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Black Cotton Soil: Results of an Experimental Study

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Abstract: *After performance standards, economic feasibility and serviceability are the most crucial requirements for any project in developing nations like India. Time-consuming and costly, conventional approaches are no longer viable options. Consequently, it's important to identify different approaches to meet the performance and cost requirements that exist. The efficiency and low cost of these enzymes have been repeatedly demonstrated. The bioenzyme's eco-friendliness provides a further benefit. Dosage, soil type, and time allowed for cure all affect how effective bio enzymes are. Black cotton soils cover a considerable portion of our country. With the growing depletion and rising cost of traditional soil stabilisers like gravel, sand, and others, it is imperative that we find suitable, environmentally friendly alternatives. Soil stabilisation with bio-enzymes has become increasingly common and popular as a result of their low cost in recent years. Terazyme is one such bio-enzyme that has been utilised here. Unconfined compressive strength and atterberg limits were investigated as a result of Terazyme. Values for unconfined compressive strength have increased noticeably in soil that has been treated with enzymes. In its natural state, the soil has a compressive strength of 71 kN/m2. The soil's strength increased noticeably after being treated with Terazyme. The strength improves as time passes for cure. It was determined that there was a 300 percent increase in strength. Terazyme enzyme treatment did not result in a statistically significant increase in the liquid and plastic limit values. After being treated with enzymes for a short time prior to curing, both the compression index and the coefficient of consolidation decrease.*

Keywords: Black cotton soil

I. INTRODUCTION

1.1 Black Cotton Soils

One of the abundant soil types in India is black cotton. Exponential black cotton soil is most commonly seen in the tropics. They might have a black or brown look. Nearly twenty percent of the land in our country is composed of black cotton soil. Generally speaking, the middle and southern regions of India are where you'll find the most expansive soil. Black cotton soil is an expansive soil type found in the Deccan plateau fields (Deccan Trap), which are located in the Indian states of Madhya Pradesh, Maharashtra, Gujarat, Andhra Pradesh, and even certain areas of Odisha. There is black cotton soil in the valleys of the rivers Tapti, Narmada, Godavari, and Krishna. Areas around the upper Krishna and Godavari basin, on the western edge of the Deccan plateau. The dark cotton soil here just goes a few inches deep. Soils like this are the result of basalt or trap rock's residual influence. Another factor in the genesis of these soils is the weathering of igneous rocks following a volcanic eruption, when lava cools. The soils in question are very malleable. Among clay minerals, montmorillonite is by far the most common.

These clays' increased swelling and shrinkage characteristics can be attributed to the presence of the mineral montmorillonite, which belongs to the group of clays known as kaolin. The fundamental issue with these minerals is the inherent instability of the earth's crust.Widespread soils are abrasive when they dry up, but soft once they've soaked up some rain.

Under load, especially because of volumetric change in addition to regular wetness variation, it presents challenges for a lightly laden structure. In response, the superstructures often mitigate the negative effects of excessive settlement and divergent developments on the underlying frameworks, fundamental components, and structural parts of an institution. When a certain threshold is reached, the building becomes dangerously unstable. Despite efforts to alleviate swelling soil, volumetric changes, responsible for billions of dollars in annual damage, can occur without the right technology. This is why we're doing the job we're doing now. The plan was to see how much of an effect increasing bearing limit value and decreasing extensiveness would have. Although these soils are strong when dry, their capacity to support weight is greatly reduced when water is allowed to permeate their clay structure. Accordingly, it's safe to assume that soil, especially expansive soil, is very sensitive to environmental changes. Because of its characteristics, this soil is no longer suitable for use in building designs, either as an embankment material or a foundation material.

Fig 1.1 Expansive soil

1.2 Objective of Research Work

There are majorly 4 types of bio-enzymes till date are Renolith, Permazyme, Fujibetonand Terazyme. In the present investigation an attempt is made to stabilize the black cotton soil with bio Enzyme (Terazyme). Detailed laboratory tests were carried out to ascertain the benefits in terms of engineering properties**.**

(a) To evaluate physical properties of Black cotton soil.

(b) To determine the effects of adding enzyme to black cotton soil on its properties.

