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Comparative Study on Black Cotton Soil Stabilization Using Terrazyme and F- Fly ash

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Abstract

For construction projects, the most important factors in any project are its cost, performance, safety, durability and time. Building any type of structure on a black cotton clay surface can be problematic due to the high spreading potential and/or low strength properties of the soil. Soil stabilization is the improvement of soil strength or bearing capacity by compaction, dosing or the addition of suitable additives or stabilizers. Many soil stabilization techniques have been proposed to prevent uneven soil settlement and degradation. Stabilization of black cotton soil using fly ash, lime, rice husks and bio enzyme, an organic, non-toxic liquid enzyme, is a common practice worldwide. called Terrazyme for improving the strength of expansive black cotton clay The present work provides a bio enzyme- and Fly Ash-based approach to soil remediation.

The aim of this research is to improve the technical properties of black cotton soil by adding different percentages of fly ash to it. (5%, 10%, 15%) by ground weight at different doses viz. 1.0 m3 / 200 ml, 1.5 m3 per 200 ml and 2.0 m3 per 200 ml Terrazyme organic non-toxic liquid enzyme and make it suitable for construction.

A series of standard Proctor tests (for calculating MDD and OMC), UCS and California Bearing Capacity (C.B.R) tests are performed on both raw black cotton soil and soil mixed with Terrazyme and fly ash. We compare the properties of raw black cotton soil, black cotton soil mixed with fly ash and Terrazyme. It was observed that the properties of black cotton soil were properly improved by mixing.

Key Words: **Terrazyme, Bio-enzyme, Class F fly ash, Dust, Stabilization, Black cotton soil, CBR, UCS, MDD, OMC** *etc…*

1.0 Introduction

Wide spread of black cotton soil in Bilaspur region has created challenges and problems in construction activities. Therefore, the task was undertaken to study and improve the technical properties of the black cotton soil of Bilaspur district. The process of improving soil and resilience is called soil stabilization. The main objective of stabilization is cost reduction and efficient use of locally available material. Soil stabilization with Class F fly ash offers many advantages, such as improving technical properties, cost-effectiveness and environmental friendliness. Sipat Super Thermal Power Station (NTPC) Sipat Dist. Bilaspur Chhattisgarh which is about 10 km. Bilaspur city generates huge amount of fly ash. Terrazyme is a natural, non-toxic, non-corrosive liquid enzyme preparation, and this Terrazyme, made from plant extracts, improves technical properties and increases soil stability. In this work, different parameters of F-fly ash and Terrazyme were studied on local soil.

1.1 Objectives

1. Determination of geotechnical properties of black cotton soil.
2. Evaluate the effect of Terrazyme on basic soil properties.
3. Evaluate the effects of Terrazyme and F-Fly Ash on basic soil properties.
4. To determine the effect of addition of enzyme and F-fly ash to black cotton soil on its properties such as consistency limits, standard proctor test, free swelling index, California bearing ratio test and unconfined compressive strength of the soil.

ADVANTAGES OF SOIL STABILIZATION

- Improves soil strength and Bearing Capacity.
- Reduce expansiveness and control swell-shrink characteristics.

- Improve the technical properties of soil and make it suitable for construction work.
- Avoid unseen settlement.
- Reduce cost and dust in work environment.

APPLICATIONS:

