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Stabilization of Soils Using Geosynthetic Material (Bamboo Fibers)

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Abstract

As we all know, structures such as buildings, bridges, highways, and dams are all supported by soil, and the soil at a construction site may not always be completely suitable. The in situ soil in granular soil deposits can be quite loose, indicating a large elastic settlement. In this situation, the soil must be modified in order to raise its unit weight, which will boost shear strength and load bearing capability. When the top layers of soil are unsuitable, they must be removed and replaced with better soil, which may then be used to build the structural foundation. As a result, improving load bearing capability is even more crucial when constructing a structural foundation.

Soil stabilisation is a procedure that involves strengthening the physical attributes of the soil by blending or mixing substances in order to improve its strength, durability, and other properties. Soil stabilisation methods include: cement stabilisation, lime stabilisation, bitumen stabilisation, chemical stabilisation, and a new emerging technology of stabilisation using Geo textiles and Geo synthetic fibers. Bamboo fibers are being used as a geo synthetic material for soil stabilisation in this project. CBR values will improve with the addition of bamboo fibers to the soil, and the thickness of the pavement layer will be reduced. Bamboo fibers are a type of geosynthetic material that is readily available, environmentally beneficial, and cost-effective. When compared to traditional construction methods, the overall cost of using soil stabilising methods in construction is lower. The liquid limit of the soil, the soil's MDD, the soil's OMC, the soil's shear strength, and the soil's CBR value were discovered. We determined from the restricted laboratory investigation that 0.75 percent bamboo fiber can significantly improve the qualities of Black cotton soil. The benefits of this project include the low cost of incorporating bamboo fiber into soil stabilisation and the ability to produce excellent concrete.

Chapter1: Introduction

1.1 General

A developing country with a big geographical area and population, such as India, necessitates extensive infrastructure, such as a network of highways and buildings. Land is being used for a variety of structures ranging from simple houses to sky scrapers, bridges to airports, and rural roads to expressways. Almost every civil engineering structure is built on a different soil layer. A material made up of rock particles, sand, silt, and clay is known as soil. It is generated by the progressive disintegration or decomposition of rocks as a result of natural processes, such as disintegration of rock as a result of pressures caused by temperature fluctuations. Weathering and decomposition are caused by chemical changes that occur when water, oxygen, and carbon dioxide slowly interact with minerals within the rock formation, resulting in the formation breaking down into sand, silt, and clay. Different soil formations, such as those found in river deltas, sand dunes, and glacial deposits, are formed by the transportation of soil components by wind, water, and ice. As in different climatic locations, temperature, rainfall, and drainage all play key roles in the formation of soils. Different soils will form from the same basic rock formation depending on the drainage regime.

Alluvial soil, maritime soil, laterite and lateritic deposits, expanding soils, sand dunes, and boulder deposits are the six types of soil in India. Lateritic soil layers cover an average of 1 lakh square kilometres, black cotton soil covers 3 lakh square kilometres, and sand dunes cover 5 lakh square kilometres. When dealing with terrain that has soft soil, it's important to pay attention to ground improvement procedures like soil stabilisation.

Soil stabilisation is the process of strengthening the physical attributes of the soil by blending or combining it with additives in order to improve its strength, durability, and other properties. Soil stabilisation technologies include: cement stabilisation, lime stabilisation, bitumen stabilisation, chemical stabilisation, and a new emerging technology of soil stabilisation using geo textiles and geo synthetic fibers.

Geo synthetics are synthetic materials manufactured from a variety of polymers that can be woven or nonwoven. These are used to improve the properties of soil and have shown to be a cost-effective technique of building civil engineering projects.

Bamboo fibers are being used as a geo synthetic material for soil stabilisation in this project. The addition of bamboo fibers to the soil may improve CBR values while simultaneously reducing the thickness of the pavement layer. It may also help to lessen the severity of stress on the subgrade. Bamboo fibers are a type of geosynthetic material that is readily available, environmentally beneficial, and cost effective. When compared to traditional construction methods, the overall cost of using soil stabilising techniques in the construction process may be lower.

1.2 Needs & Advantages of soil stabilization

Because soil qualities vary greatly and building design is heavily reliant on the carrying ability of the soil, we must stabilise the soil to increase load bearing capacity. When working with soils, it's also crucial to bear in mind the gradation of the soil. The soils can be well-graded, which is preferable since it has fewer voids, or uniformly graded, which appears stable but contains more voids.

- If weak soil strata are discovered during the construction phase, it is common practise to replace the weak soil with another good quality soil. The qualities of locally accessible soil (soil on site) can be improved with the use of soil stabilisation techniques, and it can be used efficiently as a subgrade material without having to be replaced.

- The expense of preparing the subgrade by replacing the weak soil with a good quality soil is more expensive than stabilising the locally available soil using various stabilisation techniques.

- Stabilization can efficiently boost the soil's strength-giving properties to the appropriate level.

- It increases the soil bearing capacity by improving the soil strength.

- Increasing the carrying capacity of the soil, rather than using a deep foundation or raft foundation, is more cost and energy efficient.

- Soil stabilisation can also be used to avoid soil erosion or dust generation, which is especially important in dry and arid climates.

- Soil water-proofing is also done using stabilisation; this stops water from entering the soil. As a result, the soil is protected from losing its strength.

- It aids in decreasing the volume change in the soil as a result of changes in temperature or moisture content.

Other advantages are listed below:

Will save Money

You can generally save extensive sums of money by soil stabilisation in comparability on the traditional "dig in addition to dump" method. Dig in addition to dump incurs the cost of car plan, purchasing aggregates as well as land fill tax.

Expense cost savings by Design

Soils dealt with binders may perhaps be put forth to become more powerful compared to regular granular sub wedge. Using the components sort for a pavement or perhaps foundation means the energy is considerably enhanced. This specific energy might be used to take on the thickness of the foundation or the thickness of consequent levels. [1]Concrete or even blacktop could be laid straight upon stabilised earth (3).

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[1] Cost savings to come down with granular sub platform, concrete as well as bituminous substances tend to be achievable.

Will conserve Time

Soil stabilisation might shortens the best period brought to complete a job by minimising the site preparation time as well as minimizing tipping or import. The process in addition causes it to be easy for terrain which is damp to get dried out away along with strengthened for immediate utilize.

Wintertime time of year Working

Soil stabilisation, making use of lime is devoid of question the greatest approach to becoming dry a moist site. Incorporating quicklime right away dries higher moist soils as well as allows extensive executing inside disorders which are damp as well as straight directly into winter season. Ideal for haul freeways as well as all of all those tough sites.

Preserves Environmental Impact

One specific 30 tonne great deal of binder can eliminate these vehicle movements. Considerably less price tag, less congestion and no furious neighbours. An eco-friendly choice with advantages which are numerous (4).

Will conserve Waste

There is merely simply no necessity to import novice driver info every time the soil on site could be used observing a simple treatment process. [2]Perhaps Type one sub platform is not necessary when the identical strength and properties might be gotten to utilizing the soils on website.

Will conserve Landfill Taxes

Our planet stabilisation uses the soils situated about the site you have. These are enhanced making the characteristics needed for creating. This may differ by developing a simple option to permit consumption discovered landscaping or embankments through you are able to utilize for sub foundation. [3]Many of the readily available soils are usually consumed, hence tipping is practically reduced.
is not necessary when the identical strength and properties might be gotten to utilizing the soils on site.

1.3 Objectives

The focus of this project is on improved understanding of natural in addition to artificial Geotextiles for strengthening of sub grade soil. This project gives result of reinforcement of Geotextiles on sub grade soil. Laboratory California bearing ratio (CBR) tests were performed to scrutinize the load-penetration performance of reinforced granular soils by way of geotextile.

[2] Time-Consuming and costly importation of brand-new generation and material of big levels of misuse is thus reduced

[3] Simply no dependence on much more tipping fees, simply stabilise the soils on site as well as make sure you use them.

Chapter 2: Literature Review

2.1 General Soil stabilization

It is a method of improving soil attributes by blending and blending various materials. You are going to find a lot of soil stabilization methods to not point out you will locate a number of items used for soil stabilization. Mentioned listed here are the a number of methods talked about to literature.

• **Soil Stabilization with Cement:** The planet earth stabilized with cement is realized as soil cement. The cementing task is believed becoming the end result of chemical reactions of cement with siliceous planet inside the training course of hydration desire. The primary key variables affecting the soil cement are characteristics of soil information, issues of blending, compaction, curing; admixtures used. The right levels of cement needed for various soils variants might be as follows: Gravels - five to ten %, Sands - seven to twelve %, Silts - twelve to fifteen %, andClays - twelve - twenty % The amount of cement for a compressive sturdiness of twenty five to thirty kg/cm2 must typically be adequate for incredible close by local weather for soil stabilization.If the quantity of soil encountering floors spot of your (m2), thickness H (dried out away density and also cm) rd(tonnes/m3), should be stabilized with p small proportion of cement by mass on the foundation of our planet that is dried out away, cement combination will be((100XP)/(1+P)) aside from that to, the quantity of cement required for soil stabilization is furnished by Volume of cement needed, within tonnes = Lime, salt carbonate,

You're competent to make use of for sub foundation. calcium chloride, salt sulphate in addition to fly ash are a number of the components commonly used with cement for cement stabilization of soil. •. Lime may be used on your own or perhaps along with cement, bitumen or perhaps get on a plane ash. Sandy soils might in addition be stabilized with the mixtures.[4]Lime continues to be primarily employed for steadying the street bases and also the subgrade . Lime alterations the characteristics of adsorbed covering and also provides pozzolanic undertaking. Plasticity listing of incredibly sharp clear plastic soils are cut back in the addition of lime with soil. There is an increase inside the the very best consuming moisture created content material in addition to a drop inside the optimum compressed density too he strength and durability of soil expands.

Soil Stabilization using Geosynthetic Material (Bamboo Fibers) Normally 2 to 8 % of lime may very well be required for difficult grained soils in addition to 5 to 8 % of lime might be needed for obvious clear plastic soils. The amount of fly ash as admixture may well differ via 8 to 20 % of the mass on the soil.

• **Soil Stabilization with Bitumen:** Asphalts along with tars are bituminous parts which are used for stabilization of soil, usually for pavement developing. Bituminous materials when placed into a planet, it imparts every cohesion and also reduced consuming drinking water absorption. In line with the above described measures as well as furthermore, the characteristics of soils, bitumen stabilization is classified to following four types:

• **Sand bitumen stabilization • Soil Bitumen stabilization** • Water proofed actual physical stabilization, after which Oiled earth.

• **Chemical Stabilization of Soil:** Calcium chloride finding hygroscopic in addition to deliquescent is required as filling a tub retentive preservative within mechanically stabilized soil bases and surfacing. The vapor pressure gets reduced, region pressure advances along with acceleration of evaporation decreases. The freezing reason for h20 which is natural gets reduced as well as it results in prevention or reduction of frost heave. The depressing the power two fold fitness level, the salt slices lower on the bathtub select installed therefore thus the damage in deep energy of face grained soils. Calcium chloride offers a planet flocculent and in addition will help

[4] Soil Stabilization applying Lime: Slaked lime is extremely efficient within dealing with serious plastic material clayey soils

with compaction. Frequent utilization of calcium chloride might be crucial to compensate for the damage inside substance dependent by leaching movement. In the event it involves the salt to be successful, the distant distant distant relative dampness on the world must be above thirty %. Salt chloride is unquestionably another chemic material that may be used for this particular performance having steadying measures of calcium chloride. Salt silicate remains an extra compound used for this specific objective within serious conjunction with a few various other chemic materials such as calcium chloride, polymers, chrome lignin, alkyl chlorosilanes, siliconites, quarternary ammonium salts; amines, salt hexametaphosphate, phosphoric acid that comes having a wetting agent.

• **Electrical Stabilization of Clayey Soils: Soil Stabilization using Geosynthetic Material** (Bamboo Fibers) stabilization of clayey soils is achieved by approach known as electro osmosis. This is an expensive method of soil stabilization also it's mainly used for clean water water drainage of cohesive soils.

• **Soil Stabilization by Grouting:** On this method, stabilizers are released by injection straight to the soil. This particular procedure is not of great help for clayey soils as a result of the lower permeability of theirs. This is a top listed ways for soil stabilization. This particular procedure is perfect for steadying installed zones of pretty little fitness level. The grouting techniques might be classified as following:

• **Clay grouting • Chemical grouting • Chrome lignin grouting • Polymer grouting, after which • Bituminous grouting •**[5]Geotextiles are porous garments made from artificial substances including polyethylene, polyester, nylons as well as polyvinyl chloride. Woven, non woven as well as power system style kinds of geotextiles could be discovered. Geotextiles have a premier strength. When properly lodged all around soil, it plays a job inside the balance of its. It is used inside the construction of unpaved freeways much more than sleek soils. In order to strengthen the soil for stabilization by metallic strips to it along with providing an anchor or perhaps tie to restrain a dealing with skin component.

2.2 Stabilization of Blackish Cotton Soil applying Geogrid and Lime

Inside India Blackish Cotton soil similarly frequently referred to as "Regurs" are found dressed in extensive parts of Deccan Trap (eleven). They have adjustable thickness and also consequently are underlain by gluey written content within the spot usually often known as "Kali Mitti". Inside respect to geotechnical Engineering, Blackish Cotton soil is but a camera which when connected with when engineering framework how about presence of h20 is able to have a tendency to enlarge or maybe bring down big top towards the framework to knowledge occasions which occur to get mainly not connected along the quick effect of loading by the framework. Black color colored cotton soil is not suitable for the structure hire account of volumetric modifications of its. It swells as well as shrinks an excessive amount of with modification of h20 content articles.

This sort of tendency of soil is due to the presence of face clay contaminants which swell, every time they're obtainable only in contact with clean water, resulting in alternate shrinking as well as swelling of soil because of which differential settlement of process happens, therefore thestabilization continues to be finished for the Stabilization of dark cotton soil is still accomplished in this particular carrying out do the task by making use of lime for being an admixture.

Most likely probably the most common sorts of stabilization are talked about below

a) Cement stabilization

b) Bitumen stabilization

c) Chemical stabilization d) Lime stabilization e) Salt stabilization 2. Division contained India As an outcome, most of soil in at the same time because close to Mumbai, Madras, Gwalior, Khandwa, Indore, Nagpur

[5] Soil Stabilization by Fabrics and Geotextiles

at the same time as a number of several with the river banks is Blackish cotton,That suggests the soils are primary found Deccan capture plateau region, i.e., states of Andhra Pradesh, Western Madhya Pradesh, Maharashtra, Gujarat, Northern Karnataka and Tamilnadu (twelve).

2.3 Geotextiles: An Overview

Geotextiles are special textiles which will direct the forthcoming textile market. Geotextiles have very good impact on guarding natural catastrophe. Nowadays a day' s lands are much poor towards the effect of neighborhood environmental change. Due to various other reasons as well as local weather alter you are going to find essential quantity of catastrophes is happening day. Geotextiles can shield the bridges of ours, roads and soil from all natural catastrophe by creating embankments and having wall surface area. Erosion managing might be transpired by this specific. Through the use of geotextiles, it is constructed temporary roads or permanent roads. Therefore, throughout the second of all natural catastrophe it cannot be damaged. The utilization of geotextiles is fantastic. Not simply catastrophe time but in addition the formulation of h20 water drainage application in addition to reinforcement of block is achieved by geotextiles. [6]Municipal technical engineers take care of the municipal component as well as textile technical engineers search following the textile components of it. Geotextiles are created by a variety of manner. However within producing method geotextiles are intended several unique fashion. With this web page it is mentioned just about the majority of it. Besides protecting from all natural catastrophe geotextiles can sort the soil. That's precisely why geotextiles are used to understand the land in addition to soils quality. With this particular content, it is gotten photograph of the usage of geotextiles, just how geotextiles can produce, simply just how can it guard the organic and natural catastrophe. This is in addition discussed relating to geotextiles historic past along with types. As a result, it might be claimed that because an outcome of the quite short post a glimpse at geotextiles might be found (thirteen).

The word "Geotextiles " is originated of "Geo and also "Textiles." Geo suggests ground or land. It is able to effortlessly be soil attached term. In line with the textile institute the word "Textile" suggests an extensive term applied to with the manufacture originating from fibers, filaments, or yarns realized by adaptability, excessive ratio; fineness of dimensions to thickness" consequently the "Geotextiles" explanation are it is a permeable garments which may be utilized all around link with soils power to protect, various, purification reinforcement as well as empty,It is created by all-natural fibers as well as manmade fibers. [7]Geotextile composites are really recognized and the products of its like geogrids as well as meshes are already created fairly recently. Geotextiles are incredibly durable, file lower and also an individual fells decreased by of it. Geotextile is the same known as geosynthetics, though there is some dissimilarity someplace in between its. It is helpful to eco-friendly science to type of establishing [one].

Types of Geotextiles

2.4 Improvement in CBR significance of Blackish satin soil and soil by steadying it with vitrified Polish

Nowadays the earth is setting up using a faster quickness. To be able to complete the developments every country needs excellent infrastructure. Freeways indulge inside a noticeable feature since they relate doorstep to doorstep. The construction and maintenance of the freeways is beginning to become more complicated as an outcome of improving targeted visitors every day. For being in a position to see an effective course and that can cater towards the website site traffic we necessitate good quality creating materials. Although the earth is working with a scarcity of quality developing ingredients since they are consuming fairly quickly. Governments are undoubtedly imposing lots and fees of clearances are important for using the resources. On the other hand you are going to find a selection of misuse substance made of industries and disposal of the squander items is beginning to become difficult since they are driving produced for huge quantity. Companies are discarding a

[6] In fact, geotextiles are blending department of civil engineering and textile engineering.

[7] The geotextile cloth is usually made by the blending of manmade or natural fibers as well.

good offer of money within an attempt to dispose the misuse materials, as prevalent approach is acreage fill, releasing straight into close by consuming normal water methods. To be able to overcome the problems a few businesses; scientists are evaluating using the misuse materials. Because utilization on the misuse materials create earnings, thus sticking to a substantial reduction of creating cost. Vitrified Polish Waste (VPW) is but 1 together with the waste materials supplies pieces which is unquestionably created through the entire generation of vitrified flooring floor tiles, which will probably be creating with a quick phase inside the current earth. Author wish to focus on a stretch of 7km (i.e., Km 6 to Km thirteen) of Samalkot Uppada block which is a tremendous District Road (MDR) within East Godavari District, Andhra Pradesh. Huge web site visitors great deal is originating onto this specific block additionally it is cultivating each day due to development in at the same time because close to this specific particular spot (fifteen).

2.5 Negative effects of Jute Fibers on Engineering Characteristics of Blackish Cotton Soil

Expansive soil are definitely the planet, that occur to get higher swelling along with shrinkage characteristics along with CBR advantage as well as shear energy. Hence, there is basic need for advancement of the attributes. In just a few current development is managed by lime or even utilizing granular stabilized soils. The concept of reinforcing soil masses with all natural fibers like coir fibre, banana fibre, sisal fiber etc. is a relatively novice driver development to fix the attributes of soil. The utilization of natural and also synthetic fibers is an excellent way of homogeneous soil reinforcing. The characteristics of stabilized our planet for instance shrinkage restrict, unconfined compressive energy and also California bearing ratio were definitely analyzed along with the variants of theirs with info in jute fibers are analyzed. Soil samples which have 0 %, one particular %, 2 % to5 % of jute dietary fiber were definitely targeted upwards and also show characteristics have been examined like a relevant Is really code of practise. The examination benefits exhibited a lot of decreasing inside the expansive behaviour of tan satin soil.[8]The shrinkage restrict improves through 13.75 % to28.68 % in the event that dark cotton soil is blended with five % lime and also jute fibers through zero % to five % by mass of dark cotton soil.

Chapter 3: Problem definition

Construction on soil is not very easy there is lot of complex process involved in from surveying to testing the soil, checking moisture, and making it capable of designing a infrastructure.

Before a project can get off the ground, a site feasibility assessment for geotechnical projects is significantly more helpful. Before the design process begins, a site survey is normally conducted to determine the subsoil features that will be used to determine the project's location. During site selection, the following geotechnical design criteria must be considered.

- The structure's design load and function.
- The foundation that will be used.
- The subsoil's bearing capacity.

  In the past, the third bullet was a big factor in site selection decisions. When the soil's bearing capacity was low, the following options were available:
- Adapt the design to the site's conditions.

[8] Generally there is significant rise in California.

- Remove the existing dirt and replenish it.
- Abandon the location.

Abandoned sites increased substantially as a result of poor soil holding capacity, resulting in land scarcity and increased demand for natural resources. Areas susceptible to liquefaction, as well as those coated in soft clay and organic soils, were affected. Other sites included landslide zones and contaminated terrain. In most geotechnical projects, however, obtaining a construction site that meets the design criteria without ground alteration is not achievable. To achieve the design standards, the current approach is to adjust the engineering qualities of the native problematic soils. Soft clays and organic soils, for example, can now be upgraded to meet civil engineering requirements. This evaluation of the state of the art focuses on the soil stabilisation approach, which is one of several soil improvement strategies. Soil stabilisation tries to increase soil strength and resistance to water softening by connecting soil particles together, water proofing the particles, or a combination of both (Sherwood, 1993). Typically, technology offers a structural option to a practical problem.

