Study on Soil Stabilization Using Bioenzyme: Terrazyme

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Abstract : Lithomargic clay constitutes an important group of residual soils, commonly found in the western coastal side (konkan region) of southern India. Most of the area in konkan hence have a tough time due to landslide and debris fall during the monsoon. Lithomargic clay loses a greater part of its strength when saturated. They are generally kaolinitic and contain high percentage of silt deposits which bring in problems like slope failure, foundation failures, embankment failures, uneven settlements etc. A potential treatment method which would improve soil behavior using green technology would be beneficial considering the cost savings and environmental synchronization in comparison to other chemical stabilization methods. The purpose of this study is to understand the effect of bio enzyme treatment on lithomargic clay. Soil stabilization using bioenzyme (Terrazyme) occurs through cationic exchange. A set of lab studies were conducted to study the change in index and strength properties of collected lithomargic clay samples by stabilization with varying dosages of terrazyme enzyme. The optimum dosage of terrazyme was found to be 0.1 ml/L. It is observed, that there is 42%, 70%, 35% increase in unconfined compressive strength, cohesion, and angle of friction respectively after 7 days curing. A series of stability analysis on embankment slope of different heights and slope angles for unstabilized and stabilized soil slope were performed. Factor of safety for slopes of varying heights (4m to 12m) and slope angles (30º to 60º) where greater than 1.5 for the stabilized soil.

***IndexTerms* – Slope stabilization, Terrazyme, Lithomargic clay, GEO5.**

I. Introduction

Lithomargic clay (shedi soil) is found along the western coastal belt (konkan region) of peninsular India extending from Cochin to Goa below hard lateritic soil varying in large depths. They are present with varying percentages of sands and fines (especially silts, with negligible amount of clays occasionally) [1]. Major clay minerals found in lithomargic clay are kaolinite, smectite [2, 3]. They are mostly sandy silts or silty sands and either whitish, pinkish or yellowish in colour. Lithomargic clays are formed by laterization at shallow depths in lateritic formations and leaching of minerals like silica, aluminium and iron oxides by rainfall temperature variations etc. It is sandwiched between hard lateritic crust at top and the parent granitic gneiss underneath [4]. Many earlier studies have proved that the behaviour of these soils is similar to dispersive soils, and they are also found to be highly erosive. Erosion and removal of lithomargic clay existing between the lateritic soil layers result in slope failure [5]. Infrastructure projects such as highways, railways, water reservoirs, reclamation etc. requires a suitable and safe embankment. This problem can be overcome by stabilizing them. Soil stabilization is the process of enhancing the engineering properties of the soil by addition of a reinforcing or cementing material, or other chemical materials, and thus making it more stable. This technique is used to improve the shear strength and to reduce the permeability and compressibility of the soil mass. The property of high viscosity and fast hardening makes chemical stabilization unsuitable for application in large areas. Foreign materials like Geotextiles and other physical soil reinforcements are often expensive and require machinery that may disturb infrastructure, and also affect plant growth. In this study, a bioenzyme, called Terrazyme is used for stabilization of lithomargic clay. Enzymes are organic catalysts which speed up a chemical reaction without being part of the end product. Bio enzymes are natural, non- flammable, non- corrosive and non- toxic [6]. Bio enzymes can be used as liquid soil stabilizers [7, 8]. Liquid soil stabilizers are of three types ionic (cationic exchange within clay mineral), polymeric and enzymes (organic catalysts). Bio enzymes are environmental friendly and less expensive as only a small amount of enzyme solution is required for stabilizing large volume of soil [9]. From Literature it was found that Terrazyme has been successfully used in stabilising black cotton soils [10,11], laterite and kaolin [12]. The studies on utilization of Terrazyme for stabilising highly erodible lithomargic clay are found to be less comparatively.

