Effect of Enzymatic Lime on Properties of Clay

Dani Jose, S. Chandrakaran

Abstract—Traditional stabilizers like lime, cement, fly ash, rice husk ash, and combinations of these have been widely used to improve the properties of problematic soil. Considering the environmental impacts of these stabilizers, researchers come up with an ecofriendly method called enzymatic stabilization. Recently combination of enzyme and lime known as enzymatic lime found to be effective in improvement of strength of soft soils. In the present work, the effect of enzymatic lime on engineering behaviour of clay is analysed. The purpose of this research is to verify the efficacy of enzymatic lime in soft clays. An extensive study was carried out on a soil sample using different dosages lime, enzyme and combination of lime and enzyme. The variation in liquid limit, plastic limit, plasticity index and unconfined compressive strength were investigated after 3,7,14 and 28 days of curing. The optimum dosage of the stabilizers was inferred from obtained results. Addition of 120 ml/m^3 of enzyme and 2 % lime by weight of soil will impart significant improvement of properties. Sufficient improvement of strength obtained after 14 days of curing indicates accelerated strength improvement by enzymatic lime. Utilization of enzyme and lime in combination can reduce the percentage of lime for soil treatment making the proposed method environmental-friendly.

Index Terms—Lime, enzyme, enzymatic lime, strength improvement..

I. INTRODUCTION

Soil stabilization aims the enhancement of the strength and durability of problematic soil by controlled compaction or by the addition of admixtures and stabilizers.Stabilization may result in increased stability, shearing resistance and bearing capacity, reduced volume changes and settlement and control of the undesirable effects associated with clay. This method is widely applied in the field of construction of roads and pavements. Several techniques have been adopted for the improvement of engineering properties of soils. These methods include incorporation of lime, cement, flyash, rice husk ash, crumb rubber, bioenzyme, geosynthetics, biopolymer and different commercial available chemicals for stabilization. Among these techniques, lime stabilization is a cost effective and commonly used method of soil improvement.

The success of lime stabilization leads to utilization of various additives along with soil-lime tried over the past few decades. The effect of climatic change, environmental concerns and increase in cost of materials necessitates an innovative ecofriendly method over these traditional methods. An economically feasible solution for overcoming this problem is the introduction of enzymatic soil stabilization.

Enzymes are biological catalyst obtained from plants and animals including microorganisms by extraction using suitable solvent. These are large protein molecules which are more efficient than inorganic catalyst. Enzyme can increase the reaction rate by a factor of 106 to 1012. They usually catalyze unique reactions therefore enzymes do not produce side reaction. Enzymes are temperature sensitive and work around temperature (35^o C) and loss their effectiveness at higher temperature. Also, they are pH sensitive too and work good at pH value 7 [1].

Bio-Enzyme is a naturally obtained, nontoxic, nonflammable, noncorrosive liquid enzyme formulation fermented from vegetable extracts.They catalyze the reactions between the clay and the organic cat-ions by accelerating the cat-ionic exchange. Enzyme provides higher soil compaction densities and enhances strength and stability of the soil [2]. Utilization of Bio Enzyme in combination with lime will also give enhanced improvement in strength.The catalytic action of enzymes in the presence of lime brought a significant improvement of strength [3]. The enzymatic lime is more effective in soil samples with higher clay fraction [4].

A very few researches have been conducted using enzymatic lime and scope of detailed study on its influence on soil properties is there. In the present work the variation of properties of a natural soil with the addition of enzymatic lime is studied in detail.

II. MATERIALS USED AND METHODOLOGY

Soil used for the present study is collected from Vytilla, Ernakulam. The bio-enzyme using is an extract from sugar molasses, and was obtained from Avijeet Agencies in Chennai, Tamil Nadu under the chemical name TerraZyme.Lime using for the study is purchased from local agent at Kunnamanglam, Calicut. The properties of soil and enzyme are given in Table 1 and 2.