Chapter 4: Methodology

4.1 General

The Highway Research Board (HRB) uses appropriate sampling procedures like the Core Cutter Method to classify soil layers like black cotton soil. To determine characteristics such as grading using sieve analysis, Atterbergs Limits (liquid limit using Cone Penetration Method and Casagrande Method), Plastic limit by rolling the sample to 3mm diameter thread, Shrinkage limit using Shrinkage apparatus, Optimum Moisture Content and Maximum Dry Density using Standard Proctor Test, and California Bearing Ratio by rolling the sample to 3mm diameter thread The liquid limit, plastic limit, shrinkage limit, optimum moisture content, maximum dry density, CBR value, and shear strength of Geo synthetic material with black cotton were all determined. The pavement thickness will be calculated using IRC SP:20-2002 pavement design catalogues. According to SR 2014-15, PW, P, and IWT circle Dharwad, the road is estimated by taking into account items such as jungle cutting, earthwork excavation for roadway and drains, compacting and grading, and specification for a mixture of Bamboo fibers as Geo Synthetic material for stabilization. ducting soaked CBR test for four days and shear with unconfined compression test. The various tests were carried out in order to determine the soil's various qualities and properties. Each of the tests has been described in detail below.

4.2 Wet Sieve Analysis [IS 2720 (Part 4) – 1985]

4.2.1 General

Mechanical analysis is used to determine the grain size distribution. Wet sieve analysis is required if the proportion of fines is higher.

4.2.2 Apparatus

Sieves according to IS: 460(part I) - 1978, 4.75 mm, 2 mm, 425µ, 75µ were among the various test apparatus used. trays or buckets, brushes, mechanical sieve shaker, oven to keep temperature between 105°C and 110°C.

4.2.3 Procedure

A suitable quantity of soil, approximately 200 g, is placed in a 75µ sieve and rinsed completely with clean water until clear water appears, with the residual portion of soil being preserved for oven drying. The remaining material is sieved manually or with a mechanical sieve shaker. The following IS sieves were used: 4.75mm, 2.0mm, 1.0mm, 600µ, 425µ, 300µ, 212µ, 150µ, 75µ. For 10 minutes, shake the dirt in a mechanical sieve shaker. 1g of material should be retained on each sieve. The percentage of soil that passes 75µ is a mixture of silt and clay, whereas soil that remains above 75µ is coarse, medium, or fine sand. The gravel fraction of the soil under inquiry is defined as particles maintained above a 2.0 mm sieve.

4.3 Liquid Limit Test [IS 2720 (Part 5) – 1985]

4.3.1 General

Casagrande test was performed to determine the liquid limit of soil. The mechanical method of Casagrande's instrument or the standard liquid limit test apparatus is usually used to determine the liquid limit. According to this method, the liquid limit is defined as the moisture content at which 25 blows or drops in a typical liquid limit apparatus will simply seal a groove made in the sample by the grooving tool by a predetermined amount.

4.3.2 Apparatus

The standard liquid limit apparatus is a mechanical device that consists of a cup and a mechanism for raising and lowering the liquid level to a specified height of 10mm. There are two common grooving instruments. A spatula, an evaporating dish, moisture containers, a balance with a capacity of 200 grams and a sensitivity of 0.01 g, and a thermostatically controlled drying oven with a temperature range of 105˚C to 110˚C degrees Celsius are also required.

4.3.3 Procedure

In the evaporation dish, 150 g of dry soil sample passing 425 micron IS sieve is weighed and thoroughly combined with distilled water to make a homogenous thick paste. In the case of clayey soil, the paste should be stored in a watertight container for the needed amount of time (up to 24 hours) to achieve consistent moisture distribution. The liquid limit device is set to have a free fall of exactly 10 mm into the cup. The cup and grooving tools have been thoroughly cleaned. The paste should be hard enough that it takes 30-35 blows or drops of the cup to seal the standard groove for a stipulated length of 12 mm at the bottom in the trial run. A piece of the soil paste is placed in the cup of the device above the lowest area and pressed down with the spatula to create a horizontal surface. By using firm spatula strokes, the soil paste is trimmed till the maximum depth of soil sample in the cup is 10 mm. To achieve a clean sharp groove, the soil sample in the cup is divided along the diameter along the centre line of the cam, followed by firm strokes of the grooving tool. The curved grooving tool can be used on any soil, however the V shaped grooving tool should only be used on clayey soils that are free of sand particles and fibre materials. The test cup is lifted and dropped as indicated by rotating the crank at a rate of 2 revolutions per second (either by hand or electrically depending on whether it is hand operated or machine controlled). This is repeated until the two parts of the soil cake flow gently beneath the blows and come into contact at the groove's bottom for a distance of 12 mm, at which point the number of blows given is noted. In the following trial, a tiny amount of water is added to the soil paste in the dish, stirred thoroughly with a spatula, and the needed quantity of paste is placed in the test cup. The number of blows necessary to close the groove decreases as the water content in the paste increases. The technique is repeated for 3 or more attempts, with slightly increased water contents each time, and the number of blows recorded, so that there are at least 4 to 6 uniformly distributed readings of the number of blows between 15 and 35.

Using Cone Penetration Method

4.3.4 General

Cone penetration is another way for determining the liquid limit of soil. The liquid limit of a soil is defined as the water content in the soil sample when the standard cone penetration depth is 20 mm, according to the cone penetration method. The depths to which a conventional metal cone penetrates soil paste samples made with various water concentrations in 5 seconds are measured.

4.3.5 Apparatus

Penetration cone with standard apex angle and weight, cylindrical cup, sensitive balance to 0.01g, and drying oven at 105°C to 110°C.

4.3.6 Procedure

About 150g of soil sample is mixed in a dish to make a paste, then put to the cone penetrometer's cylindrical cup and levelled without entrapped air. The cone is clamped and adjusted to just touch the soil paste's surface, and the initial reading is taken. The clamp is released, enabling the cone to enter the soil paste for 5 seconds under its own weight, with the final penetration reading recorded. The difference between the final and first penetration readings in a 5-second period is the cone penetration value in mm. The test is performed four to five times with varying water contents in the soil paste, with penetration values ranging from 14 to 28 mm each time.

Chapter 5 Analysis of Data and Results

5.1 General

On **Black Cotton Soil** and **Sedu Soil**, **Wet Sieve Analysis**, **Atterberg Limits**, **Compaction Tests**, **CBR**, and **UCS** testing were performed. In the next paragraphs, the analysis is discussed.

5.2 Wet Sieve Analysis

Wet sieve analysis of Black Cotton Soil collected from Haliyal was taken out in

Order to classify the soil. The following observations were made:

- 200 gm Sample was taken from the site and passed through on a 4.75 mm sieve before washing.
- 115 gm Sample retained on 0.075mm sieve after washing and then drying it.
- 85 gm Sample passed through on 0.075mm sieve after washing, 42.5%

Table 5.1: Sieve analysis of Black cotton soil

Sl. No.	IS Sieve Size	Particle Size (D) (mm)	Mass Soil Retained (M_1) (g)	% Mass Retained (M_1/M) *100	Cumulative % Retained (C)	Cumulative % Fine (N=100-C)
1	2	2	0	0	0	100
2	1	1	6	5.22	5.22	94.78
3	0.6	0.6	37	32.17	37.39	62.61
4	0.425	0.425	9	7.83	45.22	54.78
5	0.3	0.3	15	13.04	58.26	41.74
6	0.212	0.212	17	14.78	73.04	26.96
7	0.15	0.15	0	0	73.04	26.96
8	0.075	0.075	29	25.22	98.26	1.74
9	Pan	0	0	0	98.26	1.74

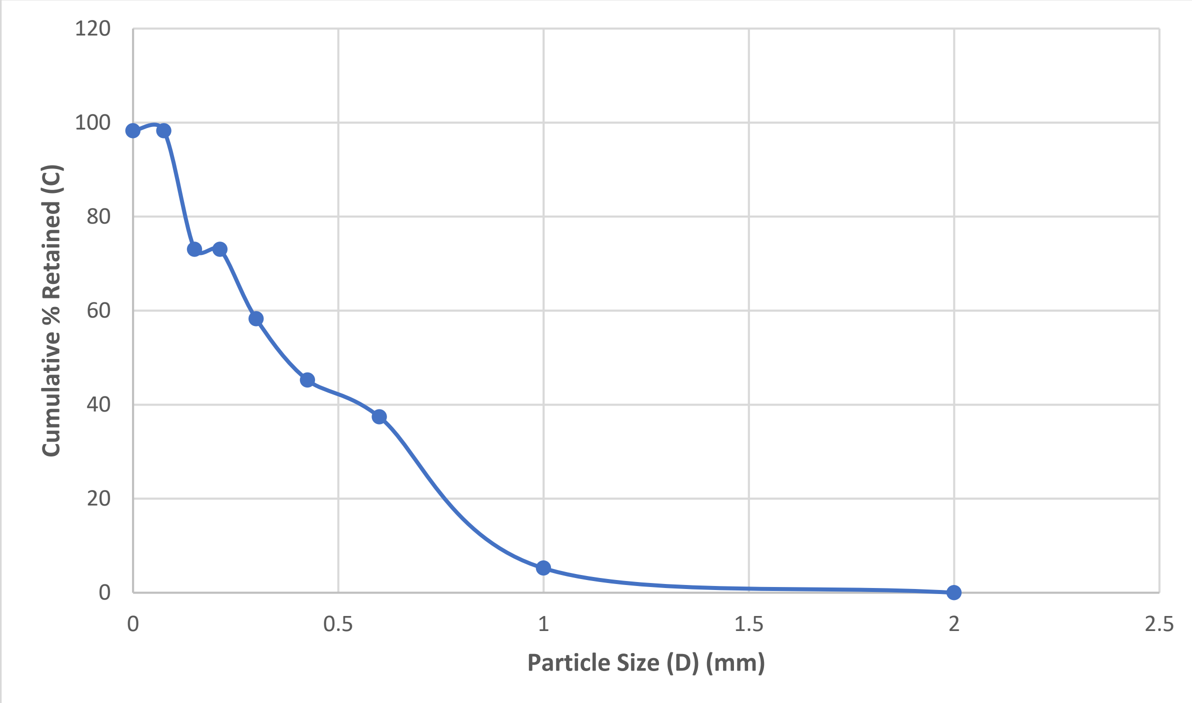

Fig 5.1: Particle size distribution curve of Black cotton soil

5.3 Liquid Limit Test(wL)

5.3.1 Cone Penetration

- 150 gm of test sample taken from the site and passing through at 425 µ

Table 5.2: Liquid limit test on Black cotton soil using Cone Penetration method

Trial No.	Water Content (%)	Water Amount (ml)	Penetration (mm)
1	50	75	16
2	55	82.5	17
3	60	90	20
4	65	97.5	35
5	70	105	44

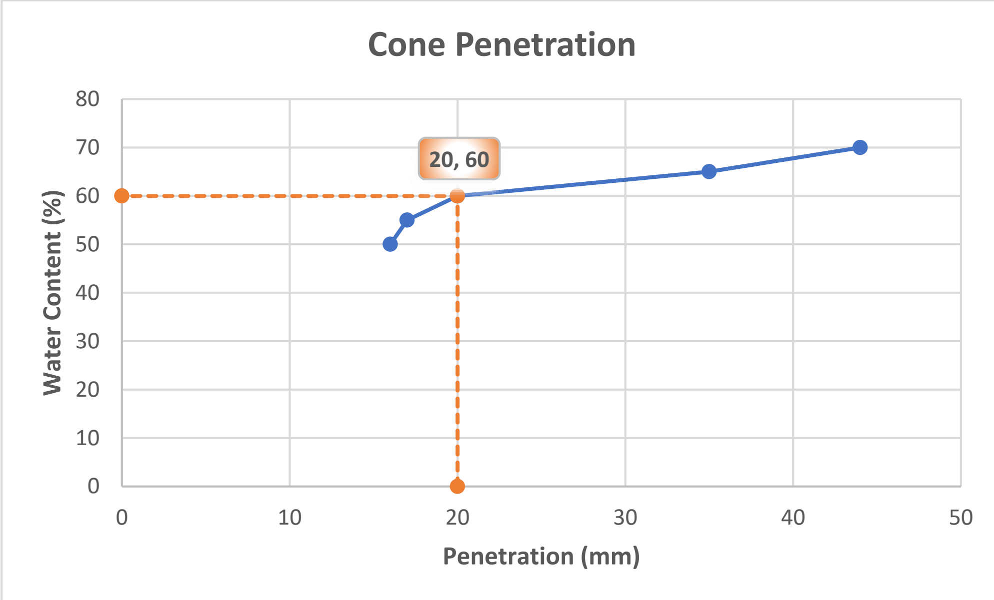

Fig 5.2: Liquid Limit curve (Cone Penetration)

The liquid limit (***w_L***) obtained from the graph is 60% corresponding to a 20 mm penetration.

5.3.2 Casagrande Method

- 150 gm of a sample taken is passing through on 425 µ

Table 5.3: Liquid limit test on Black cotton soil using Casagrande's method

Trial No.	Water Content (%)	Water Amount (ml)	No. of Blows
1	50	75	108
2	54.33	81.5	25
3	55	82.5	20
4	60	90	4

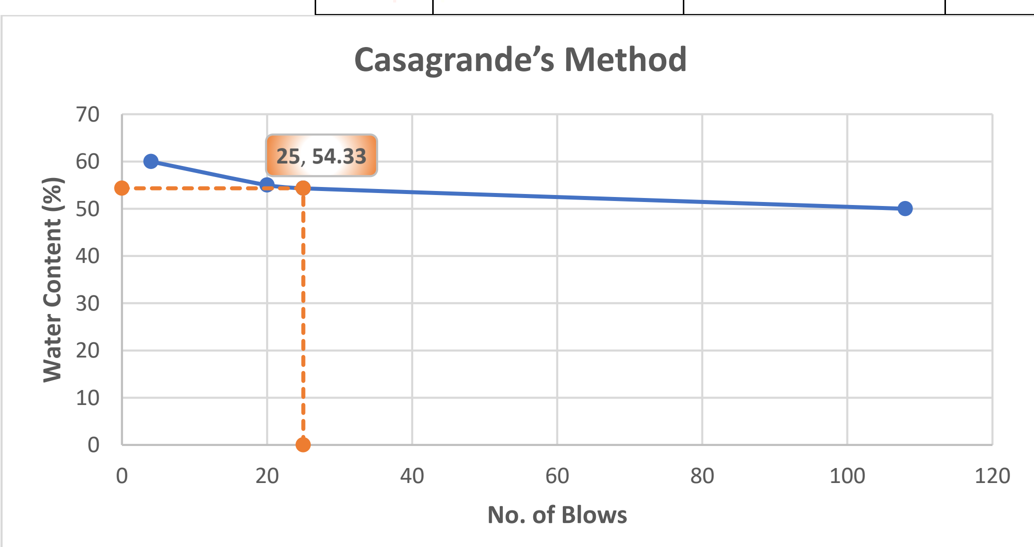

Fig 5.3: Liquid Limit curve (Casagrande's method)

The liquid limit (w_L) obtained from the graph is 54.33% corresponding to 25 blows.

5.4 Plastic Limit test

Table 5.4: Plastic limit test on Black cotton soil

Trial Number	1
Container No.	GT-19
Mass of empty container (M_1) (g)	32.15
Mass of container + wet soil (M_2) (g)	47.15
Mass of container +dry soil (M_3) (g)	44.5
Mass of water = Mw= M_2-M_3	2.65
Mass of dry soil= M_d= M_3-M_1 (g)	12.35
Plastic Limit (%) W_p=(Mw/M_d) *100	21.46

5.5 Plasticity Index

Soil Sample - 1

$I_p = w_L - W_p = 60 - 21.46 = 38.36\%$

5.6 Soil classification by the Highway Research Board (HRB)

Passing 0.074 mm Sieve = 42.5%

Liquid limit (Ll) = 60%

Plasticity index (P.I) = 38.36%

Group index (G.I) = 0.2a + 0.005ac + 0.01bd

a = (42.5 – 35) = 7.5

b = (42.5 – 15) = 27.5

c = (60 – 40) = 20

d = (38.36 – 30) = 8.36

G.I.= (0.2*7.5 + 0.005* 7.5*20 + 0.01*27.5* 8.36) = 4.549 ≈ 5

Table 5.5: HRB Classification

Soil Group	Sub Group	General Stability Property and rating as Subgrade Material	Max. dry density (I. S. Light Comp c/μM2)	CBR %	Subgrade Modulus (kg/cM 2)	Drainage Characteristics	Volume Change Characteristics	Potential Frost Action	Approximate Equivalent Unified Classification
A-1	A-1-a	High Stability very good to Excellent Subgrade	2.03 (min)	60 -90	> 8.33	Excellent	Almost None	None to Slight	GW, GP, GM
	A-1-b			20 - 70		Good			SW, SM
A-3		Stable When confined very good to fair subgrade material	1.29 - 2.03	10 -80	> 5.55	Excellent	None	None	SP
A-2	A-2-4	Stable when dry; may ravel, Very good to good subgrade material	1.92 - 2.08	8 - 70	> 5.0	Good to Fair	Very Slight	Slight to High	GM, SM
	A-2-5								
	A-2-6	Good stability, very good to fair subgrade material				Fair to Poor	Slight to Medium	Very Slight to Medium	GC, SC
	A-2-7								
A-4		Satisfactory stability when dry. Loss of stability when wet or by frost action. Good to poor subgrade material	1.76 - 1.29	4 - 20	2.78 - 5.0	Fair to Poor	Slight to Medium	Very High	ML, OL
A-5		Difficult to coMPact doubtful stability, poor to very poor subgrade material	1.28 - 1.60	2 - 7	1.39 - 3.48	Poor	Medium to High	High to Very High	MH
A-6		Good stability when coMPacted in unsoaked condition, Fair to poor subgrade material	1.28 - 1.76	2 - 15	1.39 - 5.55	Very Poor	High	Medium to High	CL
A-7	A-7-5	Good stability when properly coMPact & in unsoaked conditions; poor subgrade	1.28 - 1.76	2 - 15	1.39 - 5.55	Very Poor	Very High	Medium	Cl, OL, CH, OH
	A-7-6								

Classification by HRB According to the Highway Research Board, the soil is classified as A-7-6 (5)

5.7 Shrinkage Limit

Table 5.6: Shrinkage limit test on Black cotton soil

Sl. No.	**a) Volume of wet soil pat (V) c.c.**	
1	Shrinkage Dish No.	1
2	Fibre added (%)	0
2	Mass of empty porcelain weighing dish (**M_1** gms)	166
3	Mass of Mercury Weighing Dish + Mercury Filling the Shrinkage Dish (**M_2** gms)	460
4	Mass of Mercury Filling the Dish, **M_3**= (**M_2-M_1**) gms	294
5	The volume of Wet Soil Pat, V=(**M_3**/13.6) cc	21.618
	b) Mass of wet-dry soil pat and its water-content	
6	Mass of Empty Shrinkage Dish (**M_4 gms**)	37
7	Mass of Shrinkage Dish + Wet Soil (**M_5 gmas**)	71
8	Mass of Shrinkage Dish + Dry Soil (**M_6 gmas**)	57
9	Mass of Water Mw= (**M_5-M_6**) gms	14
10	Mass of Dry Soil, **M_d**= (**M_6-M_4**) gms	20
11	Water Content, w=(Mw/**M_d**)	0.7
	c) Volume of dry soil pat (V_d) cc	
12	Mass of Mercury Weighing Dish + Mercury Displacement by Dry Soil Pat (**M_7 gms**)	333
13	Mass of Mercury Displaced by Dry Soil Pat, M8= (**M_7-M_1**) gms	167
14	Volume of Dry Soil Pat, **V_d**=(M8/13.6) cc	12.279
	d) Calculation	
15	Shrinkage Limit (%) **W_s**= (w-{V-**V_d**/**M_d**}) *100	23.309

5.8 Standard Proctor Test

- 2500 gm Sample was taken from the site and passing it through 4.75mm sieve before washing
- Volume of mould is 1000cc

Table 5.7: Standard Proctor Test on Black cotton soil

Trials	1	2	3	4
Mass of Empty mould (M_1) (g)	3686	3686	3686	3690
Mass of mould + CoMPacted soil (M_2) (g)	5358	5390	5421	5430
Mass of CoMPacted soil, M= M_2-M_1(g)	1672	1704	1735	1740
Bulk density, Ɣb = (M/V) (g/cc)	1.67	1.7	1.74	1.74
Container number	2	3	4	GT-24
Water added	0.22	0.24	0.26	0.28
Mass of container (M_1) (g)	29.5	22.5	16	29.5
Mass of container+ Wet soil (M_2) (g)	102	113.5	78	96.5
Mass of container +Dry soil (M_3) (g)	92	99	67	84
Mass of Water, Mw=M_2-M_3(g)	10	14.5	11	12.5
Mass of Dry soil, M_d=M_3-M_1(g)	62.5	76.5	51	54.5
Water Content, w=(Mw/M_d)*100	0.16	0.19	0.216	0.229
Dry Density, Ɣd= Ɣb/(1+w) (g/cc)	1.37	1.374	1.377	1.359

