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Soil Stabilization Using Bio-Enzyme: A Review

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Abstract. The growing needs of population and industrial activities compels the engineers to make use of weaker soils which were earlier left out. There is no choice left whether to choose or not to choose a land and hence roads and embankments have to be built on the existing weak soil deposits. Pavement constructed over such weak subgrade will deteriorate significantly leading to significant increase in cost of maintenance and construction. So in order to overcome such situations some soil reinforcement techniques have to be adopted. It helps in revamping poor soils. As conventional methods such as use of lime, fly-ash and cement for soil stabilization are time-consuming and less economically feasible, environmental friendly material based methods have come into picture. Recently bio-enzymes have emerged as a leading soil stabilizer. Bio-enzyme is a natural and non-flammable liquid formulated by fermenting the vegetable extracts that improves the engineering properties of soil by changing it's matrix. This paper deals with all the information regarding terrazyme including its physical properties, working mechanism, dosage and its effect on soil. Various advantages and disadvantages of using terrazyme and case studies related to it's use in geotechnical fields have also been discussed.

Keywords: bio-enzyme, enzyme stabilization, expansive soil, pavement, poor soil

1 Introduction

Soil stabilization is the process in which soil stabilizer is added to soil so as to alter its engineering properties and enhance the soil strength. On altering the various engineering properties of soil through stabilization, previously unsuitable soil becomes suitable for construction. Various reinforcement methods namely physical, chemical, mechanical or granular are used for stabilization purpose which includes surface compaction, grouting, meal strips, synthetic and natural geotextiles, geo-grid sheets, randomly distributed synthetic and natural fibers[1, 2].Black cotton soil is widely spread over central part of the country and it covers about 20% of the total land area of India. These soils show large volumetric changes when exposed to varied moisture content environment. They possess high clay and silt content which have low strength, low bearing capacity and high shrinkage and swelling properties due to the presence of montmorillonite clay minerals [3]. An ideal soil stabilizer is one which should be easily available, economical, ecofriendly and effective for longer period of time or makes soil permanently stable [4]. Recently, bio-enzymes have

gained a reputation as a good alternative non-standard stabilizer. The idea of using enzyme as a soil stabilizing agent came after their effective application in horticulture field where enzyme products were used to treat soil [5]. Moreover, bonding and wetting capacity of soil particles increases significantly when treated with bio-enzymes [6]. Enzymes are protein in structure and a catalyst that accelerates the reaction without becoming the part of end product. Bio-enzyme is a natural, innocuous, non-flammable liquid derived from vegetables. They are bio-degradable, easily decompose and dissolve in water. Some of bio-enzymes readily available in market are renolith, permazyme, earthzyme, terrazyme, fujibetonetc [7].Terrazyme is a bio-enzyme which is a natural, non-toxic liquid formulated from vegetable extracts. It is diluted before being applied to soil. Improved load bearing capacity and weather resistance were reported for soils treated with terrazyme. They are more effective for fine grained soils as compared to coarse grained soils where it allows ease in compaction with greater compactive effort [8]. The present paper reviews about the stabilizing mechanism, properties, recommended dosage and case studies related to use of terrazyme in soil.

2 Stabilization Mechanism of Terrazyme

Terrazyme is a liquid based enzyme which is completely organic in nature. It is dark brown in texture and has molasses like smell. The mixture is not dangerous and has no effect on skin. Handling of terrazyme is very easy as it requires neither gloves nor masks. They are diluted in water before application. Terrazyme is an ionic surface-active agent which changes the deliquescent nature of clay minerals to hydrophobic. Its application helps in expulsion of water from voids of soil and this water imparts lubrication to soil particles and makes soil highly compatible [9].

$$H_2O + \text{Clay} \xrightarrow{\text{Terrazyme}} \text{Calcium Silicate Hydrates}$$

Terrazyme reacts with the absorbed layer of clay particles and reduces the thickness around the soil particles due to which void spaces between soil particles reduces and thus soil gets compacted with minimal efforts [10]. Fig.1. shows the working mechanism of terrazyme on clay particle. Table 1 shows the various physical and chemical properties of terrazyme. Table 2 shows the dosages and dilution application ratios of terrazyme bio-enzyme.

