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An Analysis of Strength Variation in Stabilized Soils using Different Dosages of Bio-Enzyme Treated at Various Curing Periods

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Abstract - *The growth of the population has created a need for better and economical vehicular operation which requires good highway having proper geometric design, pavement condition and maintenance. The highways have to be maintained so that comfort, convenience and safety are provided to the travelling public. Hence, it is necessary to have a proper diagnostic study of the soil to be used as a subgrade. Sustainable development cannot be done without introduction of new technology. Bio-Enzymes have come to the market which can be used as stabilizing agent. Bio-Enzyme is a natural, non-toxic, non-flammable, non-corrosive liquid enzyme formulation fermented from vegetable extracts that improves the engineering properties of soil, facilitates higher soil compaction and increases strength. One such stabilizing agent is Terrazyme, which is used in the present investigation to further stabilize blended soil. Terrazyme is a natural, non-toxic liquid, formulated using vegetable extracts. In this experimental study, three different soil samples such as red soil, marine soil and clay soil have been selected and collected. Various laboratory tests have been conducted to determine the physical, index and mechanical properties of soil samples. The selected soil samples have been stabilized using bio-enzymes in three different dosages such as 0.5 ml, 1 ml, 1.5 ml for every 5 kg of soil samples. The prepared soil samples are allowed for curing periods of 1 and 7 days. The physical, index and mechanical properties of these modified soil samples have been determined using various laboratory tests. The best modified soil samples have been selected in each type of soil based on its strength, economic and feasible criteria to be used as a subgrade soil for highway pavements.*

Key Words: Stabilization; Soil Properties; Bio-Enzyme; Terrazyme

1. INTRODUCTION

The unconsolidated mineral material of earth crust is known as soil. The soil may also contain air, water, organic matter, consisting of more or less decomposed remains lot of plants and animal organism and other substance which remain dispersed throughout the mineral particles of the soil. According to IS: 2809-1972, soil is defined as, "sediments or other unconsolidated accumulation of solid particles produced by the physical and chemical disintegration of rocks which may or may not contain organic matter. Thus soil is non-homogeneous, porous and extremely variable in its composition as well as in properties. The loads from any structure have to be ultimately transmitted to a soil through the foundation for the structure. Thus, the foundation is an important part of a structure, the type and details of which can be decided upon only with the knowledge and application of the principles of soil mechanics. Soil not only forms the foundation of road pavements but also is the principal material used for their construction. Since there is a wide variation in soil types, an adequate knowledge of the properties of different types of soil is, therefore, essential for proper design and construction of road pavements.

1.1 Types of Soil

India is a country of vast dimensions with varied conditions of geology, relief, climate and vegetation. Therefore, India has a large variety of soil groups, distinctly different from one another. Different criteria have been applied to classify Indian soils, the outstanding being geology, relief, fertility, chemical composition and physical structure, etc.., The Indian council of Agricultural Research (ICAR) set up an All India Soil Survey Committee in 1953 which divided the Indian soils into eight major groups. They are alluvial soil, black soil, red soil, laterite soil, mountain soil, desert soil, etc..,

1.2 Properties of Soil

The soil has some of the special properties in it and they are physical properties and mechanical properties. Some of the physical properties are colour, structure, texture, atterberg limits and consistency. The mechanical properties of soil includes bearing capacity, shear strength, permeability, maximum dry density and optimum moisture content of soil.

1.3 Soil Stabilization

Soil Stabilization is the alteration of soils to enhance their physical properties. Stabilization can increase the shear strength of a soil and/or control the shrink-swell properties of a soil, thus improving the load bearing capacity of a sub-grade to support pavements and foundations. These include increasing the shear strength of an existing ground condition to enhance its load-bearing capacity, achieve a desired improved permeability and enhance the durability of the soil to resistance to the process of weathering, and traffic usage among others. There are various methods available for stabilization of soil. It includes mechanical stabilization, use of geosynthetics for soil stabilization and chemical admixture stabilization.