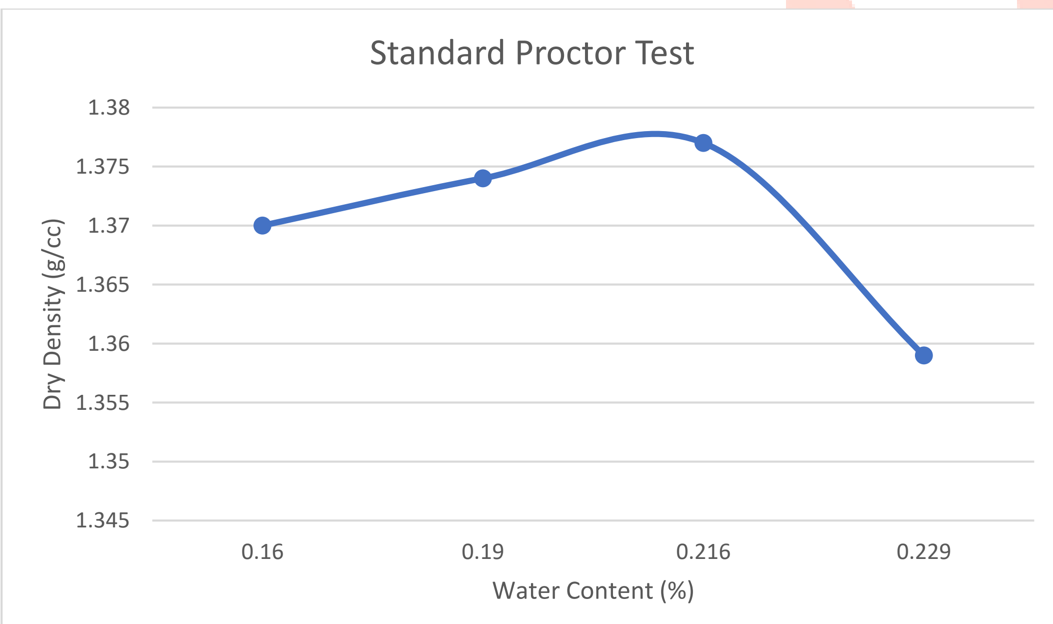

Fig 5.4: Compaction Curve for Black cotton soil

- **OMC** OBTAINED FROM THE GRAPH IS 21.4%
- **MDD** OBTAINED FROM THE GRAPH IS 1.378 g/cc

5.9 Unconfined Compression Test

- Following observations were seen at the time of UCS test

OMC = 21.40%, h = 7.8cm, d = 3.8cm , h1 = 7.1cm, d1 = 3.8cm

load per div. = 3.417N φ = 58°

Table 5.8: Unconfined Compression Test on Black cotton soil

Dial Gauge Readings	Strain (ϵ)	Proving Ring Readings (Trial 1)	Proving Ring Readings (Trial 2)	Avg Proving Ring Readings	Corrected Area	Load (N)	Axial Stress (MPa)
0	0	0	0	0	11.34	0	0
50	0.06	2.6	0.4	1.5	11.34	5.13	0.45
100	0.13	4.2	1.4	2.8	11.34	9.57	0.84
150	0.19	4.4	3.4	3.9	11.34	13.33	1.18
200	0.26	4	4.4	4.2	11.34	14.35	1.27
250	0.32	4	4.3	4.15	11.34	14.18	1.25

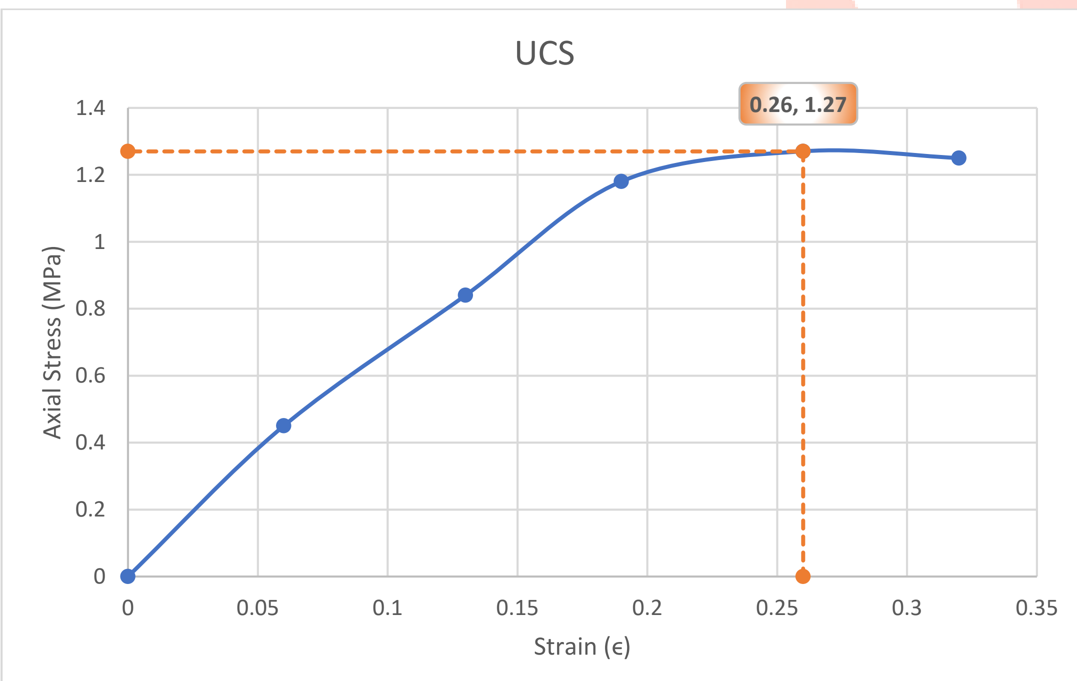

Fig 5.5: UCS Curve for Black cotton soil

5.10 California Bearing Ratio (CBR) Test

- Added water percentage was equal to **OMC** at 21.40%

Table 5.9: California Bearing Ratio (CBR) Test on Black Cotton Soil.

Penetration (mm)	Trial 1	Division	Load (kg)
0	0	0	0
0.5	0.8	4	6.4
1	1.8	9	14.4
1.5	2.4	12	19.2
2	2.8	14	22.4
2.5	3	15	24
3	3.2	16	25.6
4	3.6	18	28.8
5	4	20	32
7.5	4.6	23	36.8
10	5	25	40
12.5	5.6	28	44.8

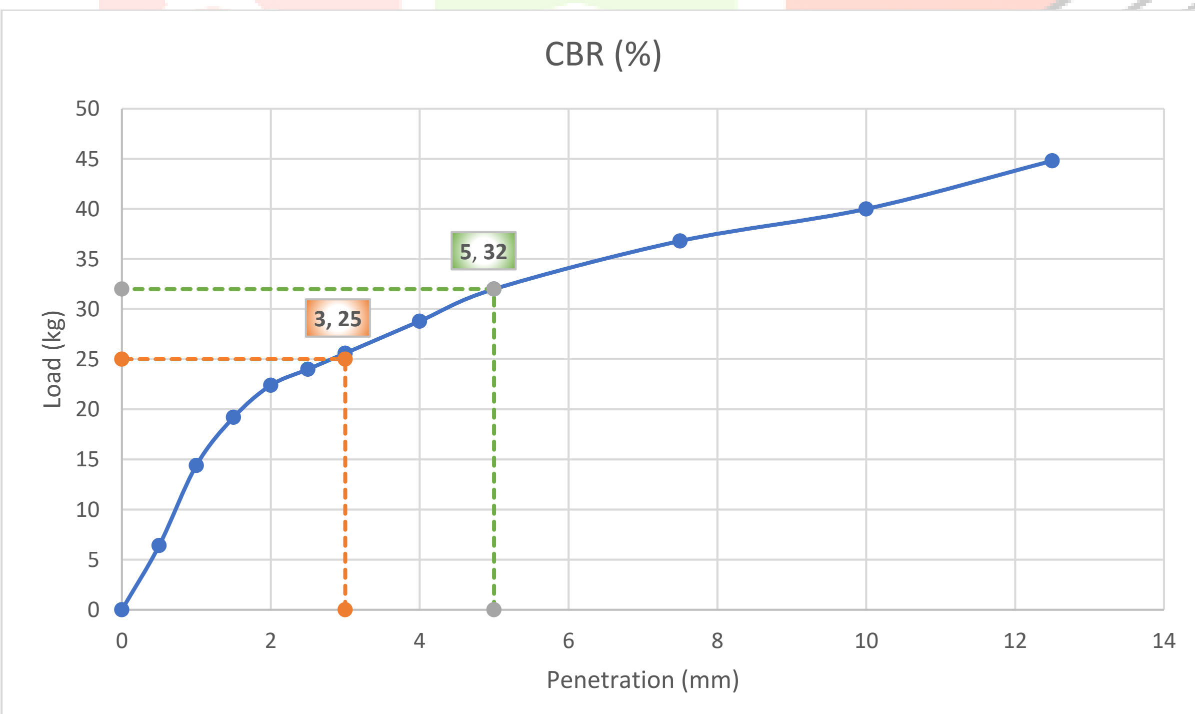

Fig 5.6: CBR Curve for Black Cotton Soil.

- From the graph Load at 2.5 mm penetration is 25 Kg
- CBR of specimen = (25/1370) *10 = 1.82%
- From the graph Load at 5 mm penetration is 32 Kg
- CBR of specimen = (34/2055) *100 = 1.65%

5.10 Liquid Limit Test of Soil Mixed with fibers (Cone Penetration Test)

- 150 gm of the sample were taken from the site and passing it through at 425µ

Table 5.10: Liquid Limit Test on Black Cotton Soil + 0.25% Bamboo fibers using Cone Penetration Method

Trial No.	Water Content (%)	Water Amount (ml)	Penetration (mm)
1	38	57	17
2	40	60	22
3	43	64.5	30

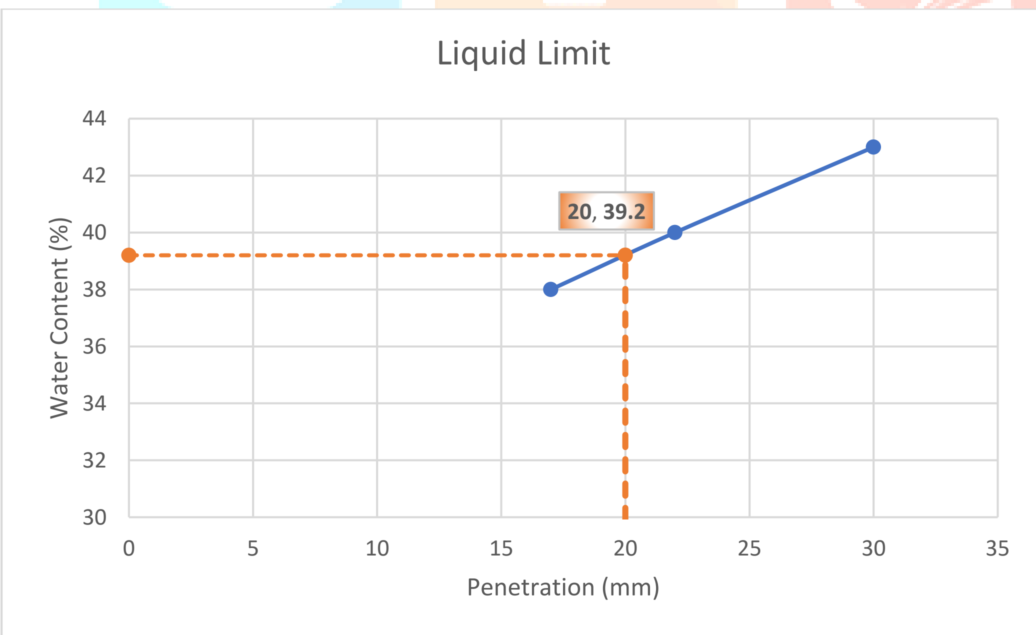

Fig 5.7: Liquid Limit curve of Black Cotton Soil + 0.25% Bamboo fibers (Cone Penetration)

- Liquid limit (w_L) *from* the graph is 39.2% corresponding to a 20 mm penetration

Table 5.11: Liquid Limit Test on Black Cotton Soil + 0.5% Bamboo fibers using Cone Penetration Method

Trial No.	Water Content (%)	Water Amount (ml)	Penetration (mm)
1	38	57	17
2	39.5	59.25	19
3	41	61.5	30

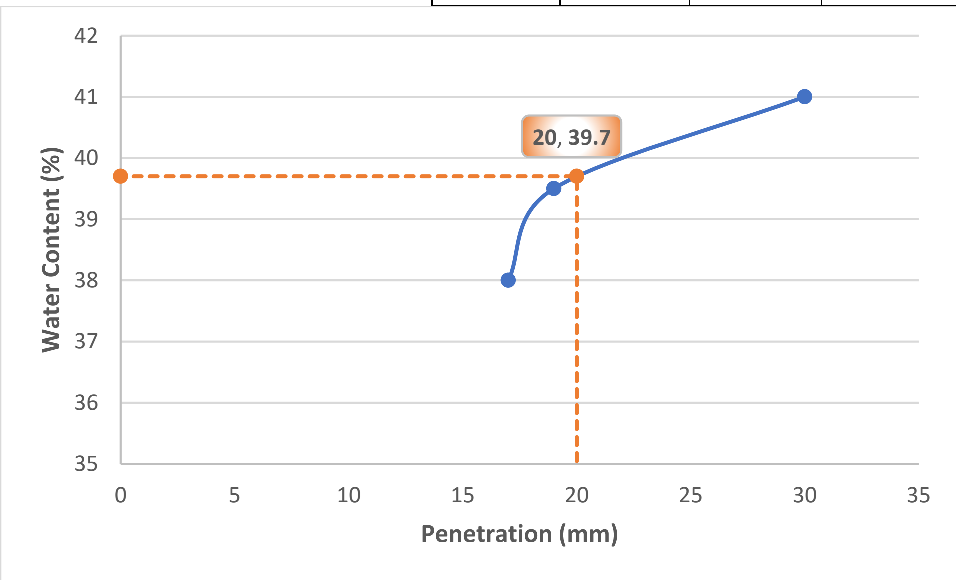

Fig 5.8: Liquid Limit curve of Black Cotton Soil + 0.5% Bamboo fibers (Cone Penetration)

- Liquid limit (w_L) from the graph is 39.7% at 20 mm penetration

Table 5.12: Liquid Limit test on Black Cotton Soil + 0.75% Bamboo fibers using Cone Penetration Method

Trial No.	Water Content (%)	Water Amount (ml)	Penetration (mm)
1	35	52.5	9
2	38	57	15
3	41	61.5	19
4	44	66	22

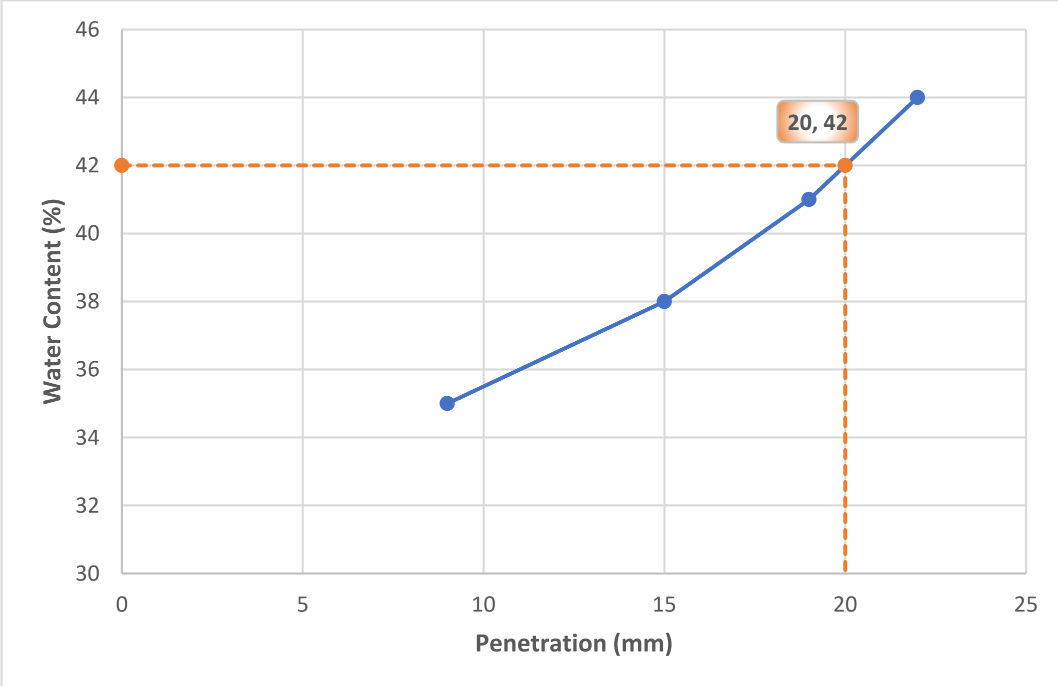

Fig 5.9: Liquid Limit curve of Black Cotton Soil + 0.75% Bamboo fibers (Cone Penetration)

- Liquid limit (w_L) from the graph can be seen as 42% at 20mm penetration

Table 5.13: Liquid limit test on Black Cotton Soil + 1% Bamboo fibers using Cone Penetration Method

Trial No.	Water Content (%)	Water Amount (ml)	Penetration (mm)
1	37	55.5	15
2	40	60	17
3	43	64.5	21

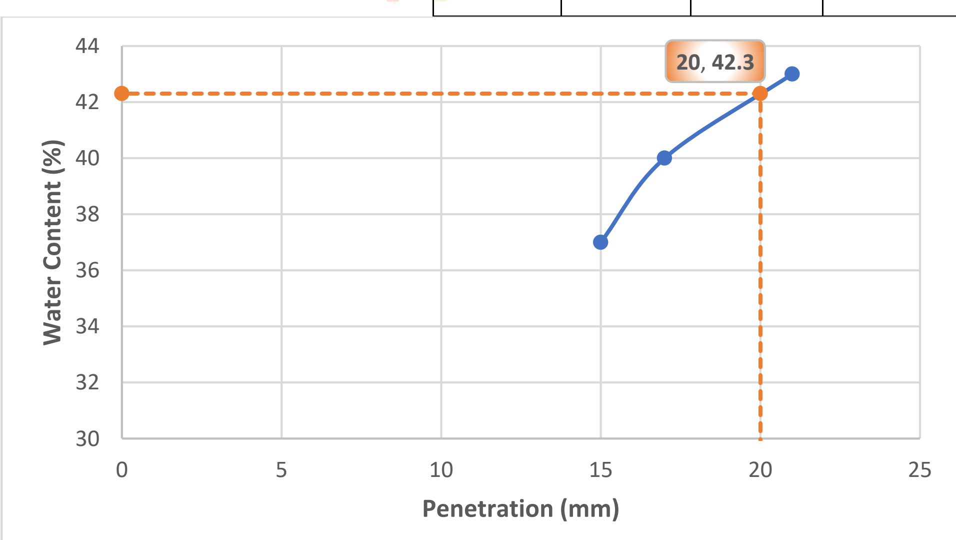

Fig 5.10: Liquid Limit curve of Black Cotton Soil + 1% Bamboo fibers (Cone Penetration)

- Liquid limit (w_L) can be seen as 42.3% at 20mm penetration

5.11 Plastic Limit Test on soil mixed up with fibers

Table 5.14: **Plastic limit test on Black Cotton Soil + 0.25%, +0.5%, + 0.75% and +1% Bamboo fibers**

Determination Number	1	2	3	4	5
Fibre added (%)	0	0.25	0.5	0.75	1
Container No.	GT-19	GT-21	GT-20	GT-14	GT-22
Mass of Empty Container (M_1 g)	32.15	29.5	34.5	30	31.5
Mass of Container + Wet Soil (M_2 g)	47.15	43.5	44.5	46	48
Mass of Container + Dry Soil (M_3 g)	44.5	40.5	42	41.8	43.5
Mass of Water = Mw = M_2-M_3	2.65	3	2.5	4.2	4.5
Mass of Dry Soil = M_d = M_3-M_1 (g)	12.35	11	7.5	11.8	12
Plastic Limit (%) W_p=(Mw/M_d) *100	21.46	27.27	33.33	35.59	37.5
Liquid Limit w_L	60	39.2	39.7	42	42.3
Plastic Limit (%) W_p	21.46	27.27	33.33	35.59	37.5
Plasticity Index	38.54	11.93	6.37	6.41	4.8

5.12 Shrinkage Limit test on soil added fibers

Table 5.15: Shrinkage Limit Test on Black Cotton Soil + 0.25%, +0.5%, + 0.75% and +1% Bamboo fibers

Sl. No.	a) Volume of wet soil pat (V) c.c.					
1	Shrinkage Dish No.	1	2	3	4	5
2	Fibre added (%)	0	0.25	0.5	0.75	1
2	Mass of empty porcelain weighing dish (**M_1** gms)	166	100.5	100.5	100.5	100.5
3	Mass of Mercury Weighing Dish + Mercury Filling the Shrinkage Dish (**M_2** gms)	460	390.5	388	398.5	393
4	Mass of Mercury Filling the Dish, **M_3**= (**M_2-M_1**) gms	294	290	287.5	298	292.5
5	Volume of Wet Soil Pat, V=(**M_3**/13.6) cc	21.618	21.324	21.14	21.912	21.507
	b) Mass of wet dry soil pat and its water-content					
6	Mass of Empty Shrinkage Dish (**M_4 gms**)	37	39.5	48	42	55.5
7	Mass of Shrinkage Dish + Wet Soil (**M_5 gmas**)	71	79.5	81.5	77	90
8	Mass of Shrinkage Dish + Dry Soil (**M_6 gmas**)	57	64.5	72.5	66.5	81.5
9	Mass of Water Mw= (**M_5-M_6**) gms	14	15	9	10.5	8.5

10	Mass of Dry Soil, $\mathbf{M_d}$= ($\mathbf{M_6}$-$\mathbf{M_4}$) gms	20	25	24.5	24.5	26
11	Water Content, w=(Mw/$\mathbf{M_d}$)	0.7	0.6	0.367	0.429	0.327
	c) Volume of dry soil pat (V_d) cc					
12	Mass of Mercury Weighing Dish + Mercury Displacement by Dry Soil Pat ($\mathbf{M_7}$ **gms**)	333	242.5	318.5	282.5	298
13	Mass of Mercury Displaced by Dry Soil Pat, M8= ($\mathbf{M_7}$-$\mathbf{M_1}$) gms	167	142	218	182	197.5
14	Volume of Dry Soil Pat, $\mathbf{V_d}$=(M8/13.6) cc	12.279	10.441	16.029	13.382	14.522
	d) Calculation					
15	Shrinkage Limit (%) $\mathbf{W_s}$= (w-{V-$\mathbf{V_d}$/$\mathbf{M_d}$}) *100	23.309	16.471	15.876	8.043	5.826

5.13Standard Proctor Test on Black Cotton Soil with fibers

- 2500gm of the sample was taken and passing it on 4.75mm sieve before washing.
- Volume of Mould is 1000 cc.

