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PREPARATION OF BIO-ENZYME AND ITS EFFECTS ON GEOTECHNICAL CHARACTERISTICS OF SHEDI SOIL

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Abstract - *Soil is a naturally occurring material used for the construction of all except the surface layers of pavements. Soil stabilization is the alteration of soils to enhance their properties. Stabilization of soil includes various techniques for modifying the properties of a soil to improve its engineering performance at a desired level. Various stabilizers have emerged into the civil engineering field and stabilization by Bio-enzymes is one among them. Shedi soil is the name given to the locally available whitish, pinkish or yellowish silty sand. The Shedi soil is an expansive soil and has great affinity towards water. Hence there is a need for improvement of these properties of soil when they are used for construction. The present study is undertaken to evaluate the effectiveness of different dosages of Bio-enzyme as soil stabilizers. For the present study, Bio-enzyme was prepared by using different chemicals compounds and the same is used for stabilization. Locally available Shedi soil with varying index properties were mixed with different enzyme dosages namely, 200ml/3m^3, 200ml/2.5m^3, 200ml/2m^3 and 200ml/1.5m^3 and kept for 0, 7, 15 and 30 days curing period to determine the changes in the geotechnical properties of Shedi soil. The obtained results were analysed and investigated in terms of consistency, compaction and unconfined compressive strength (UCS). Analysis of the test results shows that stabilization of Shedi soil by Bio-enzyme improves geotechnical properties of soil up to great extent for the dosage of 200ml/3m^3.*

Key Words: SOIL STABILIZATION, SHEDI SOIL, BIO-ENZYME, UNCONFINED COMPRESSIVE STRENGTH (UCS)

1. INTRODUCTION

Soil is the basic foundation for any civil engineering structures. In some places, soil may be weak which cannot resist the oncoming loads. Civil engineers often faces problems with constructing facilities on soft or problematic soils, which do not have adequate potency to sustain the obligatory loads upon them either during construction or during the service time of structure. Design and construction of road embankments and foundation structures on soft or problematic soil is a challenging task for all civil engineers, particularly for a geotechnical engineer. With the increase in construction activities both onshore and offshore, it has impressive to solve geotechnical problems concerned with soft and compressible soils. In India, many areas consist of earth with more silt contents with low strength and minimum bearing capacity, Shedi soil is one among them. When poor quality soil is available at the construction site, the best option is to modify the properties of soil so that it meets the design requirement. There are various methods that could be used to improve the performance of poor quality soils. Soil stabilization is an effective method for improving the properties of soil. Since the nature and the properties of natural soil vary widely, a suitable stabilization technique has to be adopted for a particular situation after considering the soil properties.

Lithomargic soil (Shedi soil) strata are very common throughout west coast of India from Malabar (Kerala) to Ratnagiri in Maharashtra – wherever lateritic soils are found. These soils are considered to be "treacherous soil" by geotechnical engineers due to its low strength and unpredictable behavior. Therefore construction on this type of soil requires special design and precautions, which leads to extra cost of construction. Therefore soil stabilization techniques are necessary to ensure the good stability of soil so that it can successfully sustain the load of the superstructure especially in case of soil which are highly active, also it saves a lot of time and millions of money when compared to the method of cutting out and replacing the unstable soil. Soil stabilization can be explained as the alteration of the soil properties by chemical or physical means in order to enhance the engineering quality of the soil. Various types of chemical stabilizers, such as Portland cement, fly-ash, hydrated lime have been prevalently used to improve the engineering properties of soil. Bio-enzyme is another new chemical for improving soil properties. 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. Stabilization using enzyme is a cost effective and commonly used method of soil improvement.

1.1 Shedi Soil

Shedi soil is the name given to the locally available whitish, pinkish or yellowish silty sand. Shedi soil is also known as Lithomargic clays, which is present at a depth of 1-3m below the top lateritic outcrop throughout the Konkan belt. This type of soil is abundantly available in the western coastal belt of southern India, starting from Cochin to Goa. These soils are the product of tropical or subtropical weathering. The top layers of lateritic formation are highly porous but hard and strong. In between the top hard layer and bottom residual or parent deposit, there lies the Shedi soil (Lithomargic clay) which is generally separated from top layer with distinct fine silica dust layer with negligible cohesion and high permeability.