- Foundations.
- Dam and Reservoir.
- Road constructions

1.2 Experimental Investigation

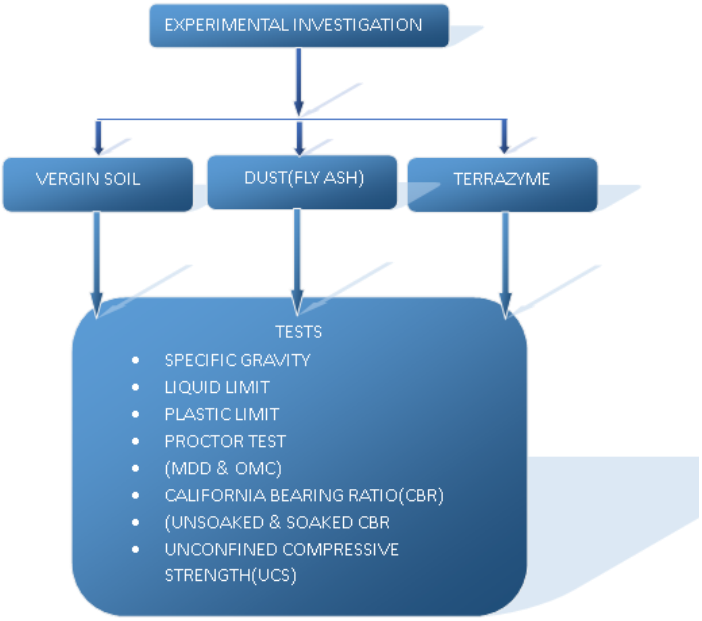

Chart -1: Experimental Investigation

2.0 Material Used

2.1 Black Cotton Soil

Natural black cotton clay soil was obtained from Bilaspur district of Chhattisgarh state. The soil was mined from a depth of 1.5 meters from the natural surface. The soil is dark gray to black and contains light clay. Black cotton ground is very hard when dry, but completely loses its strength when wet. 40-60% of black cotton soil (BC Soil) is less than 0.001 mm. The clay mineral montmorillonite is mainly responsible for the expansion properties of soil. It has a very low load capacity and high swelling and shrinking properties. The resulting soil was air-dried, ground by hand, and soil passing through a 4.75 mm IS sieve was used. The geotechnical and properties of the soil used in this study are given in the table below.

Fig -1: Black Cotton Soil

Table -1: Geotechnical Properties of Soil

S.No.	Property	Value
1	Specific Gravity	2.47
2	Grain size distribution	
	Gravel (%)	2.82
	Sand (%)	66.73
	Clay & Silt (%)	30.45
3	Consistency Limits	
	Liquid Limit (%)	46.46
	Plastic Limit (%)	23.85
	Plasticity Index (%)	22.61
4	I.S .Soil Classification	Clayey Sand (SC)
5	Engineering properties	
	.Max. Dry Densitv, kN'm2	16.1
	OMC (%)	23.2
6	C.B.R (%)	
	Unsoaked	9.16
	Soaked	2.96
7	Unconfined Compressive Strength N/Cm2	15.967

2.2 Terrazyme

Terrazyme is a natural enzyme. Terrazyme was made from molasses obtained during the fermentation process. Terrazyme is a non-toxic, environmentally friendly, non-flammable material. Terrazyme is a natural, non-toxic liquid created from plant extracts, which is widely recognized as a healthy and innovative road construction technology. Terrazyme® Soil Stabilizer is a safe, effective, non-corrosive liquid enzymatic soil stabilizer that significantly improves the properties of soil used in road infrastructures & construction projects. The result is a better and long-lasting soil stabilized road with increased CBR load, reduced soil permeability and increased road strength. They reduce road construction and maintenance costs and improve the overall quality of the road structure. Terrazyme is easy to use and does not harm the soil or its applicators.

Fig -2: Terrazyme

Table -2: Properties of Terrazyme

PARTRICULARS	RESULT
Identity (As It Appears On Label)	N-Zyme
Hazardous Components	None
Boiling Point	100 Degree Celsius
Specific Grayitv	1.05
Melting Point	Liquid
Vapor Density	I
Evaporating Rate	Same as Water
pH Value	4.35
Appearance/Odor	Brown liquid,Non obnoxious
Solubility in Water	Complete

