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## Optimization of Black Cotton Soil Stabilization Using Lime and Bamboo Fiber Mixture for Sustainable Road Subgrade Construction

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**Abstract-** Black cotton soil is highly expansive in nature and exhibits significant swelling and shrinkage behavior due to variations in moisture content, making it unsuitable for construction purposes without proper stabilization. This study focuses on improving the engineering properties of black cotton soil by using lime and bamboo fibres as stabilizing agents. The experimental investigation was carried out to evaluate the effect of varying percentages of lime (0% to 8%) and bamboo fibres (2% to 8%) on the physical and mechanical properties of the soil. Laboratory tests such as sieve analysis, Atterberg limits, Standard Proctor test, California Bearing Ratio (CBR), and Unconfined Compressive Strength (UCS) were conducted to determine the changes in soil characteristics. The results showed that the addition of lime reduces the liquid limit and plasticity index while increasing the plastic limit, indicating improved soil stability. Compaction characteristics revealed a decrease in maximum dry density (MDD) and an increase in optimum moisture content (OMC) with increasing lime content. The strength parameters, including CBR and UCS, showed significant improvement up to an optimum lime content of 4%. Further enhancement in strength was observed with the inclusion of bamboo fibres, where optimum performance was achieved at 2% fibre content. The combined effect of lime and bamboo fibres resulted in increased load-bearing capacity, improved shear strength, and reduced swelling characteristics of black cotton soil. Based on the experimental results, the optimum proportions of lime and bamboo fibres were found to be 4% and 2%, respectively. The stabilized soil can be effectively used as a subgrade material in pavement construction, providing a cost-effective and sustainable solution for weak soil improvement.

**Keywords:** Black Cotton Soil, Soil Stabilization, Lime, Bamboo Fiber, CBR, UCS, Sustainable Construction, Subgrade.

### I. INTRODUCTION

The construction industry has a significant impact on the environment. Therefore, it is important to acquire knowledge about improvements or use of alternative materials that reduce the impact on the environment from construction. Besides, the development of the society requires more environmentally friendly construction. A developing country like India which has a large geographical area and population, demands vast infrastructure i.e. network of roads and buildings. Everywhere land is being utilized for various structures from ordinary house to sky scrapers, bridges to airports and from rural roads to expressways. Almost all the civil engineering structures are located on various soil strata. Soil can be defined as a material consisting of rock particles, sand, silt, and clay. It is formed by the gradual disintegration or decomposition of rocks due to natural processes that includes disintegration of rock due to stresses arising from expansion or contraction with temperature changes. Weathering and decomposition from chemical changes that occur when water, oxygen and carbon dioxide gradually combine with minerals within the rock formation, thus it is breaking down to sand, silt and clay. Transportation of soil materials by wind, water and ice forms different soil formations such as those found in river deltas, sand dunes and glacial deposits. Temperature, rainfall and drainage play important roles in the formation of soils as in the different climatic regions. Under different drainage regimes, different soils will be formed from the same original rock formation.

In the Soil stabilization process, soil properties are improving the engineering performance of the soils. The properties are mostly density, water content, plasticity and strength. Changes in the soil properties is the temporary enhancement of sub grade stability. Stabilization can be used to treat a wide range of sub-grade materials from expansive clays to granular materials. The main advantages of soil stabilization process have higher resistance, reduces in plasticity, lower permeability, and reduction of pavement thickness. Stabilization of expansive soils its controls the potential of the soils for changes in volume, and improves the strength. In the field of geotechnical engineering. Expansive soils are known as shrink swell or swelling soils. In India, soils are classified into six groups namely alluvial soil, marine soil, laterite and lateritic deposits, expansive soils, sand dunes and boulder deposits. On an average 1 lakh sq.km area is covered by lateritic soil deposits, 3 lakhs sq.km area is covered by black cotton soil, and 5 lakhs sq.km area is covered by sand dunes. Encountering land having soft soil for construction leads to an attention towards adopting ground improvement techniques such as soil stabilization. Soil stabilization is the process which involves enhancing the physical properties of the soil in order to improve its strength, durability etc. by blending or mixing it with additives. The different types of methods used for soil stabilization are: Soil stabilization using cement, Soil stabilization using lime, Soil stabilization using bitumen, Chemical stabilization and a new emerging technology of stabilization that is stabilization of soil by using Geo textiles and Geo synthetic fibers. In this project, we are making use of lime and bamboo fibers (as geo synthetic material) for stabilization of black cotton soil. With various proportions of this additive (i.e. lime 2%, 4%, 6%, and 8% and bamboo fiber 2%, 4%, 6% and 8%) and mix proportion (i.e lime + bamboo fiber (1+1), (2+2), 3+3), (4+4)) black cotton soil is stabilized. With the introduction of lime and bamboo fibers to the soil the CBR values will improve and thickness of pavement layer also gets reduced. It also reduces the intensity of stress on subgrade. Lime is very actual in treating heavy plastic clayey soils and bamboo fibers is such a geosynthetic material which is easily available, eco-friendly and also cost effective. With the application of soil stabilization method in construction the overall cost gets reduced when compared to the ordinary method of construction. The advantages of this project are that to add bamboo fiber in soil stabilization is economically cheap as well as a superior concrete can be made.