1.4 Bio-Enzymes

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. Enzyme catalyze the reactions between the clay and the organic cat-ions and accelerate the cat-ionic exchange process to reduce adsorbed layer thickness. Bio-Enzymes are chemicals, organic and liquid concentrated substances which are used to improve the stability of soil of soil sub base of pavement structures. Bio-enzyme is convenient to use, safe, effective and dramatically improves road quality. 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. The available bio-enzymes are Perrazyme, Terrazyme, etc..,

2. NEED FOR STUDY

Soil is one of the vital resources which is obtained by weathering of rock. The nature of soil in a place is largely influenced by such factors as climate, natural vegetation and rocks. The formation of swelling soil is generally attributed to sedimentation and environmental conditions in geological past. They are prone to have low shear strength. Because of this alternate swelling and shrinkage, structures erected on them are severally damaged. These technical problems leads to the study of soil stabilization in different soils using bio-enzyme treated for various curing periods.

3. OBJECTIVES OF THE RESEARCH

The objectives and scope of the research work are: (1) To compare the physical and mechanical properties of various control soil samples. (2) To compare the properties of various modified soil samples which are stabilized using bio-enzyme of different dosages. (3) To analyze the intrusion of bio-enzyme in strength variation of different soils for various curing periods.

4. RESEARCH METHODOLOGY

Three different types of soil have been identified and selected for the research work. The selected soil samples have been collected from the appropriate sites. Then, the physical and index properties of selected soil samples have been studied to determine the exact soil classification according to the results obtained from the various laboratory tests. The following mechanical properties such as Maximum Dry Density and Optimum Moisture Content using standard proctor test, unconfined compressive strength using UCS test, confined Compressive Strength using Triaxial Shear Test and CBR value using CBR test. The appropriate bio-enzyme has been selected as the soil stabilizing agent. The modified soil samples have been prepared in various proportions using the selected bio-enzyme. The physical, index and mechanical properties of the various prepared modified samples have been determined for various curing periods of bio-enzyme. The effect of bio-enzyme intrusion in modified soil samples have also been studied. It has been followed by the analysis of strength variation in the prepared modified soil samples. The obtained results have been correlated. Last but not the least, the best combination of modified soil sample which is suited for foundations and highway pavements as well has been selected from the correlated results based on strength, economic and feasible parameters.

5. COLLECTION OF SOIL SAMPLES

Three different types of soil have been used in this research work. The selected soil samples are red soil, marine soil and clay soil. The selected soil samples which have been used in the project are collected from the various site as per IS 2720 (Part-I). The selected soil samples are red soil, marine soil and clay soil. The red soil used in this project has been collected from the heaping ground at Sirkazhi. The marine soil sample has been collected from the beach side at Thiruvettakudy. The clay soil sample has been collected from the agricultural farm land at Thirunallar.

6. PROPERTIES OF CONTROL SAMPLES

Various laboratory tests have been conducted on the selected soil samples to determine the physical and mechanical properties of control samples. The tests have been conducted as per IS 2720 Part 1 to Part 17. The physical, index and mechanical properties of the three collected control soil samples are tabulated as follows:

Table-1: Properties of Control Soil Samples

S.No	Properties of Soil	Red Soil	Marine Soil	Clay Soil
1	Specific Gravity	2.25	2.35	1.7
2	Co-efficient of Uniformity	4.583	35.34	2.45
3	Co-efficient of Curvature	0.606	0.25	1.074
4	Liquid Limit (%)	-	-	34
5	Plastic Limit (%)	-	-	21.67
6	Plasticity Index (%)	-	-	12.33
7	Flow Index (%)	-	-	52.284
8	Toughness Index (%)	-	-	0.235
9	OMC (%)	18.56	15.13	16.2
10	MDD Value (kN/m^3)	18.89	16.8	16.2
11	UCS Value(kPa)	125	76	208
12	CBR Value (%)	5	2	4

The OMC value is more for red soil, moderate for clay soil and low for marine soil whereas the maximum dry density is more for red soil, moderate for marine soil and low for clay soil. The unconfined compressive strength of soil is more for

red soil, moderate for clay soil and low for marine soil. It is also observed that CBR value is more for red soil, moderate for clay soil and low for marine soil.

