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Experimental Study of Ground Improvement of Black Cotton Soil Using Enzyme & Polymer

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Abstract - *The most important requirement of any project after performance criteria is its economical feasibility and serviceability criteria. The conventional methods are time consuming and are not economically feasible. Hence there is a need to discover the other possible ways to satisfy the performance as well as economical criteria. Vast areas of India consist of Black Cotton Soil which has high clay content, low strength and minimal bearing capacity. The poor engineering performance of such soils has forced Engineers device a cost effective and ecofriendly methods for improving the engineering properties of poor soils.*

This research project investigates the impact of bio-enzyme and polymers on the strength of clayey soils.The effect of the bio-enzyme and acrylic polymer on Atterberg's limits, compaction characteristics, and shear strength of soil was studied. On the basis of experimental results the optimum dosage of Bio-enzyme and polymer was obtained. The Bio-enzyme has emerged as a material which drastically improves the properties of soil, is eco-friendly and is economical in long run. Supplied in liquid form, acrylic polymers are easily soluble in water, simplifying soil compaction and reducing the time and cost associated with traditional stabilizers. Bio-enzymes and polymer being non-toxic and biodegradable, offer a sustainable solution for enhancing soil stability, making them a promising alternative to conventional methods

***Key Words*: Bio-enzymes, polymer, Black Cotton Soil, cost-effective, eco-friendly, biodegradable**

1.INTRODUCTION

Sub-grade soil, crucial in construction, often lacks the strength to bear loads. Traditional stabilizers like lime and cement have drawbacks: lime dust is environmentally harmful, and materials like fly ash can be costly to transport. Grouting, an older method, increases soil bearing capacity but is uneconomical for sub-grade stabilization. Bio-zyme and acrylic polymer offer eco-friendly, cost-effective alternatives. Derived from natural substances, they enhance soil properties without environmental pollution. This study analyzes the effects of Bio-zyme and polymer on improving soil shear strength, presenting them as promising alternatives to conventional stabilizers.

1.1 Aims & Objectives

- To characterize the effect of Bio-enzyme (Bio-zyme) and polymer (Acrylic polymer) on the soil.
- To study the effect of varying dosages of Bio-enzyme (Bio-zyme) and polymer (Acrylic polymer) on strength & other characteristics identified soil.
- To find out optimum Bio-enzyme (Bio-zyme) and polymer (Acrylic polymer) dosage required for selected soil
- To study the properties of stabilizer used in soil stabilization.

1.2 MATERIALS USED

Black cotton soil is a highly clayey soil. The black colour in Black cotton soil is due to the presence of titanium oxide in small concentration. The Black cotton soil has a high percentage of clay, which is predominantly montmorillonite in structure and black or blackish grey in colour. Expansive soils are the soils which expand when the moisture content of the soils is increased. The clay mineral montmorillonite is mainly responsible for expansive characteristics of the soil. The expansive soils are also called swelling soils or black cotton soils. The structures on Black cotton soil bases develop undulations at the road surface due to loss of strength of the sub-grade through softening during monsoon.

Bio-enzymes is a natural, non-toxic, noncorrosive and non-inflammable liquid, produced by formulating vegetable extracts. Organic enzymes come in liquid form. They are perfectly soluble in water, brown in colour with smell of molasses. Their aroma has no effect. Neither gloves nor masks are required during handling. Bio-zyme is specially formulated to modify the engineering properties of soil. They require dilution in water before application. Bio-zyme when added to water and mixed with soil alters the engineering properties depending upon the type of the soil and dosage of enzyme. These enzymes are liquid additives, which act on

the soil to reduce the voids between soil particles and minimize absorbed watering the soil for maximum compaction. The application of Bio-zyme enhances weather resistance and increases load bearing capacity of soils.

Acrylic Polymer are formed of long molecular chains (monomers) which are held together by covalent bonds. Polymers may be natural or synthetic and are classified functionally as cationic, anionic and non-ionic polymers. Polymers provide physical bonding between the soil particles rather than forming a new mineral by means of chemical reaction acrylic polymers are produced during the manufacturing of plastic goods like acrylic name plates etc. The material used in this study was collected from manufacturing unit of name plates from local vicinity.

2. RESULTS & DISCUSSION

Optimum Moisture Content and Maximum Dry Density value on soil and soil with enzyme + polymer is presented. The 0% enzyme + polymer mixture on soil taken for making correlation between soil having 0% enzyme + polymer and soil with 2.5%, 5%, 7.5%, 10%.

Table -1: Properties of Black cotton soil.