## II. METHODOLOGY

### MATERIALS USED:

In this project soil stabilization of black cotton soil by using lime and bamboo fiber.

1. Lime proportions (i.e 2%, 4%, 6%, and 8%)
2. Bamboo Fiber proportions (i.e. 2%, 4%, 6%, and 8%)
3. Mix proportions (i.e. (1+1), (2+2), 3+3), (4+4))



[Fig.4.1: Black cotton soil was acquired from the site at Achalpur, Amravati]



[Fig.4.2: Collect lime from local market, Laxmi Hardware, Achalpur, Amravati]



[Fig.4.3: Bamboo fiber collects from local market, Sakpal bamboo work, Achalpur, Amravati]



[Fig.4.4: Collect Undisturbed sample by using core cutter]



[Fig.4.5: Bamboo fiber cuts into grain size]



[Fig.4.6: Mixing lime with black cotton soil]



[Fig.4.7: Mixing bamboo fiber with black cotton soil]



[Fig.4.8: Mixing of lime, bamboo fiber and black cotton soil]

In this project, we are making use of lime and bamboo fibers (as geo synthetic material) for stabilization of black cotton soil. With various proportions of this additive (i.e. lime 2%, 4%, 6%, and 8% and bamboo fiber 2%, 4%, 6% and 8%) black cotton soil is stabilized. With the introduction of lime and bamboo fibers to the soil the CBR values will improve and thickness of pavement layer also gets reduced. It also reduces the intensity of stress on subgrade. Lime is very actual in treating heavy plastic clayey soils and bamboo fibers is such a geosynthetic material which is easily available, eco-friendly and also cost effective. With the application of soil stabilization method in construction the overall cost gets reduced when compared to the ordinary method of construction.