7. SELECTION OF BIOENZYME

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. The available bio-enzymes are Perrazyme, Terrazyme, Earthzyme, etc.., The bio-enzyme which has been used in this project is "Terrazyme". TerraZyme is a natural, non-toxic, non-flammable, non-corrosive liquid enzyme formulation fermented from vegetable extracts that improves the engineering properties of soil; facilitate better workability of soil and increases stability by catalyzing the reactions between the clay and the organic cations and accelerate the cationic exchange process to reduce adsorbed layer thickness. TerraZyme is specially formulated to modify the engineering properties of soil. Terrazyme are liquid additives, which act on the soil to reduce the voids between soil particles and to minimize the absorbance of water to the soil particles to maximize compaction. The enzymes react with the organic matter (humid matter) in the soil to form cementitious material. This decreases the swelling capacity of the soil particles and reduces permeability. A commercially available organic, enzyme based stabilizer known as TerraZyme is used as additive to the soil. This bio-enzyme has been collected from the Avijeet Agencies, Chennai, India.

7.1 Properties of Terrazyme

TerraZyme replaces adsorbed water with organic cations, thus neutralizing the negative charge on a clay particle. The properties of the Terrazyme are tabulated as follows:

Table-2: Properties of Terrazyme

Properties	Values
Boiling Point	212°F
Specific Gravity	1.05
pH Value	3.50
Total Dissolved Solids	19.7 ppm
Evaporating Rate	Same as Water
Solubility in Water	Complete
Appearance	Dark Brown

8. PREPARATION OF MODIFIED SAMPLES

The modified samples have been prepared using the selected bio-enzyme. Terrazyme is added to the control soil samples in three different dosages such as 0.5 ml, 1 ml and 1.5 ml for every 5 kg of the soil samples. The mixed and prepared soil samples have been kept aside for a curing periods of 1 day and 7 days. Terrazyme is applied to the surface of the dry soil sample. The required bio-enzyme is taken in a hydraulic syringe and applied to the soil. Then, the soil mixed thoroughly in such a way that the applied bio-enzyme is evenly distributed throughout the soil sample. It is added in three different dosages such as 0.5 ml / 5 kg, 1 ml / 5 kg and 1.5 ml / 5kg of samples. Two sets of modified soil samples for each soil in all the three dosages of bio-enzyme is prepared. One set has been kept aside for the curing period of 1 day. The other set has been kept for the curing period of 7 days.

9. PROPERTIES OF MODIFIED SAMPLES

The physical, index and mechanical properties of all the modified samples have been determined through various laboratory tests. The properties of modified soil sample which are determined are specific gravity, liquid limit, plastic limit, optimum moisture content, maximum dry density, unconfined compressive strength and CBR value. The physical, index and mechanical properties of modified red soil samples have been determined. The determined values are tabulated as follows:

Table-3: Properties of Modified Red Soil Samples

Sl .No	Properties of Red Soil	Terrazyme of different dosages					
		0.5 ml		1 ml		1.5 ml	
		1	7	1	7	1	7
1	Specific Gravity	2.3	2.2	2.5	2.1	2.4	2.1
2	LL (%)	-	-	-	-	-	-
3	PL (%)	-	-	-	-	-	-
4	I_P (%)	-	-	-	-	-	-
5	OMC (%)	18.56	18.04	17.84	17.42	17.18	16.94
6	MDD (kN/m^3)	18.36	19.88	19.15	18.86	18.64	19.67
7	UCS (kPa)	152	228	178	249	185	250
8	CBR Value (%)	7	10.5	9	12.6	12	16.2

