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Effect of Bio-Enzymatic Soil Stabilisation on Unconfined Compressive Strength and California Bearing Ratio

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Abstract: Design of the various pavement layers is very much dependent on the strength of the sub-grade soil over which they are going to be laid. Sub-grade strength is mostly expressed in terms of CBR (California Bearing Ratio). Weaker sub-grade essentially requires thicker layers whereas stronger sub-grade goes well with thinner pavement layers. The pavement and the sub-grade mutually must sustain the traffic volume. The Indian Road Congress (IRC) encodes the exact design strategies of the pavement layers based upon the sub-grade strength which is primarily dependant on CBR value for a laboratory or field sample. For an engineer, it is always important to focus on optimal design of thickness of pavement which fulfills both strength and economy criteria. The strength of soil can be improved by suitably adding stabilizing agent resulting reduction in thickness of layer. Hence in the present study, three different soils with four different dosages for 2 and 4 weeks of period after application of bio-enzyme on its strength parameters were studied. It is inferred from the results that addition of bioenzyme significantly improve UCC and CBR values of selected samples.

Key words: Layers, soil, ratio, sample, IRCI, India

INTRODUCTION

Soil is a gathering or deposit of earth material, derived naturally from the breakdown of rocks or decay of undergrowth that can be excavated readily with power equipment in the field or disintegrated by gentle reflex means in the laboratory. The supporting soil below pavement and its special under course is called sub-grade. Without interruption soil beneath the pavement is called natural sub-grade. Compacted sub-grade is the soil compacted by inhibited movement of heavy compactors. The CBR test is a small scale penetration test in which a cylindrical plunger of 3 in 2 (5 cm in dia) cross-section is penetrated into a soil mass (i.e., sub-grade material) at the rate of 0.05 min^{-1} (1.25 mm min^{-1}). Observations are taken between the penetrations resistances (called the test load) versus the penetration of plunger. The penetration resistance of the plunger into a standard sample of crushed stone for the corresponding penetration is called standard load.

The California bearing ratio, abbreviated as CBR is defined as the ratio of the test load to the standard load, expressed as percentage for a given penetration of the plunger. In most cases, CBR decreases as the penetration increases. The ratio at 2.5 mm penetration is used as the CBR. In some case, the ratio at 5 mm may be greater than that at 2.5 mm. If this occurs, the ratio at 5 mm should be used. The CBR is a measure of resistance of a material to penetration of standard plunger under controlled density and moisture conditions. The test is simple and has been extensively investigated for field correlations of flexible pavement thickness requirement. Bio-enzyme is a natural, non-toxic, non-flammable, non-corrosive liquid enzyme formulation fermented from vegetable extracts that improves the engineering qualities of soil, facilitates higher soil compaction densities and increases stability. Enzymes catalyze the reactions between the clay and the organic cat-ions and accelerate the cat-ionic exchange process to reduce adsorbed layer thickness. For other types of chemical stabilization, chemicals are mixed with soil which is difficult to mix thoroughly but bio-enzyme is easy to use as it can be mixed with water at optimum moisture content and then it is sprayed over soil and compacted.

In order to stabilize soils for improving strength and durability, a number of chemical additives both inorganic and organic were used. Recently bio-enzymes emerged as a new chemical for soil stabilisation. Bio-enzymes are chemical, organic and liquid concentrated substances which are used to improve the stability of soil sub-grade for pavement structures. Bio-enzyme is convenient to use, safe, effective and dramatically improves road quality.

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

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product. In the present study, one type of bio-enzyme has been used for stabilization of three types of soil with varying index properties. Detailed laboratory tests were carried out to ascertain the benefits in terms of reduction in design thickness.

Literature review: Escario and Juca (1989) studied the variation of axial stress with respect to axial strain from unconfined compression tests. Their results show a regular trend of increase in the shear strength of the soil specimens with a decrease in the degree of saturation. The reduction in the degree of saturation is associated with an increase in matric suction values (Escario and Juca, 1989). Similar to this study, Vanapalli *et al.* (1996) suggested that there is a non-linear increase in the shear strength of unsaturated soils (Vanapalli *et al.*, 1996).