Sr.No.	Properties	Values obtained
1	Specific Gravity	2.53
2	Co-efficient of Curvature	1.024
3	Uniformity Co-efficient	6.4
4	Liquid Limit	22
5	Plastic Limit	20.64
6	MDD	1.477
7	OMC	23.33

Table -2: Grain Size Analysis of Black Cotton Soil

Sieve Size (mm)	Mass of soil retained (gm)	% Of soil retained (%)	Cumulative % retained (%)	% soil passing (%)
12.50	0	0	0	100
9.5	162	10.8	10.8	89.2
6.7	124.5	8.3	19.1	80.9
4.75	155.5	10.36	29.47	70.53
2.36	232.5	15.5	44.97	55.03
1.18	342.5	22.83	67.81	32.19
0.600	258.5	17.23	85.04	14.96
0.300	114.5	7.63	92.66	7.34
0.150	68	4.53	97.20	2.8
Pan	42	2.8	100	0

Table -3: Mould Weight of Standard Proctor Test of BC Soil

Trial No.	1	2	3	4	5	6
Wt. of mould without collar (W1) gm	5680	5680	5680	5680	5680	5680
Wt. of mould + compacted soil (W2) gm	7200	7315	7390	7470	7555	7540
Wt. of compacted soil (V1) gm	1520	1635	1710	1790	1875	1860
Bulk density (V1/V)	1.548	1.665	1.822	1.823	1.909	1.894

Table -4 Water Content by Standard Proctor Test of Black Cotton Soil

Trail No.	1	2	3	4	5	6
Mass of empty cylinder (M1)	21.5	19	18	20	19.5	19.5
Mass of container + wet soil (M2)	55.5	56.5	36.5	51.5	52.5	45.5
Container + dry soil (M3)	51.5	50.5	33	45	43.3	39.5
Water content (%)	13.33	19.04	23.33	26	25.31	30

Table -5: Dry density Vs Water Content of Black Cotton soil

Sr. No.	Dry Density	Water Content
1	1.365	13.33
2	1.398	19.04
3	1.477	23.33
4	1.446	26
5	1.438	30

Table -6: liquid limit test of black cotton soil without enzyme + polymer

Determination No.	1	2
Number of blows	17	30
Wt. of container (W0)	11	11
Wt. of container + Wt. of wet soil (W1)	29.5	20.718
Wt. of container + Wt. of dry soil (W2)	22.16	17.160
Wt. of water (W1-W2)	7.34	14.558
Wt. of oven dry soil (W2-W0)	11.16	17.160
Water content (%)	65.7	57.75

Table -7: liquid limit test of black cotton soil with 2.5% enzyme + polymer

Determination No.	1	2	3
Number of blows	38	28	33
Wt. of container (W0)	-	-	-
Wt. of container + Wt. of wet soil (W1)	6.486	4.479	6.049
Wt. of container + Wt. of dry soil (W2)	4.125	3.470	3.850
Wt. of water (W1-W2)	2.361	2.009	2.199
Wt. of oven dry soil (W2-W0)	4.125	3.470	3.850
Water content (%)	57.12	57.24	57.90

Table -8: Liquid limit test of black cotton soil with 5% enzyme + polymer

Determination No.	1	2	3
Number of blows	32	29	30
Wt. of container (W0)	-	-	-
Wt. of container + Wt. of wet soil (W1)	6.888	6.035	9.718
Wt. of container + Wt. of dry soil (W2)	4.300	3.716	6.160
Wt. of water (W1-W2)	2.588	2.319	3.558
Wt. of oven dry soil (W2-W0)	4.300	3.716	6.160
Water content (%)	60.18	62.4	57.75

Table -9: Liquid limit test of black cotton soil with 7.5% enzyme + polymer

Determination No.	1	2	3
Number of blows	32	20	40
Wt. of container (W0)	-	-	-

Wt. of container + Wt. of wet soil (W1)	55.827	.536	4.974
Wt. of container + Wt. of dry soil (W2)	3.638	3.433	3.130
Wt. of water (W1-W2)	2.189	2.103	1.844
Wt. of oven dry soil (W2-W0)	3.638	3.433	3.130
Water content (%)	60.17	61.25	58.91

Table -10: Liquid limit test of black cotton soil with 10% Polymer + Enzyme

Determination No.	1	2	3
Number of blows	44	17	33
Wt. of container (W0)	-	-	-
Wt. of container + Wt. of wet soil (W1)	4.233	5.150	5.207
Wt. of container + Wt. of dry soil (W2)	3.331	2.694	3.347
Wt. of water (W1-W2)	0.902	2.456	1.860
Wt. of oven dry soil (W2-W0)	3.331	2.694	3.347
Water content (%)	27.07	91.1	55.57