2.3 Fly Ash(F-Class)

Fly ash is a by-product of thermal power plants using coal as fuel. It is a finely divided residue produced during the pulverized combustion of coal, which is transported from the combustion chamber together with the exhaust gases. Generally, fly ash can be classified into C-class fly ash and F-class fly ash. The classification is based on the percentage of calcium oxide in the fly ash. Currently, about 100 thermal power plants in India produce 1.3 million tons of fly ash. Fly ash particles also typically consist of hollow spheres of silicon, aluminum, and iron oxides. as unoxidized carbon, all of which together make up both classes of fly ash pozzolans—silicon, or silicon- and aluminum-containing materials—despite the fact that the chemical can have many varieties, it is generally not considered a plastic fine sludge (ML) (USCS) when using the Unified Soil Classification System. Class F fly ash is not used as often because it is not a self-cementing material and requires an activator such as lime or cement to create pozzolan-stabilized mixtures **(PSM).**

Fig -3: Fly Ash

Table -3: Properties of F - Class Fly Ash (Dust)

S.No.	Property	Value
1	Specific Gravity	1.9801
2	Grain size distribution	
	Gravel (%)	0.20
	Sand (%)	32.93
	Clay & Silt (%)	66.87
3	Consistency Limits	
	Liquid Limit (%)	NP
	Plastic Limit (%)	NP
	Plasticity Index (%)	0
4	Engineering properties	
	.Max. Dry Densitv, kN'm2	11.5
	OMC (%)	28.24
5	C.B.R (%)	
	Unsoaked	30.69
	Soaked	13.76

3.0 EXPERIMENTAL TESTING PROCEDURE

The laboratory studies were carried out on the sample of Black Cotton Soil collected from Bilaspur district and Black cotton soil+ Terrazyme + Fly ash. The tests were carried out both on original soil and Black Cotton soil with Terrazyme and Fly ash collected from National Thermal Power plant Sipat Bilaspur. The clay soil was studied with various percentage of fly ash material. The proportions are 5%, 10% and 15% respectively the fly ash was added with soil sample previously prepared soil mixed with proportion 1.0m3 /per 200ml, 1.5m3/ per 200ml and 2.0m3 /per 200ml an organic, non-toxic, liquid enzyme called Terrazyme and mixed thoroughly by hand mixing in the laboratory. The following tests were carried out by using stabilized clay soil with Terrazyme mixed fly ash material.

The following laboratory tests were carried out as per **IS: 2720.**The test were carried out on both normal soil and stabilized soil.

1. Specific gravity test
2. Atterberg's limits
3. Proctor compaction test
4. California Bearing Ratio value (CBR) test
5. Un Confined Compressive strength (UCS) test

The Mixing was thoroughly carried out manually and the tests were conducted as per standard procedures with under given combination of stages:

