

Laboratory investigation on Black cotton soils and Red soil stabilized using Enzyme

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Abstract - The most important aspect in any project is its durability and economic criteria. Recently many bio-enzymes have come into existence and these were used in many constructions works. The areas of Bagalkot are covered with Black cotton soil and few areas with Red soil which have less bearing capacity. The present paper describes a study carried out for improving of geotechnical properties of soils. The collected soil samples were treated with the commercially available Enzyme and were cured for 7, 14 and 21 days. The results of Consistency limits, Compaction test, Free swell index (FSI), Unconfined Compressive Strength (UCS and California Bearing Ratio (CBR) of untreated soils are presented in this paper. The engineering properties obtained for different mix proportions of soil and curing period were studied. The Free swell index (FSI) and the soaked CBR tests were conducted for the stabilized soil at different curing period.

Key Words: Soil stabilization, Terra-Zyme, Free swell index (FSI) and Soaked CBR

1. INTRODUCTION

The soil is the only material which supports the structural foundation of buildings, dams and roads. In About one third of Indian areas are covered with black cotton soil, which occurs in western and central parts of India. Many areas are covered with silt and clay soils as these possess poor bearing capacity problems during the construction or during the life service of structures. For the poor engineering properties of these soils it has forced Engineers to improve the bearing capacity problem by improving the engineering properties of soil by using different soil stabilization methods. These methods of soil stabilization involves of replacing of soil or using complex methods of chemical stabilization [5]. The clay of medium to high compressibility characterized by high swelling and shrinkage properties which covers the area of north Karnataka regions has become a challenge to the engineers in construction.

This soil when becomes dry is very hard but loses its strength properties completely when it is in wet condition [7]. Therefore, it is very important to know various properties of soil such as physical and engineering properties. Soil can be stabilized by chemically or mechanically. The chemical stabilizers are the substances that can enter in the natural reactions of the soil and control the moisture which is getting into the clay particles. Chemical stabilizers are divided into three groups they are as follows;

- 1) Traditional stabilizers (hydrated lime, Portland cement and fly ash),
- 2) Non- Traditional stabilizers (sulfonated oils, ammonium chloride, enzymes, polymers and potassium compounds) and
- 3) By-product stabilizers (lime kiln dust, cement kiln dust) [10].

The compaction is the most basic form of mechanical stabilization, which increases the performance of a natural material. Soil stabilization is the process of improving engineering properties of soil. The enzyme stabilizer is a natural organic compound, similar to properties of soil. The enzyme stabilizer is a natural organic compound, similar to proteins, which acts as a catalyst and wide variety of soils can be stabilized using Terra-Zyme. When enzyme is added to soil, bearing capacity and the strength behaviour of soil can be improved and it makes the soil wet which can be more densely compacted [10]. Several field study were conducted on the effect of bio-enzyme in enhancing properties of soil have been presented by many investigators as (Hitam, A et al. 1998) [1]. The durability tests such as free- thaw, wet dry and leaching test were conducted on the effective dosage of lime, cement, class C fly ash, and Perma-Zyme 11-X (Milburn, J.P et al. 2004) [4]. The properties of changes in fibre of soil particles were also studied, however many experimental studies were conducted at laboratory on the physical and engineering properties of different type of clayey soils mixed with different type of dosages of Terra-Zyme and was tested at different curing periods (A. U. Ravi Shankar

et al. 2009) [6]. The mineralogical properties like Cation exchange capacity for exchangeable Cation properties were studied under X-Ray diffraction (Sureka Naagesh et al. 2011) [7]. The durability tests of soil by using enzyme as Terra-Zyme (Lekha B. M et al. 2013) [9]. Many tests were carried out to study the effect of enzyme on lateritic soil and blended with sand in terms of permeability, compaction, UCS, CBR characteristics. It has been observed that the enzyme treated soil showed significant improvement in UCS, CBR for longer curing period, but it is not much effective on cohesionless soil.