1.2 Problems of Construction on Shedi Soil Strata

The Lithomargic clay (Shedi soil) is an expansive soil and has great affinity towards water. When it comes become in contact with water it expands and it behaves as a liquid by losing its strength (especially in rainy season). When it loses water from it (especially in summer), it shrinks. This property of expansive and shrinkage cause serious problems like formation of potholes, dilation problems etc in the cement constructed over this soil. Shedi soil is highly porous but hard and strong. They have negligible cohesion (bonding between particles) and high permeability. This makes it unsuitable for construction of any civil structure.

These problems are caused because of the weakness of soil in saturated or wet condition and it less permeable and strength is very less under wet condition compared to any other soil. The soil contains mainly quartz and kaolinite which increases expansion characteristics of the soil. The soil is also not easily compactable. Underground structures like tunnels, deep excavations and caverns are increasingly constructed in all type of soils including Lithomargic soils. Konkan railway line which passes through the west coast of Indian coastal line had to be delayed due to the innumerable problem encountered while constructing deep cuts and tunnels. Therefore, for better performance of structures which are built on Shedi soils, the performance characteristics of such soils need to be improved.

1.3 Bio-enzyme

Bio-enzyme is a natural, nontoxic, 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. Bio-enzymes are biological catalyst that speeds up a chemical reaction, that otherwise would happen at much slower rate, without becoming a part of the end product. Since the Bio-enzymes do not becomes the part of end product and are not consumed by the reaction, a very small amount of Bio-enzyme is required for soil stabilization. Bio-enzymes are present in all living organisms. They are obtained from plants and animals including microorganisms by extraction using suitable solvent. Bio-enzymes are large protein molecules which are more efficient than inorganic catalyst; the reaction rate is often increased by a factor of 106 to 1012. They usually catalyze one particular reaction therefore enzymes do not produce side reaction. They are temperature sensitive and work at mild temperature (35^0C) and loss their effectiveness at higher temperature. Also, they are pH sensitive too and work good around pH value 7.

For a Bio-enzyme to be active in a soil, it must have mobility to reach at the reaction site. The pore fluid available in the soil mass provides means for mobility of the molecules of Bio-enzyme, the specific soil chemistry provides the reaction site, and time is needed for the Bio-enzyme to diffuse to the reaction site. A Bio-enzyme would stay active in a soil until there are no more reactions to catalyze. Each Bio-enzyme is specifically tailored to promote a chemical reaction within or between other molecules. The Bio-enzymes themselves are unchanged by these reactions. They serve as a host for the other molecules, greatly accelerating the rate of normal chemical and physical reactions. The Bio-enzyme allows soil materials to become more easily wet and more densely compacted. They also improve the chemical bonding between soil particles and creating a more permanent structure that is more resistant to weathering, water penetration and wear and tear.

1.4 Mechanism of Soil Stabilization by Bio-enzyme

In clay water mixture positively charged ions (cat-ions) are present around the clay particles that remains attached or absorbed on the clay surface. The absorbed water or double layer gives clay particles their plasticity. In some cases, the clay can swell and the size of double layer increases, but can be reduced by drying. Therefore, to truly improve the soil properties, it is necessary to permanently reduce the thickness of double layer. Cat-ion exchange processes can accomplish this. By utilizing fermentation process specific microorganisms can produce stabilizing Bio-enzyme in large quantity. The soil stabilizing Bio-enzyme catalyzes the reaction between the clay and the organic cat-ions that accelerate the cat-ionic exchange without becoming the part of the end product. Bio-enzyme replaces absorbed water with organic cat-ions, this neutralizing the negative charge on the clay particle.

Bio-enzyme reacts with the absorbed water layers of clay particles and reduces the thickness around the soil particle due to which void between soil particles reduces and the soil particles get closer orientation wit lower compactive effort. This decreases the swelling capacity of the soil particles and also reduces permeability. The mechanism of soil stabilization with Bio-enzyme as an additive is pictorially represented in the Fig-1.