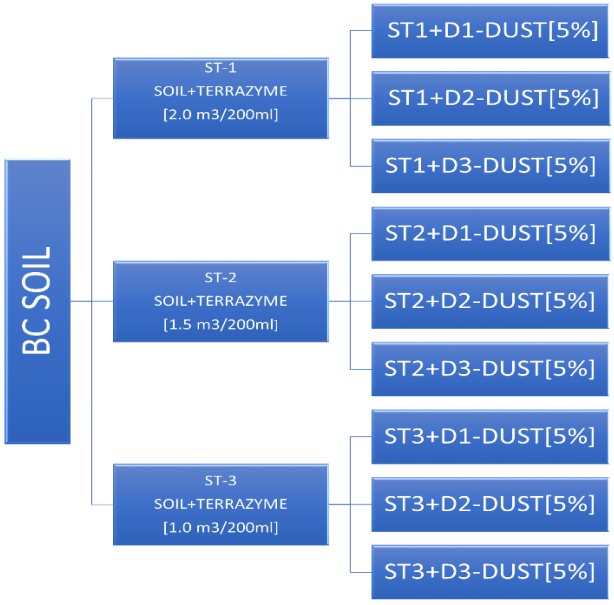

Chart -2: Experimental Stages of stabilized Soil

3.1 Specific Gravity Test

Table -4: Specific Gravity Test Result

SYMBOL	PARTRICULARS	SPECIFIC GRAVITY
S	Black Cotton Soil	2.41
ST1	Soil+Terrazyme(2.0m^3/200ml)	2.442
ST1D1	Soil+Terrazyme(2.0m^3/200ml) + Dust 5%)	2.451
ST1D2	Soil+Terrazyme(2.0m^3/200ml) + Dust 10%)	2.494
ST1D3	Soil+Terrazyme(2.0m^3/200ml) + Dust 15%)	2.489
ST2	Soil+Terrazyme(1.5m^3/200ml)	2.481
ST2D1	Soil+Terrazyme(1.5m^3/200ml) + Dust 5%)	2.51
ST2D2	Soil+Terrazyme(1.5m^3/200ml) + Dust 10%)	2.490
ST2D3	Soil+Terrazyme(1.5m^3/200ml) + Dust 15%)	2.445
ST3	Soil+Terrazyme(1.0m^3/200ml)	2.447
ST3D1	Soil+Terrazyme(1.0m^3/200ml) +DUST 5%	2.435
ST3D2	Soil+Terrazyme(1.0m^3/200ml) +Dust 10%	2.426
ST3D3	Soil+Terrazyme(1.0m^3/200ml)+ Dust 15)	2.421

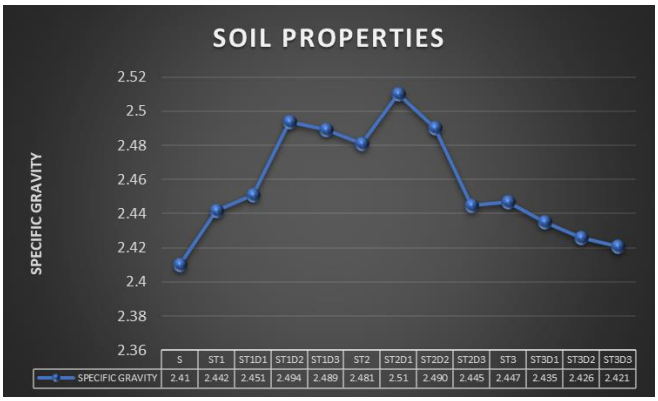

Chart -3: Comparison of Specific Gravity values of soil with Stabilized soil (BC Soil +Terrazyme +F Fly ash)

3.2 Atterberg's Limit (Consistency Limit) Test

Table -5: Atterberg's Limit

SYMBOL	PARTRICULARS	ATTERBERG'S LIMIT		
		LL	PL	PI
S	Black Cotton Soil	46.46	23.85	22.61
ST1	Soil+Terrazyme(2.0m^3/200ml)	46.19	25.84	20.35
ST1D1	Soil+Terrazyme(2.0m^3/200ml) + Dust 5%)	39.46	23.57	15.89
ST1D2	Soil+Terrazyme(2.0m^3/200ml) + Dust 10%)	39.46	23.57	15.89
ST1D3	Soil+Terrazyme(2.0m^3/200ml) + Dust 15%)	36.01	20.53	15.48
ST2	Soil+Terrazyme(1.5m^3/200ml)	43.34	25.04	18.3
ST2D1	Soil+Terrazyme(1.5m^3/200ml) + Dust 5%)	40.16	24.8	15.36
ST2D2	Soil+Terrazyme(1.5m^3/200ml) + Dust 10%)	41.49	22.52	18.97
ST2D3	Soil+Terrazyme(1.5m^3/200ml) + Dust 15%)	34.4	22.51	11.89
ST3	Soil+Terrazyme(1.0m^3/200ml)	46.46	23.85	22.61
ST3D1	Soil+Terrazyme(1.0m^3/200ml) +DUST 5%	46.14	21.7	24.44
ST3D2	Soil+Terrazyme(1.0m^3/200ml) +Dust 10%	44.36	22.61	21.75
ST3D3	Soil+Terrazyme(1.0m^3/200ml)+ Dust 15)	36.36	20.27	16.09