II. LITERATURE REVIEW

Isaac et al. (2003)[6]had conducted laboratory study on five types of soil namely CL, OH, CH,CI SX. to improve the five soil properties they mixed with bio enzyme. They conducted CBR test for a pre fixing curing period. From the results it is clear that Terazyme is very effective, economical. Most effective in case of silt content is more.

Velasquez et al. (2005) [22] studied the enzyme mixing on soil stabilization. they used two types of enzymes namely enzyme A and enzyme B. They conducted chemical analysis of enzyme A before the mechanical testing. After that they conducted resilient modulus and shear strength test on two soils which were stabilized with two different enzymes. Two types of soil are used named as soil 1 and soil 2. soil 1 mechanical properties are not affected by the enzyme A with enzyme B. The stiffness of soil 1 was increased. The resilient modulus of soil 2 increases by the application of both enzymes A and B. With time the enzyme activity on the soil stabilization increases. From the observations minimum four months of time required to get improvement in the shear strength of the soil.

Shankar et al. (2009) [18] studied the effect of Terazyme on locally available lateritic soil. The investigated lateritic soil was collected from udipi district region in Karnataka state. The lateritic soil is not full fill the requirements of sub base coarse so to brought down the atterberg limits they mixed the lateritic soil with locally available river sand. The blended soil is mixed is stabilized by using Terazyme enzyme.

Mgangira MB et al (2009) [8] conducted laboratory results on the effect of enzyme based liquid chemicals as soil stabilizer. Soil 1 had plasticity index of 35 and the other had PI of 7. Tests –Atterberg limits, Standard proctor and unconfined compressive strength.

1. Treatment with enzyme based products to lead a slight decrease in PI of both soil.

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2. Enzyme based chemical treatment of two soils using the two products showed a mixed effect on the UCS. No consistence significant improvement in the UCS could be attributed to treatment.

Naagesh and Gandgadhara et al (2010) [20]made experiments on an expansive soil treated with an organic, non-toxic, eco-friendly bio-enzyme stabilizer in order to assess its suitability in reducing the swelling in expansive soils. They stated that reduction in void ratio of bio enzyme treated specimens with curing period significant reduction in swell properties. The experimental results indicate that the bio enzyme stabilizer used in the present investigation is effective and the swelling of an expansive soil reduces on wet side of OMC

III. FILED DATA COLLECTION

Primarily focused on geology, engineering geology, etc., fieldwork was conducted to obtain primary data. Pitting and sample, together with geological and engineering geological mapping, were the mainstays of fieldwork.

3.1 Local Geology

Geological mapping at a scale of 1:50000 has been performed to better distinguish the various rock and soil units at the research area's surface. This region's surface geology may be summed up as follows;

Upper Miocene-Pliocene

Pleistocene-Holocene

- Residual soil
- Alluvial soil

Pliocene-Pleistocene

- Basalt
- Andesite
- Ignimbrite
- Lithic-Tuff

The outcroppings of rock in the region are predominantly volcanic in origin (pyroclastics and lava flows) and range in age from the Pliocene to the Holocene. Two types of soil exist: dirt that has been left where it was originally created and soil that has been transferred. Alluvial soil is the most common kind of soil in the study region, making up roughly 90% of the ground. Other common units include andesite, ignimbrite, basalt, and lithic tuff. Areas of flatness or mild slope are covered by soil, whereas higher elevations are occupied by rock, most notably andesite. This article's geology is shown in Figure 5.1.