Table -11: plastic limit test of black cotton soil with 0% enzyme + polymer

Determination No.	1	2	3
Empty weight of container (W1)	9.353	11.276	8.792
Wt. of container + Wt. of soil (W2)	11.667	13.391	13.391
Wt. of container + dry soil (W3)	11.078	15.797	12.200
Wt. of dry soil (W3-W1)	1.725	4.521	3.408
Wt. of water in soil (W3-W2)	0.589	1.572	1.191
Water content (%)	34.64	34.77	34.95
Average plastic limit (%)	34.786		

Table -12: plastic limit test of black cotton soil with 2.5% enzyme + polymer

Determination No.	1	2	3
Empty weight of container (W1)	20.17	20.97	21.15
Wt. of container + Wt. of soil (W2)	25.45	26.16	23.019
Wt. of container + dry soil (W3)	24.09	24.86	21.80
Wt. of dry soil (W3-W1)	3.92	3.71	3.63
Wt. of water in soil(W3-W2)	1.35	1.30	1.22
Water content(%)	34.43	35.05	33.5
Average plastic limit (%)	34.33		

Table -13: plastic limit test of black cotton soil with 5% enzyme + polymer

Determination No.	1	2	3
Empty weight of container (W1)	18.212	19.603	21.612
Wt. of container + Wt. of soil (W2)	21.635	22.091	24.391
Wt. of container + dry soil (W3)	20.657	21.383	23.550

Wt. of dry soil (W3-W1)	2.445	1.780	1.938
Wt. of water in soil (W3-W2)	0.978	0.708	0.841
Water content (%)	40.00	39.77	43.39
Average plastic limit (%)	41.05		

Table -14: plastic limit test of black cotton soil with 7.5% enzyme + polymer

Determination No.	1	2	3
Empty weight of container (W1)	19.346	20.042	22.133
Wt. of container + Wt. of soil (W2)	21.750	22.635	24.636
Wt. of container + dry soil (W3)	21.052	21.867	23.900
Wt. of dry soil (W3-W1)	1.706	1.825	1.767
Wt. of water in soil (W3-W2)	0.698	0.768	0.736
Water content (%)	40.91	42.08	41.65
Average plastic limit (%)	41.55		

Table -15: plastic limit test of black cotton soil with 10% enzyme + polymer

Determination No.	1	2	3
Empty weight of container (W1)	11.276	20.765	11.300
Wt. of container + Wt. of soil (W2)	13.950	23.763	13.241
Wt. of container + dry soil (W3)	13.190	22.947	12.727
Wt. of dry soil (W3-W1)	1.914	2.189	1.427
Wt. of water in soil (W3-W2)	0.760	0.816	0.514
Water content (%)	39.70	37.27	36.01
Average plastic limit (%)	37.66		