The optimum moisture content and maximum dry density of the modified red soil samples have been determined by plotting the values of OMC against MDD. The CBR values of the various modified red soil samples have been determined by plotting the penetration values in mm against load in kg. The physical, index and mechanical properties of modified marine samples have been determined. The optimum moisture content and maximum dry density of the modified marine soil samples have been determined by plotting the values of OMC against MDD. The CBR values of the various modified marine soil samples have been determined by plotting the penetration values in mm against load in kg. The physical, index and mechanical properties of modified marine soil samples have been determined. The determined values are tabulated as follows:

Table-4: Properties of Modified Marine Soil Samples

Sl.No	Properties of Marine Soil	Terrazyme of different dosages					
		0.5 ml		1 ml		1.5 ml	
		1	7	1	7	1	7
1	Specific Gravity	2.5	2.6	2.6	2.6	2.3	2.6
2	LL (%)	-	-	-	-	-	-
3	PL (%)	-	-	-	-	-	-
4	I_P (%)	-	-	-	-	-	-
5	OMC (%)	15.13	15.03	15.18	15.88	13.92	16.34
6	MDD (kN/m^3)	16	16.22	16.67	16.37	16.88	15.83
7	UCS (kPa)	120	156	135	176	105	137
8	CBR Value (%)	3	3.9	3.5	4.55	3.98	5.17

The physical, index and mechanical properties of modified clay soil samples have been determined and are tabulated as follows:

Table 5: Properties of Modified Clay Soil Samples

Sl. No	Properties of Marine Soil	Terrazyme of different dosages					
		0.5 ml		1 ml		1.5 ml	
		1	7	1	7	1	7
1	Specific Gravity	1.87	1.92	1.87	1.93	1.95	1.97
2	LL (%)	36	37	37	34	39	36
3	PL (%)	20.4	19.6	18.5	18.9	28	23.6
4	I_P (%)	15.6	17.4	18.5	15.1	11	12.4
5	OMC (%)	11.89	12.14	12.26	12.32	12.37	12.63
6	MDD (kN/m^3)	16.46	16.67	15.37	16.86	16.48	16.77
7	UCS (kPa)	220	308	260	390	275	440
8	CBR Value (%)	5	7	8.4	12.6	10.3	16.48

10. STRENGTH ANALYSIS

Soils consist of individual particles that can slide and roll relative to one another. Shear strength of a soil is equal to the maximum value of shear stress that can be mobilized within a soil mass without failure taking place. The shear strength of a soil is a function of the stresses applied to it as well as the manner in which these stresses are applied. A knowledge of shear strength of soils is necessary to determine the bearing capacity of foundations, the lateral pressure exerted on retaining walls, and the stability of slopes. Sometimes it is cheaper to take the undisturbed soil sample and test its strength in the laboratory. Also to choose the best material for the embankment, one has to conduct strength tests on the samples selected. Under these conditions it is easy to perform the unconfined compression test on undisturbed and remoulded soil sample.

10.1 UCS of Soil Samples

The unconfined compressive strength (qu) is the load per unit area at which the cylindrical specimen of a cohesive soil falls in compression. The primary purpose of the Unconfined Compression Test is to quickly determine a measure of the unconfined compressive strength of rocks or fine-grained soils that possess sufficient cohesion to permit testing in the unconfined state. As per the calculated values, the UCS value of modified red soil (1.5 ml) sample treated at 1 day curing is more among the 1 day values. Similarly, the UCS value of modified marine soil (1 ml) sample at 1 day curing is more among the 1 day values. The UCS value of modified clay soil (1.5 ml) sample is more among the 1 day values. The clay soil sample treated at 1 day with 1.5 ml of dosage has more UCS value among the overall 1 day values. As per the calculated values, the UCS value of modified red soil (1 ml & 1.5 ml) samples treated at 7 days curing is more among the 7 day values. Similarly, the UCS value of modified marine soil (1 ml) sample at 7 days curing is more among the 7 days values. The UCS value of modified clay soil (1.5 ml) sample is more among the 7 days values. The clay soil sample treated at 7 days with 1.5 ml of dosage has more UCS value among the overall 7 days values.