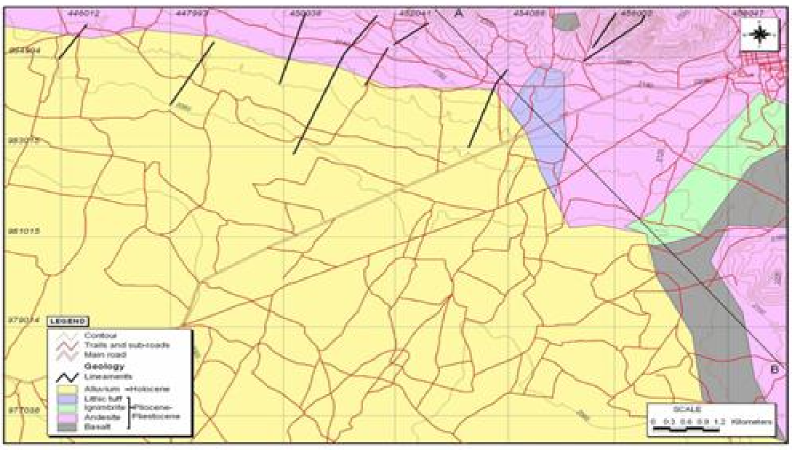

Figure 3- 1 Geological Map of the Study area

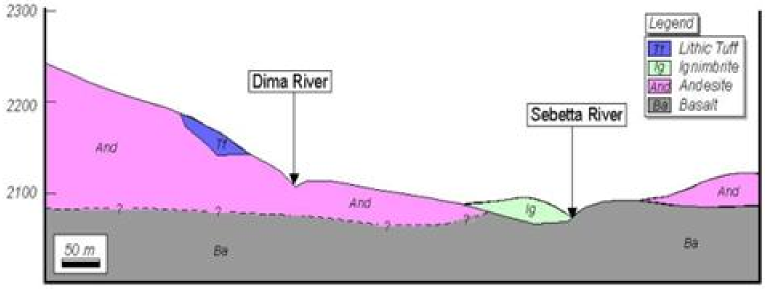

Figure3-2 Geological cross section, drawn along AB line (Fig. 5.1)

3.2 Engineering Geological Mapping

Soil and rock types that have similar engineering geological features are the focus of engineering geological mapping. This soil classification system takes into account soil's origin, texture, and particle size. It is the degree of weathering and jointing that is used as the primary criterion for categorizing rocks into varying strength levels. Annexure 1 of this study displays the guidelines45 used for qualitative engineering geological categorization of rocks and soils.

A. Rock Units

The various rocks exposed in the study area were classified and described according to their designation in the engineering geological map (Fig.5.4).

ba: fresh, closely jointed, strong to very strong basalt.

And: slightly to moderately weathered close to widely jointed, medium strong rock.

And$_1$: moderately to highly weathered closely to moderately jointed, medium strong to weak.

Ig: slightly to moderately weathered, closely jointed, weak.

Tf: highly weathered, massive, very weak

B. Basalt (ba)

The basalt forms a soft resistant shape and covers just a tiny region in the research area's extreme east and south east. Grayish-black in colour, fine-grained and newly formed, sometimes exhibiting spheroidal weathering, and with highly developed columnar jointing. The rock's mineralogical makeup is as follows: euhdral plagioclase (65%), anhedral pyroxene (23%), and opaque (12%) in a fine to microcrystalline form (grey to black in colour).

According to engineering geology, this unit is a kind of young, tightly jointed, strong to extremely strong basalt. Construction of roads in the research area basalt is used as coarse concrete aggregate.

IV. RESULT

4.1 Particle Size Distribution

The techniques used were those prescribed for examination of fine-grained soils samples since more than 98% of the soil samples analyzed were fines (material passing a 63 m screen). Soil fraction >63 m was obtained using a wet sieve, and the sedimentation technique was used on the remaining material (pipette method). After a soil has undergone a combined screening and sedimentation technique, a continuous particle size distribution curve may be produced, from the size of the tiny sand particles to the size of the clay size. A grain size distribution curve showing the relative amounts of clay, silt, and sand was generated from the samples analysed