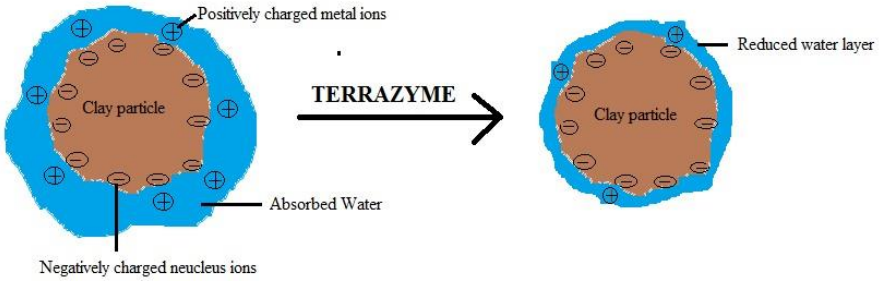

Fig.1. Mechanism of terrazyme *Source: Gupta et. al (2017) [10]*

Table 1. Properties of terrazyme

Properties description	Values
Specific gravity	1.05
pH value	3.50
Appearance or color	Dark brown and non-obnoxious
Total dissolved solids	9.7 ppm
Cation exchange capacity	3.87%
Hazardous content	None
Boiling point	212^0 F
Evaporation rate	Same as water
Solubility in water	Complete
Melting point	Liquid
Reactivity data	Stable

Source: info@avijeetagencies.com

Table 2. Recommended dosages, dilution ratios, and diluted application ratios of bio-enzymes

Stabilizer	Values
Suppliers recommended dosage	1 litre per $25m^3$
Equivalent dilution mass ratio (DMR)	1/1000
Equivalent application mass ratio (AMR)*	1/44600
Diluted application ratios*	22mL per kg of soil

*Maximum dry density of soil was taken as – 1785 kg/m^3

Source: Khan and Taha (2015) [11]

3 Literature Review

Velasquez et. al (2006) [12] studied the effect of adding enzyme products (i.e. A and B) on two soil samples using resilient modulus testing and chemical analysis for subgrade stabilization purpose. The two soils used in the study have varied clay content and percentage of fines (96.4% passing 200 sieve, 75.2% clay content) and (59.7% passing 200 sieve, 14.5% clay content) respectively. It was found that addition of enzyme A causes significant improvement in type 2 soil, whereas no effect was reported in type 1 soil. However, addition of enzyme B significantly increased resilient modulus of both soils. The study revealed that the effectiveness of enzyme-based stabilizers depends upon percent of fines and clay content present in soil.

Mitikie et al. (2017) [13] studied the effect of adding enzyme on mechanical properties of clay bricks by varying the clay content. Compressive strength and water absorption tests are conducted at varying curing periods (i.e. 7,14, 21 and 28 days). Maximum strength of 6.89Mpa was reported when clay/silt ratio of 85/15 was used to form bricks and reinforced with enzyme after 28 days curing. Higher density, lower water absorption and porosity were reported in bricks having high clay content. It was concluded that the average compressive strength of enzyme clay brick was over 5.50MPa after 28 days curing period. It was concluded that formation of cross-linking and bonding structure in enzyme clay brick is the main cause for strength improvement.

Eujine et al. (2017) [14] conducted comparative studies to understand the effect of lime and bio-enzyme alone and in combinations as stabilizer on five different soft soils (having different clay content) using CBR tests in both soaked and unsoaked conditions. It was found that rate of strength gained in soil samples reinforced with lime and enzyme both is much higher than for individual reinforcement. However, for stabilizing bentonite clay, enzymatic lime treatment was found less effective. It was concluded that use of enzyme in lime not only have environmental benefits but reduces the project cost considerably.

Sunil et al. (2018) [15] studied the effect of adding terrazyme in different dosages (i.e. 100, 150 & 200ml/m^3 of soil) on the strength values of poor subgrade soil. It was observed that as the percentage of enzyme dosage increases from 0-200ml/m^3 of soil there was decrease in the liquid limit from 37.25% to 29.46% with slight decrease in plastic limit from 26.20% to 22.10%. Maximum improvement in strength values was reported at 150ml/m^3 concentration where CBR for soaked and unsoaked conditions are 20.83% and 13.22% respectively as compared to 1.70% and 3.14% for virgin soil. It was concluded that improvement in unconfined compressive strength (UCS) values depends on the curing period.