1.1 Stabilization by Enzyme

Mechanism used by Terrazyme in soil stabilization is cationic exchange. In this process voids between the soil particles are minimized by reduction of absorbed water around the clay particle. It reacts with the organic matter in soil to form a cementatious material. This results in the formation of chemical bonding between soil particles and makes a permanent structure. These are especially effective in soil containing high percentage of clay [7]. Clay particles have water molecules surrounding them as these soil particles are negatively charged. This absorbed water layer contains metal ions like sodium, potassium, aluminium, magnesium etc. in it. These ions are responsible for the bonding between clay particles and water. Terrazyme helps in the reduction of this adsorbed water layer on the particle. This reduces the size of the particles and they come closer to form a dense soil structure[7]. In enzymatic stabilization the clay lattice adsorbs the enzyme added to the treated soil and in exchange cations are released. This process of exchange of ions is called cationic exchange. This results in the reduction of adsorbed water layer on the clay particles. As a result the soil particles come closer and the soil lattice becomes densely packed [6,7].

II. MATERIALS

2.1 Lithomargic Clay

Lithomargic clay sample was obtained from Kanjirappally, Kerala, India. The samples were collected at a depth of 2-2.5m below the lateritic layer. The properties of soil were determined based on Indian Standard Code of practice and are given in the table 1. Soil was air dried and sieved using 4.75 mm IS Sieve. The soil was found to be kaolinitic in nature from Xray diffraction studies.

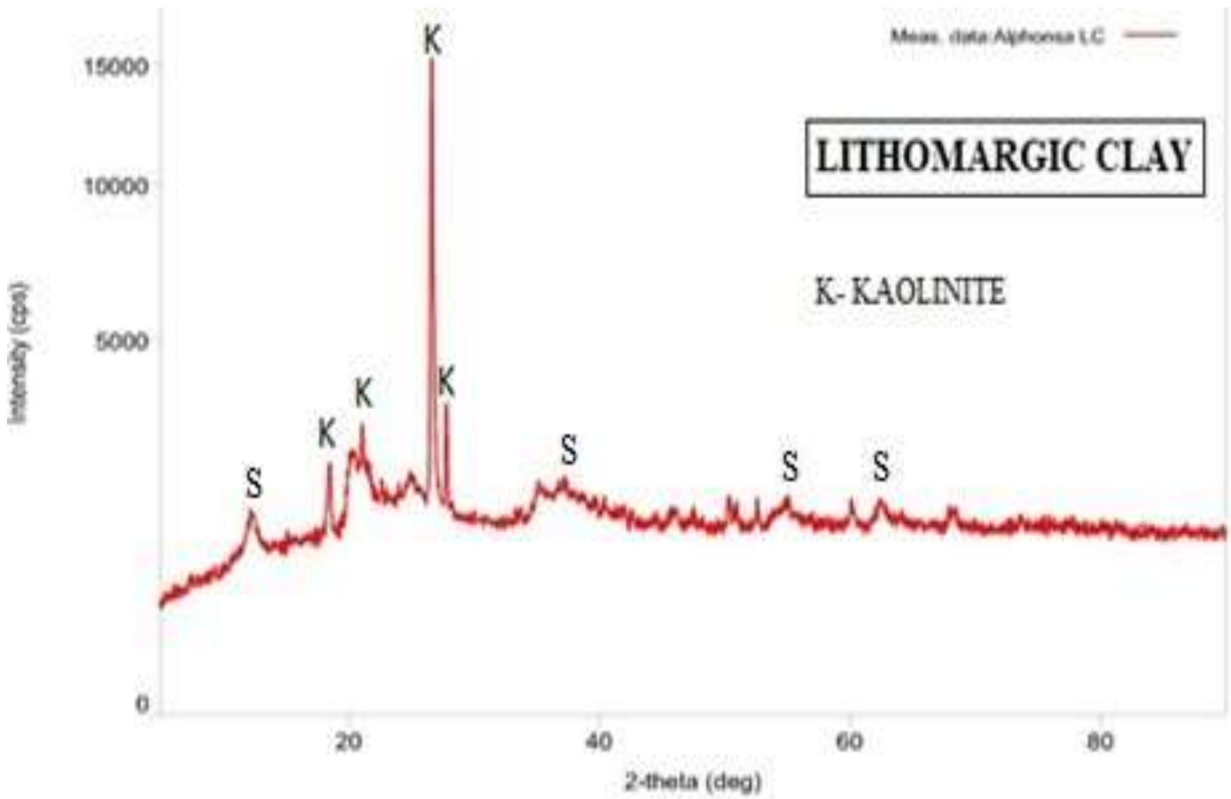

Fig. 1 X – ray diffraction pattern for shedi soil with minerals Kaolinite - $Al_2(Si_2O_5)(OH)_4$ and Saponite - $Mg_3(Si\ Al)_4O_{10}(OH)_2.4H_2O$

