A STUDY ON EXPERIMENTAL INVESTIGATION OF BIO-ENZYME STABILIZED EXPANSIVE SOIL

Prof. Guruprasad Jadhav[1] , Mr. Ganesh Panchal[2] , Mr.Randhir Mane[3]

[1]*Dept. of Civil Engineering, Parvati Bai Genba Moze College of Engineering Wagholi, Pune Maharashtra, (India)*

[2,3]*B.E Student Of Dept. of Civil Engineering, Parvati Bai Genba Moze College of Engineering Wagholi, Pune Maharashtra, (India)*

ABSTRACT

Improvement and stabilization of soils are widely used as an alternative to substitute the lacking of suitable material on site. Soils may be stabilized to increase strength and durability or to prevent erosion and dust generation. The use of non-traditional chemical stabilizers in soil improvement is growing daily. A new stabilizing agent was developed to improve the mechanical performance and applicability of clayey soils. In this study a laboratory experiments are conducted to evaluate the effects of Bio-enzymes(TerraZyme) with different dosages and curing time on the Atterberg's limit, compaction, unconfined compression (UCS) and durability for black cotton soil.

Keywords: Unconfined Compression, Bio-Enzymes (Terrazyme) , Liquid Limit, Shrinkage Index.

I INTRODUCTION

A liquid chemical product are actively marketed for stabilizing soils on pavement projects. Usually supplied as concentrated liquids, these products are diluted in water on the project site and sprayed on the soil to be treated before compaction. Pressure injection is sometimes used to treat deeper soil layers [2]. However, supplier claims of product effectiveness are often not well substantiated with independent field or laboratory evaluations performed under controlled conditions. Chemical treatment of pavement base, sub-base, and sub-grade materials is undertaken to improve workability during compaction, to create a firm working surface for paving equipment, to increase the strength and stiffness of a foundation layer, to reduce potential shrink and swell due to moisture changes or frost action, or both, or to control dust on unpaved roads [4]. Every civil engineer is concerned, is closely associated to the structures and mineralogy of the clay particles, clay-water interactions, clay particles ionic exchange capacity and the clay-organic or clay-inorganic interaction. Majority of road failures are associated with the action of water, or perhaps more precisely, the interaction between water and the clay particles in the road. The main objectives of chemical stabilization on soils are maintaining the characteristics of the soil, favorable from the aspects of the given engineering target, regardless of the moisture in its environment [5]. It is intended to modify the interactions between water and soil by surface reactions in such a manner as to make the behavior of the soil with respect to water effects most favorable for the given purpose [1].

1.1 Soil Stabilization

Soil stabilization is the alteration of one or more soil properties, by mechanical or chemical means, to create an improved soil material possessing the desired engineering properties. Soils may be stabilized to increase strength and durability or to prevent erosion and dust generation. Regardless of the purpose for stabilization, the desired result is the creation of a soil material or soil system that will remain in place under the design use conditions for the design life of the project. There are various methods for soil stabilization like mechanical stabilization, cement stabilization, lime stabilization, bituminous stabilization, chemical stabilization, thermal stabilization, electrical stabilization, stabilization by grouting etc.

1.2 Basic principles of soil stabilization

Evaluating the properties of stabilizing soil. Deciding the lacking property of soil and choose effective and economical method of soil stabilization. Designing the stabilized soil mix for intended stability and durability values.

1.3 Need for soil stabilization

Limited financial resources to provide a complete network road system to build in conventional method. Effective utilization of locally available soils and other suitable stabilizing agents. Encouraging the use of industrial wastages in building low cost construction of roads.

1.4 Enzymes as a Soil Stabilizer

The Enzymes are adsorbed by the clay lattice, and then released upon exchange with metals cations. They have an important effect on the clay lattice, initially causing them to expand and then to tighten. The enzymes can be absorbed also by colloids enabling them to be transported through the soil electrolyte media. The enzymes also help the soil bacteria to release hydrogen ions, resulting in pH gradients at the surfaces of the clay particles, which assist in breaking up the structure of the clay [4].