Two modes of failure are considered in the bearing capacity design approach for roadway systems by Oloo *et al.* (1997). The 1st failure criteria are based on the limit equilibrium method. This method assumes that the base layer acts as an elastic material to distribute load to the sub-grade. Complex factors such as pore water pressure and soil layering can be modelled in a simpler form using this method (Oloo *et al.*, 1997). The 2nd mode of failure is based on extending the general shear failure criteria for all the pavement layers (McLeod, 1953). This method is realistic however, it involves a complex and tedious series of calculation. Also, incorporation of matric suction and pore water pressures into this failure mode criteria is difficult and complex. Due to these reasons, it is not the preferred method of determining the bearing capacity of a layered soil system (McLeod, 1953). Hitam and Yusof (1998) carried out study in Malaysia on roads constructed with soil stabilization indicated that roads that normally needed re-building several tines per year have remained in excellent condition through four monsoon seasons (Hitam and Yusof, 1998). National Road Department, Thailand studied the effect of Bio-enzyme use as soil stabilizer to determine the effects on CBR indicated that after 1-3 and 14 weeks period CBR was found as 37, 62, 66 and 100 +, respectively as compared to 28% of untreated soil.

Ministry of works, transport and communication, entebbe, Uganda studied the effect of bioenzyme after 3 months of stabilisation on soil indicated improvement in CBR up to 2 times at various locations at soil mechanics laboratory, Uganda and average reduction in plasticity index after bio-enzyme treatment was found to be 5%. Brazetti and Murphy (2000) conducted field experiment in Brazil to study the use of Terrazyme as the bio-enzymatic stabilizer for road construction and found that it was serving good (Brazetti and Murphy, 2000). Ravishankar studied the effect of different dosage of enzyme on lateritic soil available in Dakshina Kannada and Udupi district, Karnataka it was reported that after 1-4 weeks period CBR, UCC values increases considerably.

Selection of soil for the study: To assess the suitability of bio-enzyme as soil stabilizer three types of soil were taken for the study. Laboratory tests were done to determine the engineering properties of soil and strength characteristics of soil with and without stabilization with bio-enzyme. All the soil samples taken for study were first tested for engineering properties of soil such as particle size distribution, attenberg limits, specific gravity, optimum moisture content and maximum dry density.

All the soils were then tested for strength parameters such as CBR and unconfined compression strength without stabilization and with stabilization for a curing period of 2 and 4 weeks. Particle size distribution of different types of soil is shown in Table 1 and grain size analysis is shown in Fig. 1 which indicates that soil 1 is clayey, soil 2 and 5 are silty clay and soil 3 and 4 are sandy in nature. Attenberg limits of these soils are shown in Table 2.

Table 1: Particle size distribution of specified soil

Types of soil	Gravel	Sand	Silt	Clay	C_u	C_c	Specific gravity
1	18.4	41.6	20.0	20.0	7.61	1.31	2.25
2	6.0	82.0	4.0	8.0	11.00	0.89	2.11
3	9.2	67.4	10.9	12.5	8.50	1.06	2.38

