"STABILIZATION OF BLACK COTTON SOIL USING FIBRES"

A PROJECT

Submitted in partial fulfillment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision of

Mr. Niraj Singh Parihar

(Assistant Professor)

By

Shaheen Negi(131668)
Alpa Bhararia (131692)
Shiv Kumar Verma(131706)

To

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CERTIFICATE

This is to certify that the work compiled and presented in the project report titled **"STABILIZATION OF BLACK COTTON SOIL USING FIBRES"** in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering and submitted to the Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat is an authentic work carried out by Shaheen Negi (131668) , Alpa Bhararia (131692) Shiv Kumar Verma(131706) during a period from July 2016 to May 2017 under the guidance and supervision of Mr. Niraj Singh Parihar (Assistant Professor), Department of Civil Engineering,Jaypee University of Information Technology, Waknaghat.

The above statement is correct to the best of our knowledge.

Date: 1st May ,2017

Dr. Ashok Kumar Gupta Mr. Niraj Singh Parihar External

Examiner Professor & Head of Department Assistant Professor

Civil Engineering Department Civil Engineering Department

JUIT Waknaghat JUIT Waknaghat

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SHAHEEN NEGI (131668)

ALPA BHARARIA (131692)

SHIV KUMAR VERMA (131706)

ABSTRACT

The construction of building and other civil engineering structures on the black cotton soil is highly risky on geotechnical conditions such as settlement of roads and buildings due to low or poor shear strength and high settlement properties of the clayey soil. There is a need for treatment of soil so that the properties used are increased. In general practice, admixtures with fly ash, lime and geo-grids are used frequently to stabilize soils and improve their strength. Fibres are extensively used in civil engineering applications for quite a lot of years. In this study three fibers namely jute, coir, bagasse fibre are used to modify the properties of black cotton soil. With addition of fibers like jute, coir and bagasse, soil properties are seen to change and hence increase drastically. Their low cost, environmental friendly nature, has owed a lot to its engineering properties. Most importantly, the fibers used are waste in nature and also help in cutting up the costs. With varying l/d ratio of different fibres, the soil properties like unconfined compressive strength and California bearing ratio was found to be increased in much higher proportion than normal soil.

Keywords - BCS (Black cotton soil), Jute fibre , Coir fibre , Bagasse fibre , OMC (Optimum Moisture Content) , CBR (California Bearing Ratio) , UCS (Unconfined Compression Test)

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CHAPTER 1: INTRODUCTION

Every civil engineering structure ,whether it is a building , bridge, tower , an embankment , road pavement , railway line , tunnel or a dam , has to be founded on the soil and thus shall transmit the dead and live loads to the soil stratum . Soil is therefore, the ultimate foundation material which supports the structure. Due to rapid urbanization and industrialization there has been gradual increase in the use of land for various constructional activities. This has resulted in the scarcity of the suitable land (soil) for construction.

Thus the geotechnical engineers are required to improve the various unsuitable soils by stabilizing it by chemical or mechanical method. One such unsuitable soil is black cotton soil. Black cotton is the Indian name given to expansive soil deposits. It is mainly found in the plateaus of Maharashtra, Shaurashtra, Madhya Pradesh, Malwa, Chhattisgarh, and extent in South-East direction along Godavari and Krishna valleys. These soils have been formed from basalt or trap and contain mineral montmorillonite which is responsible for the excessive swelling and shrinkage characteristics of soil. Due to its poor bearing capacity and excessive settlement it is very difficult for geotechnical engineers to design the foundation on such highly compressible soil. To overcome the same, different soil improvement techniques such as ground reinforcement, ground improvement and ground treatment has been researched. Our project involves the reinforcing the soil with natural fibres. With addition of fibres desired properties of soil like compaction, unconfined compression, shear strength, swelling properties, and permeability can be obtained. The reinforcement resists the tensile stress developed within the soil thereby restricting shear failure. Thus project aims at using the eco-friendly and economical approach of stabilizing the black cotton soil by reinforcing it with natural fibres (coir, coconut and bagasse) .

Fig.1- Black cotton soil

From Nagpur(Maharashtra)

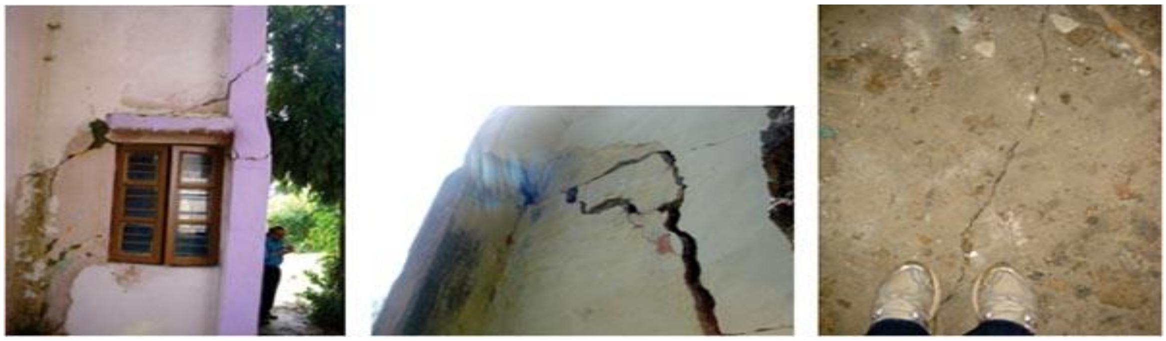


Fig.2-Damaged structures constructed on black cotton soil

(Picture reference –www.ijrdet.com)

CHAPTER 2: SIGNIFICANCE

Soil improvement technique involves altering the soil properties by inclusion of stronger materials. It has been found to be one of the most effective ways in improving the engineering properties of soil. Moreover it is advantageous to use natural fibres in soil reinforcement because of its vast availability, low cost ,ease of work, more feasibility and environment friendliness in all weather conditions. Also , with the addition of natural fibres , the strength and bearing capacity of soil is greatly improved because of the function of fibre characteristics such as aspect ratio , skin friction and modulus of elasticity. In order to improve and enhance the soil properties, optimum amount of fibres has been added and suitable tests have been performed.

