29
8	Maximum dry density (kN/m^3)	12.46
9	CBR value of soil (%)	1.295

Atterberg's limits

The effect of Bioenzyme at different dosages on Liquid limit and Plastic limit of Black Cotton (BC) soil is shown in Table II.The enzyme treated soil sample's consistency limits were tested immediately after the mixing. The mix becomes very stiff after weeks of curing.

TABLE III - ATTERBERG'S LIMITS OF BLACK COTTON SOIL

Dosages of Bioenzyme	Liquid limit (%)	Plastic limit (%)
200ml/m^3	66	36.4
400ml/m^3	61.4	35.7
600ml/m^3	59.2	33.2
800ml/m^3	57	32.7
1000ml/m^3	55.9	31.9

By the mixing of black cotton soil with bio enzyme it is identified that the values of Atterberg's limits are decreasing with increasing the stabilizing content.

Compaction tests

For determining the optimum moisture content and maximum dry density of the soil, standard proctor test was conducted at laboratory .With the variable dosage of Bioenzyme OMC and MDD were calculated for one week of curing. The effect of different dosages of Bioenzyme after one on OMC and MDD of soil is shown in Table III.

TABLE IIIII
MAXIMUM DRY DENSITY AND OPTIMUM MOISTURE CONTENT OF BLACK COTTON SOIL

Dosages of Bioenzyme	OMC (%)	Maximum Dry Density (kN/m^3)
200ml/m^3	27.1	15.21
400ml/m^3	26.0	16.64
600ml/m^3	22.5	19.8
800ml/m^3	22.2	17.35
1000ml/m^3	23.6	16.5

The optimum dosage of Bioenzyme is obtained for a dosage of 600ml/m^3, where a maximum dry density of 19.8kN/m^3 and optimum moisture content of 22.5% are achieved. The Fig.3 plots the variation in results obtained from compaction tests.

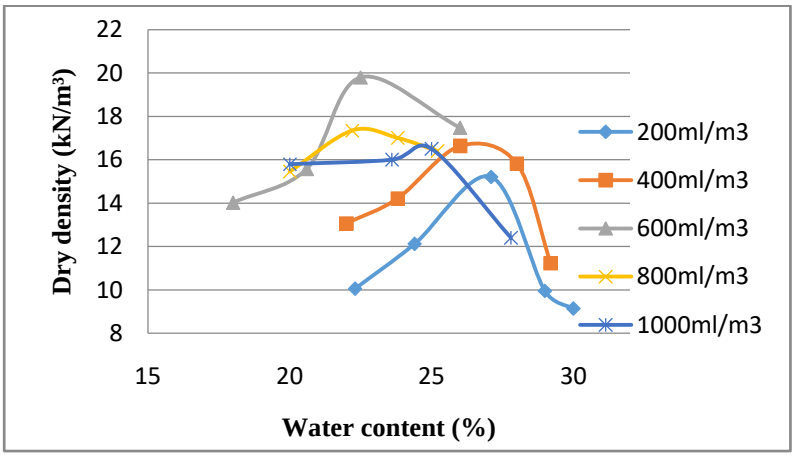

Fig. 3 Compaction curves for various dosages of Bioenzyme

California Bearing Ratio(CBR) tests

Black cotton soil was treated with 5 dosages of bioenzyme at optimum moisture content 22.5%. CBR moulds were prepared with different dosages by standard proctor method and kept by covering plastic bags for testing on 7th day. The results obtained are plotted as shown in Fig 4 and the CBR values for corresponding bioenzyme dosages are given in the Table IV.

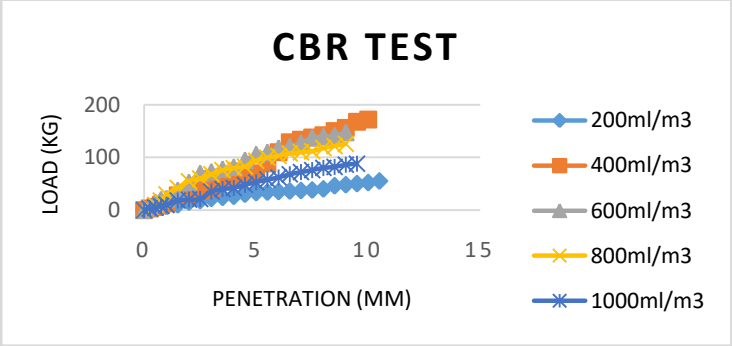

Fig. 4 Load – penetration curves for various dosages of Bioenzyme

TABLE IVV - CBR VALUES FOR VARIOUS BIOENZYME DOSAGES

Dosages of Bioenzyme	CBR (%)
200ml/m^3	1.619
400ml/m^3	3.2
600ml/m^3	5.26
800ml/m^3	4.65
1000ml/m^3	2.71