The collected soil is highly plastic and of medium consistency in nature. From UCS it's found that the soil has got medium strength and so the strength can be improved. according to IS Classification the soil is highly compressible clay.

All specimens using in this study were prepared and tested using standard procedures described by the Bureau of Indian Standards. Soil sample used for the test was air dried, pulverized manually, sieved through 425micron sieve and preserved in large containers. TerraZyme was preserved in an airtight bottle in its original liquid form.Lime was sieved using a 425micron sieve and preserved in an airtight container.

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TABLE I: Properties of soil

Properties	Obtained Values
Specific gravity	2.62
Liquid Limit (LL)	76 %
Plastic Limit (PL)	30 %
Shrinkage Limit	13 %
Plasticity Index (PI)	46%
Free Swell	14.3 %
pH	7.74
Bulk Density (kN/m^3)	17.82
Max. Dry Density (kN/m^3)	13.86
Optimum Moisture Content (%)	27
Unconfined compressive strength (kN/m^2)	106.61
Cohesion (kN/m^2)	53.31
Clay Fraction	38.76 %
Silt	34.52 %
Sand	26.72%
Soil Classification	CH

TABLE II: Properties of Bio-Enzyme [3]

Properties	Obtained Values
Boiling point	100^{0}C
pH	2.8-3.5
Vapour pressure: mmHg	As water
Melting point	Liquid
Vapour density (air=1)	1
Solubility in water	Infinite
Evaporation rate	As water
Appearance and odour	Light gold liquid, characteristic odour
Production	Extracted from sugar molasses
Major constituents	Rhodasurf B1, Calcium Chloride
Boiling point	100^{0}C
pH	2.8-3.5
Vapour pressure: mmHg	As water
Melting point	Liquid

Literature reveals that the optimum lime content for soil stabilization varies from 2% to 6% by weight whereas higher percentage may require for soil having higher clay fraction. The range of dosage of lime to be used was determined from Liquid limit tests. Then, the soil is treated with 2%- 3.5% lime content and unconfined compressive strength tests were conducted to verify and confirm the actual optimum lime content. 3 samples of the same mix type were tested after 3, 7,14,21,28 days and the average of the values were recorded.

A dilution ratio chart provided by manufacturer (that calculated the required dosage of TerraZyme for a soil based on particle size and plasticity index) is used to determine the range of optimum Enzyme content. Soil samples were mixed with TerraZyme dosages between 110 ml/m3 to 130 ml/m3, cured up to four weeks in air-tight bags. The same tests were repeated on the samples and the variation in properties were studied. From the results the actual optimum enzyme content is determined.The dosage of enzyme is fixed at optimum enzyme dosageand the lime content is varied. The combinations involve 1.5%, 2%, 2.5% of lime with 120ml/m^3 of enzyme. The variation of properties on the soil lime enzyme system is studied for 3,7,14 and 28 days. From the obtained results the optimum enzymatic lime content is fixed

III. RESULTS AND DISCUSSIONS

Based on the values of tested parameters the optimum dosage of additives was fixed. Addition of 3 % lime impart maximum improvement in strength as well as reduction in plasticity. So, the optimum dosage of lime is fixed as 3% by weight of soil. The optimum dosage of enzyme was found as 120 ml/m^3 based on the analysis of results. It was observed that addition of 2% of lime with 120 ml/m^3 of enzyme will impart maximum improvement of properties. So, the optimum enzyme and lime content for enzymatic lime treatment is found as 120 ml/m^3 of enzyme and 2% of lime. The results obtained when soil is treated with enzymatic lime is given in Table 3.