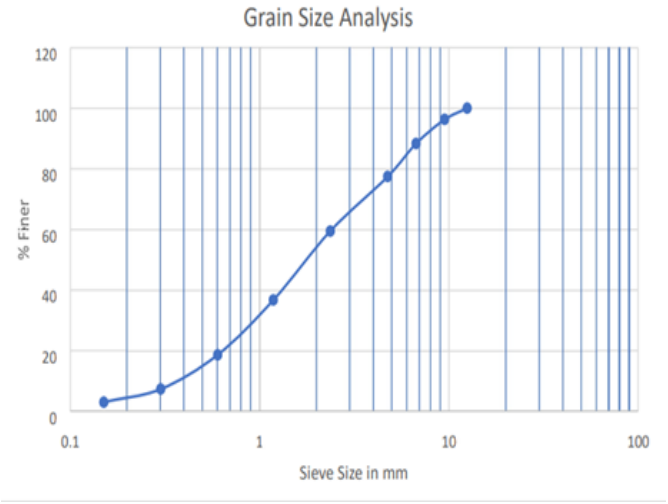

Chart -1: Grain Size Analysis of Black Cotton Soil

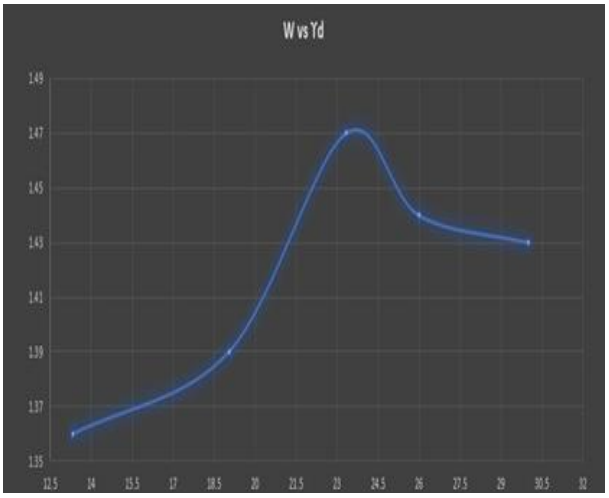

Chart -2: Dry Density V/s Water Content for Black Cotton Soil

Normal Stress (kPa)	Max. Shear Stress (kPa0
50	34
100	54.33
200	92.33

Automatic Calculations	
Cohesion (kPa)	15
friction angle (ϕ)	21.24939952

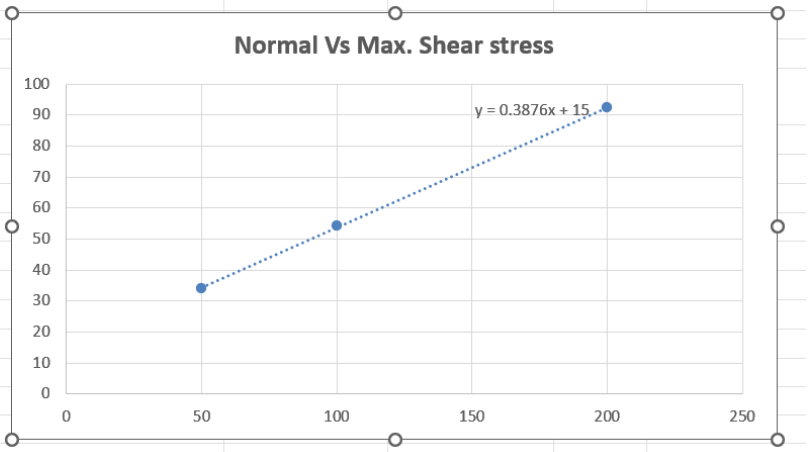

Chart -3: Direct Shear Test results without Bio-enzyme + Polymer

Normal Stress (kPa)	Max. Shear Stress (kPa)
50	40.36
100	58.42
200	95.83

Automatic Calculations	
Cohesion (kPa)	21.655
friction angle (ϕ)	20.29439375

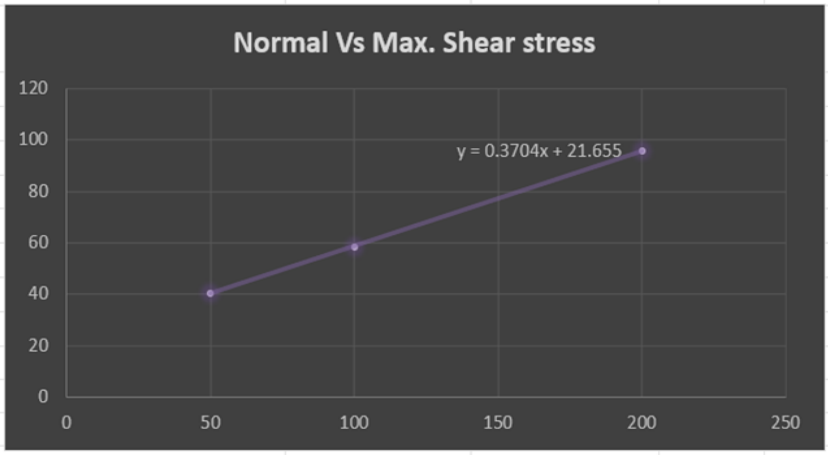

Chart -4: Direct Shear Test results with 2.5% Bio-enzyme + Polymer

Normal Stress (kPa)	Max. Shear Stress (kPa)
50	53.52
100	78.95
200	132.86

Automatic Calculations	
Cohesion (kPa)	26.565
friction angle (ϕ)	27.87585572

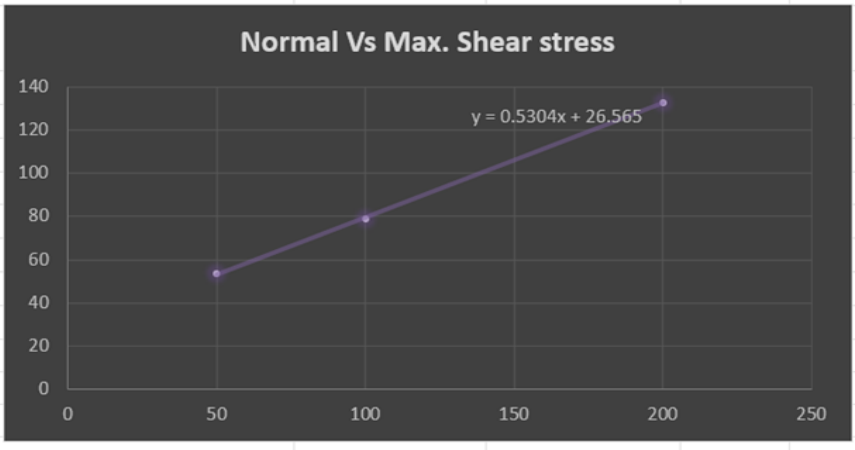

Chart -5: Direct Shear Test results with 5% Bio-enzyme + Polymer