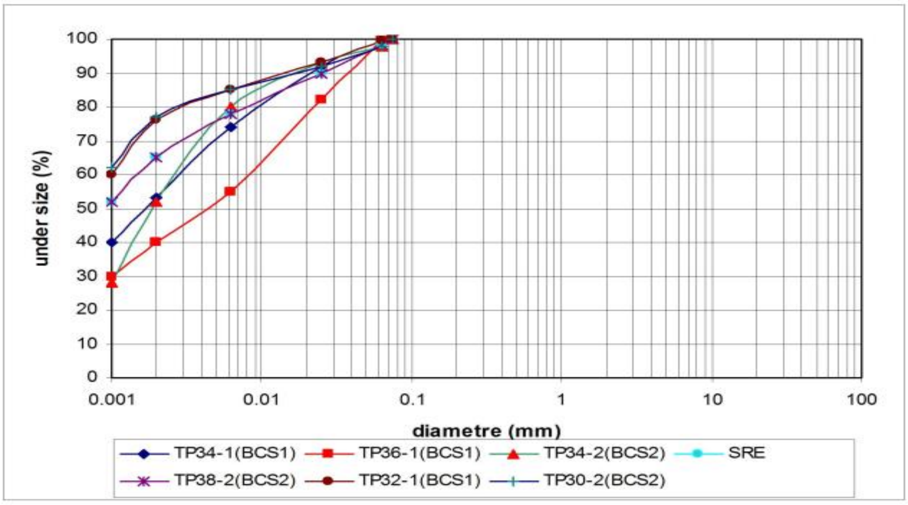

Figure 4.1: Grain size distribution curve

4.2. Atterberg Limits

The most effective method of recognizing and categorizing fine grained soils is through the determination of their plastic and liquid limitations. Based on their plasticity qualities, silt and clay are separated using the Casagrande's plasticity chart. Figure 4.2 displays the LL vs PI plot of black cotton soil samples collected along five important roads: Ambo, Jima, Debra Marcos, and Debra Berhan (MekonenTsegaw, 2003). The vast majority of samples lie above or parallel to the A-line, suggesting that the clay is inorganic and has a high to extremely high plasticity (CH & CV).

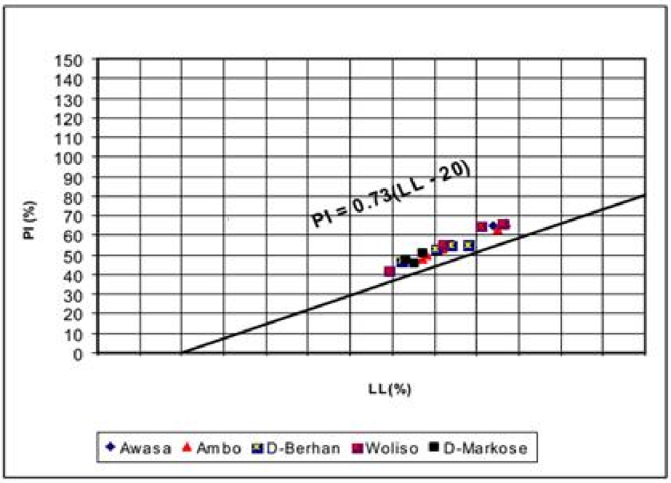

Figure 4. 2 Liquid limit against plasticity index for placing major trunk roads expansive soil into Unified Soil Classification (USC).

4.3 Free Swell

The volume shift from the air-dried state to the unrestricted swelling is determined by conducting a free swell test on a soil specimen that has been air-dried. The free swell values for the black cotton soil samples were between 118% and 140%. (Plate 6.1) Six trenches were dug into the black cotton soil, and samples were taken at depths of 0.50-1.60 metres. At a depth of 0.50-0.70 m in the south western portion of the region, in the marshy terrain, test pit (TP34-1) yields the highest result of 140%. The test pit (TP-Q) 4 m deep sample had the lowest value, at 22%. Soil mapping shows a reddish brown residual soil in the region's northeast. Free swell LL is highly correlated with a soil fraction of

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2mm or less. There has been some effort put into trying to determine the relationship between the LL and free swell, and the results of this effort are depicted graphically in Figure.4.3.

Figure 4.3 Free Swell test

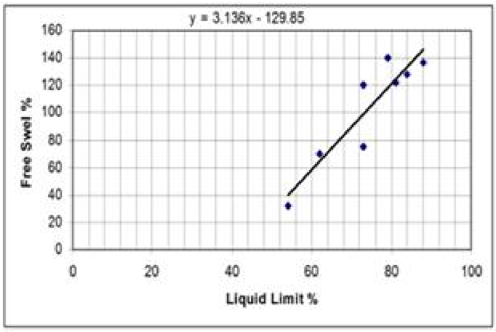

Figure4.4 Correlation between LL and FS as derived for the soil samples collected from the present study area.

V. CONSEQUENCES OF USING BLACK COTTON SOIL FOR ROADWORK

Shrinkage fractures on the order of 15 cm width and travelling approximately 174 cm to 305 cm deep are a familiar sight in the field when such deposits exist in the expansive soil, such as black cotton soil. Long-term infrastructure projects, such as railways and roads, confront difficulties in these regions due to the sub grade's exceptionally low bearing capacity when wet and its significant swelling and shrinkage pressure characteristics.