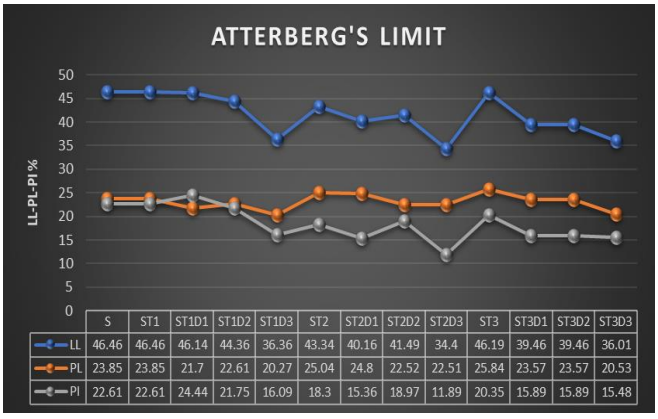

Chart -4: Comparison of Atterberg's Limit values of soil with Stabilized soil (BC Soil +Terrazyme +F Fly ash)

3.3 Proctor Compaction Test

Table -6: Standard Proctor Test Result

SYMBOL	PARTRICULARS	COMPACTION TEST	
		MDD	OMC
S	Plain Soil(Black Cotton Soil)	1.610	23.20
ST1	Soil+Terrazyme(2.0m^3/200ml)	1.616	22.32
ST1D1	Soil+Terrazyme(2.0m^3/200ml) + Dust 5%)	1.610	20.48
ST1D2	Soil+Terrazyme(2.0m^3/200ml) + Dust 10%)	1.580	17.60
ST1D3	Soil+Terrazyme(2.0m^3/200ml) + Dust 15%)	1.604	17.20
ST2	Soil+Terrazyme(1.5m^3/200ml)	1.623	18.50
ST2D1	Soil+Terrazyme(1.5m^3/200ml) + Dust 5%)	1.633	15.06
ST2D2	Soil+Terrazyme(1.5m^3/200ml) + Dust 10%)	1.665	16.55
ST2D3	Soil+Terrazyme(1.5m^3/200ml) + Dust 15%)	1.669	18.40
ST3	Soil+Terrazyme(1.0m^3/200ml)	1.664	16.80
ST3D1	Soil+Terrazyme(1.0m^3/200ml) +DUST 5%	1.665	15.43
ST3D2	Soil+Terrazyme(1.0m^3/200ml) +Dust 10%	1.662	15.32
ST3D3	Soil+Terrazyme(1.0m^3/200ml)+ Dust 15%)	1.661	15.15

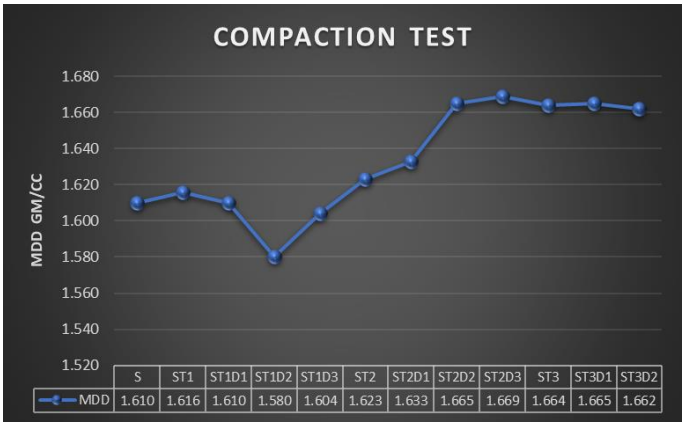

Chart -5: Comparison of MDD values of soil with Stabilized soil (BC Soil +Terrazyme +F Fly ash)

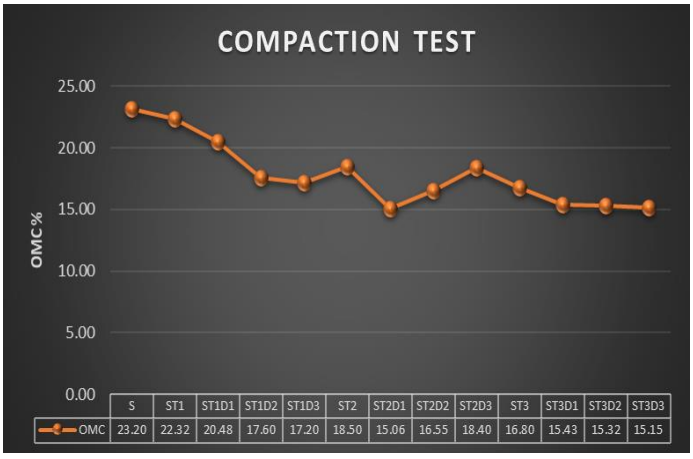

Chart -6: Comparison of OMC values of soil with Stabilized soil (BC Soil +Terrazyme +F Fly ash)

