

Stabilization of Black Cotton Soil Using Bioenzyme, Lime and Fly Ash

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Abstract - Engineers often encounter difficulties when building on or with Black Cotton soil because of its poor engineering performance, which includes high clay content, low strength and an inadequate bearing capacity. The need to find a stabilizing substance was prompted by the poor performance of BC soil. Conventional stabilizers like gravel, sand, cement are depleting and becoming expansive day by day. Therefore, it became imperative to search for alternative stabilizers that are both economical and environmental friendly. Lime, fly ash, and bioenzyme (Terrazyme) have recently shown effectiveness as stabilizing agents. In this paper, soil samples were evaluated using fly ash, lime, and bioenzymes. The results of the Compaction test, Consistency limit, California Bearing Ratio have all been examined and discussed. It has been noted that a notable improvement has occurred to engineering properties of B.C. soil with these stabilizers.

Key Words: Black cotton (B.C.) soil, Bioenzyme, Terrazyme, Lime, Fly ash, Soil Stabilization

1. INTRODUCTION

Expansive soils or black cotton soil cover over 51.8 million hectares of land in India. When dry, Black cotton soils are extremely hard; yet, when wet, they entirely lose their strength. A global issue, expansive soils challenge civil engineers with a number of difficulties. To enhance the engineering properties of expansive soils, a variety of techniques are modified. The problematic soils are either treated with additives or removed and replaced with material of higher quality. The stabilization of the problematic soils is very important for many of the geotechnical engineering applications such as pavement structures, roadways, building foundations, channel and reservoir linings, irrigation systems, water lines and sewer lines to avoid damage due to settlement of soft soil or to the swelling action of expansive soil.

Black Cotton Soil

Black clays or tropical black earth or black cottons are known to be potentially expansive soils which are "black" or "greyish black" or in their eroded phase "greyish white" heavy loam or clay (usually 50%), with predominant clay mineral of the smectite group, rich in

alkali earth elements and the horizons sometimes contain calcium carbonate or magnesium oxide concretions. Many other terms have been applied locally, such as "regur" soils in India, "margalitic" soils in Indonesia, "black turf" in Africa and "tirs" in Morocco. Although there are several names, the term "black cotton soil" is adopted in this paper because of its extensive use in literature. The term "black cotton" is believed to have originated from India where the locations of these soils favour cotton growth. Black cotton soils have been defined differently by different authors, for instance Mohr and Van Baren (1959) proposed the term "margalitic soils" which they defined as "black or greyish black, grey or in the eroded phase greyish-white" heavy loam or clays; which crack when dry and swell when moist.

Problems in Black Cotton Soils

It is a well-known fact that water is the worst enemy of road pavement, particularly in expansive soil areas. Water penetrates into the road pavement from three sides viz. top surface, side berms and from sub grade due to capillary action. Therefore, road specifications in expansive soil areas must take these factors into consideration. The road surfacing must be impervious, side berms paved and sub grade well treated to check capillary rise of water.

- Black Cotton soils absorb water heavily, swell, become soft and lose strength.
- These soils are easily compressible when wet and possesses a tendency to heave during wet condition.
- Black Cotton soils shrink in volume and develop cracks during summer. These properties make them poor foundation soils and earth construction material.
- The stability and performance of the pavements are greatly influenced by the sub grade and embankment as they serve as foundations for pavements.
- The wetting and drying process causes vertical movement in the soil mass which leads to failure of a pavement, in the form of settlement, heavy depression, cracking and unevenness.

Soil Stabilization

Soil stabilization is the process of altering some soil properties by different methods, mechanical or chemical

in order to produce an improved soil material which has all the desired engineering properties. Soils are generally stabilized to increase their strength and durability or to prevent erosion and dust formation in soils. The main aim is the creation of a soil material or system that will hold under the design use conditions and for the designed life of the engineering project. The properties of soil vary a great deal at different places or in certain cases even at one place; the success of soil stabilization depends on soil testing. Various methods are employed to stabilize soil and the method should be verified in the lab with the soil material before applying it on the field. Principles of Soil Stabilization include evaluating the soil properties of the area under consideration. Deciding the property of soil which needs to be altered to get the design value and choose the effective and economical method for stabilization, designing the Stabilized soil mix sample and testing it in the lab for intended stability and durability values.