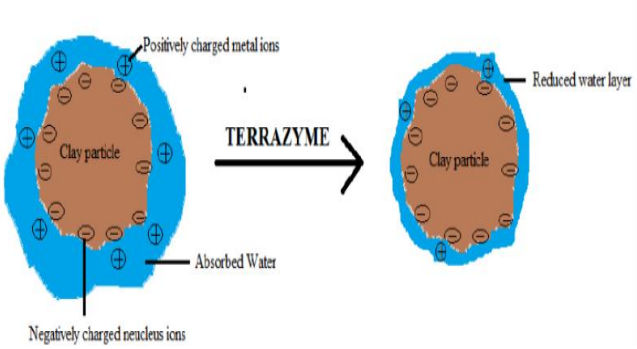

Fig -1: Mechanism of Soil Stabilization

1.5 Objectives of Present Study

The primary objectives of this study are to improve the geotechnical properties of Shedi soil so as to make it suitable for construction of any civil engineering structures. The specific objectives of this work include:

- To determine the Index and Engineering properties of Shedi Soil.
- To determine the effects of addition of different dosages of Enzyme on geotechnical properties of Shedi soil.
- To determine the change in geotechnical characteristics (like consistency, compaction and strength) with the addition of different dosages of Bio-enzyme by varying curing period.

2. LITERATURE REVIEW

With reference to the source of information, we can summarize that most of the researchers found that the application of Bio-enzyme on the soil improves the strength to a large extent and reduces plasticity index of soils and swelling properties. Stabilization using Bio-enzyme improves characteristics of soil. From the research work done by various researchers and by laboratory studies, it can be seen that both curing period and dosage of Bio-enzymes affect the properties of stabilized soils. Also, the studies are soil specific and the effect of Bio-enzymes is different for different soils which necessitate studying the effect of Bio-enzymes on the required soil.

The researchers concluded that specimens treated with a high dosage of Bio-enzyme solution were no more stabilized than specimens treated with low dosage. A high dosage of Bio-enzyme created an unbalanced electrical charge in the water molecule. According to researchers, the Bio-enzyme stabilizer will reduce the electrical charge of water molecule when there is a sufficient negative charge to exert adequate pressure on the positively charged metal ions in the absorbed water film. Thus, when there are more positively charged metal ions than negatively charge metal ions, the existing electrostatic potential barrier is broken, and the film of absorbed water enveloping the particles is reduced. Therefore, the particles lose their swelling capacity, and the soil acquires a friable structure. When the amount of Bio-enzyme is increased, the strength reaches a peak point and then declines. Also, the studies are soil specific and the effect of Bio-enzymes is different for different soils which necessitate studying the effect of Bio-enzymes on the required soil. The literature study bring out the potential benefits of using enzymatic stabilization to reduce the plasticity properties and increase volumetric stability of soil, thus making the soil less susceptible to crack formation. This beneficial effect of making the soil volumetrically stable and less susceptible to crack formation can be effectively used for stabilized earthen construction elements like rammed earth, CSEBs and adobe blocks. From the literature study it is also found that small addition of Bio-enzyme would help in improving the strength of the un-stabilized earthen construction.

3. MATERIALS

The following materials have been used in this investigation.

1. Shedi Soil
2. Bio-enzyme

3.1 Shedi Soil

For the present research work Shedi soil (Lithomargic clay) was collected from opposite of Kwality Hotel near Koteshwar Road, Soosgadi, NH 66, Bhatkal taluk loacated at 13°99'10.63" N latitude 74°55'30.56" E departure. The soil was collected from a depth of 1.5m below the existing ground surface. The obtained soil was air dried and pulverized manually and was sieved through 425 μ IS sieve, except for sieve analysis. The Fig-2 shows the site from which the Shedi soil was collected for the present study.

Fig -2: Site Image of Shedi Soil

The selected soil was characterized by its physical properties namely liquid limit, plastic limit, particle size distribution, compaction characteristics and specific gravity as well as by its engineering properties namely strength characteristics using the standard procedures as specified by Bureau of Indian Standards. The test results are summarized in the Table-1 and Table-2.

Table -1: Particle Size Distribution

Sieve Size (mm)	Percentage Finer
4.75	100
2.36	100
1.18	100
0.6	100
0.3	62.15
0.15	21
0.075	5.85

Table -2: Basic Properties of Shedi Soil

SI No.	Parameters	Values
1	Grain Size Distribution	
	a) Gravel (%)	0
	b) Sand (%)	94.15
	c) Silt + Clay (%)	5.85
	d) Coefficient of uniformity, Cu	33.33
	e) Coefficient of curvature, Cc	1.34
	f) Type of gradation	Poorly Graded
2	Specific Gravity	2.44
3	Atterberg's Limits	
	a) Liquid Limit (%)	63.8
	b) Plastic Limit (%)	31.54
	c) Plasticity Index (%)	32.26
4	Soil Classification	CH
5	Compaction Characteristics	
	a) Maximum Dry Density (g/cc)	
	b) Optimum Moisture Content (%)	
6	Unconfined Compressive Strength (kN/m^2)	168.62

The gradation curve for Shedi Soil is as shown in Chart-1. From the gradation curve it is observed that Shedi soil collected was Poorly Graded soil. Based on the plasticity properties of the fines fraction, the position of untreated Shedi soil fines on the plasticity chart as shown in Chart-2 is above A-line, indicating that the fines fraction is essentially clay. Hence, as per Indian soil classification system, the Shedi soil is classified as CH: Inorganic Clays of High plasticity.