3.4 California Bearing Ratio (CBR) Test

Table -7: CBR Test Result

SYMBOL	PARTRICULARS	CBR(UNSOAKED)		CBR(SOAKED)	
		2.5 mm Penetration	5.0 mm Penetration	2.5 mm Penetration	5.0 mm Penetration
S	Black Cotton Soil	9.16	8.08	2.96	2.31
ST1	Soil+Terrazyme(2.0m^3/200ml)	9.74	7.81	3.39	2.55
ST1D1	Soil+Terrazyme(2.0m^3/200ml) + Dust 5%)	10.000	8.54	3.47	2.7
ST1D2	Soil+Terrazyme(2.0m^3/200ml) + Dust 10%)	8.14	7.64	4.09	3.16
ST1D3	Soil+Terrazyme(2.0m^3/200ml) + Dust 15%)	8.07	7.49	5.91	4.26
ST2	Soil+Terrazyme(1.5m^3/200ml)	13.58	13.38	4.45	3.36
ST2D1	Soil+Terrazyme(1.5m^3/200ml) + Dust 5%)	14.49	12.6	3.72	2.87
ST2D2	Soil+Terrazyme(1.5m^3/200ml) + Dust 10%)	12.41	11.8	4.71	3.8
ST2D3	Soil+Terrazyme(1.5m^3/200ml) + Dust 15%)	6.61	6.03	4.93	3.87
ST3	Soil+Terrazyme(1.0m^3/200ml)	9.45	8.35	3.78	3.67
ST3D1	Soil+Terrazyme(1.0m^3/200ml) +DUST 5%	10.00	8.35	3.7	3.19
ST3D2	Soil+Terrazyme(1.0m^3/200ml) +Dust 10%	10.15	8.66	3.77	3.48
ST3D3	Soil+Terrazyme(1.0m^3/200ml)+ Dust 15)	8.28	7.54	3.96	3.23

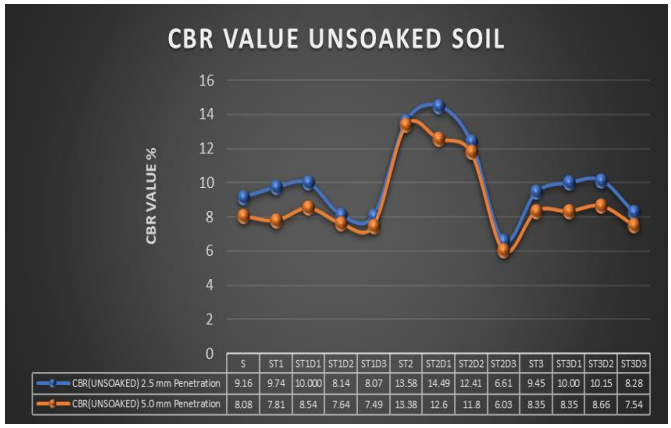

Chart -7: Comparison of CBR(Unsoaked) values of soil with Stabilized soil (BC Soil +Terrazyme +F Fly ash)