The project involves testing of soil for the unconfined compression test and California bearing ratio test on untreated soil specimen and with soil mixed with natural fibers (coir, jute and bagasse).

Water is by far the most important variable controlling the behavior of fine grained soil. Due to the high absorption of water in fibres , the effect of water on black cotton soil is greatly reduced.

Fig.3- Coconut fibres

Fig.4- Jute fibres

Fig. 5 –Bagasse Fibres

CHAPTER 3: LITERATURE REVIEW

3.1 Experimental study of stabilisation of clay soil using coir fibre by <u>T.Subramani, D.Udayakuma (2016)</u>

From this research we concluded that the strength of soil-coir mix is seen to increase as increasing percentage of coir Fibre, CBR and UCS values of soil-coir Fibre mix increases with its increasing percentage. When we reinforce the soil with coir Fibers/coir geo-textiles it is seen to be a cost effective method regarding the ground improvement techniques. The use of coir in geotechnical developments is desirable.

3.2 Potential of jute fibre reinforced polymer composite by <u>M. K. Guptaa, R. K. Srivastava (2015)</u>

Jute is found to be a better replacement of synthetic fibres as it is environmental friendly. Polymers may be thermoplasts or thermosets , for which there is requirement of chemical treatment . Its low cost ,mechanical properties , eco-friendly , serve as a better replacement for numerous applications. Mechanical properties of jute fibre reinforced polymer composite increases up to a certain point then decreases due to poor adhesion force between fibres and the matrix.

3.3 Improvement in properties of black cotton soil with an addition of natural fibre (coir) derived form coconut covering by <u>Priyanka Goyal, Ashutosh Shanker Trivedi, Manoj Sharma (2015)</u>

On blending the coir fibre with black cotton soil , it results in increase of shrinkage limit values. It prevents the swelling behavior of the soil. It leads to increase in the optimum moisture content as coir got blended ,appreciable increase in unconfined compressive strength was learnt.There was change in OMC and MDD of soil .As shrinking occurs, fiber will impart more inter surface resistance between the reinforcing fiber and soil which results in higher bearing capacity.

3.4 Analysis of strength characterstics of black cotton soil using bagasse and additives as a stabilizer by Kiran R.G., Kiran L (2015)

There was increased strength values and the CBR and UCS values also increased. If the stability of soil is inadequate for supporting the loads of wheels ,the oil properties should be improved by soil stabilisation technique. Soil stabilisation is the modification of one or more soil properties by mechanical or any chemical methods to create an improves strength of soil.

3.5 Effect of jute fibres on engineering characterstics of black cotton soil by Harshita Bairagi, R.K. Yadav, R Jain (2014)

On adding the jute fibres to the soil , a decrease in its swelling behavior is observed. The CBR is seen to increase and unconfined compressive strength increases. As jute is an ecofriendly fibre its application on black soil engineering land is of extreme importance and increases its properties tremendously.

3.6 Improvement of Soil Characteristics Using Jute Geo-Textile by Barnali Ghosh , Dr V Ramesh, Rajarajeswari B Vibhuti(2014)

Jute geotextile in the soil has a significant influence on the soil properties. Its shear strength , permeability , dry density and CBR are compared from the past and after they have been laid as jute geo-textile. While shear strength, dry density and CBR is seen to increase , the permeability and penetration (check for settlement) decreases on introduction of jute geo-textiles, which indicatesthere is significant improvement in the engineering behaviorof soil. Hence, jute geo-textile plays an effective role in the improvement of soil properties by reducing its compressibility.

3.7 Studies on soil stabilisation by using bagasse ash by Prakash Chavan and Dr. M.S. Nagakumar (2014)

It was observed that there was decrease in plasticity index of soil reinforced with bagasse fibre. Bagasse is an eco friendly fibre which is biodegradable also. Values of UCS and CBR increased with its addition .Optimum moisture content also increased. Sugarcane bagasse improved some properties of the clayey soil and also helpful in rural road construction purpose .

3.8 Application of Coir Geotextile in rural roads construction on BC Soil subgrade by Kundan Meshram , S.K. Mittal , P.K. Jain , P.K. Aggarwal (2013)

Intensity of stress on the subgrade is considerably reduced on addition of coir geotextile in roads constructed in villages. Soil has greater scope after reinforcement. Coir helps in restricting the movement of upper pavement layers due to the seasonal variation in moisture in subgrade soil which is highly expansive. Hence , inclusion of coir geotextile can improve performance of roads on such soils.

CHAPTER 4: MATERIALS

4.1 Soil

Black soils, generally called black cotton soils, and internationally named as 'tropical black earths' or 'tropical chernozems' are been formed by weathering of the Deccan lava in parts of Maharashtra, specific areas in Madhya Pradesh, Gujarat and a few places in Andhra Pradesh and Tamil Nadu.

The colour of the soil experimented on is varying from dark black to faint black and chestnut colour . The soil sample is collected from Nagpur, India.

Montmorillinite, a mineral found in black soil owes its unusual swelling properties to the soil. Hence the soil swells on when water is added to it and it shrinks when water is removed from it. The soil used becomes quite hard in dry state and possess high bearing capacity. In summer, the cracks are easily noticeable , with vertical cracks wide up to 10mm and extends up to a deep height of 3m or more. The soil tend to stick when wet and are usually characterized by cracks on surface when it dries off .