Table 1 Properties of unstabilized soil

Geotechnical Properties	IS code	Results
Specific gravity	IS 2720: Part 3: 1980	2.62
Percentage of sand	IS 2720: Part 5: 1985	30%
Percentage silt	IS 2720: Part 5: 1985	42%
Percentage clay	IS 2720: Part 5: 1985	28%
Unconfined compressive strength	IS 2720: Part 10: 1991	36.66 kPa
Cohesion	IS 2720: Part 12: 1981	21.64 kPa
Angle of internal friction	IS 2720: Part 12: 1981	17º
Main mineral (X- Ray diffraction)		Kaolinite

2.2 Terrazyme

Terrazyme is brown in colour, smells like molasses, non- toxic bioenzyme, obtained by fermentation of sugarcane extract and has surfactants and natural protein acquired from cereals, vegetable exracts, ferments of carbohydrates [7,13]. The enzyme solution was procured from Avjeet Agencies (P) Ltd., Chennai. Properties of Terrazyme are shown in table 2.

Table 2 Properties of Terrazyme

Colour	Brown
Solubility	Soluble in water
Hazardous Content	None
pH	3.5 -5
Boiling Point	100˚C

Melting Point	Liquid
Stability	Stable
Specific Gravity	1.05
Evaporation Rate	Same as water

III. Tests conducted

The dosages of Terrazyme used are given in table 3. Different dosages of Terrazyme were first diluted in one litre of water. Soil samples were mixed with the required dosage of diluted Terrazyme solution and kept for curing for the desired number of days. Then, they were tested for their index and engineering properties. The untreated and treated soils were tested for determining liquid and plastic limits (IS 2720: Part 5: 1985). The unconfined compressive strength (UCS) tests (IS 2720: Part 10: 1990) were conducted for the treated as well as the untreated soil and the optimum dosage was determined. The UCS tests were conducted for curing periods 7, 14, 28 days and effect of increase in time of curing is studied. The cohesion and angle of internal friction for the treated and untreated soils were determined after 7 days curing period from triaxial tests (IS 2720: Part 12: 1981).

Table 3 Dosages of Terrazyme

Dosage Notation	Dosage of Terrazyme (ml/L)
T1	0.05
T2	0.1
T3	0.15
T4	0.2

IV. Slope stability analysis using GEO5 software

Slope stability analysis is performed to assess the safe design of human-made or natural slopes, such as embankments, road cuts, open-pit mining, excavations, landfills etc [14, 15]. Slope stability is defined as the resistance of inclined surface to failure by sliding or collapsing [16, 17]. Here, the numerical analysis of the experimental results is performed using Geo 5 software for a typical embankment slope stability problem. The failure points were analyzed based on Bishop's circle method for different heights and angles provided.

V. Results and discussions

5.1 Atterberg Limits

The liquid limit and plastic limit results of lithomargic clay, stabilized with Terrazyme and cured at 7, 14 and 28 days are shown in Figure 2. It was found that the liquid limit value decreased with increased curing period and had the least values at 0.1ml/L dosage (LL =35%, PL =17%) While plastic limit values also decreased with aging. This may be a result of stabilizing effect of Terrazyme due to aggregation of soil particles [4].