Normal Stress (kPa)	Max. Shear Stress (kPa)
50	48.66
100	76.28
200	124.86

Automatic Calculations	
Cohesion (kPa)	24.37
friction angle (ϕ)	26.93056953

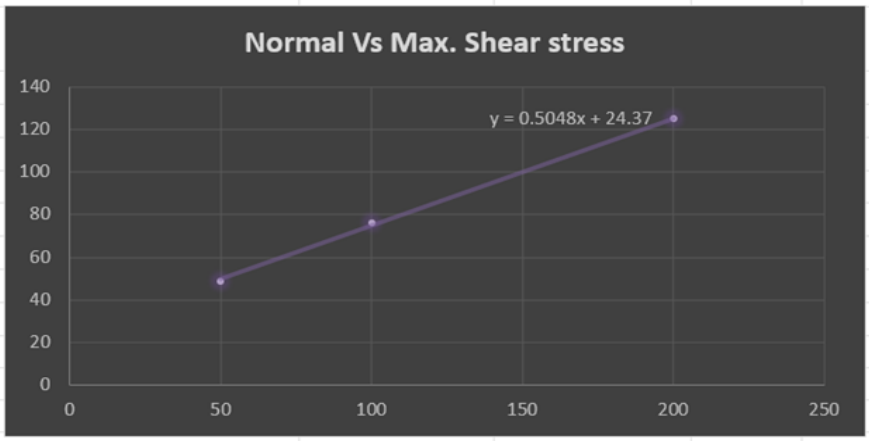

Chart -6: Direct Shear Test results with 7.5% Bio-enzyme + Polymer

Normal Stress (kPa)	Max. Shear Stress (kPa)
50	46.36
100	69.87
200	118.23

Automatic Calculations	
Cohesion (kPa)	22.18
friction angle (ϕ)	25.6006343

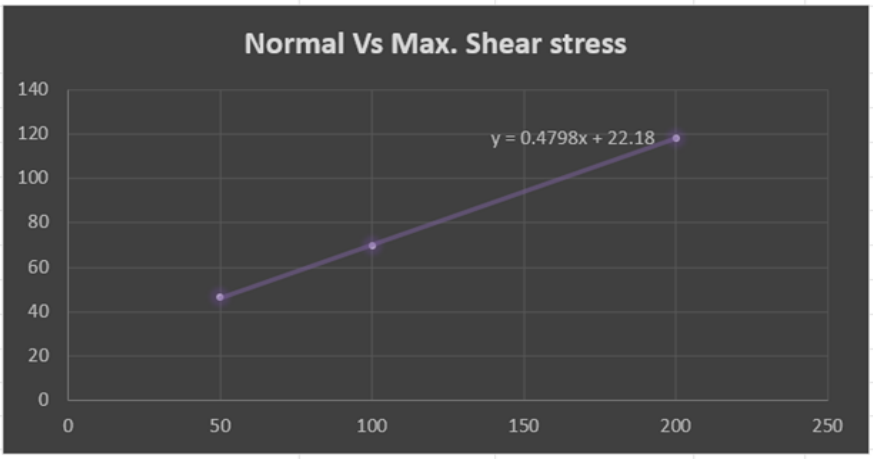

Chart -7: Direct Shear Test results with 10% Bio-enzyme + Polymer

Discussion:

The specific gravity of black cotton soil is **2.53**.

The soils taken for study are well graded clayey soils.

The MDD of Black soil is **1.477 gm/cc** & OMC is **23.33%.**

3. CONCLUSIONS

- Stabilization of soil using Polymer and bio-enzyme resulted in significant increase in Shear strength value of black cotton soil.
- Maximum Shear strength value is achieved at dose of 5% Polymer and bio-enzyme for black cotton soil.

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