The engineering properties of black cotton soil used is given in Table 1

Properties	**Value**
Natural Water Content	28.37%
Specific gravity	2.525
Percentage retained on 200 no. sieve	95.3% retained on 75 µm sieve
Liquid limit	49.8%
Plastic limit	24.33%
Shrinkage limit	8.73%
OMC	21.2%
Permeability	0.7705 $*10^6$ cm\sec

Table 1- Engineering properties of black cotton soil

4.2 Coir fibre

It is a natural fibre obtained by extraction from the husk of coconut. It is a fibre obtained from the outer shell of coconut which is a pure waste material .Hence, it being a waste can be put to use instead of getting dumped. Coir is shown to exhibit good strength properties when reinforced with soil .Coir is found upto 35 cm in length and has a diameter of about 12-25 microns. Coconut gets harvested in 45 days. Coir is a material used widely in overcoming erosion. Coir geotextiles have an excellent ability to retain the moisture and also protect it from the radiation of sun involving natural soil. The coir fibre sample is collected from GO GREEN PRODUCTS, Chennai.

The engineering properties of coir fibre used is given in Table 2

Type	**Coir Fibre**
Length(inches)	6-8
Density (g/cc)	1.40
Tenacity(g/Tex)	10
Breaking Elongation %	30%
Diameter (mm)	0.1-1.5
Rigidity of modulus (%)	1.8924
Swelling in water (diameter)	5%
Moisture at 65% RH	10.50%

Table 2-Engineering properties of coir fibre

4.3 Jute fibres

As it is known as the ‘golden fibre’, it is one of the fibre used massively in textile industries. Jute mill waste is called jute caddies. Around 40,000 tonnes of jute caddies is generated by jute industry. This fibre is very efficient in controlling soil erosion ,protection of river bank and construction of road. Jute is extracted from bark of the white jute plant (Corchorus capsularis) . It is a natural fibre with silky shine and golden colour . The fibre is generally extracted by chemical retting or some biological processes. It can be recycled easily and is very biodegradable.. The jute fibre sample is collected from GO GREEN PRODUCTS, Chennai.

The engineering properties of jute fibre used is given in Table 3

Type	**Jute**
Density	1.3 g/cm^3
Tensile Strength	230 MPa
Elongation	1.7 %
Youngs modulus	26.5 GPa

Table 3 – Engineering properties of jute fibre

4.4 Bagasse fibre

Bagasse is a fibrous matter which is obtained from remains of sugarcane after juice is extracted from it. It is a dry pulpy solid residue after the extraction of juice from sugar cane. It is a pure waste of sugar industry and with adequate knowledge can be put to use. Bagasse when reinforced in soil shows increase in its shear strength. Bagasse is used in pulp materials and used as bio fuel also. At present, materials which are extracted from renewable sources, environment friendly, are widely used. Bagasse is the most eco-friendly resources suitable for various applications.The process of extraction of bagasse from sugarcane sticks does not require any kind of technological innovation. It is mostly suitable for producing high quality paper making. The bagasse fibre sample is collected from GO GREEN PRODUCTS, Chennai.

The engineering properties of bagasse fibre used is given in Table 4

Type	**Bagasse**
Flexural Rigidity	0.015 g cm^2
Torsional rigidity	190 dyne cm^2
Fineness	27.8 tex
Tensile Strength	112.16 MPa
Breaking elongation	2.89 %

Table 4 – Engineering properties of bagasse fibre

CHAPTER 5: OBJECTIVE

- To study the basic geotechnical and physical properties of expansive soil available at Nagpur.
- To find the optimum aspect ratio of jute, coconut coir, bagasse to obtain maximum unconfined compressive strength of fiber mixed soil.
- To study the effect of jute, coconut coir, bagasse fiber on the unconfined compressive strength and California bearing ratio of soil.
- To compare the all the three fibers on the basis of strength gain of reinforced soil and economy of the reinforced fiber.

CHAPTER 6: TESTS PERFORMED

6.1 Determination of water content

Objective

To determine the water content of given soil sample by oven drying method

Reference Standard

IS: 2720 (Part II) – 1973

Equipment and Apparatus

- Containers
- Oven
- Balance

Preparation Sample

After receiving the soil sample it is weighed with the container and then the sample is dried in electric oven at a temperature of 105 to 115°C for a period of 24 hrs.

Procedure

- The soil sample was placed in three different containers .
- All the three samples were weighed (W1gm) on the electric weighing machine of sensitivity 0.001gm.
- Then the container was filled with wet soil were weighed and there weights were taken(W2gm)
- Then the three samples were placed in an oven for drying for 24 hours at 110 °C

- After complete drying of the samples they were again weighed (W3gm).
- From the difference between the two weights (W1-W2), natural water content present in the given soil sample was determined .
- Using (W3-W1) the weight of dry soil was calculated.

Precautions

- The soil to be tested should be placed loosely in the container.
- Overheating should not be done.
- Before weighing, the dry soil sample should not be left in open.

6.2 Determination of specific gravity

Fig. 6 - Pycnometer

(Picture Reference – www.civilblog.org)

Objective

To determine the specific gravity of soil using pycnometer method

Reference Standard

IS : 2720(Part 4)-1985-Method of test for soil (Grain Size analysis)

Equipment and Apparatus

- Pycnometer
- Sieve (4.75mm)
- Vacuum pump
- Oven
- Weighing balance
- Glass rod

Preparation Sample

After receiving the soil sample it is dried in oven at a temperature of 105 to 110°C for a period of 24 hours.