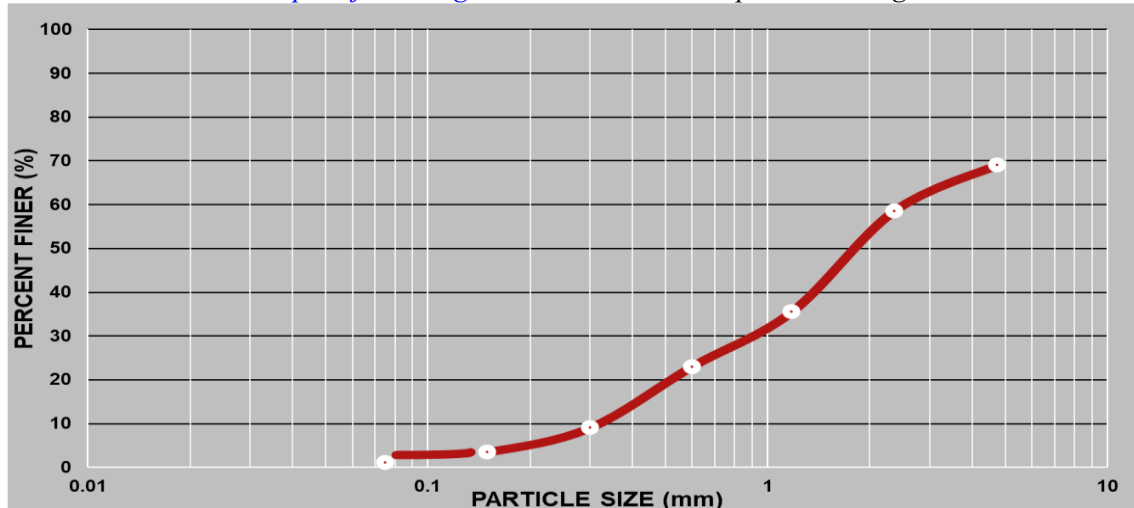
### III. RESULTS AND DISCUSSION

Table 5.1: Various Tests Results on Black Cotton Soil

Test Name	Unit	Test 1	Test 2	Test 3	Test 4	Test 5
Liquid Limit	%	65.29	67.28	62.15	64.28	66.69
Plastic Limit	%	35.86	34.20	29.58	30.50	29.88
Plasticity Index	%	29.42	33.08	32.57	33.78	36.81
Shrinkage Limit	%	13.20	14.60	14.12	14.60	15.11
Free Swell Index	%	100	90	95	90	110
UCS	Kg/cm <sup>2</sup>	0.600	0.850	0.660	0.820	0.732
Light Compaction (MDD)	g/cc	1.55	1.52	1.50	1.54	1.51
Light Compaction (OMC)	%	20.67	21.00	22.15	21.50	22.86
CBR at 2.5 mm (Soaked)	%	4.98	4.07	3.17	3.62	3.62
CBR at 5 mm (Soaked)	%	4.22	3.92	3.02	3.02	3.32

#### 1. Sieve Analysis of Black Cotton Soil

D10 = 0.3mm D30 = 0.9mm D60 = 2.6mm  
 Coefficient of Uniformity (Cu)= 8.67  
 Coefficient of Curvature (Cc)= 1.04  
 Hence, soil is classified as well graded soil.



[Graph.5.1: Sieve Analysis of black cotton soil]

## 2. Specific Gravity Test

Table 5.2: Specific Gravity of Black cotton soil

No. Of Tests	Specific Gravity	Average
Test 01	2.68	2.69
Test 02	2.64	
Test 03	2.74	
Test 04	2.69	
Test 05	2.70	

## 3. Atterberg Limit

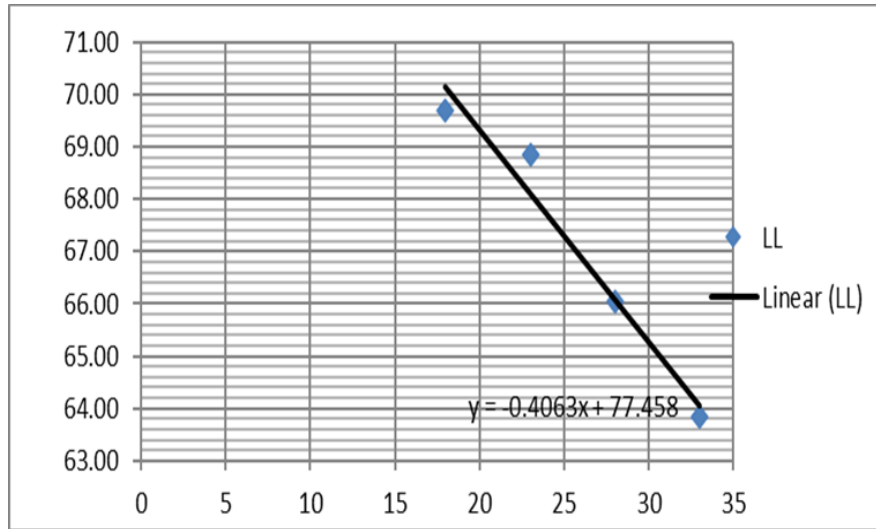
The Atterberg limits are a basic measure of the critical water contents of a fine-grained soil: its shrinkage limit, plastic limit, and liquid limit. Depending on its water content, a soil may appear in one of four states: solid, semi-solid, plastic and liquid.

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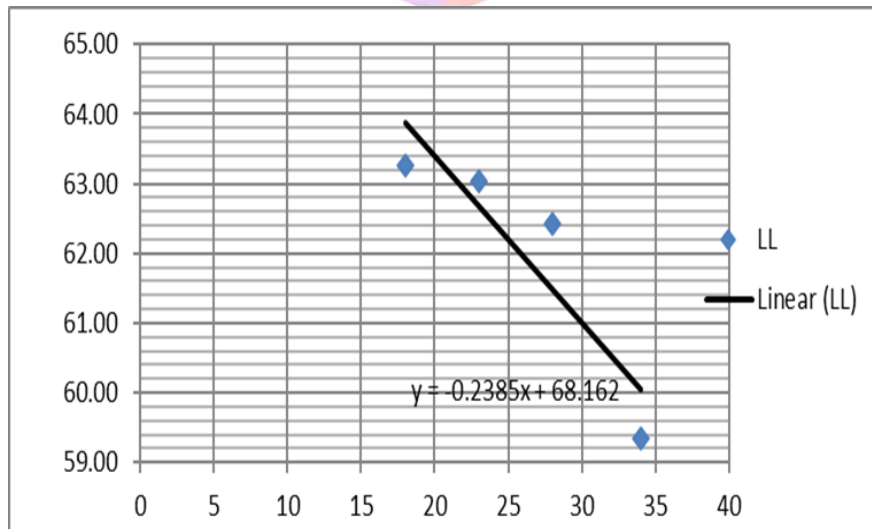
**Table 5.3: Atterberg limit of black cotton soil**