Manu and Mahendra (2018) [16] studied the effect of adding terrazyme in various dosages (i.e. 200ml/2m^3, 200ml/1.5m^3, 200ml/1m^3 and 200ml/0.5m^3) on the geotechnical properties of black cotton soil for 7 days curing period. It was found that liquid and plastic limit decreases and shrinkage limit increases with increase in

terrazyme dosage. Specimens treated with 200ml/1m^3 of bio-enzyme showed maximum improvement in UCS value with 318kpa at 7 days curing as against 159kpa for unreinforced one. CBR value showed an improvement of 170% (i.e. 3% for virgin soil to 8% for treated one) causing significant reduction in thickness requirement of pavement. It was concluded that terrazyme require curing time to initiate its treatment process since it involves micro-biological process for stabilizing soil.

AbouKhadra et al. (2018) [17] conducted an experiment investigation in which two different enzymatic preparations were used on five different soil samples (2 coarse grained and 3 fine grained) taken from Egypt. Significant improvement in UCS and CBR values of fine grained soils were found as compared to sandy soils. Maximum improvement of 2.75 to 4.5 times in various soil properties were reported than unreinforced one. For all reinforced samples considerable improvement in soil permeability was observed. It was concluded that higher is the clay content in soil greater is the improvement in soil characteristics.

Joshi and Solanki (2019) [18] studied the effect of adding terrazyme (in three doses i.e. 200ml/2.5m^3, 200ml/2.0m^3 and 200ml/1.5m^3) and lime (2%, 4%, 6% and 8%) on the strength and swelling properties of two soil samples. Soil samples are collected from Surat and were classified as clay of high compressibility (CH) and silt of intermediate compressibility (MI). Curing period for UCS test (7, 14 and 28 days) and CBR test (3, 10 and 24 days) are considered. Maximum increase of 14 and 8 times in UCS values are reported for black cotton soil and yellow soil respectively. Maximum increase in CBR was 750% and 400%, respectively for CH and MI soil sample. Free Swell index (FSI) values for treated soil sample shows reduction upto 80% compared to virgin soil.

Renjith et al. (2020) [19] conducted a series of experiments under a 4-stage test program which involved macroscale mechanical tests and microscale imaging tests to investigate the stabilization effects of enzyme-based additive known as Eko soil. The soil used was taken from Victoria, Australia. In stage 1, it was observed that enzyme stabilized soil has no affected by oven drying upto temperature of 40^{0}C, in stage 2, reduction in optimum moisture content (OMC) level of stabilized soil was observed (i.e. lower demand of water for compaction). In stage 3, energy-disperse x-ray spectroscopy (EDS) and x-ray diffraction (XRD) technique results showed no new compound formation neither any chemical reaction in stabilized soil. In stage 4, it was observed that at stabilized optimum moisture, the stabilizer`s efficiency was significantly larger (i.e. up to 500% increase in CBR strength) as compared to reference OMC of the soil.

4 Case Studies Related to Use of Terrazyme in Road Construction

4.1 Odisha roads under the scheme of Pradhan Mantri Gram Sadak Yojana (PMGSY) India

A 1.924km rural road reinforced with bio-enzyme was constructed between Harinjipada to Jamunapur in Odisha, India in year 2017. Dilution ratio for first layer was kept 200ml of terrazyme for every 2.8m^3 of soil and second layer was treated with 200ml of terrazyme for every 3m^3 of soil. Fig. 2. shows the condition of road after one monsoon season without any rutting.

Fig. 2. Road treated with terrazyme
Source: info@avijeetagencies.com

In 2017, road construction initiated between L064-SH42 to Barpitha in Odisha, India which was having a length of about 1.850km whose first layer was treated with 200ml of terrazyme for every 2.8m^3 of soil and second layer was treated with 200ml of terrazyme for every 3m^3 of soil. Fig. 3. shows the condition of road reinforced with terrazyme having no undulations and pot holes.

Fig.3. Road constructed by treating with terrazyme (***Source:*** *info@avijeetagencies.com)*

Another road had been constructed from LO64-Suanabahal to Muribahal in Odisha, India which was having a length of about 2.000km whose first layer was treated with 200ml of terrazyme for every 2.8m^3 of soil and second layer was treated with 200ml of terrazyme for every 3m^3 of soil. Fig. 4. shows the road surface with no depressions and deformations.