Procedure

- The given soil sample was passed through 2mm IS test sieve .
- From the passed soil, 50gm of the soil was taken for the experiment.
- Distilled water was used to clean oven dried specific gravity bottle and was weighed W1(g).
- Then 5-7gm of the soil sample is filled into the specific gravity bottle and is weighed W2 (g).
- Water was added into the specific gravity bottle containing 5-7gm of soil ,the water being poured with constant shaking so no air voids are left. After filling the bottle completely with water it was weighed W3(g).
- Again the empty sp gravity bottle is taken and was completely filled with distilled water and was weighed W4(g).

Precautions taken

- Soil whose specific gravity is being determined should be dry.
- On drying if lumps are formed in soil, they are first broken to its actual size.
- The inaccuracies seen in weighing and the failure to eliminate the entrapped air completely were seen as the main sources of error.

6.3 Determination of liquid limit

Fig.7 - Cassagrande apparatus

(Picture Reference – en.wikipedia.org/wiki/atterberg_limits)

Objective

To determine the liquid limit of soil by Cassagrande apparatus

Reference Standard

IS 2720 (PART 5)-1985

Equipment and Apparatus

- Cassagrande liquid limit device
- A.S.T.M. and B.S. grooving tool
- Spatula
- Balance
- Drying Oven
- Distilled water

Preparation Sample

After adjusting the soil in the Cassagrande apparatus with the help of the grooving tool consequent blows are given to it.

Procedure

- Soil sample was passed through 425 micron sieve .
- About 120 gm of soil sample passing through the 425 micron sieve was taken and mixed thoroughly with distilled water in the evaporating dish .
- After the formation of uniform paste ,a portion of paste was placed in the cup and was leveled so as to have maximum depth of about 10mm.
- A groove cut in the soil in the cup ,using grooving tool .
- The handle was rotated at the rate of 2 revolution per second and the number of blows necessary to close the groove for a distance of 13mm noted .
- 10gm of soil near the closed groove was taken to determine its water content .
- The same operation repeated by altering the water content of the soil .
- For four to five reading of water content range , from 10 – 40 blows are obtained .
- A graph plotted between number of blows, N on a logarithmic scale and water content, w on the natural scale.
- From the graph the liquid limit was determined by reading the water content corresponding to 25 blows on the flow curve .

Precautions taken

- Distilled water should be used in order to minimize the possibility of iron exchange between the impurities and the soil.
- Soil which is used for liquid limit determinations should not be oven dried before its testing.
- In liquid limit test, the groove should not be closed by slippage but done by a flow of soil.
- For each test performed, cup and grooving tool should not be unclean.

6.4 Plastic limit test of soil (IS-2720-part-5-1985)

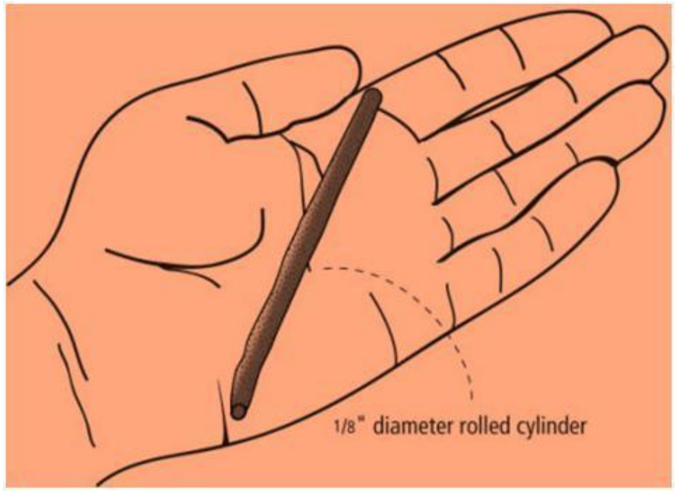


Fig 8 – Sample of plastic limit test

Objective

To determine the plastic limit of soil.

Reference Standard

IS : 2720(Part 5)-1985-Methods of test for soils : Determination of liquid and plastic limit.

Equipment & Apparatus

- Sieve [425 µ]
- Balance (0.01g accuracy)
- Oven
- Flat glass surface for rolling

Preparation of sample

The soil sample is dried in the oven at a temperature of 105-115 degree centigrade for a period of 18-24 hours.

Procedure

- About 30 gm of soil sample was mixed thoroughly with distilled water in an evaporating dish till the soil mass became plastic enough to be easily moulded with fingers.
- After the formation of mould the ball of soil mass of 8 gm was formed.
- The ball was then rolled between the fingers and the glass plate with just sufficient pressure to roll the mass into the thread of uniform diameter throughout its length.
- The rolling was done till the thread is of 3mm diameter.
- The soil was then kneaded together to a uniform mass and rolled again.
- This process of alternate rolling and kneading was continued until the thread crumbled under the pressure required for rolling and the soil could no longer be rolled into a thread.
- At the point of crumble, the satisfactory end point was considered.
- After the formation of crumble the sample was weighed.
- Then the sample was placed in the oven for drying for 24 hours at 105C.
- The dried sample was again weighed.
- The difference between the two weights gave the moisture content.
- The same procedure was performed for two more samples.
- The mean of the three readings gave the moisture content at plastic limit.

Precautions taken

- Distilled water was used in order to minimize the possibility of iron exchange between the soil and any impurities in water.
- After mixing distilled water to the soil sample, it was kept undisturbed for sufficient time so that the water could permeate throughout soil mass.
- Wet soil taken in the container for moisture content determination was not left open in the air rather the soil samples were immediately weighed.

6.5 Shrinkage limit test of soil

Fig. 9 - Shrinkage dish containing soil pat

Fig. 10 - Mercury used for measuring volume of dry soil pat

Objective

To determine the shrinkage limit of soil.