Name of Test	Unit	Test 1	Test 2	Test 3	Test 4	Test 5
Liquid Limit	%	65.29	67.30	62.20	64.16	66.42
Plastic Limit	%	35.86	34.10	29.76	31.04	29.24
Plasticity Index	%	29.43	33.20	32.44	33.12	37.18

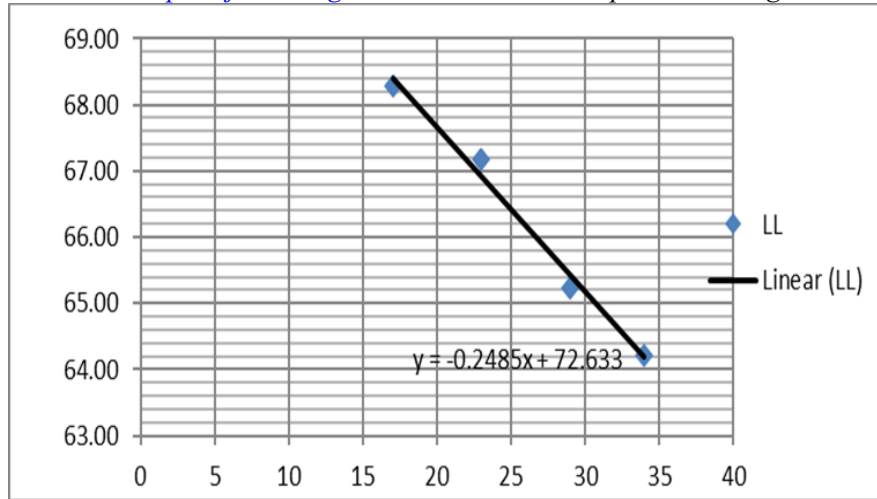
**[Graph.5.2: Atterberg limit of black cotton soil Test-1]**



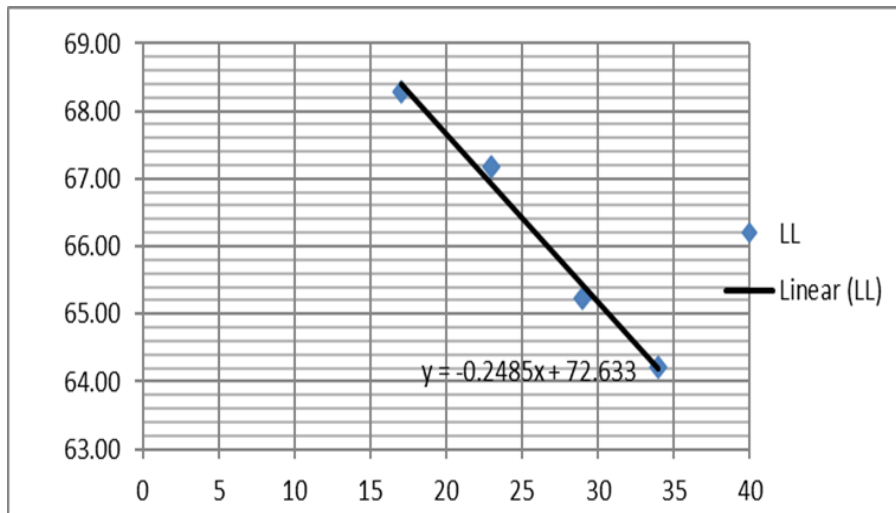
**[Graph.5.3: Atterberg limit of black cotton soil Test-2]**