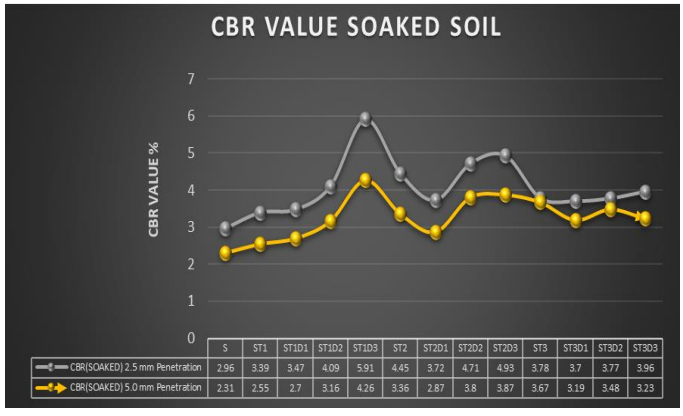

Chart -8: Comparison of CBR(Soaked) values of soil with Stabilized soil (BC Soil +Terrazyme +F Fly ash)

3.5 Un Confined Compressive Strength (UCS) Test

Table -8: UCS Test Result

SYMBOL	PARTRICULARS	UCS N/Cm2
S	Black Cotton Soil	15.919
ST1	Soil+Terrazyme(2.0m^3/200ml)	16.132
ST1D1	Soil+Terrazyme(2.0m^3/200ml) + Dust 5%)	17.874
ST1D2	Soil+Terrazyme(2.0m^3/200ml) + Dust 10%)	19.075
ST1D3	Soil+Terrazyme(2.0m^3/200ml) + Dust 15%)	21.476
ST2	Soil+Terrazyme(1.5m^3/200ml)	23.332
ST2D1	Soil+Terrazyme(1.5m^3/200ml) + Dust 5%)	25.369
ST2D2	Soil+Terrazyme(1.5m^3/200ml) + Dust 10%)	27.898
ST2D3	Soil+Terrazyme(1.5m^3/200ml) + Dust 15%)	29.938
ST3	Soil+Terrazyme(1.0m^3/200ml)	29.123
ST3D1	Soil+Terrazyme(1.0m^3/200ml) +DUST 5%	29.292
ST3D2	Soil+Terrazyme(1.0m^3/200ml) +Dust 10%	29.421
ST3D3	Soil+Terrazyme(1.0m^3/200ml)+ Dust 15)	29.142

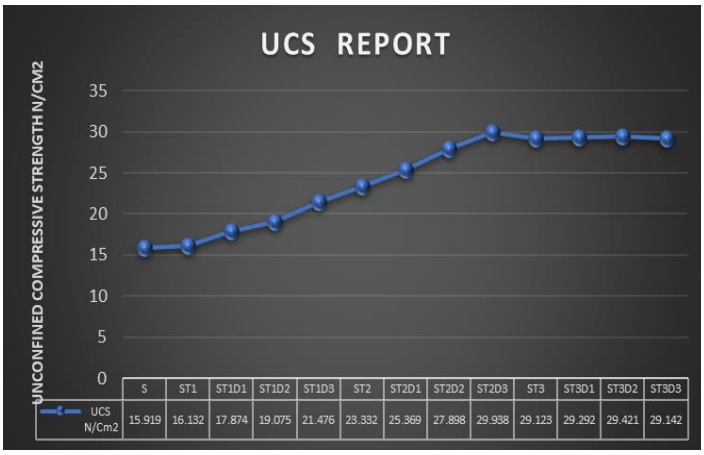

Chart -9: Comparison of UCS values of soil with Stabilized soil (BC Soil +Terrazyme +F Fly ash)

4.0 RESULT DISCUSSION

4.1 Atterberg Limit Tests

The results of plastic limit and liquid limit tests are presented in Table -5 & Chart-5. Plasticity index was calculated as the difference between liquid limit and plastic limit. The value of plasticity index is a critical indicator of the swelling characteristics of the soil; the lower the plasticity index value, the less is the swelling potential. It is seen that the plasticity index of clay (and the potential of swelling) decreased with the addition of Terrazyme & fly ash. In this way, it could be said that the potential of swelling also decreased. According to the plasticity chart, the classification of the soil changed from SC to SP with addition of 15 % fly ash and Terrazyme dose of 2.0m3 /200ml).