1.5 Present Work

Black cotton soil is considered in the present study with high plastic. So as to meet the specified limits of liquid limit and plasticity index and other strength characteristics for airfields and roads as sub-base course, soil stabilization was tried using liquid stabilizer TerraZyme. By using of these materials economizes the overall cost and improves stability of sub-base for pavements. Black cotton soil were stabilized by using variable Enzyme dosages and strength of the stabilized soil has been evaluated after curing period of 0, 7 & 14 days. The tests were carried out to determine the consistency limits, CBR and unconfined compressive strength, swelling pressure and durability test of the soil specimens with and without stabilizer Bio-enzyme.

In the present investigation attempt is made to stabilize black cotton soil with Enzyme (TerraZyme). The consistency Limit test, compaction, swelling pressure, durability test, unconfined compressive strength tests were carried out in the laboratory for different mix proportions of Bio-enzyme with black cotton soil.

1.6 Objectives of Present Study

To determine the geotechnical properties of investigating soils (BC soil)

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

To determine the change in geotechnical properties associated with sub grade strength with addition of different percentages and curing time of Enzyme (TerraZyme).

II LITERATURE REVIEW

2.1 Necessity

As a prelude to begin with a project it is more essential to have general and detailed information regarding the subject content, strategic approaches, available research in the subject area, interpreted results and drawn conclusions. Keeping above in mind, a detailed review is conducted to know the available information in the subject is, need to research, development and improvements. It gives us an idea about the objective to be achieved from the present work. Literature review is carried out by referring the journals, dissertation reports, relevant IS codes and browsing the websites. The list of journals, books, website referred is given in reference section. This chapter reviews the attempts made by several researchers to understand the behavior of Enzymes as reinforcing material in soil. Literature reviewed in the present chapter reveals many studies on behavior of liquid stabilizer in unconfined compressive strength (UCS) and California bearing ratio (CBR) tests. Researchers have experimented on various parameters such as variation in binder content, reinforcement content and aspect ratio of reinforcement content past experience and knowledge of material behavior on different types of soil is required for further experiments.

2.2 Problems Associated With Expansive Soils

Construction of any infrastructure over a weak or a soft soil is highly typical on the geo-technical grounds as the soil undergoes differential settlements, poor shear strength and high compressibility. Normally, the type of foundations varies depending upon the availability of soil strata as well as cost involvement. Sometimes, it is essential to have a high rise building over a weak soil, in such conditions, improvement of load bearing capacity of soil is very much essential. In these aspects, improvement of load bearing capacity of soil has been improved by adopting various techniques like soil stabilization, adoption of reinforcement etc. Generally, admixing technique in soil has an effective ground improvement because of its easy adaptability. Therefore, the present investigation describes the behavioral aspect of soils mixed with liquid Enzyme to improve the load bearing capacity of the soil.

2.3 Brief Summary of Literature Review

2.3.1 Faisal Ali et.al (2012) [1] The focus on this research is on the improvement of engineering properties of three natural residual soils and mixed with different proportions of liquid chemical. Series of laboratory test on engineering properties, such as unconfined compressive strength (UCS), consistency limits, moisture-density relationship (compaction) was undertaken to evaluate the effectiveness and performances of this chemical as soil stabilizing agent. The results show that addition of the liquid stabilizer can reduce plasticity and shrinkage by eliminating re-absorption of water molecules; It reduces optimum moisture content by ionizing and exchanging the water molecules on the surface of the clay platelets; It increases maximum dry density by neutralizing and orderly re arranging the clay platelets and increases the compressive strength by increasing the inter particles bonding.

2.3.2 C. Venkatasubramanian et.al (2011) [3] Three different soils with four different dosages for 2 and 4 weeks of period after application of enzyme on its strength parameters were studied. It is inferred from the results that addition of bio enzyme significantly improve UCC values of selected samples. 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.