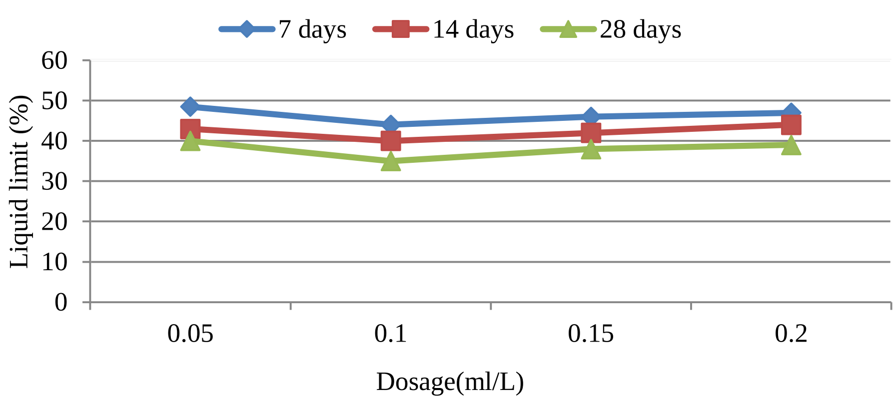

Fig. 2 Stabilizing effect of Terrazyme on liquid limit

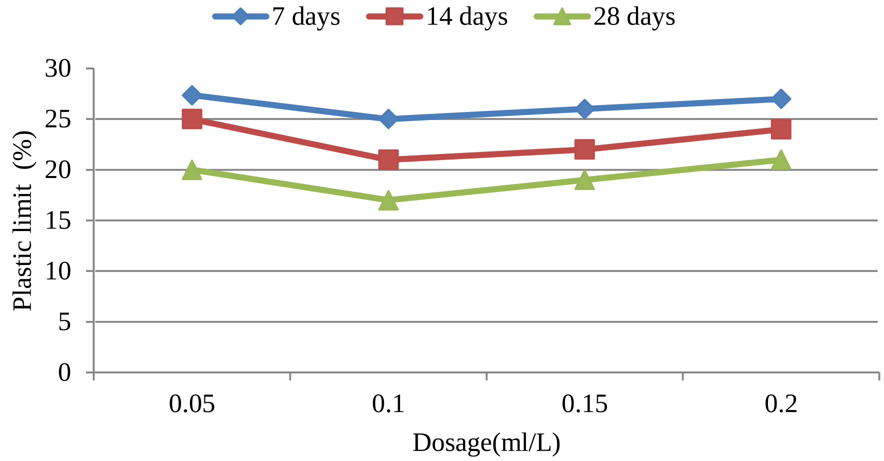

Fig. 3 Stabilizing effect of Terrazyme on plastic limit

5.2 Unconfined Compressive Strength

It was found that, the unconfined compressive strength increased to about 42% when the soil was stabilized with Terrazyme. Lithomargic clay was stabilized using Terrazyme with different dosages such as. 0.05ml/L, 0.1ml/L, 0.15ml/L and 2ml/L by weight of soil sample with different curing periods i.e. 7, 14, 28 days. The unconfined strength is found to be maximum at 0.1ml/L and then reduced by the further increase of Terrazyme dosages. The optimum stability of the sample was thus obtained by the addition of 0.1ml/L of the Terrazyme dosage. Here the unconfined compressive strength obtained for 7, 14, 28 days were 52kN/m2, 90kN/m2 and 111kN/m2 respectively. The maximum strength was obtained by 28 days cured sample. The increase in strength may be due to the more flocculated structure of Terrazyme treated soil with aging [4,18]. This flocculated structure may be due to the formation of calcium silicate hydrates [19,20,21].