Table 2: Atterberg limits of specified soil

Types of soil	LL (%)	PL (%)	PI	IS classification
1	46	40	6	
2	28	22	6	
3	30	25	5	

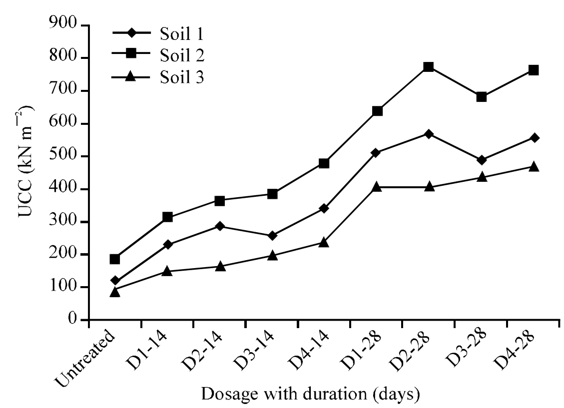

Fig. 1: Variation of unconfined compressive strength of bio-enzyme treated soil

RESULTS AND DISCUSSION

Unconfined compressive strength: Among three different selected soils, UCC of soil 2 has got higher value compare to two other soils. At the same time, the UCC of soil 1 falls in between values of soil 1 and 3 and soil 3 has got lowest UCC value. For soil1, the value of UCC varies from 112.82 kN m^{-2} for untreated soil to 554.45 kN m^{-2} for soil after 28 days of bio-enzyme application (Table 3). Though, the values of UCC increases with increase in dosage of bio-enzyme and duration after application of bio-enzyme in general for dosage 3 during 2 and 4 weeks period, the values shows descending trend and increases with further increase of dosage of bio-enzyme. Similar trend was observed for soil 2 for a period of 4 weeks duration. For soil 3, rate of increase of strength was observed due to the addition of bio-enzyme and increase of duration. The rate of increase of UCC values of bio-enzymatic soil with reference to untreated soil are shown in Fig. 2. From the results, it is understood that for 2 weeks after application of bio-enzyme, the rate of increase varies from 102-200%, 70-160%, 58-152% for soil 1-3, respectively. Similar increase for soil treated with bio-enzyme after 4 weeks are 330-404%, 246-321% and 337-400% for soil 1-3, respectively. Higher rate of increase observed for dosage 2 and 4 in the case of 2 and 4 weeks treated soil for soil 1. For other 2 soils (soil 2 and 3), highest value observed for 4 weeks duration. Out of 3 soils tested, higher UCC observed for soil 2 and lesser strength observed for soil 1 and 3 in the descending order.

California bearing ratio: The variation of CBR value for untreated soil and bio-enzyme treated soil with different dosage are shown in Fig. 3 to understand the effect of bio-enzyme stabilization and duration of stabilization. The CBR value of untreated soils shows similar trend as observed in UCC. The UCC value for soil 1 varies from 12-23%, 15-53% for soil 1 and 10-35% for soil 3. Unlike UCC, CBR value of soil 3 falls in between CBR values of soil 1 and 3. Soil 2 observed to have higher CBR and soil 1 with lower CBR among the 3 soils tested. The variation of rate of increase of CBR values of three different soils with reference to untreated soil are plotted in Fig. 4. Maximum rate of increase in CBR due to bioenzymatic stabilization observed to be 157, 613 and 673% for soil 1-3, respectively. This higher rate of increase observed for all the soils treated with bio-enzyme with 4 weeks of duration. For all the soils, soil treated with dosage 3 for a period of 2 weeks duration shows descending trend in CBR. For soil 3 except for dosage 1, for other three dosages of bio-enzyme there is descending

Table 3: Modified proctor compaction test results

Types of soil	MDD (kN m^{-2})	OMC (%)
1	15.79	10
2	14.03	11
3	15.60	12

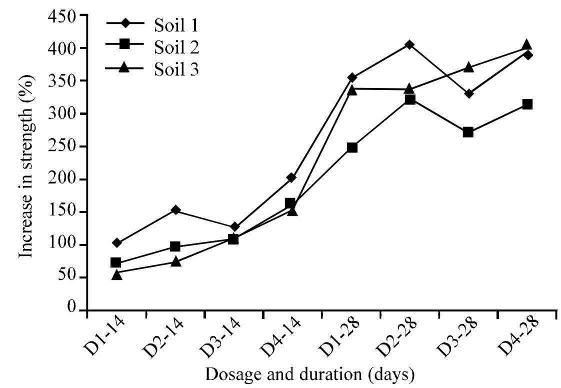

Fig. 2: Rate of increase in unconfined compressive strength of bio-enzyme treated soil with reference to treated soil