2.3.3 Peng et al. (2011) [4] Conducted unconfined compression tests on three soils; fine-grained, silty loam and coarse grained textures named as Soil I, Soil II and Soil III respectively. Three soils were stabilized with quicklime and an enzyme (Perma-zyme). The samples were cured up-to 60 days in two different conditions; air-dry and in sealed container. In air-dry curing the samples were allowed to dry at room temperature where as in sealed container the moisture was preserved in the samples during the curing time. The enzyme was found more effective in air-dry curing for Soil I and Soil II than quicklime where as it was not effective for Soil III in air-dry curing and for three soils in sealed curing too. In sealed containers, the quicklime was found more effective than the enzyme as the water in the specimens was not allowed to evaporate which promoted the further hydration of quicklime.

2.3.4 Shukla.M et al (2010) [5] 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. 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.

2.3.5 M B Mgangira et al (2009) [7] Thus the aim of this paper is to present laboratory results on the effect of enzyme based liquid chemicals as soil stabilizer. 1 soil had plasticity index of 35 and the other had PI of 7. Tests –Atterberg limits, Standard proctor and unconfined compressive strength. Treatment with enzyme based products to lead a slight decrease in PI of both soil. 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.

2.3.6 A.U. Ravishankar et.al(2009) [8] Conducted a comprehensive study of the Terrazyme soil stabilizer product with abundantly available lateritic soil in Dakshina Kannada and Udupi districts does not satisfy the requirements (Liquid Limit ≤25% and Plasticity Index ≤6 %) to be used as a base course material in pavements. In order to improve its properties the soil is blended with sand at different proportions unless until it satisfies the Atterberg's Limits for sub-base course. The effect of enzyme on soil and blended soil in terms of Unconfined Compressive Strength (UCC), and permeability are studied.

2.3.7 R.A.VELASQUEZ et.al (2006) [9] The sub-grade stabilization effectiveness and mechanisms of two enzyme products (enzyme A and B) were investigated using chemical analysis and resilient modulus testing. Two types of soil were tested in this study. A soil with a high percentage of fines (96.4% passing 200 sieve) and high clay content (75.2%) (Soil I) and a soil with a relatively low fines content (59.7% passing 200 sieve) and low clay content (14.5%) (Soil II). Enzyme A and B reduced the compaction effort and improved soil workability during specimen preparation. Thus, less pressure was used to obtain the target density of the treated specimens compared to the untreated specimens; the addition of enzyme A did not improve the resilient modulus of Soil I but increased by an average of 54% the resilient modulus of Soil II; the addition of enzyme B to Soils I and II had a pronounced effect on the resilient modulus. MR of Soil I increased by an average of 69% and for Soil II by 77%; the resilient modulus increased as the curing time increased; enzyme A increased the shear strength of Soil I by an average of 9% and of Soil II by 23%; enzyme B increased the shear strength of Soil I by an average of 31% and of Soil II by 39% and the type of soil, percent of fines and the chemical composition are properties that affect the stabilization mechanism. Therefore, special attention should be paid to select the proper treatment to be used for different soils.

2.3.8 Marasteanu et al. (2005) [10] Conducted resilient modulus and tri-axial tests on two soils which were stabilized with two different enzymes. Soil-I has 96% of fines (75% of clay) a SPG of 2.73 and plasticity index of 52%. Soil-II has 60% of fines (14.5% of clay) and plasticity index of 9.4%. Chemical analysis of only one enzyme (A) was conducted, as the supplier of the other enzyme (B) did not agree for this. The chemical analysis for the enzyme included pH, metals concentrations (e.g., Ca, Fe, and Al), total organic carbon concentration, and inorganic anion concentrations (e.g., Cl-, NO3- and SO4 2-). The pH of product A was 4.77 and had very high concentration of potassium (K), and moderate to high concentrations of calcium (Ca), magnesium (Mg), and sodium (Na). The metal concentration and inorganic anion concentration are given in Tables 1 and 2. The tests were conducted on a base (Base-1) as well to compare the results. The protein concentration in the undiluted product A was 9230 mg/L. The presence of protein alone does not indicate that the solution will exhibit enzymatic activity therefore enzyme activity tests were conducted and it was found that the product A exhibited no detectable enzymatic activity for the used substrates. This indicates two possibilities: Product A is a highly purified enzyme solution that contains only a single enzyme or group of enzymes that catalyze reactions not tested for in our experiments or product A may not stabilize soil via enzymatic activity but rather via some other mechanism, possibly due to their surfactant-like characteristics.