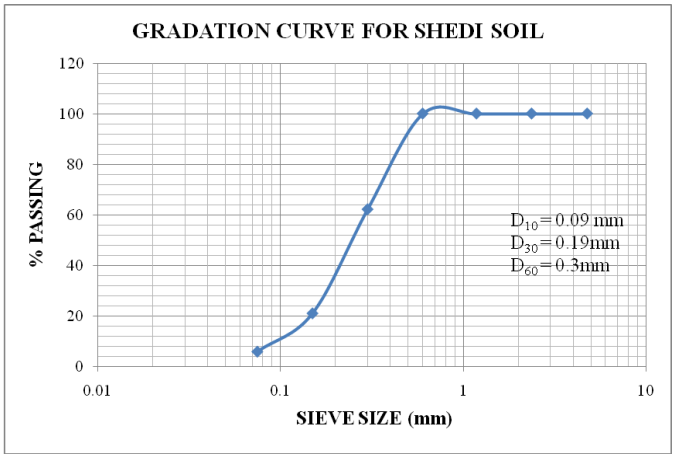

Chart -1: Gradation Curve of Shedi Soil

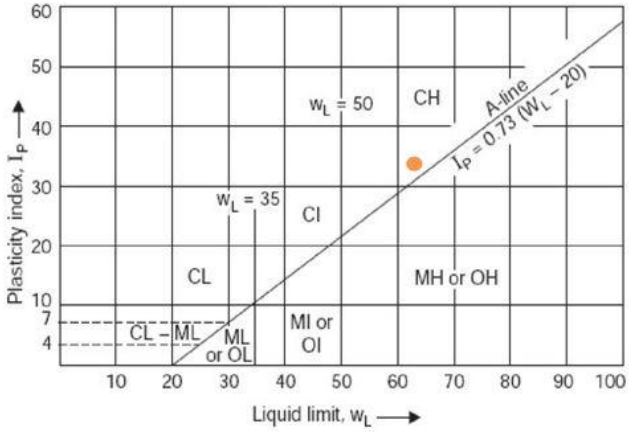

Chart -2: Classification of Soil using IS Plasticity Chart

3.2 Bio-enzyme

The Bio-enzyme used in this study was prepared by the addition of the following chemical compounds.

Table -3: Chemicals used for Bio-enzyme Preparation

Substance	Quantity
Water	600g
Molasses (unrefined)	300g
Magnesium Sulphate	50g
Urea	50g
Instant yeast (saccharomycetaceae)	1g
Ammonium Sulphate	10g
Ammonium Chloride	20g

4. METHODOLOGY

The collected soil was air dried and the boulders and gravel particles are pulverized by using a metallic hammer. The soil passing through 4.75mm sieve will be used for the laboratory investigation.

4.1 Bio-enzyme Preparation

The Bio-enzyme used in this study was prepared as per the procedure given below.

1. Initially 600g of water is heated not more than 40°C.
2. Then about 300g of molasses (unrefined) is added to this warm water and stirred well.
3. To this above mixture 50g of Magnesium Sulphate and 50g of Urea is added and the mixture is stirred well.
4. Then Instant yeast (saccharomycetaceae) of 1g is added to the above mixture and the solution is kept for 14 days for the fermentation process.
5. During the fermentation period the solution is stirred several times daily (need of oxygen for fermenting process).
6. After fermentation period, 10g of Ammonium Sulphate is added and is kept for 24 hours.
7. After 24 hours, 20g of Ammonium Chloride is added to this fermented mixture as clay stabilizer to reduction of swelling of clay minerals and stirred well.

This prepared Bio-enzyme is used in our study for stabilization of Shedi soil. The Fig-3 shows the prepared Bio-enzyme used in the present study.