**[Graph.5.4: Atterberg limit of black cotton soil Test-3]**



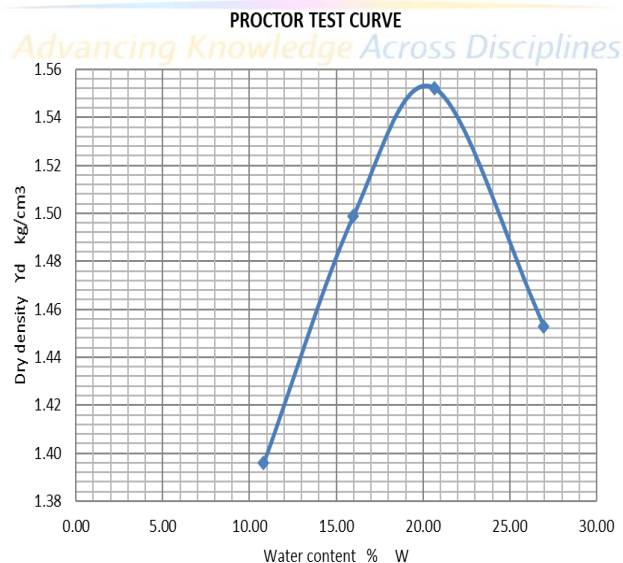
[Graph.5.5: Atterberg limit of black cotton soil Test-4]



[Graph.5.6: Atterberg limit of black cotton soil Test-5]

#### 4. Standard Proctor Test

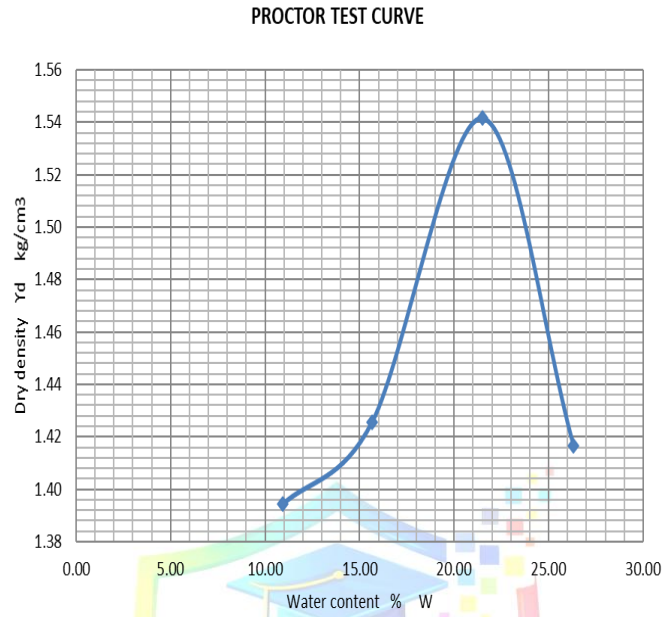
Test-1  
 O.M.C- 20.6  
 M.D.D- 1.5



[Graph.5.7: Proctor Test Curve Test-1]