4.2 Compaction

Table 6 and Chart- 6 & 7 demonstrate optimum moisture content and maximum dry density relationships for the soil stabilized with different doses of Terrazyme and fly ash contents. It is seen that the maximum dry density initially decreased, the initial decrease may be caused due to the difference of the particle density between kaolinite and fly ash. However, there was a gradual increase with addition of Terrazyme and fly ash with combination from 5 % to 10 % fly Ash. This may be due to the fly ash particles starting to fill the voids of kaolinite resulting in higher density. Terrazyme improves the chemical and physical characteristics of soil through closer particle bonding and higher compaction densities. The optimum moisture content increased with 10 % of fly ash, thereafter, it generally decreased with further increase in fly ash content. This could be due to chemical reactions starting with enough fly ash that leads to excess heat.

4.3 CALIFORNIA BEARING RATIO(CBR)

When Terrazyme was added at 200 ml/1 m3, 200 ml/2 m3 and 200 ml/3 m3 additional percentages of fly ash (5%, 10%, 15%), it was found that 200 ml/1.5 m3. higher CBR value than other combinations. When fly ash was added to soil at 5, 10 and 15% higher levels of Terrazyme and tested for CBR, the optimum percentage was found to be 200ml/1.0m3 of Terrazyme added. Comparing fly ash and Terrazyme, it was found that 200ml/1.5m3 added Terrazyme had a higher CBR value than 200ml/1.0m3 added Terrazyme. we Found that the CBR value increased as the dose decreased and the CBR value was higher at the optimum dose Terrazyme.

5.0 CONCLUSION

According to the data and results acquired from the experimental work on soil stability investigation with different percentages of fly ash i.e. (0%,5%,10%,15%) with combination of different doses of Terrazyme proportion 1.0m3 /per 200ml, 1.5m3/ per 200ml and 2.0m3 /per 200ml the following conclusion can be drawn as under in the aspect of strength properties due to application o as a stabilizing agent for the natural black cotton soil.

From the above data, the maximum dry densities are found to be virgin soil 'S" is 1.610 g/cc, 1.601 g/cc for ST1D3, 1.669 g/cc for ST2D3, 1.661 g/cc for ST3D3. Based on the results from the compaction test, it can be stated that with increase in percentage of Terrazyme &

fly ash the compaction parameter i.e. MDD (maximum dry density) is increased up to 1.669g/cc at 15% fly ash content with 1.5m3/ per 200ml dose of Terrazyme and then decreases. Other compaction parameter i.e. OMC (optimum moisture content) is found out to be 17.20 % for ST1D3. So it is concluded that for effective soil stabilization at 15% fly ash content with 1.5m3/ per 200ml dose of Terrazyme gives better result.

Based on CBR test results, it is observed that addition of fly ash & Terrazyme as stabilizing agent for clayey soils produces significant increase in CBR value. It is concluded that, with increase in fly ash & Terrazyme doses the CBR values are also increased considerably and is found to be maximum 14.49 for ST2D1.

6.0 RESULT

The following conclusions are made from the following study:

- The results from this study bring out the potential benefits of using Terrazyme & Fly Ash to reduce the plasticity properties & increase volumetric stability of soil.
- Addition of Terrazyme & Fly Ash in the soil increases the percentage of coarser particles and reduce in the clay content and also reduces the liquid and plastic limit of the undefined soil.
- This liquid and plastic limit decreases which are irrespective to percentage of Terrazyme used in the soil. Terrazyme also reduces the void spaces in the soil and thus, increase in the compaction and the density of soil.
- The unconfined compressive strength of black cotton soil will increase with of Terrazyme dosage.
- From the study of results of experiments, it was observed that changes in index properties (i.e., specific gravity, liquid limit, plastic limit, shrinkage limit and sieve analysis).
- Enzyme (Terrazyme) & Fly Ash reduces the compaction effort and improves soil workability during specimen preparation; where MDD increases and OMC decreases with addition of Bio-Enzyme (Terrazyme)
- It decreases the swelling property as addition of Terrazyme increases with black cotton soil.

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