Reference Standards

IS -2720(Part6)-1972-Method of Test for soil

Equipment & Apparatus

- Three circular shrinkage dish (porcelain / stainless steel / brass with flat bottom about 4.5 cm in diameter and 1.5 cm high.
- One glass plate with three prongs.
- One glass or stainless steel cup (about 5.0 cm in diameter and 2.5 cm high with level and smooth ground top rim).
- Mercury

- 425 micron sieve
- Oven
- Weighing balance
- Spatula

Preparation of sample

The soil sample is dried in oven , the dried soil passing 425 micron sieve is used in this test.

Procedure

- 30 gm of soil was thoroughly mixed with distilled water.
- Then clean empty shrinkage dish was weighed.
- Capacity of the shrinkage was determined by filling the shrinkage dish to overflowing with mercury which is equal to the volume of the wet soil pat.
- Then the inside of the shrinkage dish was coated with thin layer of silicone grease.
- The dish was filled with the prepared soil paste.
- The dish with the filled soil was weighed.
- Then the dish was placed in the oven for 24 hours at 110C.
- The dish with the dry soil was weighed.
- Volume of dry soil pat was determined by placing the soil pat in glass cup full of mercury.
- On placing the soil pat in the glass of full of mercury and forcing the pat under the mercury by means of glass plate , the mercury was displaced.
- The displaced mercury was weighed and its volume was determined.
- The obtained volume was the volume of the dry soil pat.

Precaution taken

- The water content of the soil taken in shrinkage dish should be above liquid limit but within 10% from liquid limit .
- To prevent the soil from adhering to the shrinkage dish and consequent cracking of the dry soil pat , the inside of the shrinkage dish was greased with Vaseline.
- During filling the shrinkage dish with soil paste , sufficient tapping was done to remove the entrapped air .
- The dry soil pat was weighed soon after it had been removed from oven so that it could not pick up moisture from the air.

6.6 Particle Size Distribution

6.6.1 Hydrometer Analysis

Fig 11– Hydrometer Apparatus

Fig 12 - Mechanical Stirrer

Objective

To determine the particle size distribution graph of soil particle less than 75 micron.

Reference standard

Is – 2720 (part-4) 1985

Equipment and apparatus

- Hydrometer
- Two 1000 ml graduated glass cylinders
- Dispersing agent solution containing sodium hexametaphosphate
- Evaporating dish
- Thermometer
- Stop-watch
- Mechanical stirrer

Sample preparation

Soil which is passing through 75 micron sieve is oven dried for about 24 hours at temperature around 105-110degrre centigrade and is then crushed into smaller size.

Procedure

- 50gm of dry soil is taken in evaporating dish and around 100 ml of dispersing agent is added to prepare a suspension.
- The suspension is transferred into mechanical stirrer and more distilled water is added and then stirrer is operated for 5 minute.
- The soil slurry is washed into a cylinder to make volume of 1000ml mark.
- Open end of the cylinder is covered with stopper and hold it securely with hand and then move it up and down for one minute.
- Cylinder is placed down and stopper is removed. Hydrometer is inserted and stop watch is started simultaneously hydrometer should be released closed to the reading depth.
- Reading is taken on the upper rim of the meniscus formed by the suspension and at stem of the hydrometer after time intervals of 0.5, 1, 2 and 4 minutes.
- The hydrometer is removed slowly after 4 minute reading and is floated in a second cylinder containing 100 ml deflocculating agent and distilled water up to 1000 ml.

- Reading is further taken after a time interval of 8, 15 and 30 minutes, and also after 1, 2, 4, 8 and 24 hours. Hydrometer is inserted just before taking the reading and is withdrawn immediately after taking the reading.
- Temperature of the soil specimen is observed and recorded.
- Solution is shaken in the second cylinder. And after that hydrometer is inserted to note the meniscus correction.
- The difference in the value of 1.000 corresponding to the usual hydrometer calibration temperature of 27°C and top meniscus reading is called composite correction. It may be negative or positive.
- The hydrometer is calibrated to find the relation between any reading and its corresponding effective depth and then a calibration plot obtained. And thus the density of the specimen is measured.

Precaution

- The soil specimen used is to be stirred in the available mechanically stirrer so that the dispersing agent is mixed carefully.
- Take the reading in the hydrometer carefully.
- Note down the temperature after each reading.
- Do not disturb the soil specimen.

6.6.2 Determination of particle size distribution by dry sieve method

Objective

Determination of particle size distribution of soil by dry sieve analysis.

Reference standard

IS: 2720 (Part 4) – 1985 – Method of test for soil (Part 4-Grain size analysis).

Equipment and apparatus

- Balance
- Sieves
  (4.75mm, 2.00mm, 1.00mm, 425µm, 212µm, 150µm, 75µm)
- Sieve shaker

Preparation sample

After receiving the soil ample the sample is Oven dried for 24 hours at temperature 105-110 degree centigrade.

Procedure

- 200 gm of soil sample is taken and is soaked with water.
- The soil specimen is then sieved through 75 micron sieve and washed with water under tap of high pressure.
- The material is washed until the clean water pass through the soil.
- The material retained on the sieve and is dried in oven and weighed.
- It is then sieved through the mechanical sieve shaker for about ten minutes and retained material on each sieve is collected and weighed.
- The material which is retained on the pan is equal to the total mass of soil minus the sum of all the masses of material retained on all sieves.
- The curve for the soil is drawn in the semi-logarithmic graph and particle size distribution curve is obtained.

Precaution taken

- Make sure filtered water is coming from the soil after washing of soil.
- Weigh the soil retained carefully.