2.3.9 Milburn & Parsons (2004) [11] Conducted different tests (freeze-thaw, wet-dry, leach testing, Atterberg limits and strength tests) on soils (classified as CH, CL, ML, SM, and SP) stabilized with lime, cement, Class C fly ash, and Permazyme 11-X. Compaction, Unconfined compression, stiffness, freeze-thaw, wet-dry and leaching tests were conducted on two silty soils (ML and SM) treated with Permazyme 11-X at a dosage recommended by the supplier. ML and SM soils had fines 88 and 30%, LL 30 and 20% and PI 7 and 3% respectively. Compaction test for treated soils was carried out at moisture content 1% less than the optimum. But only 4% and 1% increase in dry density was found for ML and SM soils respectively. The soil samples for two soils after 28 days of curing were tested for stiffness and no improvement was recorded. Similarly for freeze-thaw very modest improvement and for wet-dry and leaching tests no improvement was observed.

III MATERIALS AND METHODS

3.1 Introduction

This chapter details the various tests conducted in the laboratory in order to study the characteristics of sub-base material. In the present study, samples were collected to assess the suitability of Bio-Enzyme (TerraZyme) as soil stabilizer on black cotton soil.

3.2 Materials

The soil used in this study is Black cotton soil (Dark grey in color) collected from site. Liquid stabilizer Bio-Enzyme (TerraZyme) is used as admixture to stabilize the investigating soils.

3.3 Black cotton soil

Expansive soil are those which show volumetric changes in response to changes in their moisture content. Such soil swells when the moisture content is increased and shrink when the moisture content is decreased. Consequently, expansive soil cause distress and damage to structures founded on them. Black cotton soil is collected from the wagholi area of Pune district; Maharashtra. The black cotton soil was collected by method of disturbed sampling after removing the top soil at 500mm depth and transported to laboratory. Little amount of sample is sealed in polythene bag for determining its natural moisture content. The soil was air dried, pulverized and sieved as required for laboratory tests.

3.4 Properties of Terrazyme

Table 3.4.1 Properties of Enzyme (TerraZyme)

Sl. No	Property	Value
1	Specific gravity	1.000-1.090
2	pH value	3.10 - 5.00
3	Appearance	liquid
4	Odour	characteristic odor
5	Flammability	inflammable
6	Solubility	Infinite
7	Colour	Brown

3.5 Working Mechanism of Bio-Enzyme

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 absorbed on the clay surface. The absorbed 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

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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[6] .Fig3.4showsthe photograph of Enzyme (TerraZyme).

Fig 3.5.1 BIO-ENZYME (TerraZyme)

3.6 Enzyme Dosage

The Enzyme Dosages assumed for Black cotton soil was 200 ml for bulk volume 3.5 m^3 to 1.5 m^3 of soil.

Table 3.6.1 Enzyme Dosages

Dosage	200 ml/m^3 of Soil	ml/kg of Soil
1	3.0	0.042
2	2.5	0.051
3	2.0	0.064
4	1.5	0.085

3.7 Methodology

3.7.1 Specific Gravity

Specific gravity G is defined as the ratio of the weight of an equal volume of distilled water at that temperature both weights taken in air.

3.7.2Atterberg limits

3.7.2.1 Liquid limit

Liquid limit (LL or wL) is defined as the arbitrary limit of water content at which the soil is just about to pass from the plastic state into the liquid state. At this limit, the soil possesses a small value of shear strength, losing its ability to flow as a liquid. In other words,

3.7.2.2 Plastic limit

The plastic limit (PL or wP) is the water content where soil starts to exhibit plastic behaviour. A thread of soil is at its plastic limit when it is rolled to a diameter of 3 mm or begins to crumble. To improve consistency, a 3 mm diameter rod is often used to gauge the thickness of the thread when conduc

3.7.2.3 Plasticity index

Plasticity index (PI or Ip) is the range of water content within which the soil exhibits plastic properties; that is, it is the difference between liquid and plastic limits.