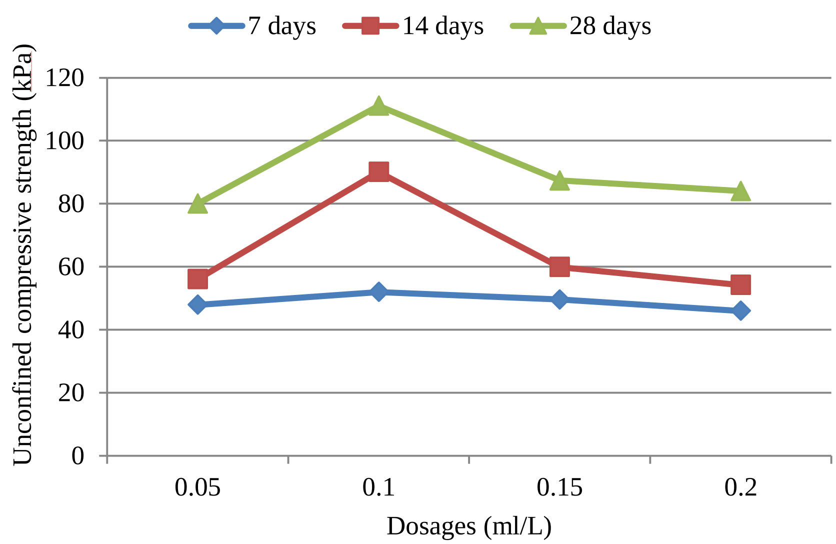

Fig. 4 Stabilizing effect of Terrazyme on unconfined compressive strength

5.3 Shear Strength Parameters

Effect of varying dosages of Terrazyme on cohesion and angle of internal friction of lithomargic clay was found out by conducting unconsolidated undrained triaxial tests. Cohesion and angle of friction of unstabilised soil were 21.64kPa and 17˚ respectively. Then the tests were conducted for 7 day cured samples. Both cohesion and angle of friction had highest value at a dosage of 0.1 ml/L which are 46.6kPa and 23˚ respectively. Here cohesion of treated soil was approximately double that of untreated soil. This may be due to the densely packed particle formation of treated soil because of the binding action caused by Terrazyme[12,19, 20].

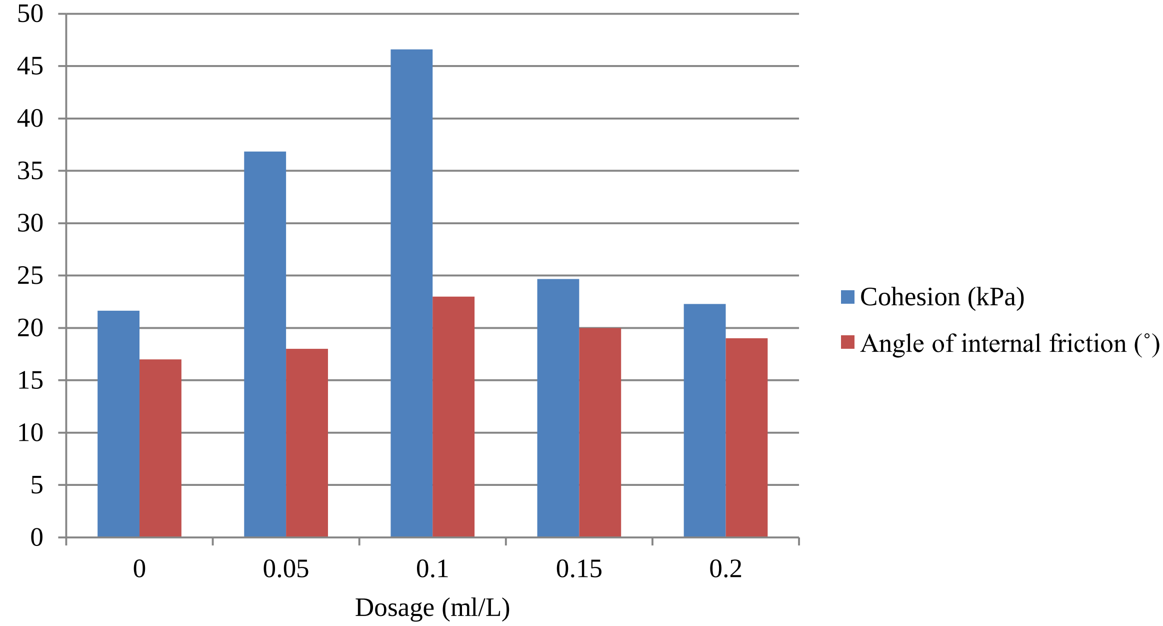

Fig. 5 Stabilizing effect of Terrazyme on shear strength parameters

5.4 Slope Stability Analysis

Slope stability analysis was performed for both unstabilized soil and the soil stabilized using Terrazyme (at Optimum dosage 0.1ml/L). The analysis was conducted on slope models of varying heights i.e. 4m, 8m, 12m and slope angles 30˚, 45˚, 60˚. This was done to analyze the effect of steepness of slopes on stabilized and unstabilized soil slopes. The final result was found through factor of safety which is the ratio of shear strength to shear stress of a possible sliding surface in a slope. Slope stability analysis was done using Bishop Circle Method. The optimum slip surface was determined and factor of safety of soil slopes were found out.