2. EXPERIMENTAL METHODOLOGY

Various laboratory and experimental work have been carried out in the present investigation. The work includes four different soils with different liquid limit, different quantity of clay content and one additive. Specimens were prepared at three different dosages of the additive and cured up to 7, 14 and 21 days. The tests on stabilized soil were conducted at 7 day intervals. All experiments were carried out as per the standard procedures described in the Bureau of Indian Standards.

Material Characterization

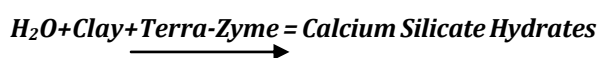
- SOIL**

The locally available four different types of soils from four different places were procured and used for the present study i.e. three black cotton soils and one red soil and they are as follows.

1. Navalgund taluk (Anigere chanamma keri), Dharwad district (**S1**).
2. Navalgund taluk (Benihala), Dharwad district (**S2**).
3. Nargund taluk (Kalikere) Gadag district (**S3**), and
4. Red soil Badami taluk (Mutulgere), Bagalkot district (**S4**).

- TERRA-ZYME**

A commercially available Enzyme is used. The cementitious property is obtained when the enzyme is mixed with water and applied this enzyme solution combines the organic and inorganic material present in the soil through catalytic bonding process [16]. Enzyme promotes the development of cementitious compounds using the following reaction.



A commercially available bio-enzyme under the trade name of Terra-Zyme is used for the present study. Properties of Terra-Zyme as per the laboratory study are as given in Table 1.

Table -1: Properties of Terra-Zyme (supplied by manufacturer)

| | |
|-----------------------------------|-----------------------------|
| Identity (As It Appears On Label) | N-Zyme |
| Hazardous Components | None |
| Boiling Point | 100 Degree Celsius |
| Specific Gravity | 1.05 |
| Melting Point | Liquid |
| Evaporating Rate | Same as Water |
| Solubility in Water | Complete |
| Appearance/Odor | Brown liquid, Non obnoxious |

- Dosage of enzyme**

The dosage recommended by the supplier of enzyme and based on literature works, different studies carried out by using enzyme are selected. In the present study the dosages selected are as follows 200ml/0.5m³, 200ml/0.75m³ and 200ml/1m³ is carried out with and without the Terra-Zyme to study the variation in the geotechnical properties.

- Methodology**

- Dosage of Terra-Zyme and curing period**

Dosage specified by company for Black cotton soil and red soil 200ml for bulk volume 0.5m³ to 3m³ of soil quantity. The above dosages are used for the present study. The example of calculation for Terra-Zyme quantity for mixing into the soil is as shown below.

Table-2: Dosage of Terra-Zyme and curing period

| Dosage | 200ml/m ³ of soil | Curing period in days |
|--------|------------------------------|-----------------------------|
| 1. | 200ml/0.5m ³ | 7 days, 14 days and 21 days |
| 2. | 200ml/0.75m ³ | |
| 3. | 200ml/1m ³ | |

Soil sample S1

Bulk density soil= 1.944gm/cc or 19.07kN/m³

Bulk density= Weight/Volume

Weight = Bulk density X Volume

For Dosage 1

200ml for 0.5 m³ of soil = 1.944X0.5X1000

= 972kg of soil

For 1kg of soil = 0.205ml quantity of Enzyme

- The tests conducted at laboratory to know the various Geotechnical properties of Black cotton soils and Red soil is given below in Table 3