PI (or Ip) = (LL - PL) = (wL - wP)

When the plastic limit cannot be determined, the material is said to be non-plastic (NP).

Plasticity index for sands is zero.

For proper evaluation of the plasticity properties of a soil, it has been found desirable to use both the liquid limit and the plasticity index values.

3.7.2.4 Shrinkage limit:

The shrinkage limit (SL) is the water content where further loss of moisture will not result in any more volume reduction. The shrinkage limit is much less commonly used than the liquid limit and the plastic limit.

3.7.3. Grain Size Distribution By Sieve Analysis

Soils having particle larger than 0.075mm size are termed as coarse grained soils. In these soils more than 50% of the total material by mass is larger 75 micron. Coarse grained soil may have boulder, cobble, gravel and sand. The following particle classification names are given depending on the size of the particle:

i. BOULDER: particle size is more than 300mm.

ii. COBBLE: particle size in range 80mm to 300mm.

iii. GRAVEL (G): particle size in range 4.75mm to 80mm.

a. Coarse Gravel: 20 to 80mm.

b. Fine Gravel: 4.75mm to 20mm.

iv. SAND (S): particle size in range 0.075mm to 4.75mm.

a. Coarse sand: 2.0mm to 4.75mm.

b. Medium Sand: 0.425mm to 2.0mm.

c. Fine Sand: 0.075mm to o.425mm.

Dry sieve is performed for cohesion less soils if fines are less than 5%. Wet sieve analysis is carried out if fines are more than 5% and of cohesive nature.

In simpler way the particle size distribution curve for coarse grain soil as follows,

Gravels and sands may be either poorly graded (Uniformly graded) or well graded depending on the value of

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coefficient of curvature and uniformity coefficient.

3.7.4 Preparation of soil samples for unconfined compressive strength test.

The soil passing through 425µ sieve is mixed with varying percent of enzyme i.e. 200 ml for 1.5, 2.0, 2.5, 3 m^3 of soil cured for 0, 7 and 21 days soil samples are prepared at optimum water content. The maximum dry density (MDD) and optimum moisture content (OMC) for the soil- enzyme mix is determined from standard Proctor test as per IS: 2720, Part VII- 1980 [20]. The samples were prepared by dynamic compaction method. The molding device consists of a steel tube with internal diameter of 33mm and height 70mm. The soil is compacted in three layers in cylindrical steel mould. After each layer is compacted the surface is scratched to obtain a rough surface to facilitate proper bonding for the next compacted layer. The surface is trimmed to circular cross-section by the trimmer. The compacted samples are ejected from the mould with the help of sample extractor. These prepared soil specimens are kept for curing ages of 0, 7 and 21 days in desiccators. Fig 3.5 shows the photograph of test samples in desiccators.

Fig 3.7.4.1 U.C.S. test samples in desiccator

3.7.5 Testing of Soil Samples for Unconfined Compression Test

The unconfined compressive strength testing machine is used to conduct the tests in accordance with IS 2720 part X, 1991 [14]. The unconfined compressive strength testing apparatus consists of screw jack with proving ring and deformation dial gauge reading to 0.01mm.The proving ring of 100 Kg capacity with 100 divisions in each cycle with a least count of 0.09Kg. The initial length and diameter of the sample is measured. The specimen is placed on bottom plate of loading device the bottom plate is adjusted to make contact with the specimen. Proving ring and deformation dial gauge are set to zero division. Force is applied so as to produce an axial strain rate of 0.5 mm/min, as per IS 2720 part X, 1991 [14] to the specimen until the shear failure or until a vertical deformation of 20% is reached. Displacement is measured by strain gauge. Finally compressive strength is calculated based on failure load and corrected area. The Fig 3.6 shows photograph of the unconfined compressive test setup with loading capacity of one tonne.

Fig.3.7.4.2Unconfinedcompression test setup

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