Soil Stabilizing Agent

A. Bio Enzyme

Enzymatic emulsions contain enzymes (protein molecules) that react with soil molecules to form a cementing bond that stabilizes the soil structure and reduces the soil's affinity for water. Categorically speaking, enzymatic emulsions work on a variety of soils as long as a minimum amount of clay particles are present. When applied at low application rates to the surface of the unbound road surface, enzymatic emulsions perform well for dust suppression. They bond soil particles together and so reduce dust generation. At higher application rates, enzymatic emulsions can be used to stabilize soils. Some of the bioenzymes are Renolith, Permazyme, Fujibeton, Terrazyme etc. Mechanism of Stabilization includes 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. In some cases the clay can swell and the size of double layer increases, but it can be reduced by drying. Therefore, to truly improve the soil properties, it is necessary to permanently reduce the thickness of double layer. Cat-ion exchange processes can accomplish this by utilizing fermentation processes specific micro-organisms can produce stabilizing enzyme in large quantity. These soil-stabilizing enzymes catalyze the reactions between the clay and the organic cat-ions and accelerate the cat-ionic exchange without becoming part of the end product. 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.

B. Fly Ash

Fly ash is a residue of coal combustion that occurs at power generation and incineration plants in many countries. Fly ash can be used to

- 1) lower the water content of soils,
- 2) reduce shrink-swell potential,
- 3) increase workability, and
- 4) increase soil strength and stiffness.

C. Lime

Lime can be obtained in the form of quicklime or hydrated lime. Quicklime is manufactured by calcinations of limestone at high temperatures, which chemically transforms calcium carbonate into calcium oxide. Hydrated lime is created when quicklime chemically reacts with water. Lime can be used to stabilize clay soils and sub marginal base materials (i.e., clay-gravel, caliche, etc.). When added to clay soils, lime reacts with water in the soil and reduces the soil's water content. The lime also causes ion exchange within the clay, resulting in flocculation of the clay particles. This reaction changes the soil structure and reduces the plasticity of the soil. These changes will increase soil workability and can increase the soil strength and stiffness.

1. MATERIALS AND METHODOLOGY

Materials used in this study are black cotton soil, lime, flyash and bioenzyme. Black cotton soil for present investigation is collected from Shingnapur, Tal-Kopargaon, Dist-Ahmednagar as shown in Figure 1,



Commercially available enzyme (Terrazyme) has been used in the present investigation (shown in figure 2). It is purchased from NATURE plus, Inc 55 Rachel Drive

Stratford, Chennai. It is available as a concentrated liquid and is to be diluted with water in specified proportion before mixing with the soil.



Lime used in the present investigation was obtained from local distributor, Kopargaon, MH, India. Commercially available lime was dry and later sieved through I.S.425 micron sieve was taken for the study. The chemical composition of lime is given in Table 1. The fly ash is collected from Thermal Power Plant Eklahare, Tal-Nasik, dist-Nasik.

Table 1 Chemical Analysis of Hydrated Lime

Chemical Characteristics	Percentage (%)
Silica	4.2
Insoluble matter	5.6
Ferric Oxide	1.7
Alumina	1.4
Calcium Oxide	51.7
Magnesia	0.7
Loss on ignition	30

Table 2 Chemical composition of Fly ash

Constituent	Percentage Range
Silica (SiO ₂)	49-67
Alumina (Al ₂ O ₃)	16-29
Iron Oxide (Fe ₂ O ₃)	4-10
Calcium Oxide (CaO)	1-4