Fig. 4. Terrazyme treated road condition after one monsoon season

Source: *info@avijeetagencies.com*

In all the above cases, aggregate saving of over 70% is reported. The cost of pavement was reduced by Rs. 1.5 lakh per km of road constructed. More than 15km road reinforced with terrazyme in the state of Odisha is constructed till now without granular sub-base course and with no possible signs of distress even after 2 years of construction

4.2 Terrazyme stabilized road in Standoff, Alberta, Canada

Two road sections of 350m each in Standoff area was stabilized using terrazyme. Reinforced section was reported with CBR of 117% as against 20% for unreinforced one, having an increase of more than 6 times. The problem of washboarding, rutting and potholes were reduced significantly. The cost of road repair and maintenance was reduced over 90% as compared to normal pavement. Dust reduction of over 75% is reported due to elimination of loose fine material. The road was found to be in good condition even after 10 months of construction. Fig. 5. shows the condition of unstabilized pavement section. Fig. 6. shows the Terrazyme application on road. Fig. 7. shows the stabilized Blood Reserve road after one year of stabilization.

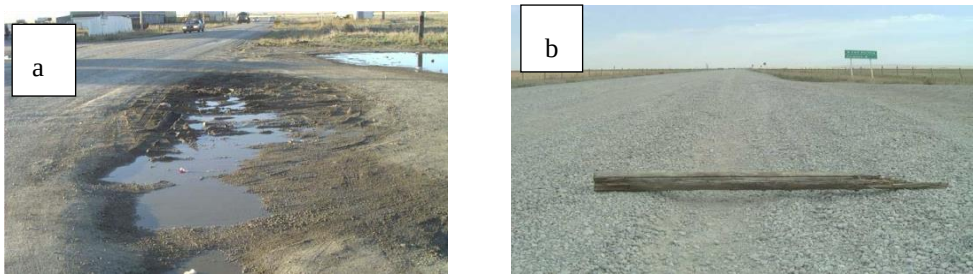

Fig. 5. a) Potholes/Erosion on pavement section, b) Rut depressions 20cm deep

Fig. 6. a) Scarifying of road surface, b) Application of Terrazyme, c) Rolling and compaction

Fig. 7. a) Improved surface, b) Reduction in dust

5 Advantages of Using Terrazyme

1. **Ecofriendly -** Since terrazyme is extracted naturally from vegetables and fruits so it is an ecofriendly and organic product. It is a bio-degradable and easily decomposes with soil with no harmful effects.
2. **Stability -** Terrazyme is a stable product because it does not take part in chemical reaction but acts as a catalyst [19].
3. **Cost-effective -** Terrazyme reduces the cost of the project by 15-40% as compared to conventional methods and have permanent applicability.
4. **Easy handling -** Terrazyme does not require any masks or gloves during itapplication which makes it very handy product.

5. **Low maintenance cost -** The soil treated with terrazyme shows enhanced weather resistance, thus reduces the need of frequent maintenance.

6 Drawbacks of Using Terrazyme

1. **Availability –** Since there are very few agencies that provide the terrazyme so for any construction works prior order of terrazyme from such agencies is necessary in order to avoid delay of the project.
2. **Types of soil -** Since terrazyme reacts with the clay materials that are present in soil hence its productivity varies with clay content and fineness percentage of soil. As it is useful for clayey soil and sandy soil but is less efficient for silty soils [12].
3. **Dosages -** Terrazyme are diluted in water before its application. Therefore, results vary with different dosages of terrazyme.

7 Conclusions

The present study reviews the available knowledge on use of bio-enzymes in particular terrazyme for soil stabilization purpose. It was found that use of bio-enzyme in soil leads to formation of calcium silicate hydrate (CSH) compound having cementious properties. Application of terrazyme in expansive soil reduces its plasticity characteristics and provides volumetric stability thus reducing susceptibility to crack formation. The strength of unstabilized earthen construction and adobe blocks can be increased effectively. Being a natural product (extracted fromvegetables and fruits) it is eco-friendly. Its application in subgrade soil significantly reduces the thickness requirement of pavement thus saving costly base and sub-base aggregate materials. However, more research work is required to fully understand the working mechanism of terrazymefor soil stabilization. Hence it's time to support bio-enzymes.

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