6.7 Permeability test of soil

Fig 13 –Permeability by variable head method

Objective

To determine coefficient of permeability of given soil sample (by variable head method).

Reference Standards

IS : 2720 (Part 17), 1966

Equipments & Apparatus

- Permeameter mould (internal diameter =100 mm) ,effective height = 11.7mm , capacity 942cc, weight of cylinder =4319.1gm.
- Accessories of the permeameter (cover , base , detachable collar , porous stones , dummy plate).
- Round filter paper of diameter 100mm.
- Graduated glass stand pipe (internal diameter of 5-20mm ,preferably 10mm)
- Support frame and clamps.
- Funnel
- Measuring flask

Preparation Sample

The soil sample is dried in the oven at a temperature of 105-115C for a period of 16 to 24 hours.

Procedure

- The cover of mould was removed and grease was applied on the sides.
- The soil was compacted at the given dry density
- Grease was applied around porous stone and base plate.
- The rubber gasket was placed on the top for proper tightening of soil.
- The water pipe was connected to outlet at the top of the mould and allowed to flow in.
- The experiment was completed when the water got drained from the outlet at bottom of mould .

Precautions taken

- All the possibilities of leakage at the joints were eliminated. All the joints and washer were thoroughly cleaned so that there were no soil particles between them.
- The grease was applied between mould , base plate and collar.
- Rubber washer was moistured with water before placing.
- Porous stones were saturated just before placing.
- To avoid the choking of flow water deaired and distilled water was used.
- Soil sample was fully saturated before taking observation.

6.8 Determination of optimum moisture content

Objective

To determine the optimum moisture content and maximum dry density of soil .

Reference standard

Using light compaction as per IS: 2720 (Part 8) – 1983.

Equipment & Apparatus

- Proctor mould of capacity of 944 cc.
- Rammer of 5.08 cm diameter face and a weight of 2.5 kg.
- A balance.
- Sample extruder, mixing tools and spatula.

Preparation sample

About 4-5 Kg of oven dried soil dried up to 24 hours in oven at temperature of about 105-110 degree centigrade is taken and is passed through 19 mm IS sieve .

Procedure

- A representative oven dried soil of about 5 KG is taken and is thoroughly mixed with sufficient amount of water to dampen it with approximate water content.
- The proctor mould is weighed without base plate and collar. The collar and base plate is fixed. The soil in the Proctor mould is placed and compacted in 3 layers giving 25 blows per layer with the 2.5 kg rammer falling through. The blows should be uniformly distributed over the surface.
- Collar is removed and then trimmed to make the surface level using straight edge and then weighed.
- The weight of the compacted soil is divided by the volume to get the bulk density.
- Remove the sample thoroughly and obtain a small sample of water content.
- The remainder of soil is thoroughly breaked and is passes through no.4 sieve as judged by eye. The water should be added so that sufficient amount of water content is increased. This process is continued until there is decrease or no change in the weight of compacted soil.

Precaution taken

- Hand gloves and shoes should be used while compaction.
- Adequate time should be allowed after mixing the water and before compacting the soil into the mould.
- The blows should be uniformly distributed over the surface.

6.9 Unconfined compression test

Objective

To determine the unconfined compressive strength of soil

Reference standard

ASTM D2166 - 06 Standard Test Method for Unconfined Compressive Strength of Cohesive Soil

Equipment and apparatus

- Compression device
- Load and deformation dial gauges
- Sample trimming equipment
- Balance
- Evaporating dish

Preparation sample

Soil is oven dried at a temperature about 110-115 degree centigrade for about 24 hours and the soil is crushed so that it pass through 2.24 mm sieve and then water equal to optimum moisture content is added to the soil.

Procedure

- The sample is ejected from the linear of spine spoon sampler carefully of standard penetration test, and then it is cut into pieces as the size of the mould. The initial length and diameter of the specimen is measured.
- Both the end of the samples should be trimmed carefully and should be placed on the loading plate of unconfined compression test machine.
- The load and displacement measuring device should be carefully placed on the plate.
- The load is initially applied by raising the lower plate.
- The load and displacement measuring device measure the load and displacement on the screen.
- The load and displacement is noted every 30 second.
- The sample is compressed until its loading becomes constant or started decreasing.

Precaution

- Both the end of the sample should be carefully trimmed so that they became flat and sit properly on bottom plate
- Rate of the loading should be constant.
- The reading of load and displacement should be taken carefully.

6.10 California Bearing Ratio Test

Fig 14- Preparation of sample for CBR test on unsoaked soil

Objective

To determine California bearing ratio of given soil sample by conducting load penetration test in laboratory.

Reference Standards

IS : 2720(Part 16)-1973-Methods of Test for soil

Equipment & Apparatus

- Cylindrical mould with diameter of 150 mm and height of 175 mm with detachable extension , collar with height of 50mm and detachable perforated base plate with thickness of 10mm.
- Spacer disc of diameter of 148mm and height of 47.7mm along with handle.
- Metal rammer : weight 2.6 kg with a drop of 310 mm.

- Weights : one annular metal weight and several slotted weights weighing 2.5 kg each , and diameter of 147 mm with a central hole of diameter of 53mm.
- Loading machine : with a capacity of atleast 5000kg and equipped with a movable head or base that travels at a uniform rate of 1.25mm/min.
- Metal penetration piston with diameter of 50mm and minimum of 100 mm in length.
- Two dial gauges reading to 0.01mm.
- Sieves used are 4.75mm and 20 mm.
- Mixing bowl, scales soaking tank or pan , drying oven , filter paper and containers.