2. RESULT AND DISCUSSION

A. Test on BC soil with Bioenzyme:-

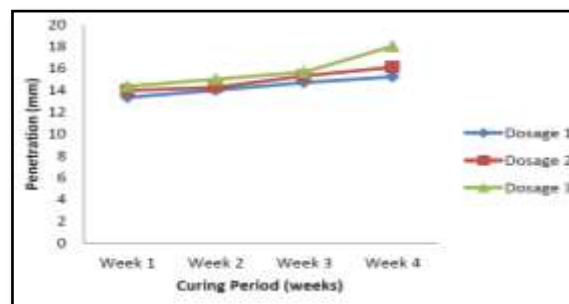
a. California Bearing Ratio Test: Unsoaked CBR test were conducted on treated soil sample having Bioenzyme dose as below,

Dosage 1:- For 1 kg = 0.020 ml of Enzyme

Dosage 2:- For 1 kg = 0.022 ml of Enzyme

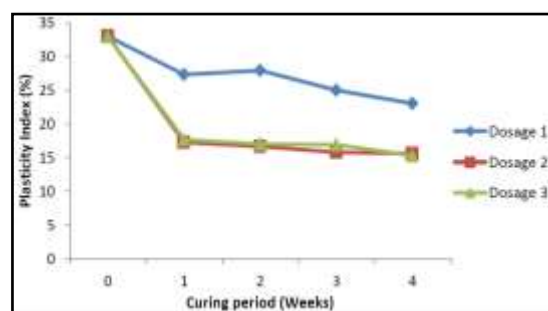
Dosage 3:- For 1 kg = 0.024 ml of Enzyme

Results for the soil samples combine with Bioenzyme are shown in Figure 7,



It is observed from figure 7 that, Unsoaked CBR values increase with the increase in curing period. This is because soil treated with enzyme renders improved density values by reducing the void ratios. This tendency may be due to effective cation exchange process which generally takes longer period in the absence of such stabilizers.

b. Consistency Limit Test: The enzyme treated soil samples consistency limits were tested immediately after the mixing. It shows the variation of consistency limit with different curing period is shown in Figure 8,



The decrease in liquid limit, plastic limit and plasticity index after 1 to 4 weeks of curing period and also with the amount of dosages is observed from the figure 4.12. Amount of clay content plays a major role in the variation of consistency limits. The mix becomes very stiff after weeks of curing.

CONCLUSIONS

After performing the entire test on BC soil in laboratory with the addition of different stabilizing agents some of the following conclusions are drawn as below,

- i. After addition of bioenzyme, unsoaked CBR values are significantly increase with the increase in curing period and also with increase in amount of dosages.
- ii. Bioenzyme decreases liquid limit, plastic limit and plasticity index of soil after 1 to 4 weeks of curing period and also with the amount of dosages. The mix becomes very stiff after weeks of curing.
- iii. As increase in curing period and dosages of bioenzyme, the MDD of treated soil increases and OMC is observed to be decreasing.
- iv. Unsoaked CBR values gradually increase with the increase in lime addition up to 44.55% for lime content 4% so, the optimum lime content is observed at about 4%.
- v. Addition of lime with the soil shows that, Plasticity index decreases with increase in lime content up to 2 %.
- vi. MDD of treated soil is increases up to 2% and then decreases with lime content and OMC is observed to be reverse of MDD result.
- vii. The Increase in Unsoaked CBR values with the increasing percentages of fly ash and then decreases after 30%.
- viii. Plasticity index is decreases with increase in addition of fly ash up to 40%.
- ix. MDD increased slightly up to 40% of fly ash and then it decreases. OMC of B,C. soil treated with fly ash decreases with the increase in fly ash content.
- x. Bioenzyme is best stabilizing agent as compared to lime and fly ash and also has life time sustainability, so it can be used in Expressways and national highways.
- xi. Lime and Fly ash are cheaper materials and has considerable scope for construction of low cost roads such as Village roads.

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