TABLE III:Properties of Enzymatic lime treated soil after 28 days

	LL %	PL %	PI %	UCS (kN/m^2)
Untreated	76	30	45	106.61
120ml/m3 Enzyme + 1.5 % lime	61	40	21	293.11
120ml/m3 Enzyme + 2 % lime	57	43	14	397.20
120ml/m3 Enzyme + 2.5 % lime	60	41	19	330.56

From the results it was found that the addition of enzymatic lime to soil will improve the strength and plasticity of soil. The performance both chemicals in combination was more successful than the individual performance. Utilization of enzyme and lime in combination can improve the strength of virgin soil substantially.Figure 1, 2, 3 shows the variation of Atterberg limits with the addition of enzymatic lime.

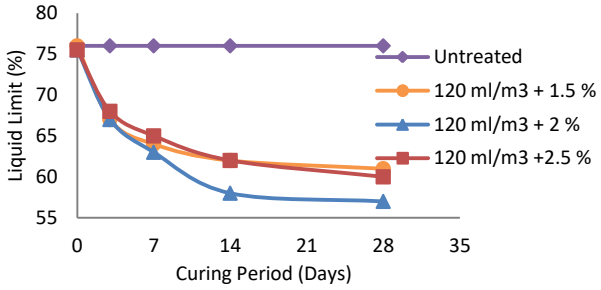

Fig. 1 Variation of liquid limit of soil treated with varying percentages of enzymatic lime

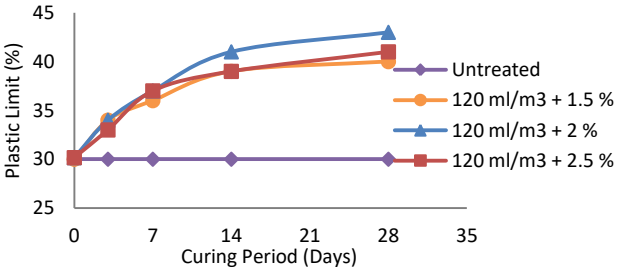

Fig.2. Variation of plastic limit of soil treated with varying percentages of enzymatic lime

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By the addition of optimum dosage of enzymatic lime, the liquid limit of the soil is reduced to57 while the plastic limit of soil has got increasedto 43. The plasticity of soil is reduced to 14. The plasticity of soil is reducing withincreased curing period. Enzyme acts as catalyst for the soil lime reaction and increased cation exchange will take place between clay and lime. The accelerated cation exchange imparts significant reduction of diffused double layer thickness and thus reduces the liquid limit of soil.The plastic limit shows an increasing trend which may be due to the reduction in thickness of diffused double layer. Decrease in the liquid limit and increase in the plastic limit leads to an overall reduction of plasticity index. Addition of enzymatic lime reduces the plasticity of the soil and sufficient curing causes significant reduction in properties too. From the observed data it's found that the improvement in properties of soil after 14 days of curing is significant when comparing with the untreated soil. Also, not much improvement in properties were obtained after 14 days of curing. The graph become flattened after 14 days indicates that curing after 14 days will not impart much improvement in properties. Thus, the study reveals the potential of enzymatic lime for accelerated improvement in index properties.Figure 4 shows the variation of UCS with the addition of enzymatic lime to the untreated soil. The strength was increased to 367.9 kN/m^2 and 397.2 kN/m^2 after a curing period of 14 days and 28 days. An improvement 3.45 % was obtained after 14 days and 3.7 % increase after 28 days.

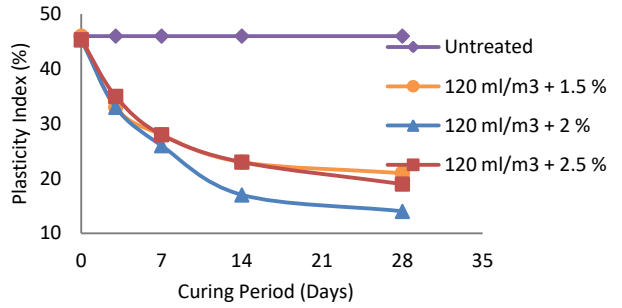

Fig.3. Variation of plasticity index of soil treated with varying percentages of enzymatic lime