Fig -3: Prepared Bio-enzyme

4.2 Bio-enzyme Dosage Calculation

Based on the literature review, which says the soil should not be disinfected before treating it with Bio-enzyme. The soil samples are prepared mixing with different Bio-enzyme dosages which are 200ml for 3m^3, 200ml for 2.5m^3, 200ml for 2m^3 and 200ml for 1.5m^3 of Shedi soil and keeping them under curing for 0 days, 7 days, 15 days and 30 days. The Bio-enzyme dosage calculation in ml/kg of soil is given below.

1. Bulk density of Shedi soil = 1.39g/cc
2. Bulk density = Weight/Volume
3. Weight = Bulk density × Volume
4. Curing period – 0,7,15 and 30 days (4 curing period with 3 specimens for each)

For Dosage 1:
200 ml for 3.0 m^3 of soil = 1.39 × 3 × 1000 = 4170 kg of soil
For 1 kg = 0.048 ml of Enzyme

For Dosage 2:
200 ml for 2.5 m^3 of soil = 1.39 × 2.5 × 1000 = 3475 kg of soil
For 1 kg = 0.0576 ml of Enzyme

For Dosage 3:
200 ml for 2.0 m^3 of soil = 1.39 × 2 × 1000 = 2780 kg of soil
For 1 kg = 0.0719 ml of Enzyme

For Dosage 4:
200 ml for 1.5 m^3 of soil = 1.39 × 1.5 × 1000 = 2085 kg of soil
For 1 kg = 0.0959 ml of Enzyme

The 4 different Bio-enzyme dosages used in the present study are mentioned in the Table-4.

Table -4: Bio-enzyme Dosages

Dosage	200ml/m^3 of soil	ml/kg of soil
1	3.0	0.048
2	2.5	0.0576
3	2.0	0.0719
4	1.5	0.0959

4.3 Soil Sample Preparation and Test Conducted

The Shedi soil samples were prepared by mixing the soil with appropriate dosage of Bio-enzyme as per the calculation and keeping them under curing for 0 days, 7 days, 15 days and 30 days. Then the Bio-enzyme treated soil samples were tested for compaction, plasticity and UCS test after each curing period. Initially these geotechnical characteristics were determined on the same day of mixing the Bio-enzyme. The remaining soil samples were covered in Polythene bags and kept for curing in desiccators as shown in the Fig-4. The following laboratory tests were conducted on the Bio-enzyme treated Shedi soil using the standard procedure as specified by Bureau of Indian Standards.

1. Plasticity Test (IS:2720(Part-V)-1985 and IS:2720(Part-VI)-1972)
2. Compaction Test (IS:2720(Part-VII) and IS:2720(Part-II)
3. Unconfined Compressive Strength Test (IS:2720(Part-X)-1986)

Fig -4: Curing of Soil Samples in Desiccators

5. RESULTS AND DISCUSSION

5.1 Effect of Bio-enzyme Dosage on Plasticity Characteristics of Shedi Soil

The plasticity test results are presented in Table-5. The liquid limit, plastic limit and plasticity index values for untreated soil were found to be 63.8%, 31.54% and 32.26% respectively. From the Table-5 it is observed that with curing period, the addition of Bio-enzyme to the Shedi soil decreases the liquid limit and plasticity index of soil, whereas an increase in the plastic limit of soil is observed. This can be attributed to the fact that, at liquid limit, the water holding capacity of the soil is more compared to that at plastic limit, leading to a better electrolyte movement in the soil. This enhanced electrolyte movement would have enabled better interaction of Bio-enzyme with soil particles. On the other hand, the plastic limit has shown an increase with curing period. This may probably be due to the aggregation of soil particles as a result of the stabilizing effect of Bio-enzyme. This reduction of the liquid limit and an increase of the plastic limit of Bio-enzyme treated soil with curing period indicate that addition of Bio-enzyme to the soil has reduced its plasticity. Chart-3 and Chart-4 shows the variation in the values of liquid limit and plasticity index of Bio-enzyme treated soil with curing period.