Preparation of sample

6 kg of soil was taken and water of 29.8% by weight of soil was mixed thoroughly . The sample was prepared by dynamic compaction . The extension collar and base plate was fixed to the mould . The spacer disc was inserted over the base . The filter paper was placed on the top of the spacer disc. The soil was compacted in the mould using light compaction. In the light compaction the soil was compacted in 3 layers . Each layer was compacted using the 2.6 kg runner in 55 blows. After the compaction was completed the collar was removed and the soil was trimmed off.

Procedure

- The mould was placed with the surcharge weights on the penetration test machine.
- For the full contact of the piston on the sample the penetration piston was seated at the centre of the specimen with the smallest possible load.
- The stress and strain load gauge was set to zero.
- The load was applied on the piston at the penetration rate of about 1.25mm/min.
- The load readings at penetration of 0.5 , 1.0 , 1.5 , 2.0 , 2.5 , 3.0 , 4.0 , 5.0 , 7.5 , 10 and 12.5 mm were recorded.
- The maximum load and corresponding penetration (for < 12.5 mm) were noted.
- From top three layer of soil 20-50 gm of soil was taken for determining the moisture content.

Precautions taken

- The holes of the base plate and that of perforated disc was thoroughly cleaned.
- The surcharge weight and the plunger was aligned carefully in order to ensure the freely penetration of plunger into the soil.

CHAPTER 7: RESULTS AND CONCLUSIONS

7.1 Determination of optimum aspect ratio

Treatment of fibres

The various fibres were treated in solution of Water and NaOH solution (5 % by weight of water) . This has been done to enhance the tensile and flexural properties of the fibre

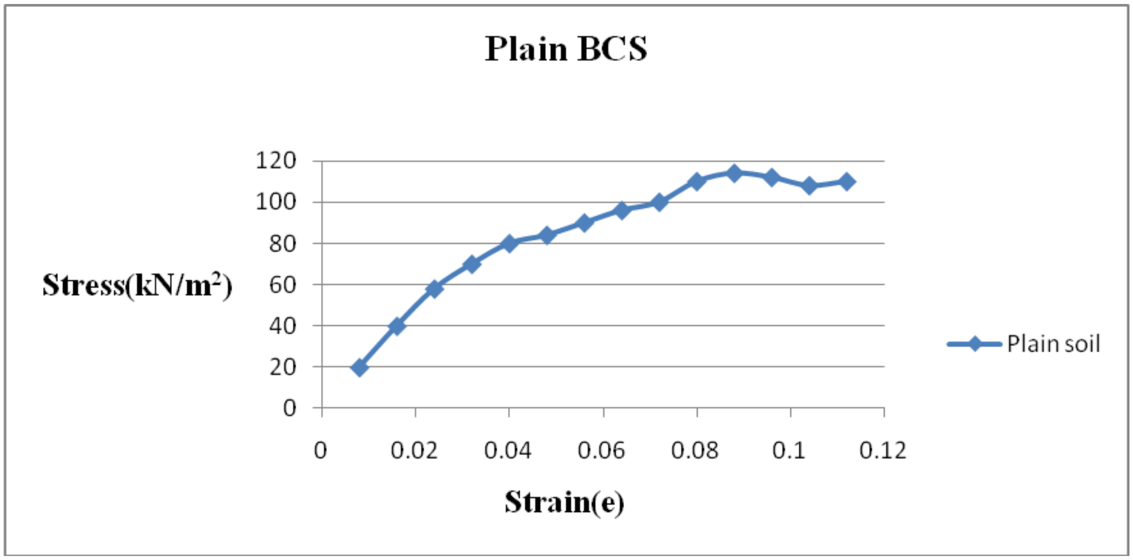
Analysis

1) The readings of load and displacement were noted digitally.
2) The sample cross sectional area is computed as $A_0 = \pi * (d^2)/4$
3) The deformation (ΔL) were noted.
4) Strain (e)= $\Delta L / L_0$
   Where, L0 is original specimen length
5) Corrected area is given as $A_c = A_0(1-e)$
6) Using the area , the stress is computed as $S_c = P/Ac$
7) The stress v/s strain graph was then plotted.

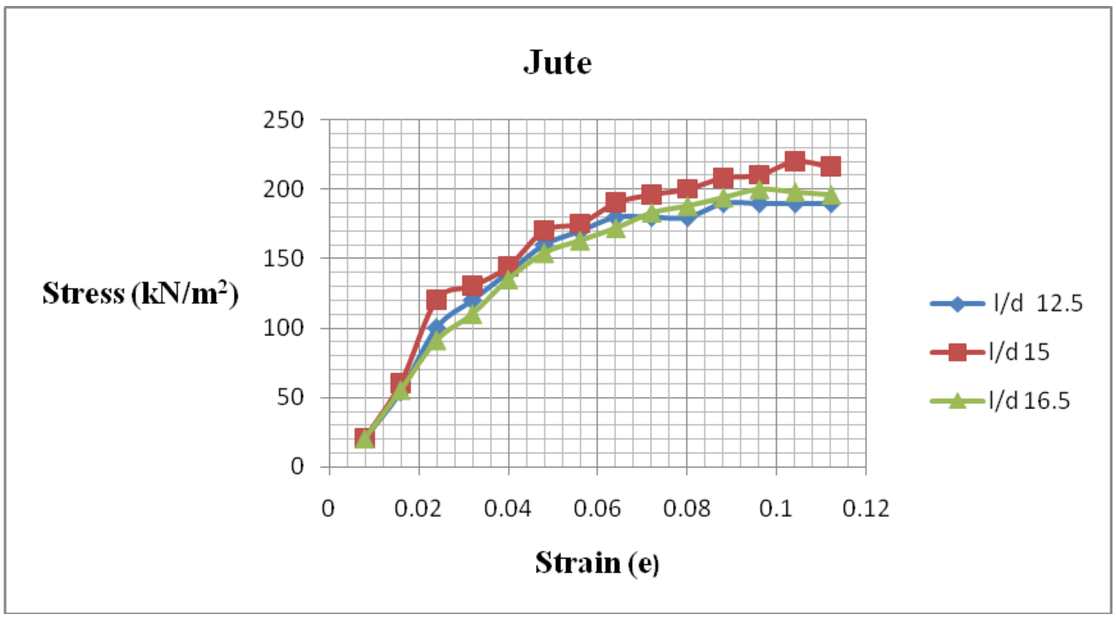
The observation table of unconfined compression test is given in Annexure 1.2