Table 5.16: Standard Proctor Test on Black Cotton Soil+ 0.25% Bamboo Fibers

Trials	**1**	**2**	**3**	**4**
Mass of Empty Mould (M_1) (g)	3686	3686	3686	3686
Mass of Mould + CoMPacted Soil (M_2) (g)	5276	5326	5369	5403
Mass of CoMPacted Soil, M = M_2-M_1(g)	1590	1640	1683	1717
Bulk Density, Yb=(M/V) (g/cc)	1.59	1.64	1.683	1.717
Container Number	GT-1	GT-16	GT-10	GT-3
Water Added	0.18	0.2	0.22	0.24
Mass of Container (M_1) (g)	28	29	33	30
Mass of Container + Wet Soil (M_2) (g)	131	119.5	125.5	118.5
Mass of Wet Soil	103	90.5	92.5	88.5
Mass of Container + Dry Soil (M_3) (g)	118	106	110	102
Mass of Water = Mw = M_2-M_3	13	13.5	15.5	16.5
Mass of Dry Soil = M_d = M_3-M_1 (g)	90	77	77	72
Water Content, w = (Mw/M_d) *100	0.144	0.175	0.201	0.229
Dry Density, Yd=Yb/(1+w) (g/cc)	1.389	1.395	1.401	1.397

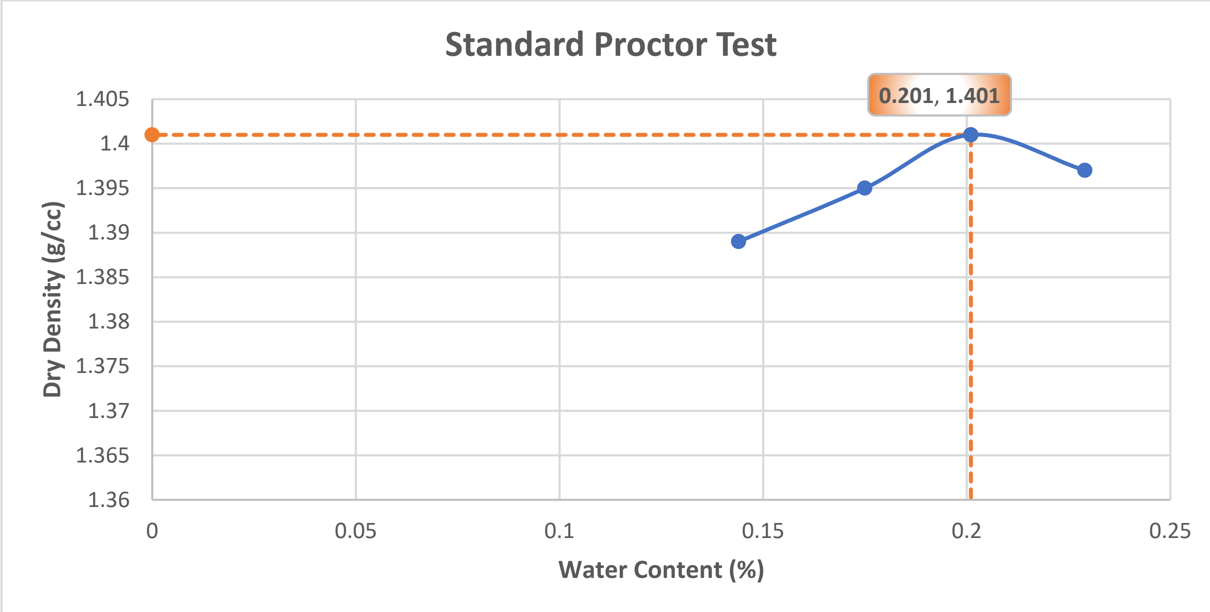

Fig 5.11: Compaction Curve for Black Cotton Soil + 0.25% fibers

- **OMC** can be seen from the graph as 20.1%
- **MDD** can be seen from the graph as 1.401 g/cc

Table 5.17: Standard Proctor Test on Black Cotton Soil+ 0.5% Bamboo Fibers

Trials	**1**	**2**	**3**	**4**
Mass of Empty Mould (M_1) (g)	4446	4446	4446	4446
Mass of Mould + CoMPacted Soil (M_2) (g)	6000	6131	6150	6189
Mass of CoMPacted Soil, M = M_2-M_1(g)	1554	1685	1704	1743
Bulk Density, Yb=(M/V) (g/cc)	1.554	1.685	1.704	1.743
Container Number	1	2	3	4
Water Added	0.18	0.2	0.22	0.24
Mass of Container (M_1) (g)	22.5	29.5	22.5	16
Mass of Container + Wet Soil (M_2) (g)	178	178.5	172	110
Mass of Wet Soil	155.5	149	149.5	94
Mass of Container + Dry Soil (M_3) (g)	156	155	147	92
Mass of Water = Mw = M_2-M_3	22	23.5	25	18
Mass of Dry Soil = M_d = M_3-M_1 (g)	133.5	125.5	124.5	76
Water Content, w = (Mw/M_d) *100	0.165	0.187	0.201	0.237
Dry Density, Yd=Yb/(1+w) (g/cc)	1.334	1.419	1.419	1.409

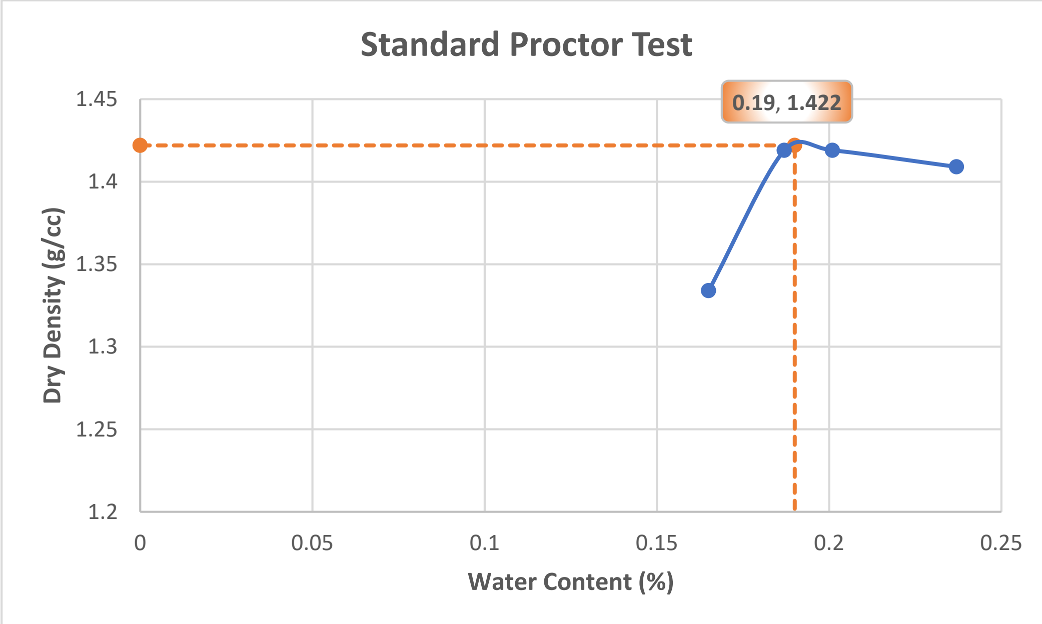

Fig 5.12: Compaction Curve for Black Cotton Soil + 0.5% fibers

- **OMC** can be seen from the graph as 19.00%.
- **MDD** can be seen from the graph as 1.422 g/cc.

Table 5.18: Standard Proctor Test on Black Cotton Soil+ 0.75% Bamboo Fibers

Trials	**1**	**2**	**3**	**4**
Mass of Empty Mould (M_1) (g)	4446	4446	4446	4446
Mass of Mould + CoMPacted Soil (M_2) (g)	6170	6282	6221	6214
Mass of CoMPacted Soil, M = M_2-M_1(g)	1724	1836	1775	1768
Bulk Density, Yb=(M/V) (g/cc)	1.724	1.836	1.775	1.768
Container Number	1	2	3	4
Water Added	0.18	0.2	0.22	0.24
Mass of Container (M_1) (g)	22.5	29.5	22.5	16
Mass of Container + Wet Soil (M_2) (g)	182.5	181.5	182	111.5
Mass of Wet Soil	160	152	159.5	95.5
Mass of Container + Dry Soil (M_3) (g)	161	159	155	94
Mass of Water = Mw = M_2-M_3	21.5	22.5	27	17.5
Mass of Dry Soil = M_d = M_3-M_1 (g)	138.5	129.5	132.5	78
Water Content, w = (Mw/M_d) *100	0.155	0.174	0.204	0.224
Dry Density, Yd=Yb/(1+w) (g/cc)	1.492	1.564	1.475	1.444

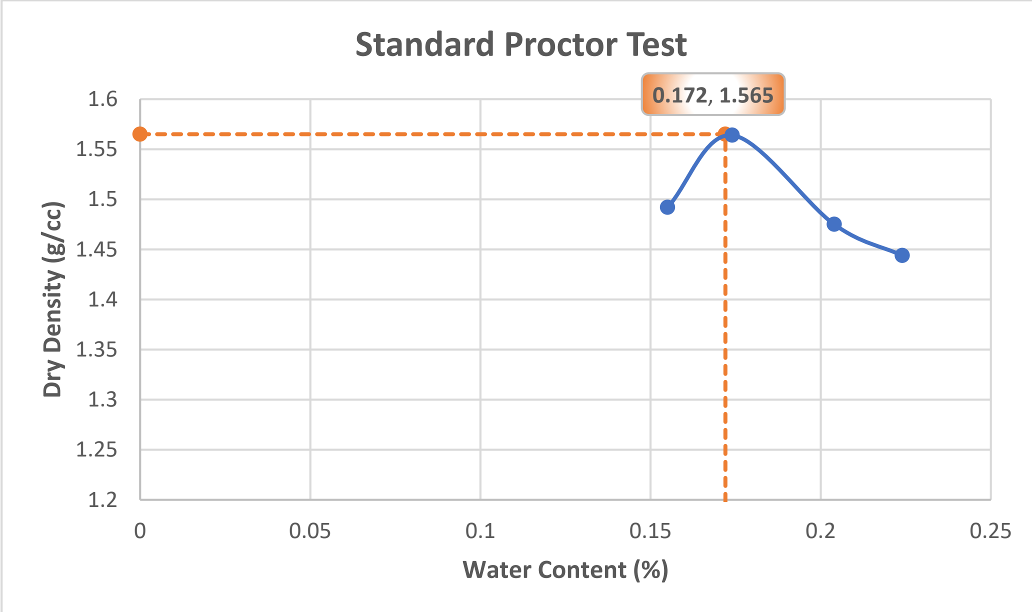

Fig 5.13: Compaction Curve for Black Cotton Soil + 0.75% fibers

- **OMC** can be seen from the graph as 17.20%
- **MDD** can be seen from the graph as 1.565 g/cc

Table 5.19: Standard Proctor Test on Black Cotton Soil+ 1.00% Bamboo Fibers

Trials	**1**	**2**	**3**	**4**
Mass of Empty Mould (M_1) (g)	4394	4394	4394	4394
Mass of Mould + CoMPacted Soil (M_2) (g)	5892	6003	6004	6087
Mass of CoMPacted Soil, M = M_2-M_1(g)	1498	1609	1610	1693
Bulk Density, Yb=(M/V) (g/cc)	1.498	1.609	1.61	1.693
Container Number	1	2	3	4
Water Added	0.18	0.2	0.22	0.24
Mass of Container (M_1) (g)	22.5	29.5	22.5	16
Mass of Container + Wet Soil (M_2) (g)	157	168	187	128
Mass of Wet Soil	134.5	138.5	164.5	112
Mass of Container + Dry Soil (M_3) (g)	140.5	148	159	104
Mass of Water = Mw = M_2-M_3	16.5	20	28	24
Mass of Dry Soil = M_d = M_3-M_1 (g)	118	118.5	136.5	91.5
Water Content, w = (Mw/M_d) *100	0.14	0.169	0.205	0.262
Dry Density, Yd=Yb/(1+w) (g/cc)	1.314	1.377	1.336	1.341

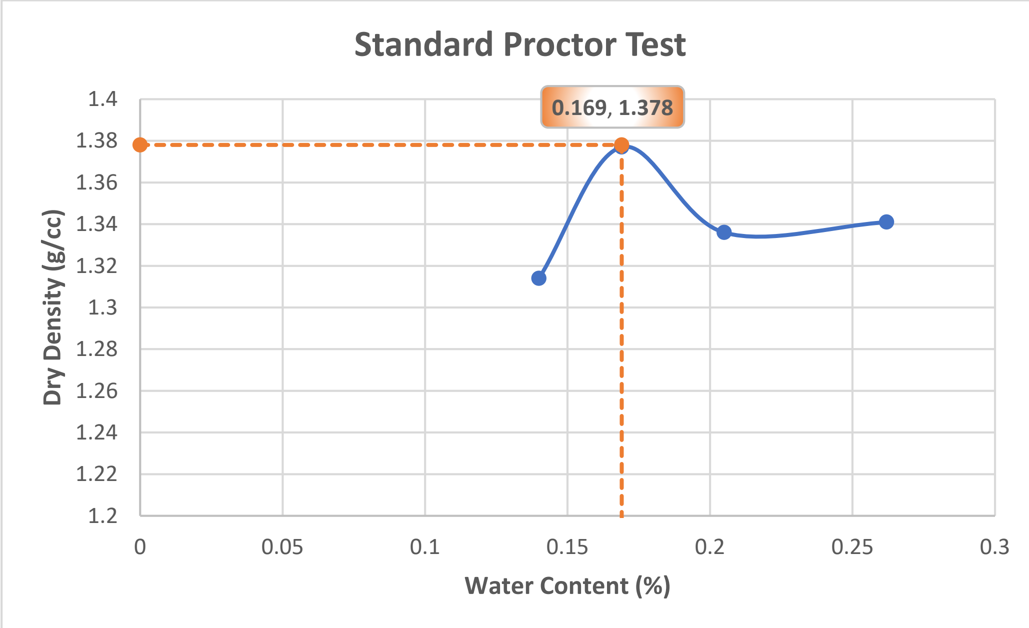

Fig 5.14: Compaction Curve for Black Cotton Soil + 1.00% fibers

- **OMC** can be seen from the graph as 16.9%.
- **MDD** can be seen from the graph as 1.378 g/cc.

5.14 Unconfined Compression Test on Black Cotton Soil with fibers

- Black Cotton Soil mixed with fibers at 0.25% by weight the following observation was seen:

The weight of the sample is 250 gm

OMC = 20.1%, d = 3.8cm, h1 = 7.1cm,

d1= 3.9cm, f = 55°, h = 7.8cm , load per div. = 3.417N

Table 5.20: Unconfined Compression Test on Black Cotton Soil+0.25% fibers

Dial Gauge Readings	Strain (ϵ)	Proving Ring Readings (Trial 1)	Proving Ring Readings (Trial 2)	Avg Proving Ring Readings	Corrected Area	Load (N)	Axial Stress (MPa)
0	0	0	0	0	11.341	0	0
50	0.064	1.2	1.2	1.2	11.341	4.1	0.362
100	0.128	2	2	2	11.341	6.834	0.603
150	0.192	2.4	2.6	2.5	11.341	8.543	0.753
200	0.256	3	3	3	11.341	10.251	0.904
250	0.321	3.2	3.6	3.4	11.341	11.618	1.024
300	0.385	4	3.8	3.9	11.341	13.326	1.175
350	0.449	4.4	4	4.2	11.341	14.351	1.265
400	0.513	4.8	4.4	4.6	11.341	15.718	1.386

450	0.577	5.2	4.6	4.9	11.341	16.743	1.476
500	0.641	5.4	4.6	5	11.341	17.085	1.506
550	0.705	5.8	4.8	5.3	11.341	18.11	1.597
600	0.769	6.2	5	5.6	11.341	19.135	1.687
650	0.833	6	5	5.5	11.341	18.794	1.657

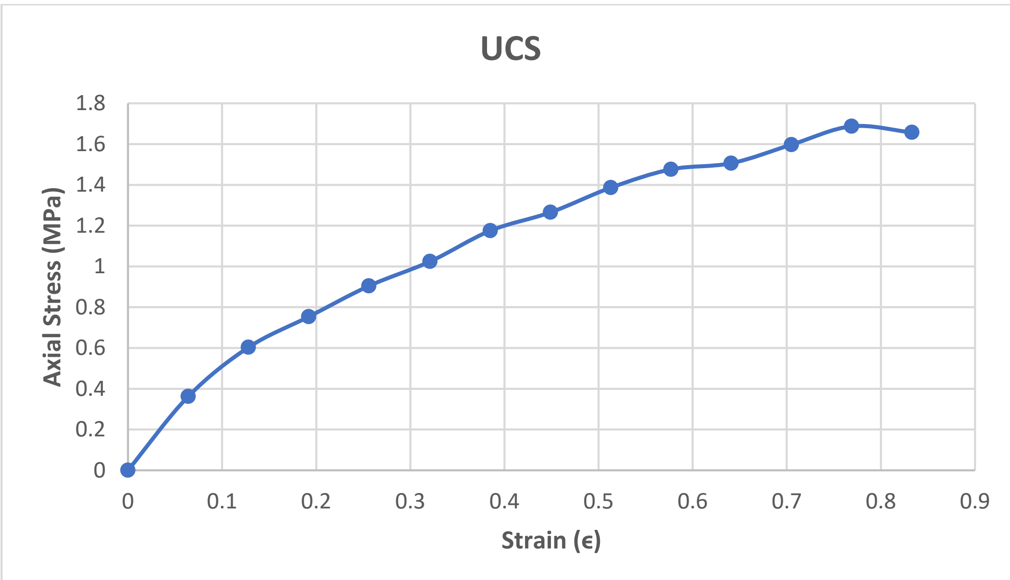

Fig 5.15: UCS Curve for Black Cotton Soil + 0.25% fibers

The following observations were recorded after adding 0.5 percent fibers to Black Cotton Soil:

OMC = 19% (weight of sample = 250 g), load per div. = 3.417 N, h = 7.8cm, d = 3.8cm, h1 = 7.2cm, d1 = 3.9cm, f = 50°

Table 5.21: Unconfined Compression Test on Black Cotton Soil + 0.5% fibre

Dial Gauge Readings	**Strain (ϵ)**	**Proving Ring Readings (Trial 1)**	**Proving Ring Readings (Trial 2)**	**Avg Proving Ring Readings**	**Corrected Area**	**Load (N)**	**Axial Stress (MPa)**
0	0	0	0	0	11.341	0	0
50	0.064	1.2	1	1.1	11.341	3.759	0.331
100	0.128	2.4	2	2.2	11.341	7.517	0.663
150	0.192	3.2	2.4	2.8	11.341	9.568	0.844
200	0.256	3.8	3.2	3.5	11.341	11.96	1.055
250	0.321	4.4	3.8	4.1	11.341	14.01	1.235
300	0.385	4.8	4	4.4	11.341	15.035	1.326
350	0.449	5	4.4	4.7	11.341	16.06	1.416

400	0.513	5.4	4.8	5.1	11.341	17.427	1.537
450	0.577	5.6	5.2	5.4	11.341	18.452	1.627
500	0.641	5.8	5.6	5.7	11.341	19.477	1.717
550	0.705	6.0.	5.8	5.9	11.341	20.16	1.778
600	0.769	6.2	6	6.1	11.341	20.844	1.838
650	0.833	6.2	6	6.1	11.341	20.844	1.838