Test -2

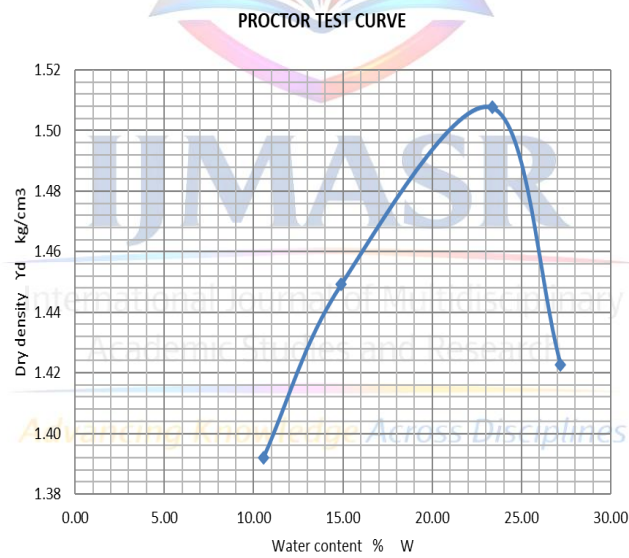
O.M.C-21.4, M.D.D.- 1.5



**[Graph.5.8: Proctor Test Curve Test-2]**

Test-3

O.M.C- 23.3, M.D.D - 1.5

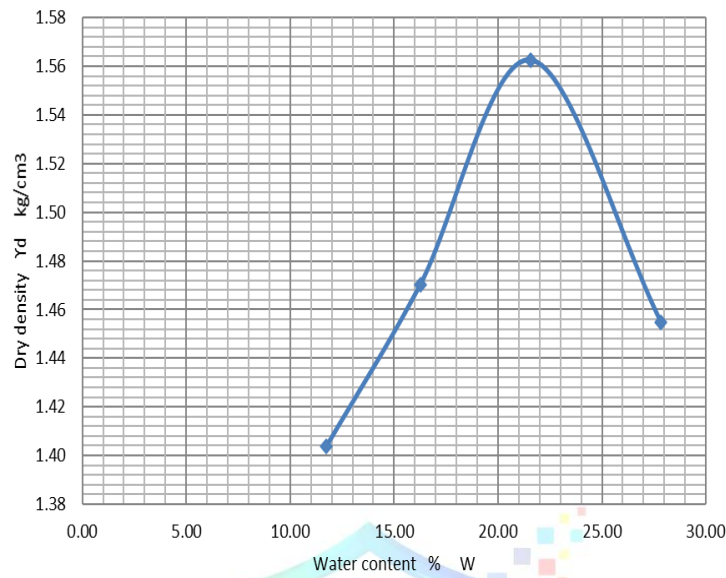


**[Graph.5.9: Proctor Test Curve Test-3]**

Test-4

O.M.C- 21.5, M.D.D -1.5

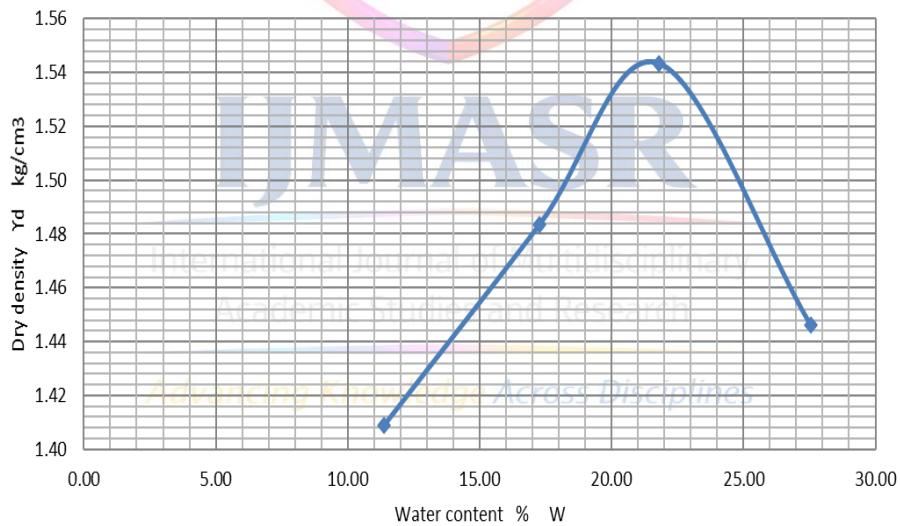
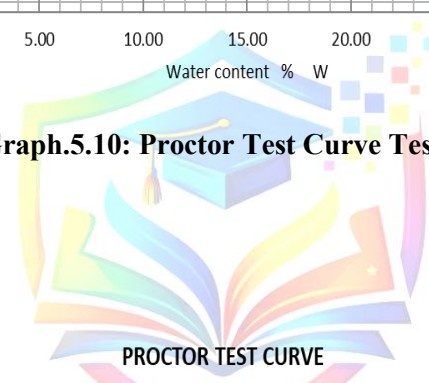
PROCTOR TEST CURVE



[Graph.5.10: Proctor Test Curve Test-4]

Test – 5

O.M.C- 21.7, M.D.D- 1.5



[Graph.5.11: Proctor Test Curve Test-5]