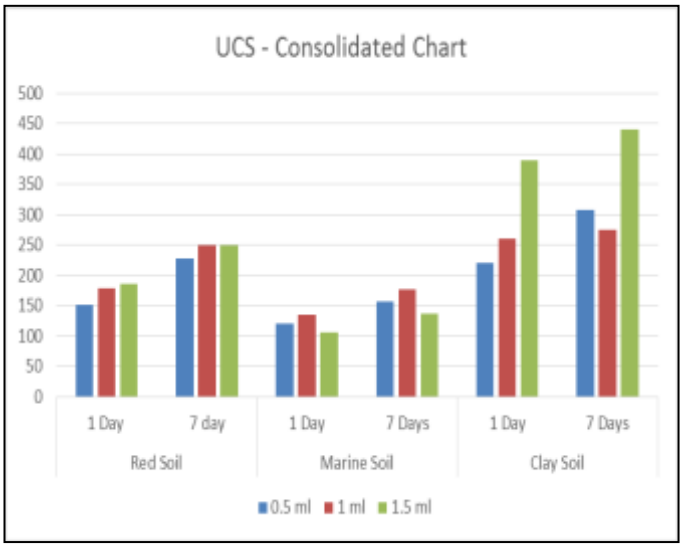

Chart-1: UCS Values of Soil Samples

From the above chart, the UCS value of modified clay soil has significance increment in strength. Among all the values of UCS, the modified clay soil sample has the highest UCS value of 440 kPa.

10.2 CBR Values of Soil Samples

The CBR is a measure of resistance of a material to penetration of standard plunger under controlled density and moisture conditions. CBR is the ratio of force per unit area required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min. to that required for the corresponding penetration of a standard material. The california bearing ratio test is penetration test meant for the evaluation of subgrade strength of roads and pavements. The results obtained by these tests are used with the empirical curves to determine the thickness of pavement and its component layers.

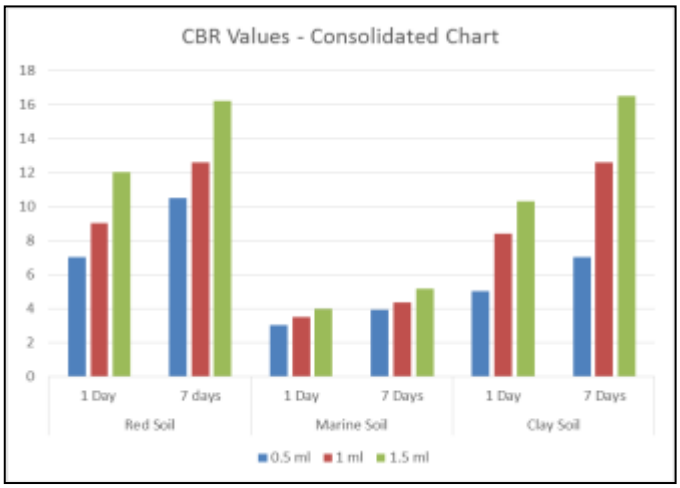

Chart 2: CBR Values of Soil Samples

From the above consolidated chart, it is observed that, the CBR values of all the modified soil samples which have been modified using 1.5 ml / 5 kg dosage of bio-enzyme has more than the other combinations. Among all the values, the modified red and clay soil samples treated at 7 days of curing has more CBR value.