Table -5: Plasticity Characteristics of Shedi Soil mixed with Different Bio-enzyme Dosages

Dosage	Consistency Limits	Curing Period (Days)			
		0	7	15	30
200ml/ 1.5m³	Liquid Limit (%)	53	52	49.4	46.1
	Plastic Limit (%)	33.3	34.5	34.9	35.5
	Plasticity Index (%)	19.7	17.5	14.6	10.6
200ml/ 2.0m³	Liquid Limit (%)	51	49.6	48	45.6
	Plastic Limit (%)	34.1	35.9	35.9	36.0
	Plasticity Index (%)	16.9	13.7	1.10	9.5
200ml/ 2.5m³	Liquid Limit (%)	50	49	47.8	45
	Plastic Limit (%)	34.0	36.7	36.7	36.7
	Plasticity Index (%)	15.9	12.3	11.1	8.3
200ml/ 3.0m³	Liquid Limit (%)	49.5	47.8	47.2	44.5
	Plastic Limit (%)	35.1	37.3	38.3	40.3
	Plasticity Index (%)	14.4	10.5	8.9	4.2

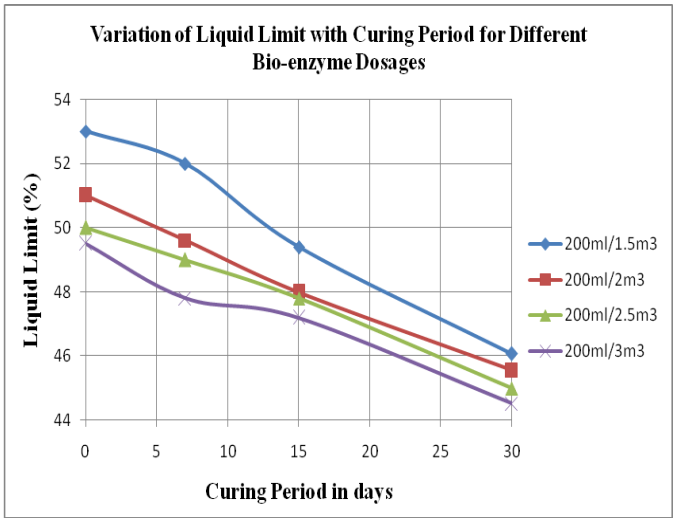

Chart -3: Variation of Liquid Limit with Varying Curing Period

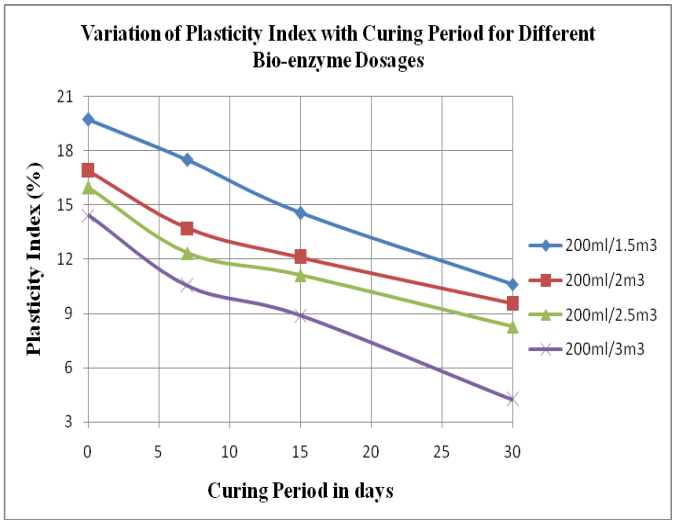

Chart -4: Variation of Plasticity Index with Varying Curing Period

5.2 Effect of Bio-enzyme Dosage on Compaction Characteristics of Shedi Soil

The results of Mini compaction tests conducted on Shedi soil mixed with different dosages of Bio-enzyme and for different curing period are presented in Table-6. The OMC and MDD of the untreated soil were found to be 29% and 1.39g/cc respectively.

From the above Table-6 it is observed that with curing period, the Bio-enzyme treated soil possesses higher maximum dry density meanwhile, there is reduction in optimum moisture content. These results are due to the catalytic enzymes action greatly increasing the wetting process and causing a binding action on the fine materials, decreasing the voids ratio and helping the particles be more densely compacted. And also the Bio-enzymes provide a surface into which the soil microbes can be absorbed. The

microbes are brought close to one another and bond together easily. The resulting products are connected through covalent bonds and once bonded, lower the surface tension of water present in the soil. As the water is dispersed, a cementation occurs, where smaller soil particles come together and fill the voids within the soil, creating dense stratum. Decrease in OMC is due to the effective cat-ion exchange process which generally takes longer period in the absence of such stabilizers.