Table 4 Values of Factor of Safety for unsatbilized and stabilized soil

Slope Angle	Height of slope	Factor of Safety for unstabilized soil (Safe only if FOS > 1.5)	Factor of Safety for soil stabilized by Terrazyme (Dosage 0.1 ml/L)
30	4	3.44	6.65
	8	2.18	4.03
	12	1.72	3.09
45	4	2.87	5.69
	8	1.74	3.31
	12	1.35	2.48
60	4	2.44	4.91
	8	1.44	2.78
	12	1.09	2.06

The values of factor of safety for both stabilized and unstabilized soil slope are given in table 4 From the results it was found that the factor of safety values of unstabilized soil slope where greater than 1.5 except for slopes with angle and heights of 45˚ and 12m, 60˚ and 8m, 60˚ and 12m. The slopes for unstabilized soil where found to be unsafe at slope angle and heights of 45˚ and 12m, 6˚ and 8m, 60˚ and 12m. Factor of safety for slopes with varying heights and slope angles was greater than 1.5 for the stabilized soil. Thus, it was observed that addition of Terrazyme helped to keep the soil slope safe compared to unstabilized soil. This could have occurred because of the strong bonding between soil particles caused due to cationic exchange by Terrazyme. Through the process of cationic exchange the soil particles were thus able to come closer by the reduction of adsorbed water layer and thus form a dense structure [19, 20]. This effect was especially visible in cases of slopes with angle and heights of 45˚ and 12m, 60˚ and 8m, 60˚ and 12m where factor of safety values where less than 1.5 for unstabilized soil and greater than 1.5 for stabilized soil. Thus Terrazyme treated soil can be found effective for steeper slopes.

VI. Conclusion

Enzymatic stabilization on soil does not result in the formation of new bonds but only acts on the surface properties of soil. Enzymatic activity is also not controlled by any external factors like pH, temperature etc. From the results it was found that the strength and plasticity properties of the stabilized soil showed significant improvement with aging. The optimum dosage of TerraZyme in the soil studied was 0.1 ml/L. It is observed, that there is 42%, 70%, 35% increase in unconfined compressive strength, cohesion, and angle of friction respectively after 7 days curing. Tests conducted on unstabilized and stabilized soil showed that there is significant effect in consistency limits which could be possibly due to aggregation of soil particles. Slope stability analysis using

GEO5 software also showed that soil stabilized using Terrazyme for varying dosages was safe for slopes of varying heights. Only a small dosage of enzyme is required for soil stabilization. Thus it could be concluded that stabilization of the highly problematic lithomargic clay using bio enzyme treatment can show substantial improvement in various engineering properties of the soil.

REFERENCES

[1] Rauch, A. F., Harmon J. S., Katz, L. E. and Lilgestrand, H. M. 2002. Measured effects of liquid soil stabilizers on engineering properties of clay. Transportation Research Record, 1787(1)**:** 33-41

[2] Shekhar, D. C., Nayak, S. and Preetham, H. K. 2016. Influence of granulated blast furnace slag and cement on strength properties of lithomargic clay. Indian Geotechnical Journal, 47(3): 1-10

[3] Amulya, S., Kumar, A. and Vikram, R. 2018. Stabilization of lithomargic clay using Alkali Activated Fly Ash and Ground Granulated Blast Furnace Slag. International Journal Pavement Engineering, 21(9):1114-1121

[4] Shivashankar, R., Ravishankar, A. U. and Rangaswamy, R. 2015. Some studies on engineering properties, problems, stabilization and ground improvement of lithomargic clays. Geotechnical Engineering Journal of SEAGS and AGGSEA, 46(4)**:** 68-80

[5] Thomas, B. C., Jacob, S., Varghese, M. S. and Shivashankar, R. 2019. Erosion studies on lithomargic clay. Indian Geotechnical Journal, (50)1: 142-156

[6] Muguda, S. and Nagaraj, H. B. 2019. Effect of enzymes on plasticity and strength characteristics of earthern construction material. International Journal of Geo-engineering, 10(2): 1-14