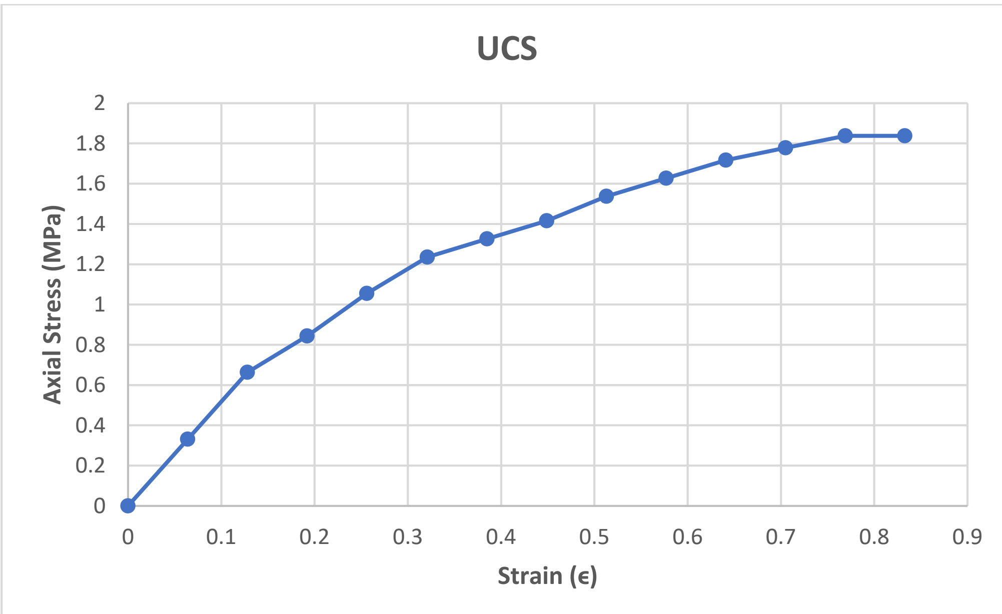

Fig 5.16: Compaction Curve for Black Cotton Soil + 0.50% fibers

The following observations were found after adding 0.75 percent fibers to Black Cotton Soil:

OMC = 17.2 percent, sample weight = 250 g, h = 7.9cm d = 3.8cm, h1 = 7.5cm, d1 = 3.9cm, f = 58°, load per div. = 3.417N

Table 5.22: Unconfined Compression Test on Black Cotton Soil + 0.75% fibre

Dial Gauge Readings	Strain (ϵ)	Proving Ring Readings (Trial 1)	Proving Ring Readings (Trial 2)	Avg Proving Ring Readings	Corrected Area	Load (N)	Axial Stress (MPa)
0	0	0	0	0	11.34115	0	0
50	0.063	1.6	1.5	1.55	11.34115	5.296	0.467
100	0.127	3	2.2	2.6	11.34115	8.884	0.783
150	0.19	3.6	2.6	3.1	11.34115	10.593	0.934
200	0.253	4	3	3.5	11.34115	11.96	1.055
250	0.316	4.6	3.4	4	11.34115	13.668	1.205
300	0.38	5	4.2	4.6	11.34115	15.718	1.386
350	0.443	5.4	4.6	5	11.34115	17.085	1.506
400	0.506	5.8	4.8	5.3	11.34115	18.11	1.597
450	0.57	6	5.2	5.6	11.34115	19.135	1.687
500	0.633	6	5.6	5.8	11.34115	19.819	1.747
550	0.696	6.2	6	6.1	11.34115	20.844	1.838
600	0.759	6.2	6.2	6.2	11.34115	21.185	1.868
650	0.823	6.2	6.2	6.2	11.34115	21.185	1.868

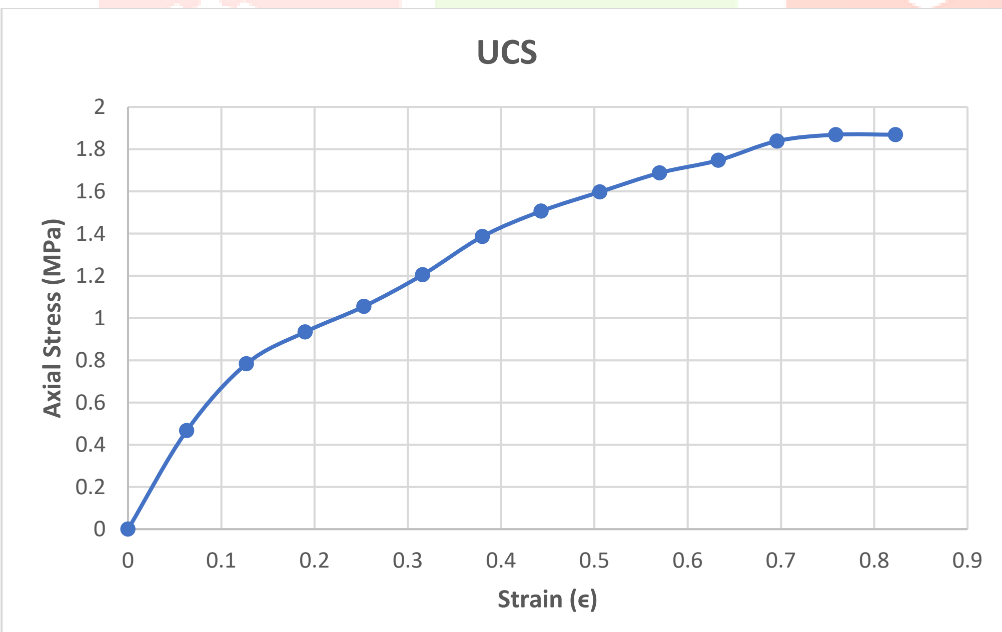

Figure 5.17: Compaction Curve for Black Cotton Soil + 0.75% fibers

- Black Cotton Soil mixed with fibers 1.0% by weight the followed observation can be seen from it:

  Weight of Sample = 250 gm, **OMC** = 16.9%, h = 7.9cm, d = 3.8cm, h1 = 7.3, d1 = 3.9 centimetre,

  F = 58°, Load per div. = 3.417 N

Table 5.23: Unconfined Compression Test on Black Cotton Soil + 1.0% fibre

Dial Gauge Readings	Strain (ϵ)	Proving Ring Readings (Trial 1)	Proving Ring Readings (Trial 2)	Avg Proving Ring Readings	Corrected Area	Load (N)	Axial Stress (MPa)
0	0	0	0	0	11.341	0	0
50	0.063	1.4	2	1.7	11.341	5.809	0.512
100	0.127	2	3	2.5	11.341	8.543	0.753
150	0.19	2.8	3.8	3.3	11.341	11.276	0.994
200	0.253	3.4	4.6	4	11.341	13.668	1.205
250	0.316	3.8	5	4.4	11.341	15.035	1.326
300	0.38	4.2	5.4	4.8	11.341	16.402	1.446
350	0.443	4.6	6	5.3	11.341	18.11	1.597
400	0.506	5	6.2	5.6	11.341	19.135	1.687
450	0.57	5.4	6.4	5.9	11.341	20.16	1.778
500	0.633	5.6	6.8	6.2	11.341	21.185	1.868
550	0.696	5.8	7	6.4	11.341	21.869	1.928
600	0.759	6	7.2	6.6	11.341	22.552	1.989
650	0.823	6	7.2	6.6	11.341	22.552	1.989

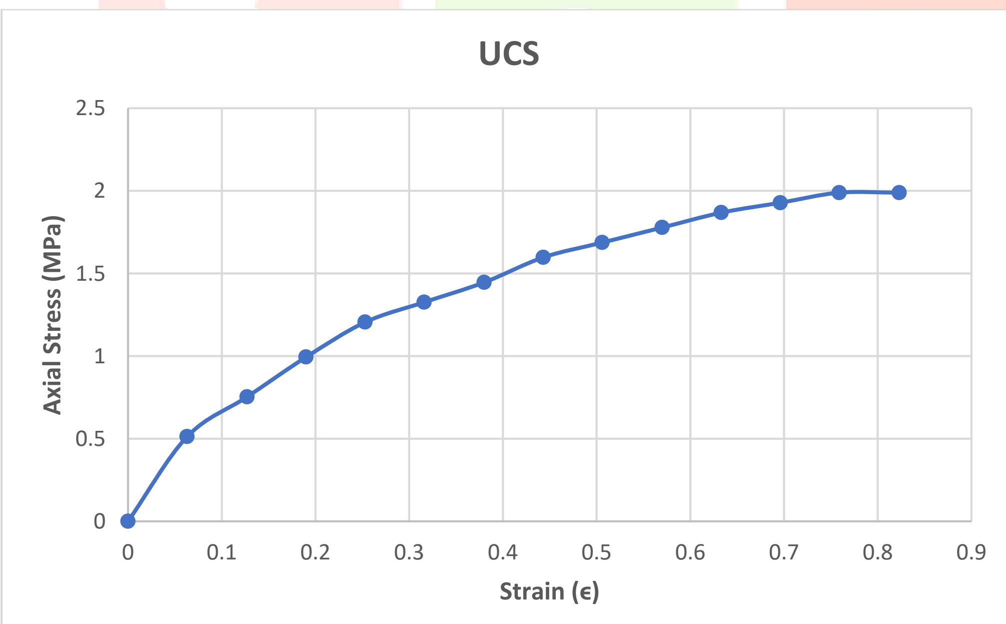

Fig 5.18: UCS Curve for Black Cotton Soil + 1.00% fibers

5.15 California Bearing Ratio (CBR) on Black Cotton Soil with fibers

- The following observations were recorded after adding 0.25 percent fibers to Black Cotton Soil:

OMC= 20.1%

Table 5.24: CBR Test on Black Cotton Soil + 0.25% fibre

Penetration (mm)	Trial 5	Division	Load (kg)
0	0	0	0
0.5	2	10	16
1	3.6	18	28.8
1.5	4.6	23	36.8
2	5.4	27	43.2
2.5	6	30	48
3	6.4	32	51.2
4	7.2	36	57.6
5	7.8	39	62.4
7.5	8.8	44	70.4
10	9.4	47	75.2
12.5	10	50	80

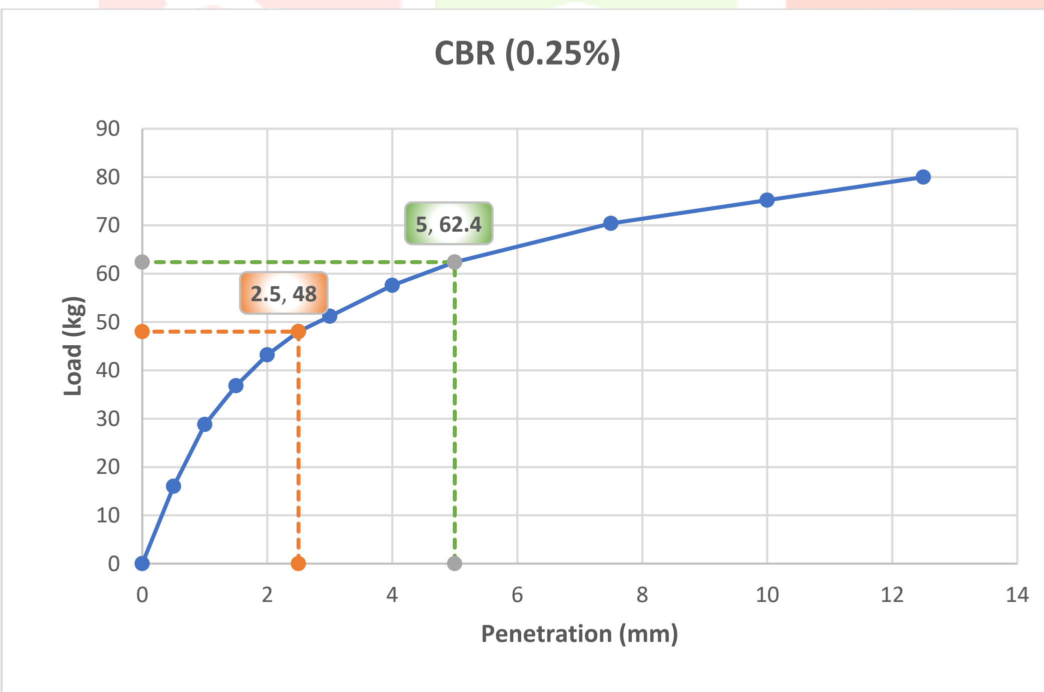

Fig 5.19: CBR Curve for Black Cotton Soil + 0.25% fibers

- Load can be seen from the graph as 48 Kg at a 2.5 mm penetration level.
- CBR of the specimen is calculated as = (48/1370) *100

= 3.49%

- Load can be seen from the graph as 62.4 Kg at a 5 mm penetration level.
- CBR of Specimen = (62.4/2055) *100

=3.02%

- The following observations were recorded after adding 0.5 percent fibers to Black Cotton Soil:

OMC= 19.00%

Table 5.25: CBR Test on Black Cotton Soil + 0.5% fibre

Penetration (mm)	Trial 2	Division	Load (kg)
0	0	0	0
0.5	2	10	16
1	3.8	19	30.4
1.5	5	25	40
2	6	30	48
2.5	6.8	34	54.4
3	7.6	38	60.8
4	8.8	44	70.4
5	9.8	49	78.4
7.5	11.4	57	91.2
10	12.4	62	99.2
12.5	13.4	67	107.2

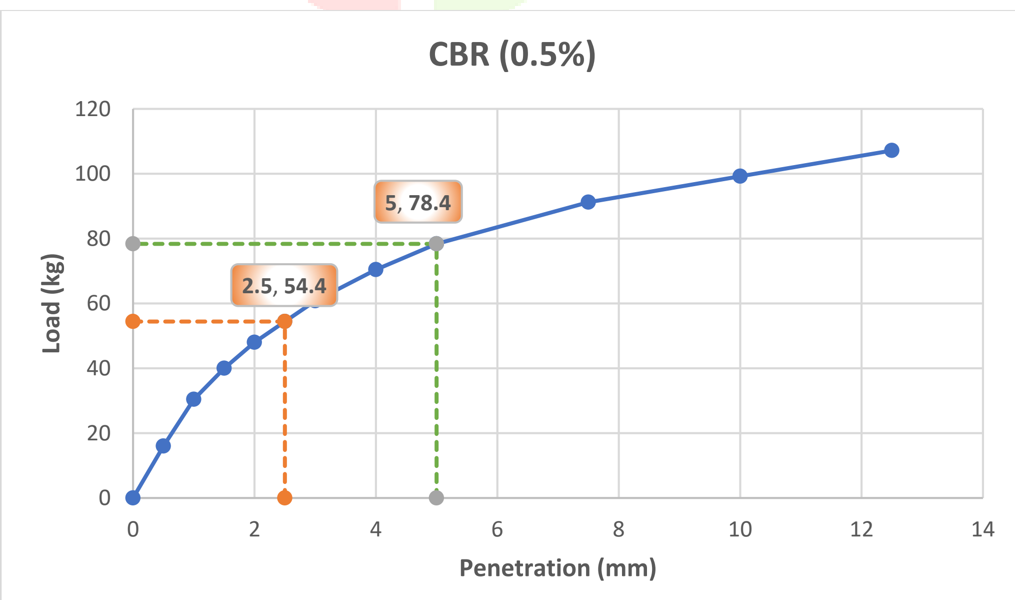

Fig 5.20: CBR Curve for Black Cotton Soil + 0.5% fibers

- Load can be seen in graph as 54.4 gg at 2.5mm penetration level.
- CBR of specimen = (54.4/1370) *100 = 3.96%
- Load can be seen as 78.4 kg at 5mm penetration level.
- CBR of specimen = = (78.4/2055) *100 = 3.80%

The following observations were found after adding 0.75 percent fibers to black cotton.

soil: **OMC**= 17.20%

Table 5.26: CBR Test on Black Cotton Soil+0.75% fibre

Penetration (mm)	Trial 3	Division	Load (kg)
0	0	0	0
0.5	4.2	21	33.6
1	6.2	31	49.6
1.5	7.6	38	60.8
2	8.6	43	68.8
2.5	9.8	49	78.4
3	10.6	53	84.8
4	12	60	96
5	13.2	66	105.6
7.5	15.4	77	123.2
10	17.2	86	137.6
12.5	18.8	94	150.4

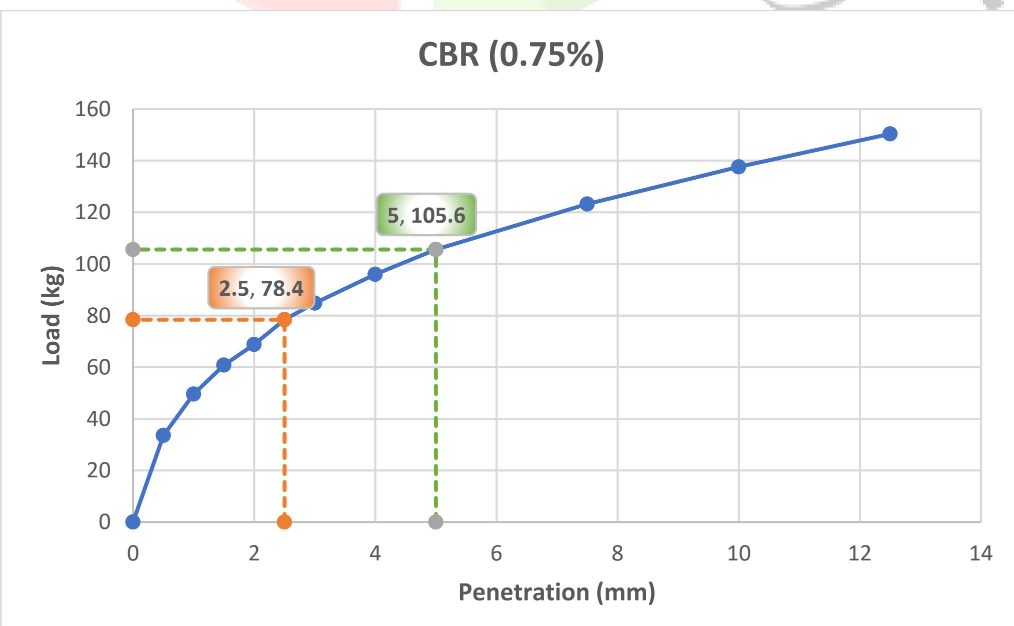

Fig 5.21: CBR Curve for Black Cotton Soil + 0.75% fibre

- Load can be seen from the graph is 78.4Kg at 2.5 mm penetration level.
- CBR of Specimen = (78.4/1370) *100 = 5.41%
- Load can be seen from the graph is 105.6 Kg at 5mm penetration level.
- CBR of Specimen = (105.6/2055) *100 = 5.12%
- The following observations were recorded after adding 1.0 percent fibers to Black Cotton Soil:

OMC = 16.9%

Table 5.27: CBR Test on Black Cotton Soil + 1.0% fibre

Penetration (mm)	Trial 4	Division	Load (kg)
0	0	0	0
0.5	2	10	16
1	3.4	17	27.2
1.5	4.6	23	36.8
2	5.8	29	46.4
2.5	6.8	34	54.4
3	7.6	38	60.8
4	9	45	72
5	10	50	80
7.5	12.2	61	97.6
10	14	70	112
12.5	15.6	78	124.8

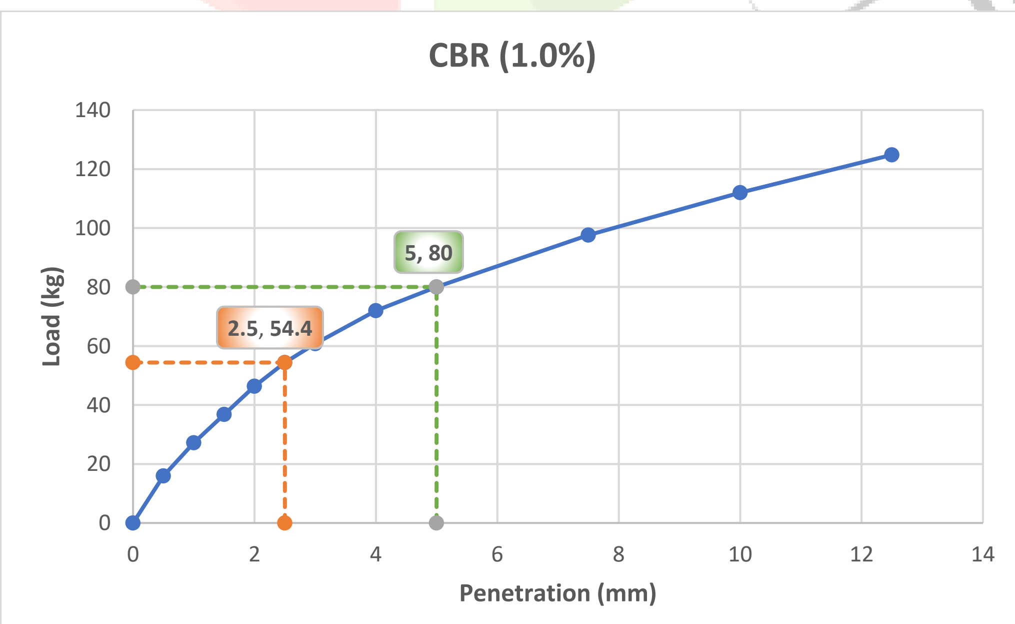

Fig 5.22: CBR Curve for Black Cotton Soil + 1.0% fibers

- Load can be seen from the graph as 54.4Kg at 2.5 mm penetration level.
- CBR of Specimen = (54.4/1370) *100 = 3.96%
- Load can be seen from the graph as 80 kg at 5 mm penetration level.
- CBR of specimen = (80/2055) *100 = 3.88%