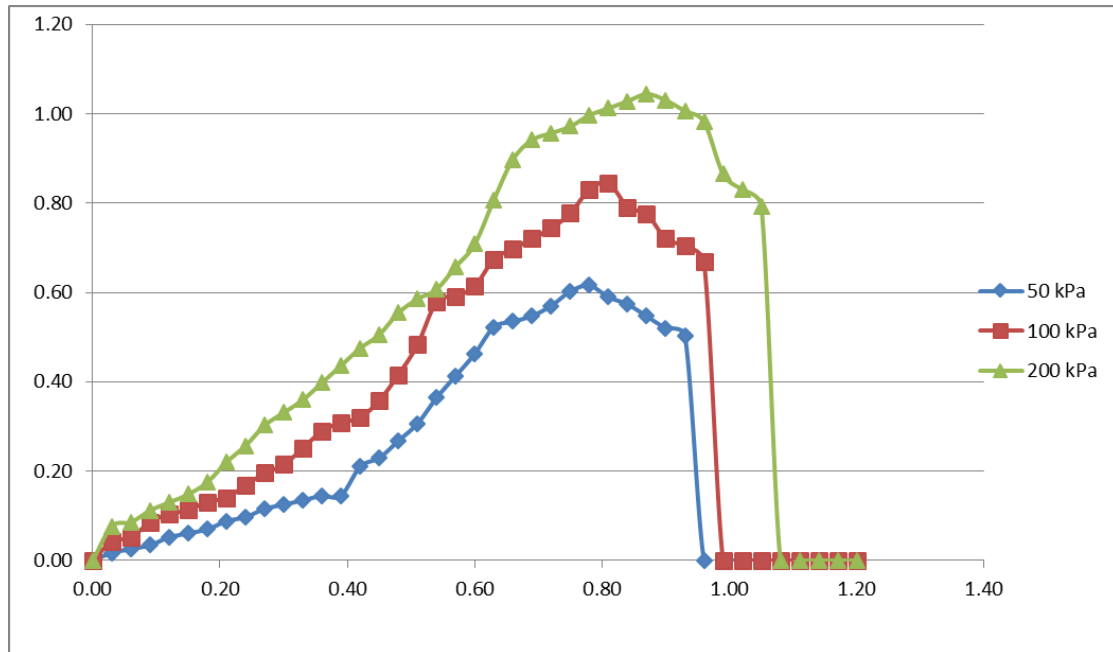
### 5. Free Swell Index Test

Table 5.4: Free Swell Index in %

Sample	Test 1	Test 2	Test 3	Test 4	Test 5
V (w)	20	19	19.5	19	21
V (k)	10	10	10	10	10

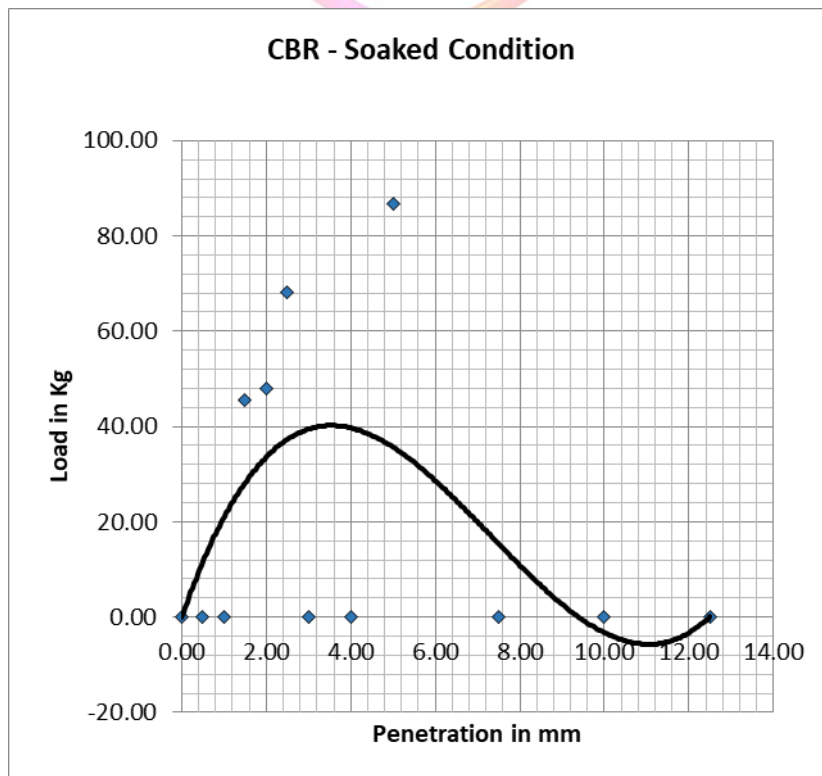
Free swell index (%)	100	90	95	90	110
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6. Direct Shear Test-