[7] Gupta, A., Saxena, V., Saxena, A., Salman, M., Arfin, S. and Kumar, A. 2017. Review paper on soil stabilization by terrazyme. International Journal on Engineering Research and Application, 7(4): 54-57

[8] Kushwaha, S. S., Dindorkar, N. and Kishan, D. 2018. Stabilization of expansive soil using eko soil enzyme for highway embankment. Materials Processing and Characterization, 5(9): 19667-19679

[9] Kushwaha, S. S., Kishan, D., Chauhan M. S. and Khetawath, S. J. 2018. Stabilization of redmud using eko soil enzyme for highway embankment. Materials Processing and Characterization, 5(9): 20500-20512

[10] Begum, A. S., Prasada Raju, G. V. R., Prasad, D. S. V. and Anjan Kumar, M. 2020. Influence of terrazyme on compaction and consolidation properties of expansive soil. Problematic Soils and Geoenvironmental Concerns, 88: 525-535

[11] Baby, M., Gowshik, A., Karthick Rajeshwar, A. V., Mohanasundram., M. 2016. Experimental study of expansive soil stabilized with terrazyme. International Journal Of Engineering Research and Technology (Ijert), 5(1): 897-899 http://dx.doi.org/10.17577/IJERTV5IS010627

[12] Yusoff, S. A. N. M., Azmi, M., Ramli, H., Bakar, I., Wijeyesekera, D. C. and Zainorabidin, A. 2017. Laboratory investigation of terrazyme as a soil stabilizer. AIP Conference Proceedings 1892, 030014 (2017) 1892 (1) https://doi.org/10.1063/1.5005680

[13] Thomas, A. G. and Rangswamy, B. K. 2019. Strength behavior of enzymatic cement treated clay. International Journal Geotechnical Engineering, 15(4): 1-14

[14] Neves, M., Cavalerio, V. and Pinto, A. 2019. Slope stability assessment and evaluation of remedial measures using limit equilibrium and finite element approaches. Advances in Transportation and Geotechnics 3, 143:717-25

[15] Chen, X., Ren, J. and Liu, J. 2017. Analysis of slope stability and software development based on single-grid and two-grid finite element methods. Geotechnical and Geoengineering, 35(4): 1369-1382

[16] Ramakrishnan, R., Sruthi, M. R., Sharma, A. and Karthik, V. 2017. Effect of random inclusion of sisal fibres on strength behavior and slope stability of fine grained soils. Materials Today: Proceedings, 5(11)**:** 25313-25322

[17] Firoozi, A. A., Olgun, C. G. and Bhagini, M. S. 2017. Fundamentals of soil stabilization. International Journal of Geo-engineeing, 8(26): 1-16

[18] Chandrakaran, S., Eugine, G. N. and Sankar, N. 2017. Accelerated subgrade stabilization using enzymatic lime technique. Journal of Materials in Civil Engineering, 29(9): 1-7

[19] Joshi, A. and Solanki, C. H. 2019. Bioenzymatic lime stabilization of different soils. Geotechnics for Transportation Infrastructure, 29: 381-392

[20] Aboukhadra, A., Zidan, A. F. and Gaber, Y. 2018. Experimental evaluation of strength characteristics of different Egyptian soils using enzymatic stabilizers. Civil and Environmental Engineering, 5(1): 1-11

[21] Khan, T. A. and Taha, M. R. 2019. Effect of three bioenzymes on compaction, consistency limits and strength characteristics of a sedimentary residual soil. Advances in Materials Science and Engineering, 2015(1)**:** 1-9

[22] Vincent, N. A., Shivashankar, R. and Lokesh, K. N. 2017. Laboratory and field electrical resistivity studies on laterites and lateritic soils. Electronic Journal of Geotechnical Engineering, 22: 2637- 2664

[23] Nafisi, A., Mohamed, M. and Araf, S. 2019. Influence of microbe and enzyme-induced treatments on cemented sand shear response. Journal of Geotechnical and Geoenvironmental Engineering, 145(9): 1-8

[24] Oliveria, P. J. V., Klare, K. E. and Sherwood P. T. 2019. Effect of organic matter content on enzymatic bio cementation process applied to coarse grained soil. Journal of Materials in Civil Engineering, 31(7): 56-60