5.16 Wet Sieve Analysis

The soil was classified using a wet sieve analysis of Sedu Soil collected from Belgavi. Following are some observations:

- 200 gm of a sample taken passed at 4.75mm sieve before washing.
- 142.5gm of sample retained on 0.075mm sieve after washing and then drying it.
- 57.5gm sample passed through 0.075mm sieve after washing, 28.75%

Table 5.28: Sieve analysis of Sedu Soil

Sl. No.	**IS Sieve Size**	**Particle Size (D) (mm)**	**Mass Soil Retained (M_1) (g)**	**% Mass Retained (M_1/M) *100**	**Cumulative % Retained (C)**	**Cumulative % Fine (N=100-C)**
1	2	2	4.5	3.16	3.16	96.84
2	1	1	23	16.14	19.3	80.7
3	0.6	0.6	27	18.95	38.25	61.75
4	0.425	0.425	23.5	16.49	54.74	45.26
5	0.3	0.3	17	11.93	66.67	33.33
6	0.212	0.212	24	16.84	83.51	16.49
7	0.15	0.15	9	6.32	89.82	10.18
8	0.075	0.075	14.5	10.18	100	0
9	Pan	0	0	0	100	0

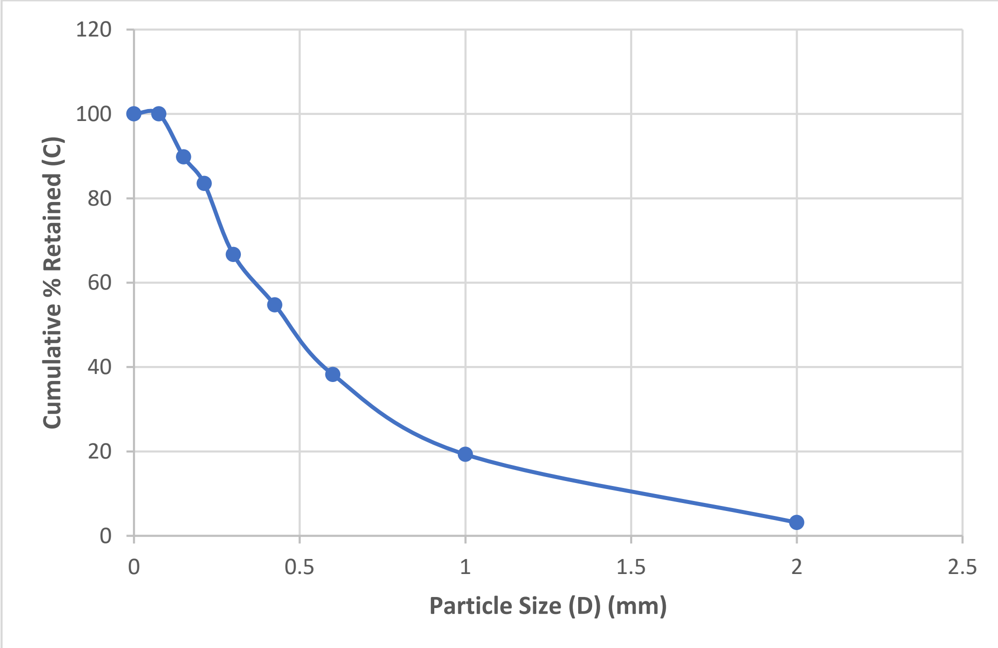

Fig 5.23: Particle size distribution curve of Sedu Soil

5.17 Liquid Limit Test

5.17.1 Cone Penetration Test

150 gm of the sample was taken and passing it through at 425µ.

Table 5.29: Liquid limit test on Sedu Soil using Cone Penetration Method

Trial No.	**Water Content (%)**	**Water Amount (ml)**	**Penetration (mm)**
1	30	45	14
2	32	48	16
3	34	51	17
4	36	54	19
5	40	60	48

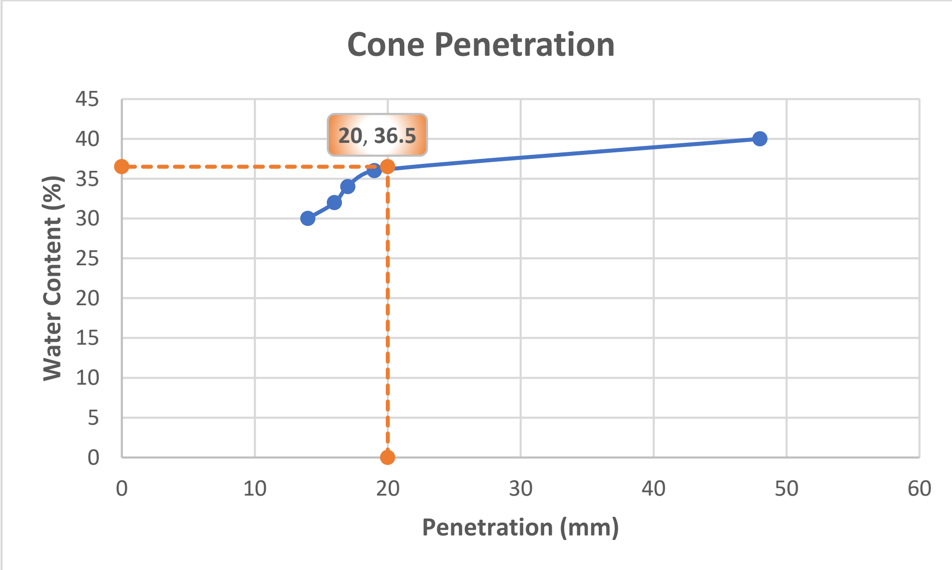

Fig 5.24: Liquid Limit curve (Cone Penetration)

Liquid limit (w_L) can be seen from the graph as 36.5% at 20mm penetration level.

5.18 Standard Proctor Test

- 2500 gm of the sample taken at passing it through at 4.75 mm sieve before washing.
- Volume of Mould is 1000 cc.

Table 5.30: Standard Proctor Test on Sedu Soil

Trials	**1**	**2**	**3**	**4**
Mass of Empty Mould (M_1) (g)	4440	4440	4440	4440
Mass of Mould + CoMPacted Soil (M_2) (g)	6450	6495	6530	6540
Mass of CoMPacted Soil, M = M_2-M_1(g)	2010	2055	2090	2100
Bulk Density, Yb=(M/V) (g/cc)	2.01	2.055	2.09	2.1
Container Number	9	5	18	6
Water Added	0.14	0.16	0.18	0.2
Mass of Container (M_1) (g)	21	22	18.5	20
Mass of Container + Wet Soil (M_2) (g)	120	120	120	120
Mass of Container + Dry Soil (M_3) (g)	109	107.5	106	105
Mass of Water = Mw = M_2-M_3	11	12.5	14	15
Mass of Dry Soil = M_d = M_3-M_1 (g)	88	85.5	87.5	85
Water Content, w = (Mw/M_d) *100	0.125	0.146	0.16	0.176
Dry Density, Yd=Yb/(1+w) (g/cc)	1.787	1.793	1.802	1.785

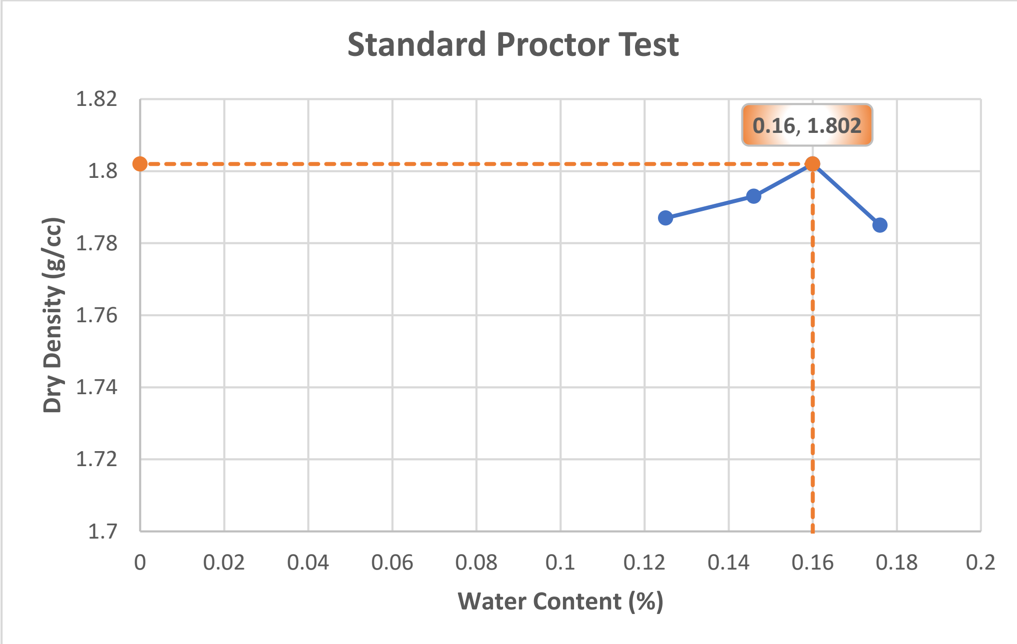

Fig 5.25: Compaction Curve for Sedu Soil

- **OMC** can be seen from the graph as 16.0 %.
- **MDD** can be seen from the graph as 1.802 g/cc.

5.19 Unconfined Compression Test

wc = 16%, h = 7.8cm, d = 3.8cm, h1 = 6.9cm, d1 = 4.1cm, load per div.= 3.417 kN, f=65°

Table 5.31: Unconfined Compression Test on Sedu Soil

Dial Gauge Readings	Strain (ϵ)	Proving Ring Readings	Corrected Area	Load (N)	Axial Stress (MPa)
0	0	0	11.341	0	0
50	0.064	1	11.341	3.417	0.301
100	0.128	2	11.341	6.834	0.603
150	0.192	2.6	11.341	8.884	0.783
200	0.256	3	11.341	10.251	0.904
250	0.321	3.2	11.341	10.934	0.964
300	0.385	3.4	11.341	11.618	1.024
350	0.449	3.4	11.341	11.618	1.024
400	0.513	3.2	11.341	10.934	0.964

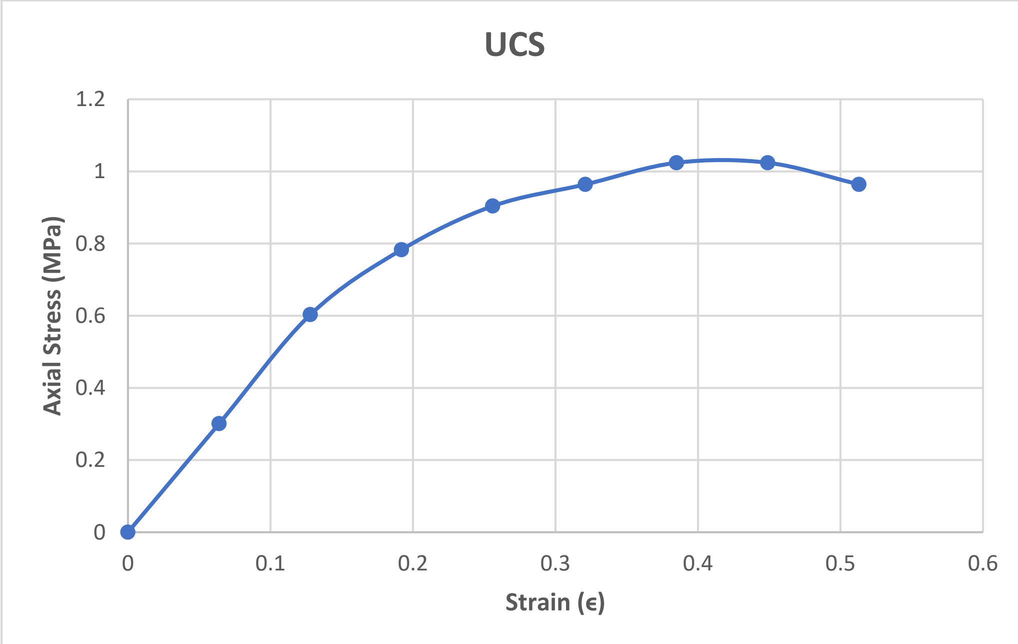

Fig 5.26: UCS Curve for Sedu Soil

5.20 California Bearing Ratio (CBR) Test

OMC = 16%

Table 5.32: California Bearing Ratio (CBR) Test on Sedu Soil

Penetration (mm)	**Trial 1**	**Division**	**Load (kg)**
0	0	0	0
0.5	1	5	8
1	1.8	9	14.4
1.5	2.4	12	19.2
2	3	15	24
2.5	4	20	32
3	4.6	23	36.8
4	6.4	32	51.2
5	8.2	41	65.6
7.5	12.4	62	99.2
10	16.2	81	129.6
12.5	20	100	160

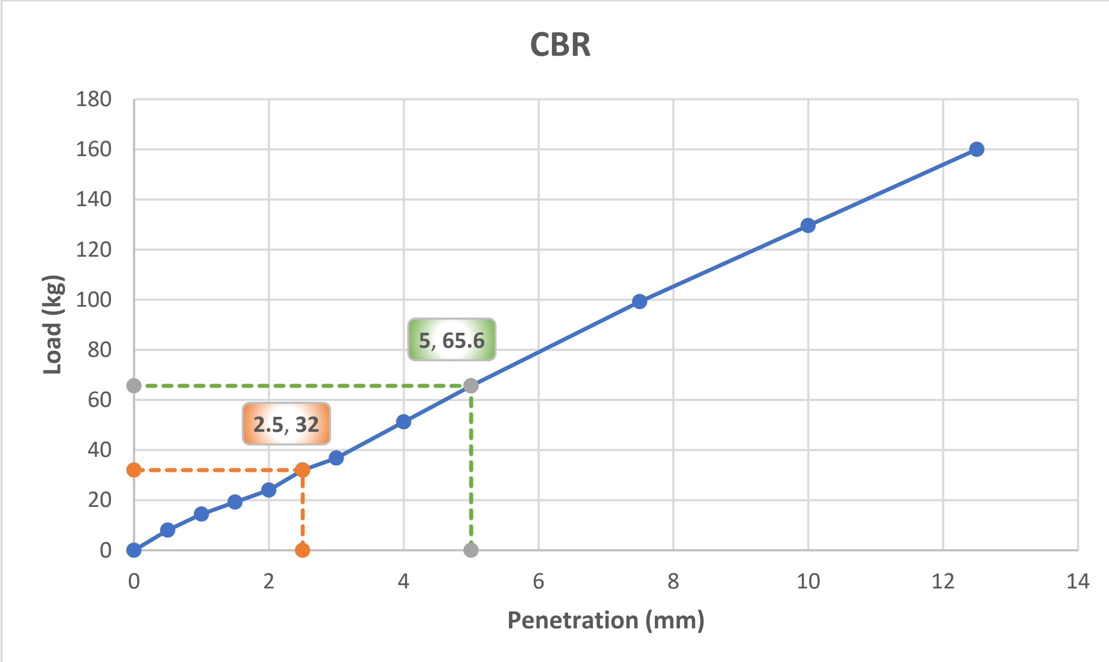

Fig 5.27: CBR Curve for Sedu Soil

- Load can be seen from the graph as 32kg at a 2.5mm penetration level.
- CBR of Specimen = (53/1370) *100 = 3.87%
- Load can be seen from the graph as 65.6kg at a 5mm penetration level.
- CBR of Specimen = (88/2055) *100 = 4.28%

5.21 Standard Proctor Test on Sedu Soil with fibers

- 2500 gm of the sample was taken and passed through at 4.75 mm sieve before washing.
- Volume of mould is 1000 cc.

The following observations were found after adding 0.25 percent fibers to Sedu Soil:

Table 5.33: Standard Proctor Test on Sedu Soil+ 0.25% Bamboo Fibers

Trials	**1**	**2**	**3**	**4**
Mass of Empty Mould (M_1) (g)	4420	4420	4420	4420
Mass of Mould + CoMPacted Soil (M_2) (g)	6325	6450	6510	6430
Mass of CoMPacted Soil, M = M_2-M_1(g)	1905	2030	2040	2010
Bulk Density, Yb=(M/V) (g/cc)	1.905	2.03	2.04	2.01
Container Number	1	2	3	4
Water Added	0.12	0.14	0.16	0.18
Mass of Container (M_1) (g)	30.5	30	33	16
Mass of Container + Wet Soil (M_2) (g)	135	118	119	120
Mass of Container + Dry Soil (M_3) (g)	104.5	88	86	104

Mass of Water = Mw = M_2-M_3	10	10.5	11	15
Mass of Dry Soil = M_d = M_3-M_1 (g)	94.5	77.5	75	89
Water Content, w = (Mw/M_d)*100	0.106	0.135	0.147	0.169
Dry Density, Yd=Yb/(1+w) (g/cc)	1.723	1.788	1.779	1.72

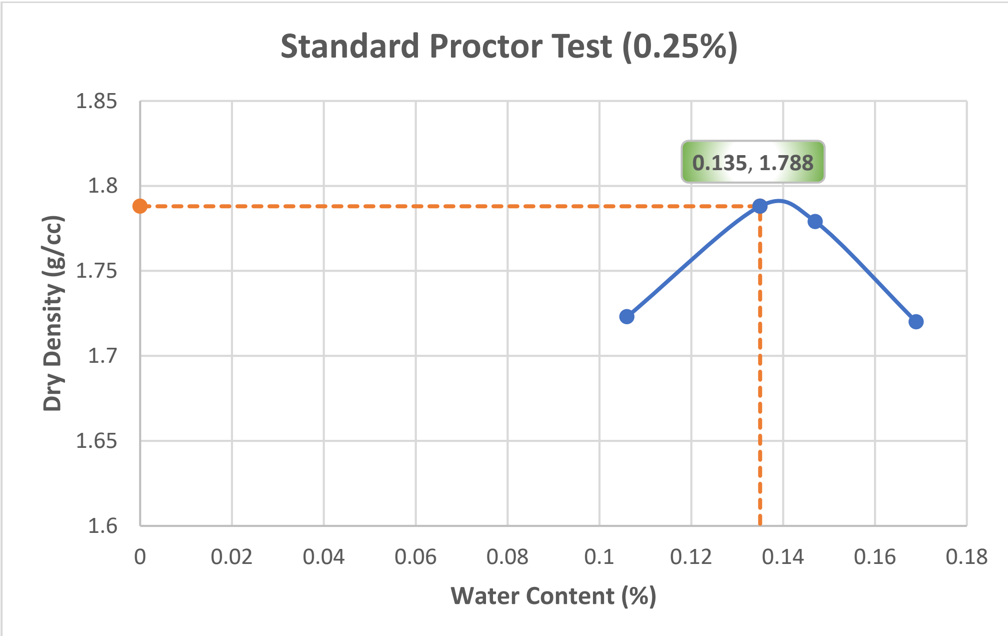

Fig 5.28: Compaction Curve for Sedu Soil + 0.25% fibers

- **OMC** can be seen from the graph as 13.5%.
- **MDD** can be seen from the graph as 1.788 g/cc

The following observations were found after adding 0.50 percent fibers to Sedu Soil:

Table 5.34: Standard Proctor Test on Sedu Soil+ 0.50% Bamboo Fibers

Trials	**1**	**2**	**3**	**4**
Mass of Empty Mould (M_1) (g)	4420	4420	4420	4420
Mass of Mould + CoMPacted Soil (M_2) (g)	6390	6450	6510	6430
Mass of CoMPacted Soil, M = M_2-M_1(g)	1970	2030	2040	2010
Bulk Density, Yb=(M/V) (g/cc)	1.97	2.03	2.04	2.01
Container Number	5	1	9	12
Water Added	0.12	0.14	0.16	0.18
Mass of Container (M_1) (g)	30.5	30	33	16
Mass of Container + Wet Soil (M_2) (g)	135	118	119	120
Mass of Container + Dry Soil (M_3) (g)	125	107.5	108	105
Mass of Water = Mw = M_2-M_3	10	10.5	11	15
Mass of Dry Soil = M_d = M_3-M_1 (g)	94.5	77.5	75	89

Water Content, w = (Mw/Md)*100	0.106	0.135	0.147	0.169
Dry Density, Yd=Yb/(1+w) (g/cc)	1.781	1.788	1.779	1.72

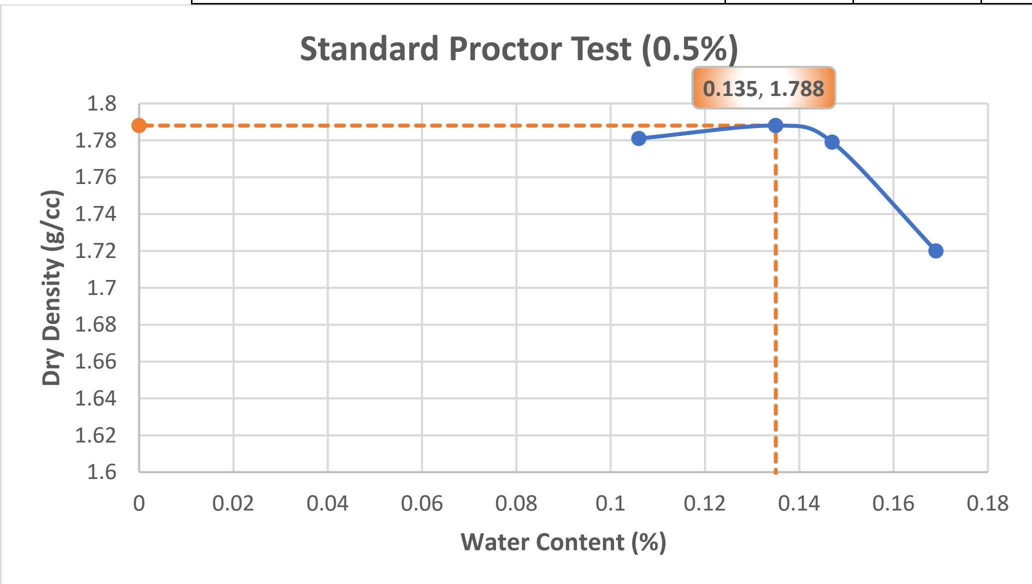

Fig 5.29: CoMPaction Curve for Sedu Soil + 0.50% fibers

- **OMC** can be seen from the graph as 13.5%.
- **MDD** can be seen from the graph as 1.788 g/cc.