11. CORRELATION OF RESULTS

11.1 Results of Red Soil Samples

From the various experimental and laboratory studies on red soil samples, the following results have been obtained:

- ✓ The specific gravity of the modified samples have no significant changes when compared to specific gravity of the control sample.
- ✓ The optimum moisture content of the modified samples has decreased slightly with increase of bio-enzyme dosage.
- ✓ The maximum dry density of the modified samples treated at 7 days has more than that of samples treated at 1 day.
- ✓ The UCS values of modified samples have been increased linearly, both in terms of dosage and curing periods.
- ✓ The CBR values of modified samples has shown tremendous increment in 7 days when compared to that of 1 day CBR values.
- ✓ It is found that the modified samples has enough CBR value and they are categorised as Good-Fair material. Hence, they can be used as the soil subgrade material for the highway pavements.

11.2 Results of Marine Soil Samples

From the various experimental and laboratory studies on marine soil samples, the following results have been obtained:

- ✓ The specific gravity of the modified samples have no significant changes when compared to specific gravity of the control sample.
- ✓ The optimum moisture content of the modified samples has decreased slightly with increase of bio-enzyme dosage.
- ✓ The maximum dry density of the modified samples has no significant difference.
- ✓ The UCS values of modified samples have been increased linearly and decreased when treated with 1.5 ml dosage of bio-enzyme (1 day). The UCS values of modified samples treated with various dosages (7 days) have been linearly increased.
- ✓ The CBR values of modified samples have shown tremendous increment in 7 days CBR values when compared to that of 1 day CBR values.
- ✓ It is found that the modified samples has enough CBR value and they are categorised as Fair-Poor material. Hence, fair combination of material (Marine Soil + 1.5 ml Bio-enzyme + 7 days) can be used as the soil subgrade material for the highway pavements.

11.3 Results of Clay Soil Samples

From the various experimental and laboratory studies on clay soil samples, the following results have been obtained:

- ✓ The clay soil sample which has been selected for the project is classified as medium plastic clay soil since its plasticity index is in the range of 7 – 17.
- ✓ The plasticity index of modified clay soil samples is also in the range of 7 – 17 and they are also classified as medium plastic clay soil since it does not lose its plasticity.
- ✓ The specific gravity of the modified samples have no significant changes when compared to specific gravity of the control sample.
- ✓ The optimum moisture content of the modified samples has decreased slightly with increase of bio-enzyme dosage.
- ✓ The maximum dry density of the modified samples has no significant difference.
- ✓ The UCS values of modified samples have been increased linearly, both in terms of dosage and curing periods.

- ✓ The CBR values of modified samples have shown tremendous increment in 7 days CBR values when compared to that of 1 day CBR values.
- ✓ It is found that the modified samples has enough CBR value and they are categorised as Good-Fair material. Hence, they can be used as the soil subgrade material for the highway pavements.

12. CONCLUSION

Engineers often face the problem of constructing facilities on or with soils, which do not possess sufficient strength to support the loads imposed upon them either during construction or during the service life of the structure. The poor engineering performance of such soils has forced Engineers to attempt to improve the engineering properties of poor quality soils. Soil stabilization is the alteration of one or more soil properties to create an improved soil material possessing the desired engineering properties. Recently many Bio-enzymes have emerged as cost effective stabilizers for soil stabilization. Three different types of soil have been selected and collected. Various laboratory tests have been conducted on all the three soil samples to determine physical, index and mechanical properties of the soil samples. From the UCS and CBR values of the samples, it has been concluded that the clay and red soil is more suitable as a soil subgrade material for highway pavements. The marine soil sample is more suited as a subgrade material when treated with 1.5 ml / 5 kg of bio-enzyme dosage with curing periods of 7 days. The combination of this marine soil sample will be more economical in design. Thus, the stabilized soil samples can be used as a subgrade material for the construction of highway pavements.

13. FUTURE SCOPE OF THE RESEARCH WORK

Directions of future research includes the analysis of strength parameters such as UCS and CBR values in the modified samples with placement of geo-synthetics such as geogrids, geocells, geonets, geotextiles at alternate depths. This will give further more strength characteristics in the selected soil samples.

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