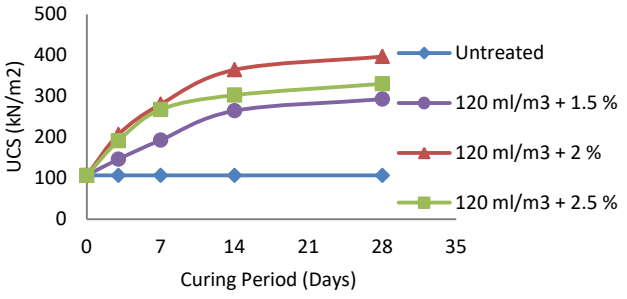

Fig.4. Variation of UCS of soil treated with varying percentages of enzymatic lime

The addition of 120 ml/m^3 enzyme and 2% lime give maximum strength improvement after 28 days, which is considered as the optimum enzymatic lime concentration.No significant strength improvement is obtained after 14 days indicating that 2 weeks of curing is sufficient for the treatment. The enzyme catalyzes the reaction between lime and soil and this impart an accelerated improvement in strength after 14 days. With the addition of enzyme and lime to the soil, the enzyme will modify the clay and this modified clay is reacting with the lime [5].In addition, lime reacts with the calcium aluminate and the calcium alumina silicate by replacing the existing aluminium cations with the calcium cations in the presence of enzyme (Rhodasurf –R(OC2H4)$_n$OH) and form compounds which can impart high strength to soil [4].

IV. CONCLUSION

Lime is commonly used for stabilization of soft soils. Utilization of enzyme and lime in combination also found to be very effective in soil treatment. By addition of enzymatic lime to soil both strength and plasticity characteristics has been improved. The liquid limit of the soil is reduced by 25% while the plastic limit of soil has got an increase of 40%. The plasticity of soil is reduced to 67% of original value. The enzyme act as catalyst for lime soil reaction and enhance the properties.The results show that by addition of 2% lime and 120 ml/m^3 of enzyme will improve the strength within 1 week itself by substantial amount. After 14 days the soil attained 3.4 times the initial strength and almost 90 % of the strength was attained by 14 days of curing. The enzyme catalyzes the reaction between lime and soil and this impart an accelerated improvement in strength.The lime content in optimum concentration of enzymatic lime is less than optimum lime content. This is significant result because the reduction in lime content can reduce the impact of lime to the environment. Thus, the obtained results show that the enzyme used with lime will improve the properties as well as we can reduce the lime content and curing period making method more economical as well as ecofriendly.The technique of addition of enzymatic lime into the soil is an innovative technique that promises to impart better and quicker stabilization according to the laboratory studies conducted in this work.conclusion section is not required.

REFERENCES

1. Norris R., Ryan L, Acaster D, *Cambridge International AS and A Level Chemistry Coursebook*. Cambridge University Press, UK, (2011).
2. Shankar A. U, Rai H. K, Mithanthaya. R., "Bio-Enzyme stabilized Lateritic Soil as a Highway material*", Indian Roads Congress Journa*l, Paper No: 553, (2009).
3. GreeshmaNizyEujine, Dr S. Chandrakaran, Dr N. Sankar, 'The engineering behaviour of enzymatic lime stabilized soils', *Ground Improvement, Proceedings of the Institution of Civil Engineers*, Paper 1600014, 2017.
4. GreeshmaNizyEujine, Dr S. Chandrakaran, Dr N. Sankar, "Accelerated Subgrade Stabilization Using Enzymatic Lime Technique", *Journal of Materials in Civil Engineering, American Society of Civil Engineers*, Volume 29, Issue 9, Paper 04017085, 2017.
5. Marasteanu MO, Hozalski R, Clyne TR and Velasquez R, Preliminary Laboratory Investigation of Enzyme. Minnesota, Department of Transportation Research, Minneapolis, USA (2005).