Table -6: Compaction Characteristics of Shedi Soil mixed with Different Bio-enzyme Dosages (MDD in g/cc and OMC in %)

Dosage	Curing Period							
	0 Days		7 Days		15 Days		30 Days	
	MDD	OMC	MDD	OMC	MDD	OMC	MDD	OMC
200ml/ 1.5m³	1.46	28.0	1.47	26.4	1.48	25.6	1.50	24.1
200ml/ 2.0m³	1.48	26.5	1.51	25.2	1.52	24.6	1.54	23.5
200ml/ 2.5m³	1.49	25.5	1.54	23.4	1.56	23.0	1.60	22.3
200ml/ 3.0m³	1.50	24.0	1.57	23.0	1.60	21.0	1.66	17.8

The variation in Compaction characteristics i.e. MDD and OMC are shown in Chart-5 and Chart-6 respectively. From the Table-6, it is clear that among all the dosage values of Bio-enzyme, at 200ml/3m³ dosage soil has achieved maximum MDD and OMC corresponding to the same dosage is least among the other dosage values.

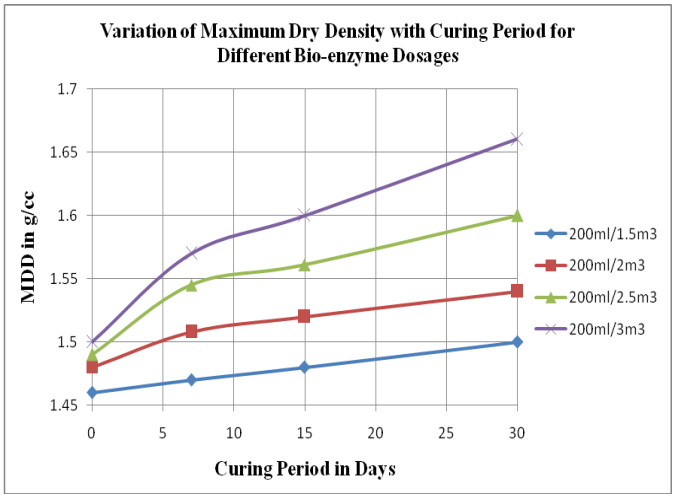

Chart -5: Variation in Maximum Dry Density with Increasing Curing Period

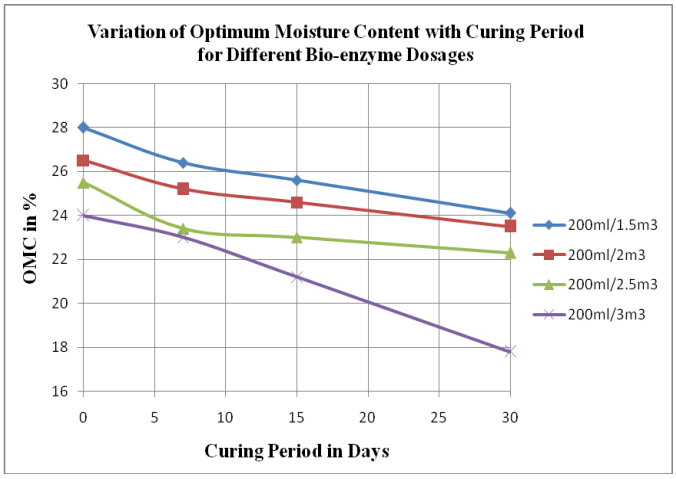

Chart -6: Variation in Optimum Moisture Content with Increasing Curing Period

5.3 Effect of Bio-enzyme Dosage on Strength Characteristics of Shedi Soil

The test results are summarized in Table-7. The Unconfined Compressive Strength (UCS) of Bio-enzyme treated Shedi soil has shown tremendous improvement. The untreated Shedi soil possesses an UCS of 168.62kPa. From the table it is observed that with increase in dosage and curing period, UCS has also increased. With the addition of 200ml/3m³ of Bio-enzyme, the Bio-enzyme treated soil after 30 days curing, has attained UCS value of 849.63kPa, which is about 5.04 times the strength of untreated soil. This is attributed to the effect of cementation and bonding caused due to enzymatic reactions. These reactions have a significant role in the improvement of stiffness and shear strength of the Bio-enzyme treated soil.

Table -7: Variation of UCS with Different Bio-enzyme Dosages

Dosages	UCS of Soil in kPa for Period of Treatment			
	0 Days	7 Days	15 Days	30 Days
Untreated	168.62			
200ml/1.5m³	228.5	239.05	402.59	687.40
200ml/2.0m³	242.36	266.76	414.56	691.69
200ml/2.5m³	267.78	284.90	424.90	709.23
200ml/3.0m³	316.47	340.70	517.72	849.63

The percentage increase in strength of Bio-enzyme treated Shedi soil for various curing period with respect to the untreated soil is presented in Table-8. It is observed from the table that at dosage 200ml/3m³ the UCS of Bio-enzyme treated Shedi soil has increased up to 403.87% after 30 days

of curing period, which was maximum compared to that at other dosages.