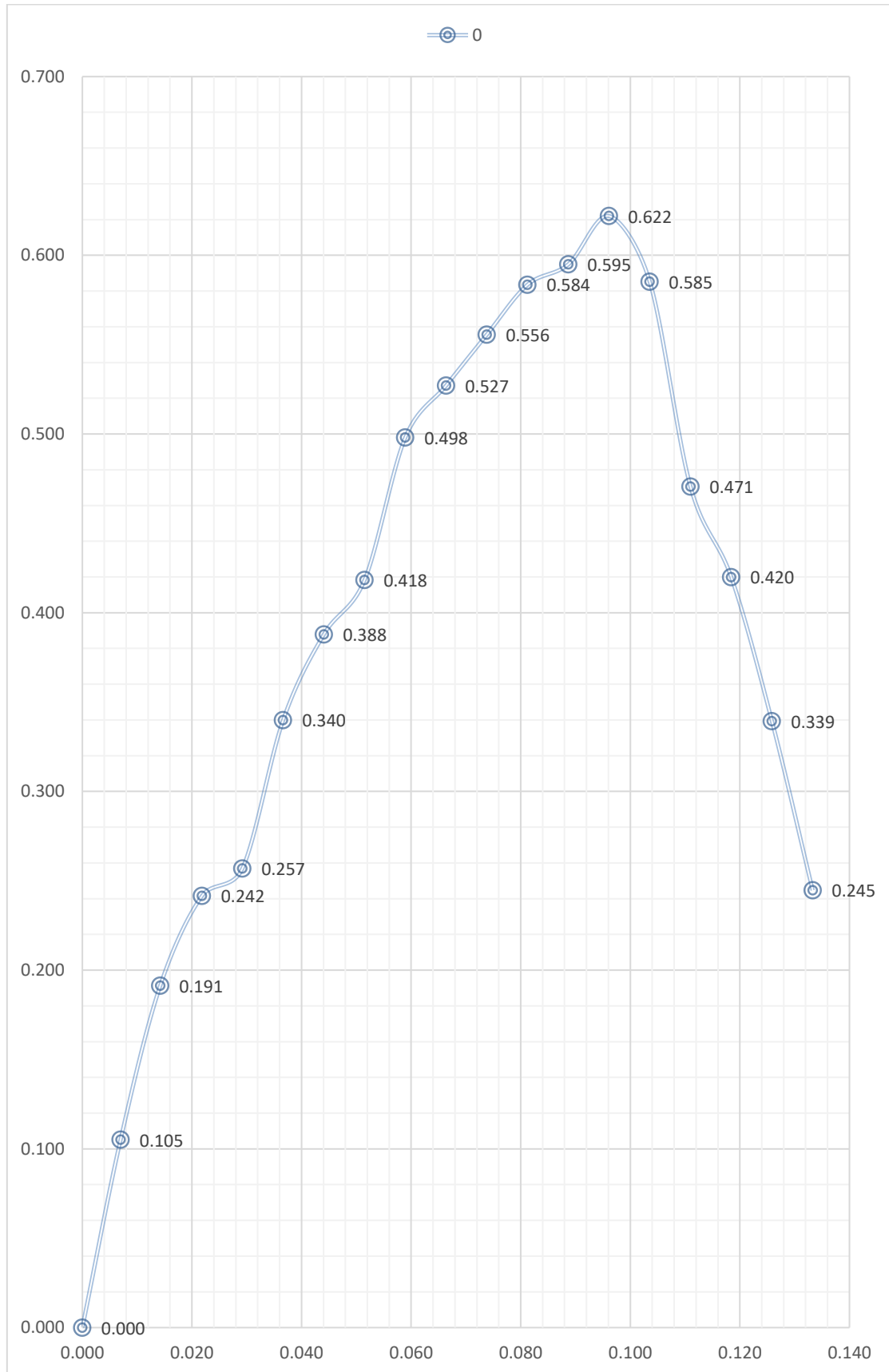
[Graph.5.12: Direct shear test Test-1]

7. CBR Test



[Graph.5.17: CBR test Test-1]

### 8. UCS Test



[Graph.5.22: UCS test Test-1]

## CONCLUSION

The following conclusions are drawn from the experimental investigations carried out on black cotton soil stabilized with lime and bamboo fibres:

### 1. Effect on Atterberg Limits

- Liquid Limit decreased from 82% to 68% with addition of lime (0%–8%).
- Plastic Limit increased from 40% to 52%.
- Reduction in plasticity indicates improved soil stability and reduced swelling behavior.

### 2. Compaction Characteristics (Lime Stabilization)

- Maximum Dry Density (MDD) decreased from 14.99 kN/m<sup>3</sup> to 13.67 kN/m<sup>3</sup>.
- Optimum Moisture Content (OMC) increased from 22.12% to 28.07% at 8% lime.
- Indicates higher water demand due to flocculation and cation exchange.

### 3. Effect of Bamboo Fibres on Compaction

- At optimum 4% lime:
  - OMC increased from 24.69% to 31.52%.
  - MDD decreased from 14.11 kN/m<sup>3</sup> to 13.23 kN/m<sup>3</sup>.
- Fibre addition reduces density but improves ductility and bonding.

### 4. California Bearing Ratio (CBR) – Lime Effect

- Unsoaked CBR increased from 2.6% to 6.87% up to 4% lime.
- Soaked CBR increased from 1.79% to 3.93%.
- Beyond 4% lime, CBR values decreased.

### 5. CBR – Effect of Bamboo Fibres

- Unsoaked CBR increased from 6.87% to 9.85% up to 2% fibres.
- Soaked CBR increased from 3.93% to 5.78%.
- Further addition of fibres caused reduction in strength.

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