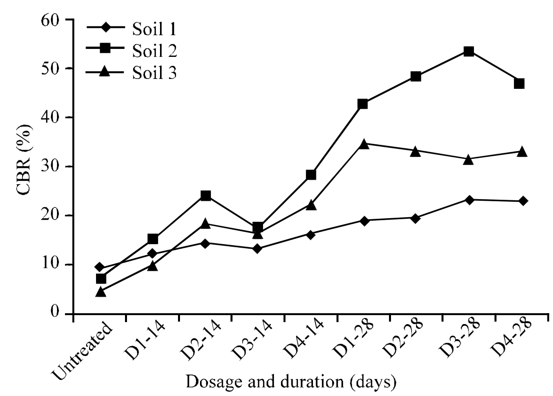

Fig. 3: Variation of California bearing ratio of bio-enzyme treated soil

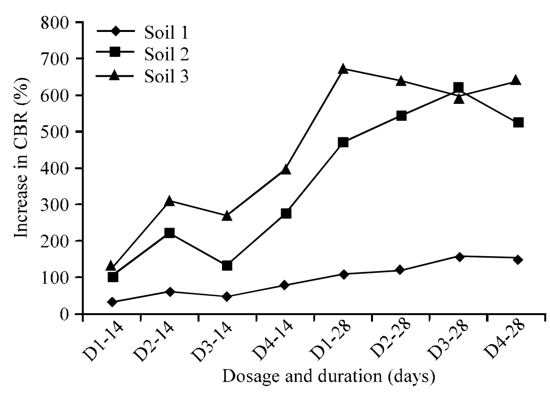

Fig. 4: Rate of increase in California bearing ratio of bio-enzyme treated soil with reference to treated soil

trend in the rate of increase of CBR. Hence, it is inferred that bio-enzymatic stabilization resulting significant improvement in strength of soil which will ensure the durability aspects and free maintenance of pavement.

CONCLUSION

- Bio-enzymatic stabilization resulted significant increase in unconfined compressive strength and California bearing ratio of all the three soils tested with varying parameters
- Duration of treatment of soil with bio-enzyme played a vital role in improvement of strength and soil treated with bio-enzyme for 4 weeks duration gives higher strength for all the soils tested
- Maximum rate of increase in UCC was observed to be 200, 160 and 152% for soil 1-3, respectively
- Maximum rate of increase in UCC was observed to be 157, 613 and 673% for soil 1-3, respectively
- In reality and practice, addition of bio-enzyme gives better performance in the field and ultimately ensures durable and maintenance free pavement

REFERENCES

Brazetti, R. and S.R. Murphy, 2000. General usage of bio-enzyme stabilizer in road construction in Brazil. Proceedings of the 32nd Annual Meeting on Paving Brazil, October 2000, Brazil.

Escario, V. and J.F.T. Juca, 1989. Strength and deformation of partly saturated soils. Proceedings of the 12th International Conference on Soil Mechanics and Foundation Engineering, (SMFE'89),: Rio de Janeiro, Brazil,-pp: 43.

Hitam, A. and A. Yusof, 1998. Soil stabilizers for plantation road. Proceedings of the National Seminar on Mechanization in Oil Palm Plantation, June 30-July 1, Selangur, Malaysia.

McLeod, N.W., 1953. Some basic problems in flexible pavement design. Highway Res. Board Proc., 32: 90-118.

Oloo, S.Y., D.G. Fredlund and J.K.M. Gan, 1997. Bearing capacity of unpaved roads. Can. Geotech. J., 34: 398-407.

Vanapalli, S.K., D.G. Fredlund, D.E. Pufahl and A.W. Clifton, 1996. Model for the prediction of shear strength with respect to soil suction. Can. Geotech. J., 33: 379-392.