Table -8: Percentage Increase in UCS with Different Bio-enzyme Dosages

Dosages	Percentage increase in UCS of soil			
	0 Days	7 Days	15 Days	30 Days
Untreated	-			
200ml/1.5m³	35.51	41.77	138.76	307.66
200ml/2.0m³	43.73	58.20	145.85	310.21
200ml/2.5m³	58.81	68.96	151.99	320.61
200ml/3.0m³	87.68	102.05	207.03	403.87

The variation in Strength characteristics i.e. UCS of Shedi soil mixed with different Bio-enzyme dosages at various curing period is shown in Chart-7 and percentage increase in UCS is shown in the Chart-8.

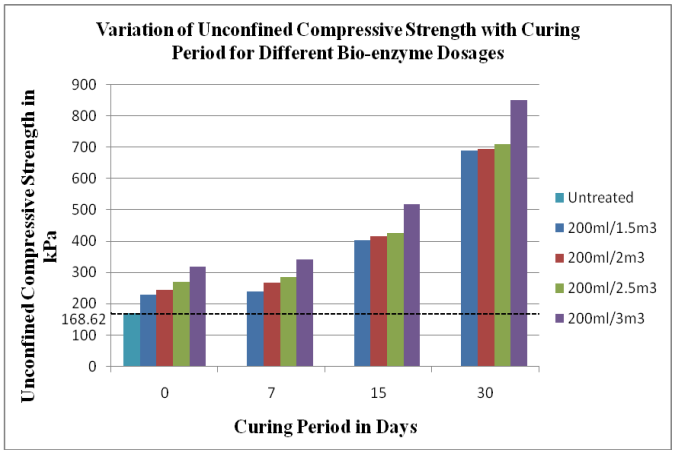

Chart -7: Variation in UCS with Increasing Curing Period

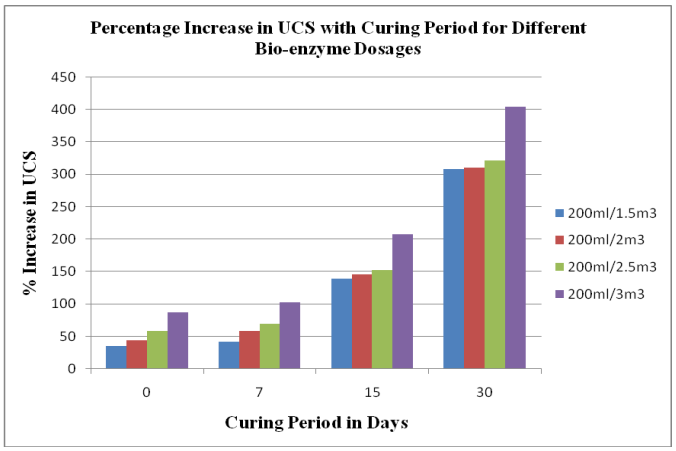

Chart -8: Percentage Increase in UCS with Increasing Curing Period

6. CONCLUSIONS

In this experimental study, the effects of Bio-enzyme on Atterberg's limits, compaction characteristics, strength characteristics and consolidation characteristics of Shedi soil were evaluated. Following conclusions can be drawn from the present study.

1. **Consistency Limits:** By the addition of Bio-enzyme to the Shedi soil the plasticity characteristics were improved. The Liquid Limit and Plasticity index of Shedi soil were decreased by 30.20% and 86.86% respectively compared to its original values after 30 days of curing for the dosage of 200ml/3m³ of soil.
2. **Compaction:** The MDD of Bio-enzyme treated Shedi soil was increased by 19.42%, while the OMC of soil was decreased by 38.62% after 30 days of curing for the dosage of 200ml/3m³ of soil.
3. **Unconfined Compression Test:** The Unconfined Compressive strength of Shedi soil was increased from 168.62kPa to 849.63kPa after 30 days of curing for 200ml/m³, which is about 403.87% when compared to virgin soil.
4. From the present study, it is concluded that 200ml/3m³ dosage of Bio-enzyme is the optimum dosage for the Shedi soil in respect of the consistency index, compaction, strength, consolidation, and swelling characteristics of the soil.

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