The following observations were found after adding 0.75 percent fibers to Sedu Soil:

Table 5.35: Standard Proctor Test on Sedu Soil+ 0.75% Bamboo Fibers

Trials	**1**	**2**	**3**	**4**
Mass of Empty Mould (M_1) (g)	4420	4420	4420	4420
Mass of Mould + CoMPacted Soil (M_2) (g)	6410	6420	6450	6214
Mass of CoMPacted Soil, M = M_2-M_1(g)	1990	2000	2030	1794
Bulk Density, Yb=(M/V) (g/cc)	1.99	2	2.03	1.794
Container Number	11	15	6	8
Water Added	0.12	0.14	0.16	0.18
Mass of Container (M_1) (g)	30.5	30	33	16
Mass of Container + Wet Soil (M_2) (g)	129	117	114	117
Mass of Container + Dry Soil (M_3) (g)	119	108	105	105
Mass of Water = Mw = M_2-M_3	10	9	9	12
Mass of Dry Soil = M_d = M_3-M_1 (g)	88.5	78	72	89
Water Content, w = (Mw/M_d)*100	0.113	0.115	0.125	0.135
Dry Density, Yd=Yb/(1+w) (g/cc)	1.788	1.793	1.804	1.581

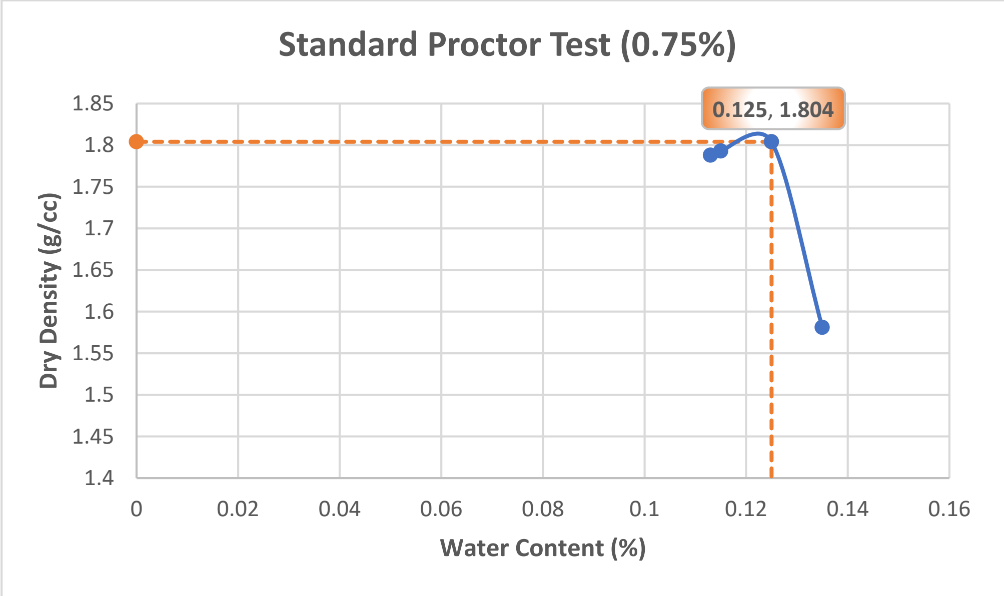

Figure 5.30: Compaction Curve for Sedu Soil + 0.75% fibers

- **OMC** can be seen from the graph as 12.5%.
- **MDD** can be seen from the graph as 1.804 g/cc

The following observations were found after adding 1.00 percent fibers to Sedu Soil:

Table 5.36: Standard Proctor Test on Sedu Soil+ 1.00% Bamboo Fibers

Trials	**1**	**2**	**3**	**4**
Mass of Empty Mould (M_1) (g)	4420	3170	4420	4420
Mass of Mould + CoMPacted Soil (M_2) (g)	6270	5500	6380	6395
Mass of CoMPacted Soil, M = M_2-M_1(g)	1850	2330	1960	1975
Bulk Density, Yb=(M/V) (g/cc)	1.85	2.33	1.96	1.975
Container Number	7	3	23	4
Water Added	0.1	0.12	0.14	0.16
Mass of Container (M_1) (g)	33	30	30	32
Mass of Container + Wet Soil (M_2) (g)	94	150.5	98.5	97
Mass of Wet Soil	61	120.5	68.5	65
Mass of Container + Dry Soil (M_3) (g)	89	139	91	89
Mass of Water = Mw = M_2-M_3	5	11.5	7.5	8
Mass of Dry Soil = M_d = M_3-M_1 (g)	56	109	61	57
Water Content, w = (Mw/M_d)*100	0.089	0.106	0.123	0.14
Dry Density, Yd=Yb/(1+w) (g/cc)	1.698	2.108	1.745	1.732

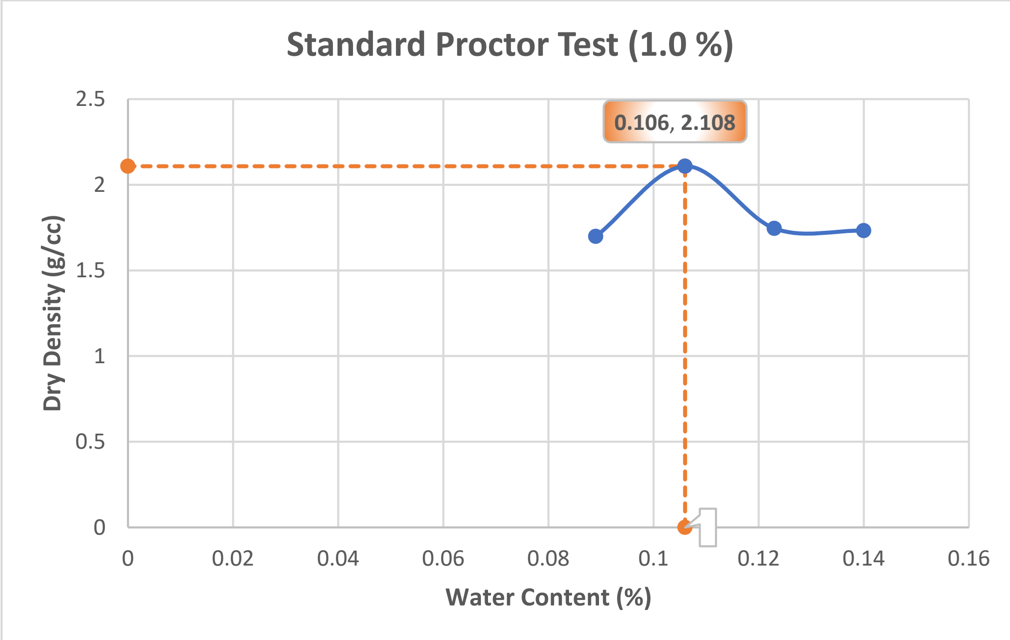

Figure 5.31: Compaction Curve for Sedu Soil + 1.00% fibers

- **OMC** can be seen from the graph as 10.6%.
- **MDD** can be seen from the graph as 2.108 g/cc.

5.22 Unconfined Compression Test on Sedu Soil with fibers

The following observations were found after adding 0.25 percent fibers to Sedu Soil:

weight of sample = 250 gms, wc = 13.7%, h = 7.9cm, d = 3.9cm,

h1 = 7.2 cm, d1 = 4cm, load per div. = 3.417 kN, f = 70°

Table 5.37: Unconfined Compression Test on Sedu Soil + 0.25% fibre

Dial Gauge Readings	Strain (ϵ)	Proving Ring Readings	Corrected Area	Load (N)	Axial Stress (MPa)
0	0	0	11.946	0	0
50	0.063	0.2	11.946	0.683	0.057
100	0.127	1.4	11.946	4.784	0.4
150	0.19	2.2	11.946	7.517	0.629
200	0.253	2.2	11.946	7.517	0.629
250	0.316	2	11.946	6.834	0.572

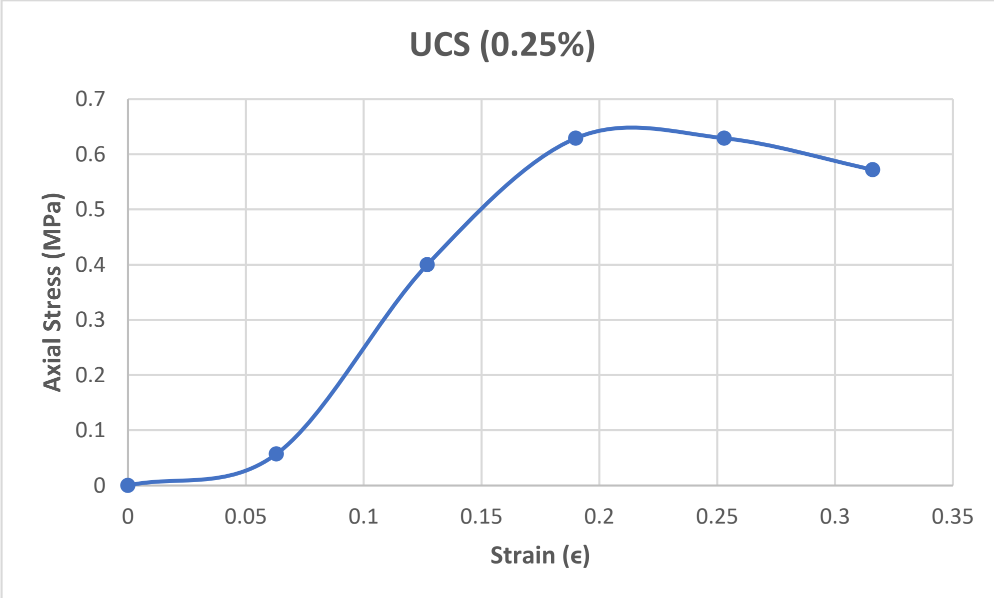

Figure 5.32: UCS Curve for Sedu Soil + 0.25% fibers

The following observations were found after adding 0.50 percent fibers to Sedu Soil:

weight of sample = 250gms, wc = 13.5%, h= 7.9cm, d= 3.9cm,

h1 = 7.2cm, d1 = 4cm, load per div. = 3.417 kN, f = 65°

Table 5.38: Unconfined Compression Test on Sedu Soil + 0.50% fibre

Dial Gauge Readings	Strain (ϵ)	Proving Ring Readings	Corrected Area	Load (N)	Axial Stress (MPa)
0	0	0	11.946	0	0
50	0.063	0.2	11.946	0.683	0.057
100	0.127	0.6	11.946	2.05	0.172
150	0.19	1	11.946	3.417	0.286
200	0.253	1.4	11.946	4.784	0.4
250	0.316	1.8	11.946	6.151	0.515
300	0.38	2.2	11.946	7.517	0.629
350	0.443	2	11.946	6.834	0.572

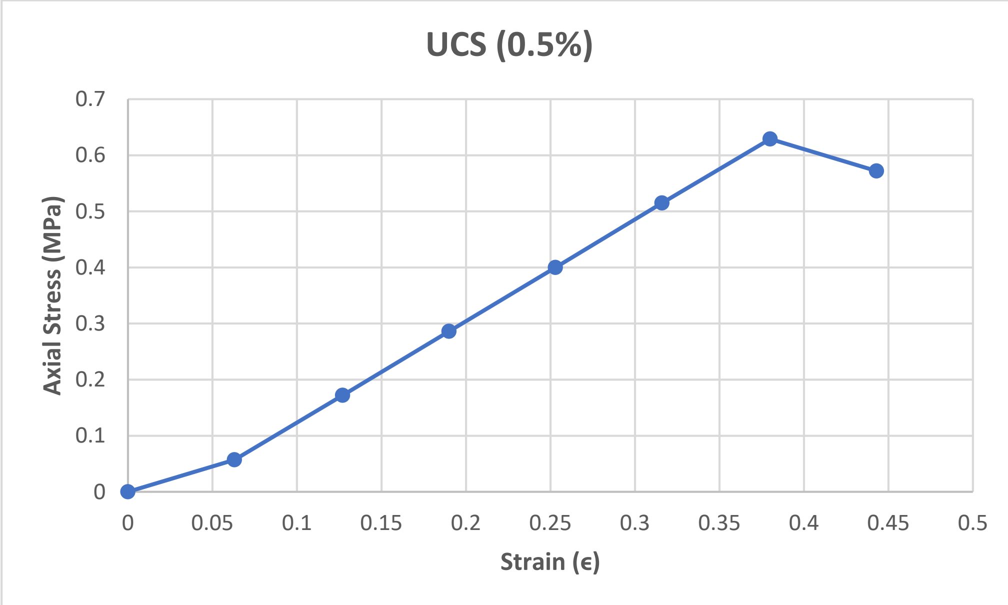

Fig 5.33: UCS Curve for Sedu Soil + 0.50% fibers

The following observations were found after adding 0.75 percent fibers to Sedu Soil:

weight of sample = 250gms, wc = 12.2%, h = 7.8cm , d = 3.8cm, h1 = 7.6 cm,

d1 = 3.5 cm, load per div. = 3.417 kN , f = 65°

Table 5.39: Unconfined Compression Test on Sedu Soil + 0.75% fibre

Dial Gauge Readings	Strain (ϵ)	Proving Ring Readings	Corrected Area	Load (N)	Axial Stress (MPa)
0	0	0	11.341	0	0
50	0.064	0.2	11.341	0.683	0.06
100	0.128	0.6	11.341	2.05	0.181
150	0.192	1	11.341	3.417	0.301
200	0.256	1.4	11.341	4.784	0.422
250	0.321	2	11.341	6.834	0.603
300	0.385	2.2	11.341	7.517	0.663
350	0.449	2.2	11.341	7.517	0.663

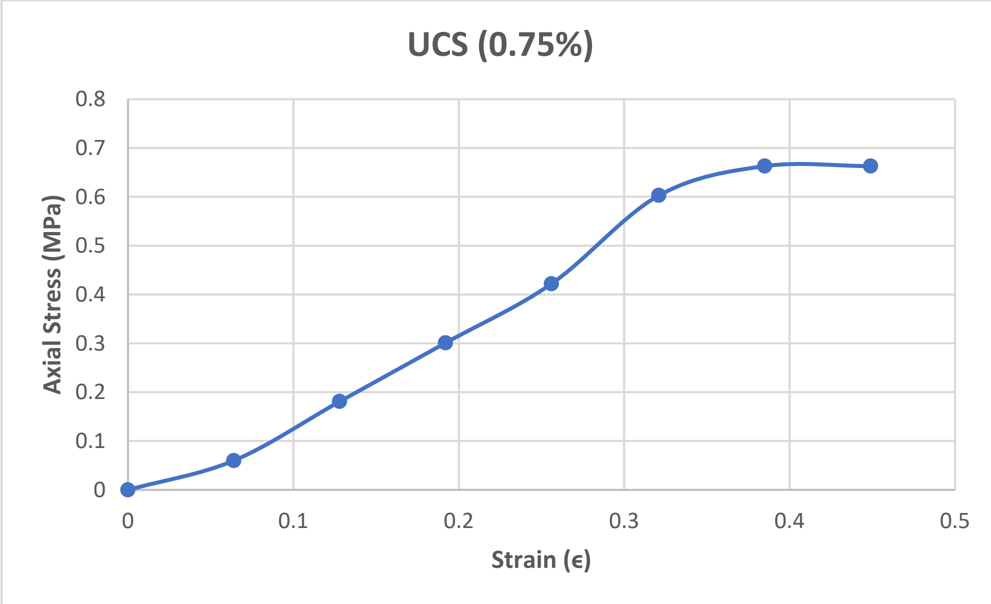

Fig 5.34: UCS Curve for Sedu Soil + 0.75% fibers

The following observations were found after adding 1.00 percent fibers to Sedu Soil:

weight of sample = 250gms, wc = 10.6%, h = 7.8cm, d = 3.8cm,

h1=7.7cm, d1=3.9 cm, load per div.=3.417 kN, f= 65°

Table 5.40: Unconfined Compression Test on Sedu Soil + 1.00% fibre

Dial Gauge Readings	Strain (ϵ)	Proving Ring Readings	Corrected Area	Load (N)	Axial Stress (MPa)
0	0	0	11.341	0	0
50	0.064	0.6	11.341	2.05	0.181
100	0.128	2	11.341	6.834	0.603
150	0.192	3.2	11.341	10.934	0.964
200	0.256	3.2	11.341	10.934	0.964
250	0.321	3	11.341	10.251	0.904

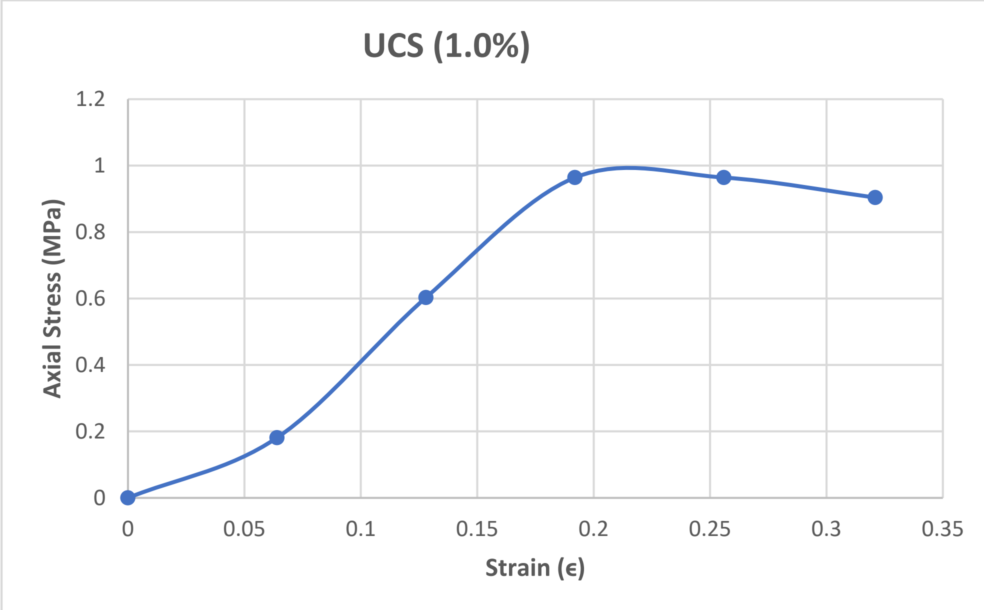

Fig 5.35: UCS Curve for Sedu Soil + 1.00% fibers

5.23 California Bearing Ratio (CBR) Test on Sedu Soil with fibers

The following observations were found after adding 0.25 percent fibers to Sedu Soil:

OMC=13.7%

Table 5.41: CBR Test on Sedu Soil + 0.25% fibre

Penetration (mm)	Trial 1	Division	Load (kg)
0	0	0	0
0.5	2.2	11	17.6
1	4.6	23	36.8
1.5	7	35	56
2	9.4	47	75.2
2.5	14.2	71	113.6
3	18.6	93	148.8
4	30.2	151	241.6
5	42.4	212	339.2
7.5	70.6	353	564.8
10	85.2	426	681.6
12.5	102.6	513	820.8

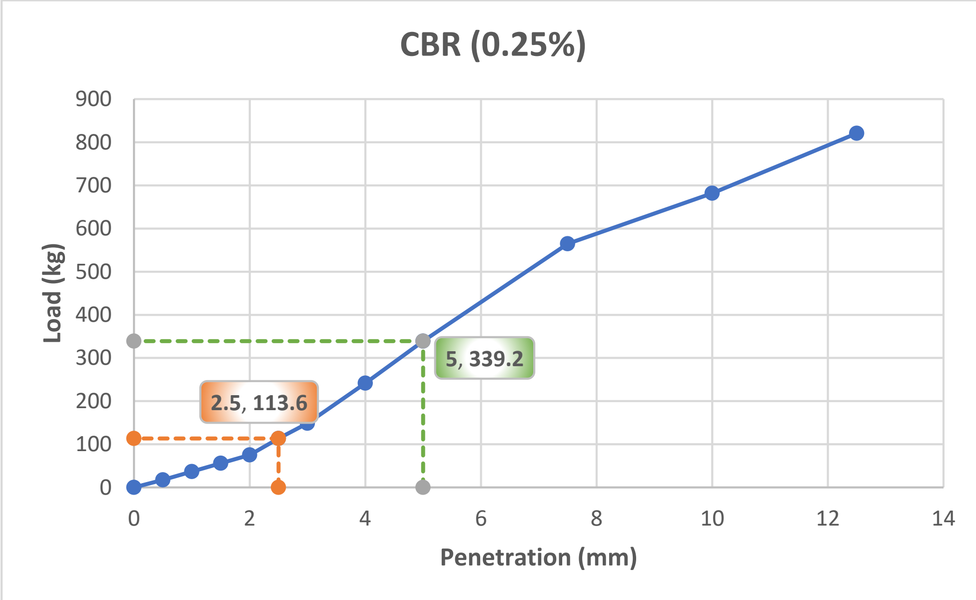

Fig 5.36: CBR Curve for Sedu Soil + 0.25% fibers

- Load can be seen from the graph as 113.6 kg at a 2.5 mm penetration level.
- CBR of Specimen = (315/1370) *100 = 22.99%
- Load can be seen from the graph as 339.2 kg at a 5 mm penetration level.
- CBR of Specimen = (570/2055) *100 = 27.74%