Table -3: Geotechnical properties Black cotton soils and Red soil

| Laboratory tests | IS code Standards | Soil sample name | | | |
|-------------------------------|------------------------------|------------------|-------|-------|-------|
| | | (S1) | (S2) | (S3) | (S4) |
| Index properties | | | | | |
| Sp. Gravity | IS-2720 (Part3): 1980 Sect/2 | 2.61 | 2.73 | 2.78 | 2.85 |
| Grain size distribution | IS-2720 (Part4):1985 | | | | |
| Sand (%) | | 4 | 6 | 2 | 60.1 |
| Silt (%) | | 18 | 10 | 6 | 39.9 |
| Clay (%) | | 78 | 84 | 92 | |
| Consistency limits | | | | | |
| Liquid limit (LL) | IS-2720 (Part V): 1958 | 55.80 | 70.50 | 84.35 | 27.5 |
| Plastic limit (PL) | IS-2720 (Part V): 1985 | 36.57 | 37.90 | 48.61 | 21.15 |
| Plastic Index (PI) | | 19.23 | 32.60 | 35.74 | 6.35 |
| Shrinkage limit | IS-2720 (Part VII): 1972 | 12.43 | 8.59 | 7.30 | 18.08 |
| IS soil classification | | CH | CH | CH | ML |
| Free swell index | IS-2720 (Part XI): 1977 | 75 | 81.82 | 90.5 | 25 |
| Engineering properties | | | | | |
| Compaction Characteristics | IS-2720 (PartVII): 1980 | | | | |
| (MDD) kN/m ³ | | 16.08 | 14.32 | 14.32 | 18.54 |
| OMC (%) | | 20 | 22 | 24 | 14 |
| CBR (%) | IS-2720 (PartXVII):1987 | | | | |
| Soaked | | 1.214 | 1.01 | 0.66 | 2.42 |
| UCS kN/m ² | IS-2720 (PartX): 1991 | 180 | 196 | 205 | 60 |
| pH value | IS-2720(Part XXVI): 1987 | 8.7 | 8.4 | 8.9 | 8.7 |

3. FREE SWELL INDEX (FSI) TEST RESULTS

The Enzyme was concentrated with water at the respective soils optimum moisture content obtained

from the standard proctor test and mixed with the soils. The stabilized soil was prepared and kept in the polythene bags air sealed polythene bags and was tested for the respective curing period of 7, 14 and 21 days. The free swell index test results of untreated soil samples are tabulated in Table III and the free swell index test results of enzyme treated soil samples are tabulated in Tables of 4,5 and 6.

Table -4: FSI of soil samples treated with Terra-Zyme of 200ml/0.5m³ at different curing period

| Curing period in days | Soil Sample S1 in % | Soil Sample S2 in % | Soil Sample S3 in % | Soil Sample S4 in % |
|-----------------------|---------------------|---------------------|---------------------|---------------------|
| Untreated | 75 | 81.82 | 90.5 | 25 |
| 7 | 74 | 78 | 87 | 25 |
| 14 | 73.8 | 76 | 83 | 25 |
| 21 | 71 | 74 | 78 | 24.9 |

Table -5: FSI of soil samples treated with Terra-Zyme of 200ml/0.75m³ at different curing period

| Curing period in days | Soil Sample S1 in % | Soil Sample S2 in % | Soil Sample S3 in % | Soil Sample S4 in % |
|-----------------------|---------------------|---------------------|---------------------|---------------------|
| Untreated | 75 | 81.82 | 90.5 | 25 |
| 7 | 73 | 77 | 85 | 25 |
| 14 | 72 | 70 | 78 | 24.8 |
| 21 | 70 | 68 | 69 | 24 |

Table -6: FSI of soil samples treated with Terra-Zyme of 200ml/1m³ at different curing period

| Curing period in days | Soil Sample S1 in % | Soil Sample S2 in % | Soil Sample S3 in % | Soil Sample S4 in % |
|-----------------------|---------------------|---------------------|---------------------|---------------------|
| Untreated | 75 | 81.82 | 90.5 | 25 |
| 7 | 74.5 | 80 | 89 | 25 |
| 14 | 74 | 78 | 85 | 25 |
| 21 | 73 | 76 | 81 | 25 |

- Summarizing results of free swell index test results**
The free swell index test was performed using various dosages of Terra-Zyme such as 200ml/0.5m³, 200ml/0.75m³ and 200ml/1m³ with the local soils and cured for 7, 14 and 21days testing are represented in above Tables IV, V and VI. The reduction in the values of FSI was found for the dosage of the enzyme

200ml/0.75m³ at the 21days of curing gave the values of soil sample S1 to S4 70%, 68%, 69% and 24%. As reduction percentage of FSI are S1 to S4 as 6.66%, 16.89%, 23.75% and 4%. This little improvement may be due to chemical constituent of the soil, which has low reactivity with Bio-enzyme Film of adsorbed water is greatly reduced for treated soil and these soil particles acquire a tendency to agglomerate. As a result of relative movement, the surface area get reduced which in turn reduces the swelling capacity. This causes decrease of FSI values with increase in curing period.