In the following paragraphs, we briefly explain the main damages of road construction based on current and past study (Netterberg, 2001). These issues are unique to the locations where they have been reported.

5.1 Road

Cracking and heaving are the main issues when using black cotton soil for road construction. Based on the research (Netterberg, 2001), the following are hypothesised to be contributing factors to the road maintenance issue:

Due to (a) a possibly very busy road bed (b) an extraordinarily large rise in moisture content (due to ponding), (c) the use of permeable fill (Tulu Bolo weathered tuff), and (d) the lack of protection against heave (such as partial replacement of the clay), heave may occur.

5.2 Cracking

Are either longitudinal or transverse, with the latter being quite uncommon, obviously thin, and only found in conjunction with culverts like the one at kilometre marker 31+920. Tension cracks, wider at the top, did not extend very far into the clay roadbed, and all observed longitudinal cracks were unfaultted (i.e., both sides were at the same height). All were linked to periods of brief flooding, and many showed up in the dry season. Those near kilometres 32 right and left, as well as those around kilometres 44 on the high embankment across the Awash River flood plain, were among the first to be spotted following the wet season.

During the course of this investigation, a fracture was discovered running longitudinally along the left side of the road at about Kilometer 32+150.

Size-wise, it averages out to 70 metres in length and 20 centimetres across (plate 6.3). Although impervious materials (clay, asphalt) were used to try to fix the problem, they ultimately proved to be simply a band-aid.

Plate 6-9 **Longitudinal cracking along left side of the road (km32+150)**

Apparent Heave

Coincides with the cracking, stretched for a considerable distance (tens to hundreds of metres), and caused noticeable uplift of the pavement's perimeter (about 50 millimetres). Some trenched cross sections clearly displayed this heave, which affected roughly the outer half a metre of the asphalt and the inner half a metre of the shoulder. The surfacing's cross falls are lower and the shoulder's are higher as a result of this heave. At kilometre 31+970 (plate 6.4) right and km 64+518 we saw instances of localised apparent heave of a more general type.

the river at roughly km 15, and these soils needed to be treated with procedures such partial replacement. Slopes steeper than 1–1.5 m had to be cut, but this should allow for better drainage and the elimination of ponding. Most of the cuttings had severely damaged floors, requiring pre-wetting or additional excavation prior to covering. The cuttings and side drains had already been broken up, micro broken, and degraded. In order to prevent erosion and creep and to line the side drains, it may be essential to reduce these slopes to a gradient of 1 in 4. Highly erodible and perhaps dispersive soils are present here.

VI. CONCLUSION

Black cotton soil is a type of alluvial soil, meaning that it was washed down from higher ground and deposited elsewhere. Round or somewhat oblong grains of carbonate rich nodules within the black soil strata are indicative of alluvium. There is a high concentration of carbonate nodules with a silt and sand mixture up to a depth of 5 m in the places where highest water pond age is occurring, especially in the westernmost part of the research area. These carbonate lumps range in size from coarse sand to coarse gravel and are primarily sub-angular to sub-rounded in shape.

Many studies have found that montmorillonite is the primary mineral in Ethiopian black clays.

Black cotton soil's key field characteristics are its intensive tensional cracking up to 1 m deep and 10 cm wide with a peculiar hexagonal geometry, which is assigned to an intrinsic component, the high content of clay montmorillonite, and an external element, moisture variation.

Soil samples were taken from test pits and analysed both before and after they were disturbed. Natural water content and bulk density tests were performed on undisturbed materials. Grain size distribution, specific gravity, Atterberg limits, shrinkage limit, and free swell were among the laboratory experiments conducted on disturbed samples.

Black cotton soil's grain size distribution, Atterberg limits, shrinkage limit, and free swell are further examined and reported. The grain size distribution shows that the percentage of fines is well above 90%, the percentage of liquid limits is between 50% and 110%, and the percentage of plastic limits is between 23% and 94%. The plastic index varies from 20% to 85%. Black cotton soil samples have values for the shrinkage limit and free swell tests that range from 15.7 to 20.7% and 118 to 140%, respectively.

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