The following observations were found after adding 0.50 percent fibers to Sedu Soil:

OMC = 14.7%

Table 5.42: CBR Test on Sedu Soil + 0.50% fibre

Penetration (mm)	Trial 1	Division	Load (kg)
0	0	0	0
0.5	2.8	14	22.4
1	4.8	24	38.4
1.5	8.2	41	65.6
2	11.8	59	94.4
2.5	16.6	83	132.8
3	22.2	111	177.6
4	34.1	170.5	272.8
5	46.8	234	374.4
7.5	79.6	398	636.8
10	90.2	451	721.6
12.5	110.4	552	883.2

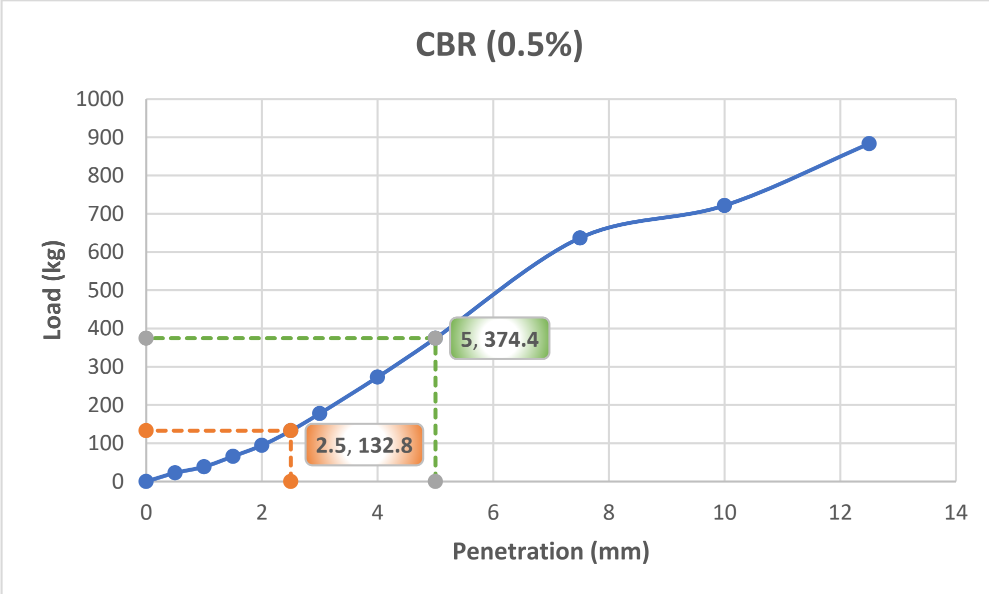

Fig 5.37: CBR Curve for Sedu Soil + 0.50% fibers

- Load can be seen from the graph as 132.8 kg at a 2.5 mm penetration level.
- CBR of Specimen = (330/1370) *100 = 24.09%
- Load can be seen from the graph as 374.4 kg at a 5 mm penetration level.
- CBR of Specimen = (600/2055) *100 = 29.20%

The following observations were found after adding 0.50 percent fibers to Sedu Soil:

OMC = 12.5%

Table 5.43: CBR Test on Sedu Soil + 0.75% fibre

Penetration (mm)	Trial 1	Division	Load (kg)
0	0	0	0
0.5	8.8	44	70.4
1	18.8	94	150.4
1.5	27.4	137	219.2
2	34.6	173	276.8
2.5	40.2	201	321.6
3	45.8	229	366.4
4	56.2	281	449.6
5	66	330	528
7.5	86.2	431	689.6
10	105.8	529	846.4
12.5	126.8	634	1014.4

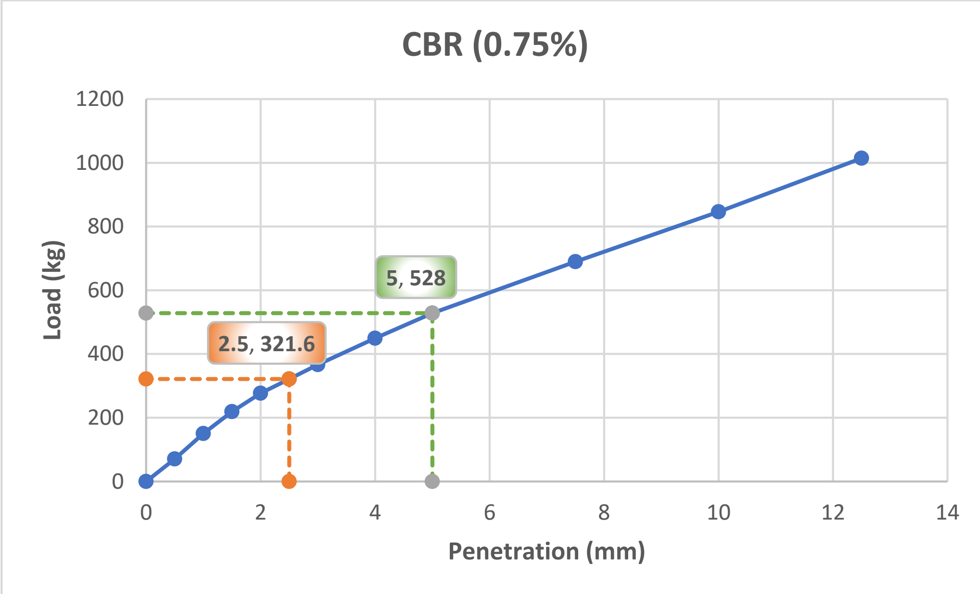

Fig 5.38: CBR Curve for Sedu Soil + 0.75% fibers

- Load can be seen from the graph as 321.6 kg at a 2.5 mm penetration level.
- CBR of Specimen = (380/1370) *100 = 27.74%
- Load can be seen from the graph as 528 kg at a 5 mm penetration level.
- CBR of Specimen = (570/2055) *100 = 27.74%

The following observations were found after adding 1.00 percent fibers to Sedu Soil:

OMC = 10.6%

Table 5.44: CBR Test on Sedu Soil + 1.00% fibre

Penetration (mm)	Trial 1	Division	Load (kg)
0	0	0	0
0.5	7.6	38	60.8
1	18.4	92	147.2
1.5	31.6	158	252.8
2	42.2	211	337.6
2.5	53.6	268	428.8
3	62.8	314	502.4
4	82.6	413	660.8
5	99.6	498	796.8
7.5	135.8	679	1086.4
10	169.8	849	1358.4
12.5	202.4	1012	1619.2

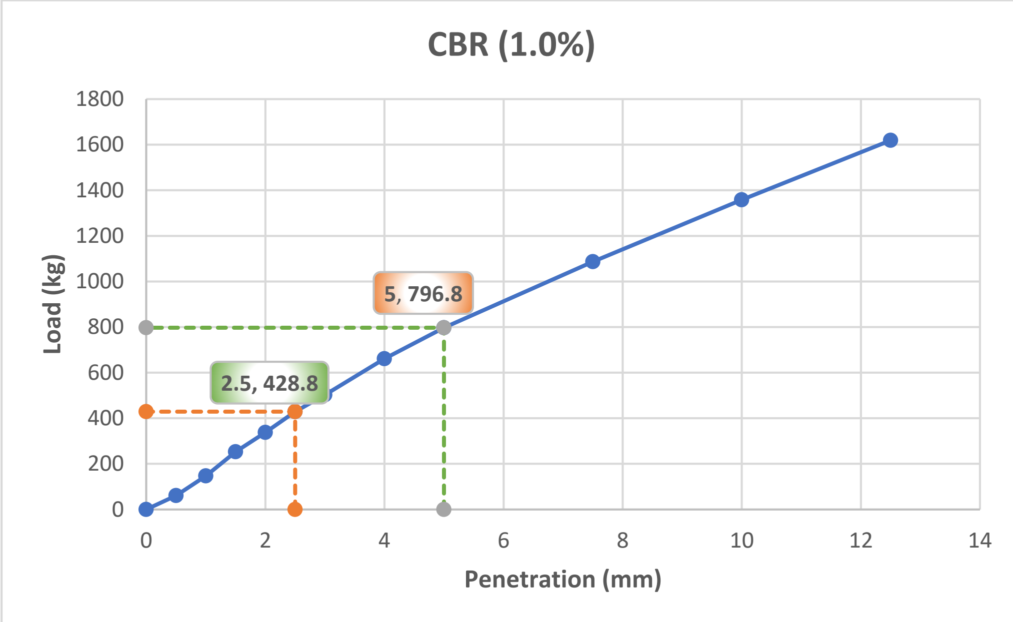

Figure 5.39: CBR Curve for Sedu Soil + 1.00% fibers

- Load can be seen from the graph as 428.8 kg at a 2.5 mm penetration level.
- CBR of Specimen = (32/1370) *100 = 43.07%
- Load can be seen from the graph as 796.8 kg at 5 mm penetration level.
- CBR of Specimen = (920/2055) *100 = 44.77%

Chapter 6 Design of Flexible Pavement

The flexible pavement is designed in accordance with SP:20 – 2002.

6.1 Pavement erected on unsterilized soil.

- The number of commercial vehicles per day ranges from = 0 to 15 vehicles per day.
- The soil's CBR value was when tested = 1.82%

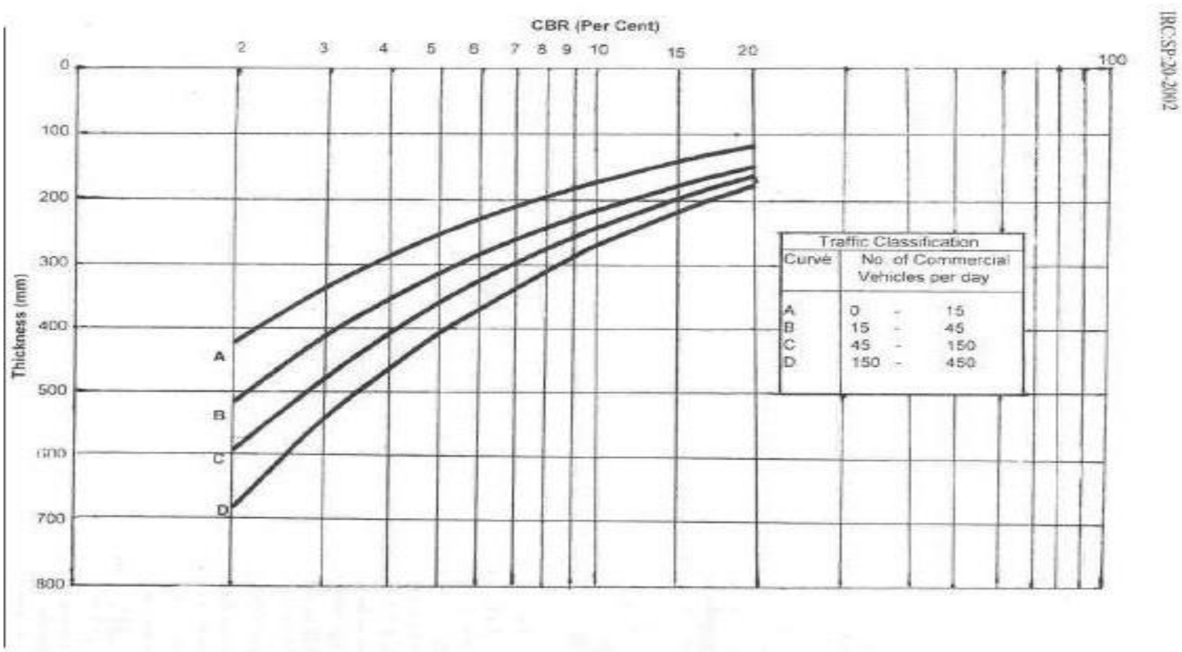

Fig. 5.1. CBR Curves for Flexible Pavement Design

Using Curve, A as an example, the thickness of the pavement is 450mm.

- Sub Base material thickness = 250mm.
- The Base Course material is = 160mm thick.
- Surface Coarse material thickness = 40mm.

6.2 To design a pavement that will be built on stabilized soil.

- The number of commercial vehicles per day ranges from = 0 to 15 vehicles per day.
- The soil's CBR value was found to be 5.41%.
- Using Curve, A as an example, the thickness of the pavement = 250mm.
  - Sub Base material thickness = 100mm.
  - The Base Coarse material = 120 mm thick.
  - Surface coarse material thickness = 30mm.

Chapter 7 Result & Discussion

7.1. General
7.2. Atterbergs Limit

7.2.1. Liquid limit

- The liquid limit of the soil was noticed to be 60%.
- After adding 0.25 percent, 0.5 percent, 0.75 percent, and 1.0 percent by weight to the soil, the liquid limit is 39.2 percent, 39.7 percent, 42.0 percent, and 42.3 percent, respectively.
- When compared to the liquid limit of soil alone, the liquid limit of soil containing 0.25 percent, 0.5 percent, 0.75 percent, and 1.0 percent bamboo fibers is shown to be reduced by 34.66 percent, 33.83 percent, 30.0 percent, and 29.5 percent, respectively.

7.2.2 Plastic limit

- The soil's plastic limit was discovered to be 21.46 percent.
- The plastic limit of the soil was determined to be 22.27 percent, 33.33 percent, 35.59 percent, and 37.50 percent, respectively, with the addition of 0.25 percent, 0.5 percent, 0.75 percent, and 1.0 percent bamboo fibers by weight of soil.
- As 0.25 percent, 0.5 percent, 0.75 percent, and 1.0 percent bamboo fibers are added to the soil, the plastic limit is reduced by 21.3 percent, 43.5 percent, 51.8 percent, and 58.8 percent, respectively, when compared to the plastic limit of the soil alone.

7.2.3 Plasticity Index

• The soil's own plasticity index was found to be 38.54 percent.

• The plasticity index of the soil was found to be 11.93 percent, 6.37 percent, 6.41 percent, and 4.8 percent, respectively, with the addition of 0.25 percent, 0.5 percent, 0.75 percent, and 1.0 percent bamboo fibers by weight of soil.

• Adding 0.25 percent, 0.5 percent, 0.75 percent, and 1 percent bamboo fibers to the soil reduces the plasticity index by 69 percent, 84.47 percent, 83.36 percent, and 87.54 percent, respectively.

7.2.4. Shrinkage limit

- The soil's shrinkage limit was discovered to be 23.309 percent.
- The shrinkage limit of the soil was determined to be 16.471 percent, 15.876 percent, 8.043 percent, and 5.826 percent, respectively, with the addition of 0.25 percent, 0.5 percent, 0.75 percent, and 1.0 percent bamboo fibers by weight of soil.
- The shrinkage limit of the soil was found to be reduced by 29.31 percent, 31.88 percent, 65.49 percent, and 75 percent when 0.25 percent, 0.5 percent, 0.75 percent, and 1 percent bamboo fibers were added.

7.3 Standard Proctor Test

- The maximum dry density (MDD) and optimum moisture content (OMC) of soil alone were found to be 21.4 percent and 1.378 g/cc, respectively.
- The MDD of the soil with 0.25 percent, 0.5 percent, 0.75 percent, and 1.0 percent bamboo fibers by weight of soil is 1.401 g/cc, 1.425 g/cc, 1.565 g/cc, and 1.378 g/cc, respectively, and the corresponding OMC is 20.1 percent, 19 percent, 17 percent, and 16 percent.
- The MDD of the soil increased by 1.6 percent, 3.4 percent, 13.5 percent, and 0 percent with the addition of 0.25 percent, 0.5 percent, 0.75 percent, and 1.0 percent bamboo fibers by weight of soil, respectively, and the corresponding OMC decreased by 6 percent, 11.2 percent, 20.56 percent, and 21.02 percent.

7.4 Unconfined Compression Test

- Soil alone has a shear strength of 1.27 MPa, according to research.
- The shear strength of the soil was determined to be 1.687,1.838, 1.868, and 1.989 percent with the addition of 0.25 percent, 0.5 percent, 0.75 percent, and 1.0 percent bamboo fibers by weight of soil, respectively.
- The shear strength of the soil was found to be reduced by 32.83 percent, 44.72 percent, 47.08 percent, and 56.61 percent when 0.25 percent, 0.5 percent, 0.75 percent, and 1 percent bamboo fibers were added.

7.5 California Bearing Ratio (CBR) Test

- The soil's CBR value was found to be 1.82 percent.
- The CBR value of the soil was determined to be 3.49 percent, 3.96 percent, 5.41 percent, and 3.96 percent, respectively, with the addition of 0.25 percent, 0.5 percent, 0.75 percent, and 1.0 percent bamboo fibers by weight of soil.

- The CBR value of the soil improved by 91.75 percent, 117.5 percent, 197.25 percent, and 117.5 percent, respectively, with the addition of 0.25 percent, 0.5 percent, 0.75 percent, and 1.0 percent bamboo fibers by weight of soil.

7.6 Atterbergs Limit (sedu soil)

7.6.1 Liquid limit

- The soil's liquid limit was discovered to be 36.5 percent.

7.7 Standard proctor test

- The maximum dry density (MDD) and optimum moisture content (OMC) of soil alone were found to be 16 percent and 1.802 g/cc, respectively.
- The MDD of the soil with 0.25 percent, 0.5 percent, 0.75 percent, and 1.0 percent bamboo fibers added by weight of soil is 1.788 g/cc, 1.788 g/cc, 1.804 g/cc, and 2.108 g/cc, respectively, and the corresponding OMC is 13.5 percent, 13.5 percent, 12.5 percent, and 10.6 percent.
- The MDD of the soil with 0.25 percent, 0.5 percent, and 1.0 percent bamboo fibers by weight of soil was found to be decreased by 0.83 percent and 0.75 percent, respectively, while the corresponding OMC was found to be decreased by 15.62 percent, 21.87 percent, and 33.75 percent.

7.8 Unconfined Compression Test

- Soil alone has a shear strength of 1.024 MPa, according to research.
- The shear strength of the soil was determined to be 0.629, 0.663, and 0.964 percent with the addition of 0.25 percent, 0.5 percent, 0.75 percent, and 1.0 percent bamboo fibers by weight of soil, respectively.
- Adding 0.25 percent, 0.5 percent, 0.75 percent, and 1 percent bamboo fibers to the soil reduces shear strength by 38.57 percent, 38.57 percent, 35.25 percent, and 5.85 percent, respectively.

7.9 California Bearing Ratio (CBR) Test

- The soil's CBR value was found to be 4.28 percent.
- The CBR value of the soil was found to be 27.74 percent, 29.20 percent, 27.74 percent, and 44.77 percent, respectively, with the addition of 0.25 percent, 0.5 percent, 0.75 percent, and 1.0 percent bamboo fibers by weight of soil.

- The CBR value of the soil was found to be raised with the addition of 0.25 percent, 0.5 percent, 0.75 percent, and 1.0 percent bamboo fibers by weight of soil.

7.10 The flexible pavement design thickness before stabilisation is determined to be 450mm.

7.11 After stabilisation, the design thickness of flexible pavement is 250mm.

Chapter 8 Conclusion

The following conclusions are reached from the current experimental stud

1. The Black cotton soil sample has been categorized as A-7-6 (4.549) by the Highway Research Board Classification.
2. MDD increases significantly with the addition of fibers up to 0.75 percent by weight, after which it decreases.
3. With the addition of fibers, there is a significant drop in OMC.
4. When comparing the shear strength of soil tested with and without bamboo fibers in an unconfined compression test, it was discovered that the shear strength of the soil rose as the percentage of bamboo fibers increased.
5. When 1 percent of the soil's weight is replaced with bamboo fibers, the shear strength of the soil reaches its maximum. As a result, 1 percent of fibers (by weight of soil) can be considered the ideal fibre content for increased shear resistance.
6. The California bearing ratio (CBR) of the soil alone was 1.82 percent, but after stabilising it with the optimal percentage of bamboo fibers, it climbed to 5.41 percent.
7. After stabilising the CBR value with the optimal amount of fibers, the percentage increase is 197.25 %.
8. In the case of sedu soil, the addition of fibers causes a significant increase in MDD.
9. In an unconfined compression test, it was discovered that as the amount of bamboo fibers increased, the shear strength of the soil dropped, compared to the shear strength of soil tested without fibre.
10. The California bearing ratio (CBR) of the soil alone is 4.28 percent, and the CBR value increases significantly when fibers are added.

SCOPE OF STUDY

1)The fibers can be utilised to stabilise a variety of soils with low CBR values.

2) A semi-test track can be used to test the soil stabilisation with bamboo fibers.

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