4. CALIFORNIA BEARING RATIO (CBR) TEST RESULTS

Soaked CBR test was conducted by mixing the soils at soaked condition. Predetermined quantity of water is mixed with Terra-Zyme at different dosages of enzyme i.e. 200ml/0.5m³, 200ml/0.75m³ and 200ml/1m³ was added corresponding to optimum moisture content by standard proctor's test for the mix, mixed thoroughly. These mixes were compacted in CBR mould to maximum proctor's density. Two identical specimens which were prepared as per IS code 2720- PART XVI, kept in air tight bags for testing 7, 14 and 21 days curing and was soaked in water for 96hours before testing of curing period, then tested for CBR. The following Fig. 2graph of soaked CBR (%) virus soil sample represents effect of enzyme reacting on the soils at different curing period. The Table -7 provides the details of soaked CBR test results of effect of Terra-Zyme dosage of 200ml/0.5m³ for soil samples.

Table -7:Effect of Terra-Zyme dosage 200ml/0.5m³ on Soaked CBR values with respect to curing period

| Soaked CBR values in % | | | | |
|------------------------|----------------|----------------|----------------|----------------|
| Curing period in days | Soil sample S1 | Soil sample S2 | Soil sample S3 | Soil sample S4 |
| Untreated | 1.214 | 1.019 | 0.66 | 2.42 |
| 7 Days | 1.500 | 1.618 | 2.053 | 2.56 |
| 14Days | 2.023 | 2.137 | 2.620 | 2.70 |
| 21Days | 2.420 | 2.590 | 3.121 | 3.15 |

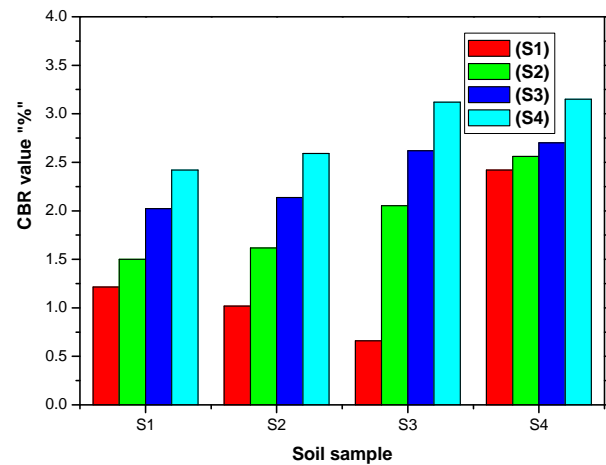


Fig-1: Effect of Terra-Zyme dosage of 200ml/0.5m³ of soil sample at varying curing period

Table -8: Effect of Terra-zyme dosage 200ml/0.75m³ on Soaked CBR values with respect to curing period

| Soaked CBR values in % | | | | |
|------------------------|----------------|----------------|----------------|----------------|
| Curing period in days | Soil sample S1 | Soil sample S2 | Soil sample S3 | Soil sample S4 |
| Untreated | 1.214 | 1.019 | 0.66 | 2.42 |
| 7 Days | 1.61 | 1.90 | 2.30 | 2.64 |
| 14Days | 2.26 | 2.42 | 2.833 | 2.90 |
| 21Days | 2.75 | 3.07 | 3.40 | 3.56 |