The above results indicate that with the addition of bioenzyme, a significant increase in the CBR value was obtained. But, the tests gave a peak result of 5.26% for a dosage of 600ml/m^3. CBR value above 5% is moderately suitable for a pavement subgrade.

Unconfined Compression tests(UCC)

Unconfined compression strength of black cotton soil was evaluated by stabilization with variable dosages of enzyme for 7days curing. The specimens were prepared and kept in desiccators to retain the moisture of the sample so that reaction between soil particle and enzyme may be continued. The results obtained are plotted as shown in Fig 5 and the unconfined compressive strength values for corresponding bioenzyme dosages are given in the Table V.

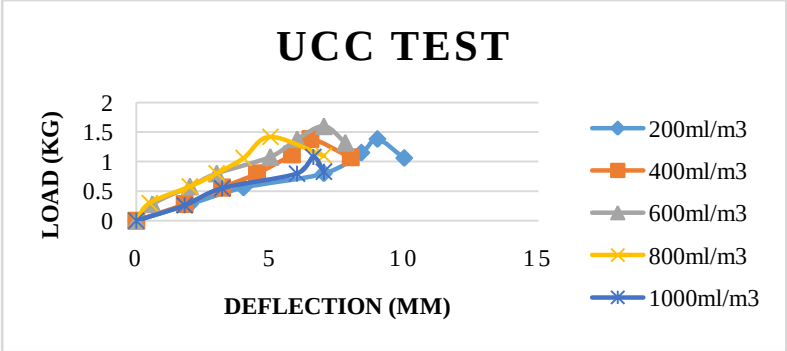

Fig. 4 Load – penetration curves for various dosages of Bioenzyme

TABLE V - UCC VALUES FOR VARIOUS BIOENZYME DOSAGES

Dosages of Bioenzyme	UCC (kg/cm^2)
200ml/m^3	0.1095
400ml/m^3	0.1386
600ml/m^3	0.1643
800ml/m^3	0.1348
1000ml/m^3	0.1107

The above results indicate that there is a significant increase in unconfined compressive strength of Black cotton soil with the addition of Bioenzyme. About 54% increase is obtained when 600ml/m^3 of Bioenzyme is added into the soil.

CONCLUSIONS

Bio-Enzyme stabilized soil has proved to enhance the properties of expansive soil subgrade. The optimum dosage of Bioenzyme was found to be 600ml/m^3, as obtained from the standard compaction test. The presence of Bioenzyme has catalysed the soil characteristics and has brought out a major drop in the consistency limits of the Black cotton soil, thereby making it suitable as a subgrade. Changes are marginal for MDD of bioenzyme treated soil which is from 12.46 kN/m^3 to 19.8kN/m^3, whereas decrease in OMC is observed to be 29.00% to 22.5%. The decrease is due to effective cation exchange process which generally takes longer period in the absence of such stabilizers. The UCC test value increased to about 54% with optimum bioenzyme dosage. This is due to the reaction of enzyme with clay which results in cementation effect. It is observed that the treated CBR values are increased because soil treated with enzyme renders improved density values by reducing the void ratios. Initially for the local soil the CBR value was 1.295% but with stabilization after 7 days of curing the CBR value was 5.26% for the optimum dosage. Moreover, Bioenzyme being an eco-friendly and economical additive, is convenient to use, safe and effectively improves the soil properties. It provides a tool for engineers to reduce the construction costs, whilst increasing the overall quality of road structures. The use of bioenyme in the construction of base and sub-base structures removes the need for the use of a sand/gravel mix, soling or water bound macadam in the construction of road structure. Bioenzyme constructed roads will have a much greater flexural strength and a higher CBR % than the conventional roads.

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