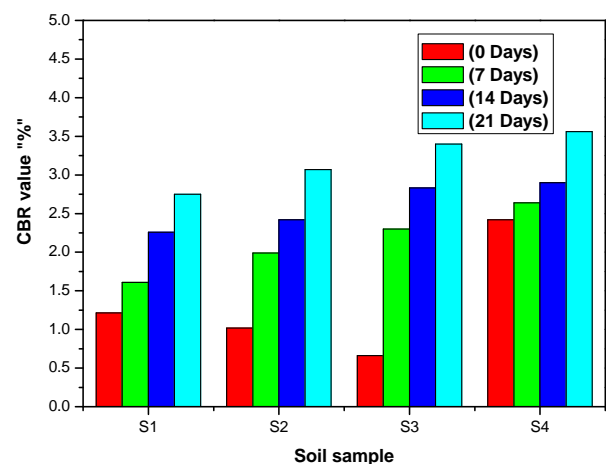


Fig-2: Effect of Terra-Zyme dosage of 200ml/0.75m³ of soil sample at varying curing period

Table -9: Effect of Terra-Zyme dosage 200ml/1m³ on Soaked CBR values with respect to curing period

| Soaked CBR values in % | | | | |
|------------------------|----------------|----------------|----------------|----------------|
| Curing period in days | Soil sample S1 | Soil sample S2 | Soil sample S3 | Soil sample S4 |
| Untreated | 1.214 | 1.019 | 0.66 | 2.42 |
| 7 Days | 1.38 | 1.457 | 1.807 | 2.50 |
| 14Days | 1.94 | 1.942 | 2.460 | 2.62 |
| 21Days | 2.26 | 2.42 | 2.83 | 2.85 |

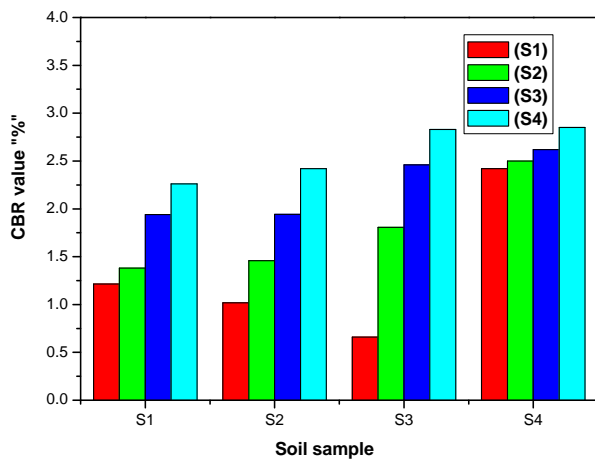


Fig-3: Effect of Terra-Zyme dosage 200ml/1m³ on Soaked CBR values with respect to curing period

Summarizing results of soaked CBR test

Above Fig-1, 2 and 3 represents the results soaked CBR test performed using various dosages of Terra-Zyme such as 200ml/0.5m³, 200ml/0.75m³ and 200ml/1m³ at different curing period of 7, 14 and 21 days the results of 200ml/0.75m³ dosage of Terra-Zyme at 21 days for soil sample S1, S2, S3 and S4 was 2.420%, 2.59%, 3.45% and 3.56%. Soil sample S3 shows maximum increase of CBR % values as that of other three soils and soil sample S4 shows the marginal increase in of CBR % values. The percentage increase in CBR values for soil samples S1, S2, S3 and S4, 126.52%, 238.56%, 365.15% and 47.10% respectively. This is because soil treated with enzyme renders improved density values by reducing void ratios. This tendency may be due to effective cat-ion exchange process which generally takes longer period in the absence of such stabilisers.

5. CONCLUSIONS

- With the application of Terra-Zyme best result for FSI values was observed with the dosage 200ml/0.75m³ of Terra-Zyme at curing period of 21 days the value of FSI decreased for soil sample S1 to S4 6.66%, 16.89%, 23.75% and 4%.
- After 21 Days of stabilization with Terra-Zyme dosage of 200ml per 0.75m³ the soaked CBR value for the local soil Samples S1, S2, S3 and S4 was 2.75%, 3.45%, 3.07% and 3.56%.
- Best result for soaked CBR value was observed with dosage 200ml per 0.75m³ the percentage increase for soil sample S1, S2, S3 and S4, 126.52%, 238.56%, 365.15% and 47.10% respectively.

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