Graphs

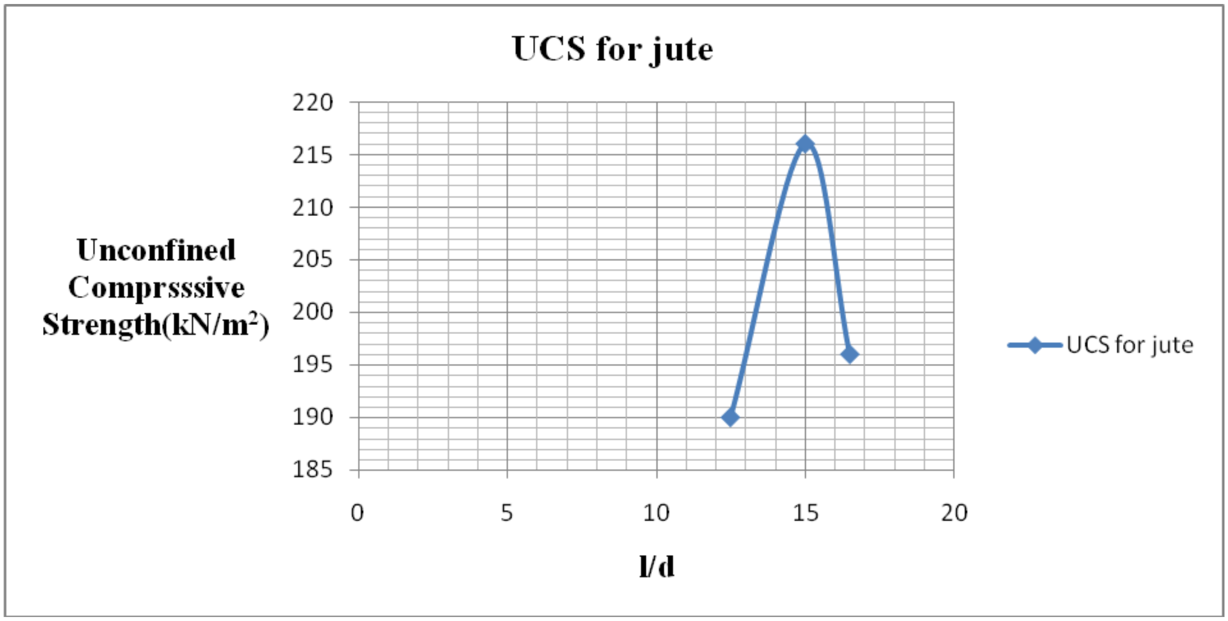
The corresponding graphs are given in Annexure 2.2



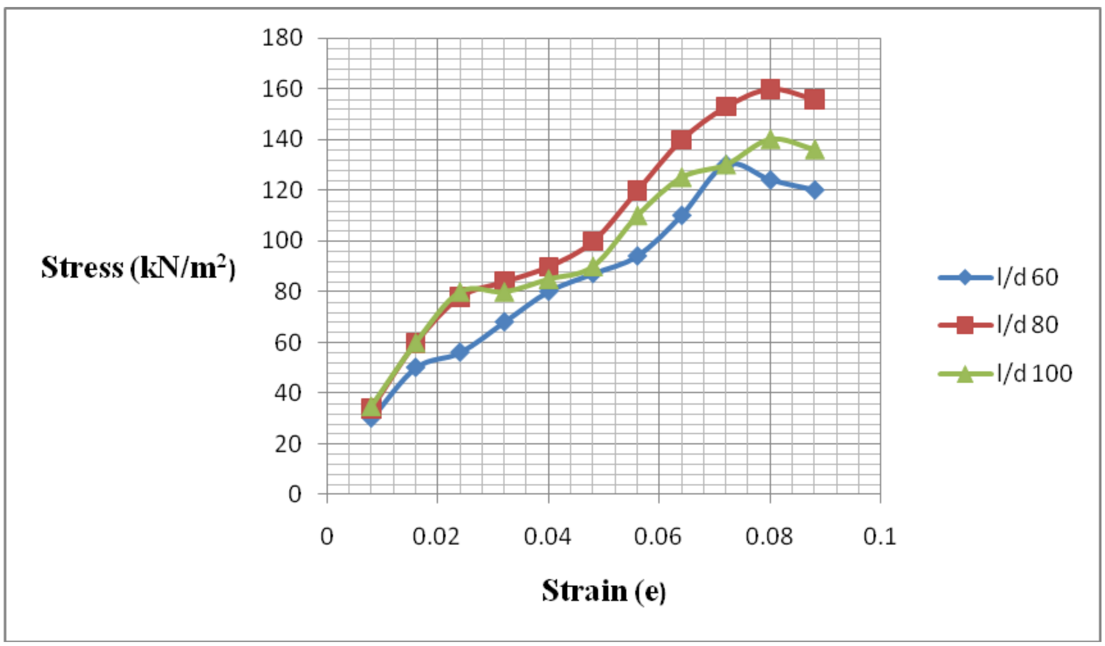
Graph 1 - Stress v/s strain graph for plain black soil



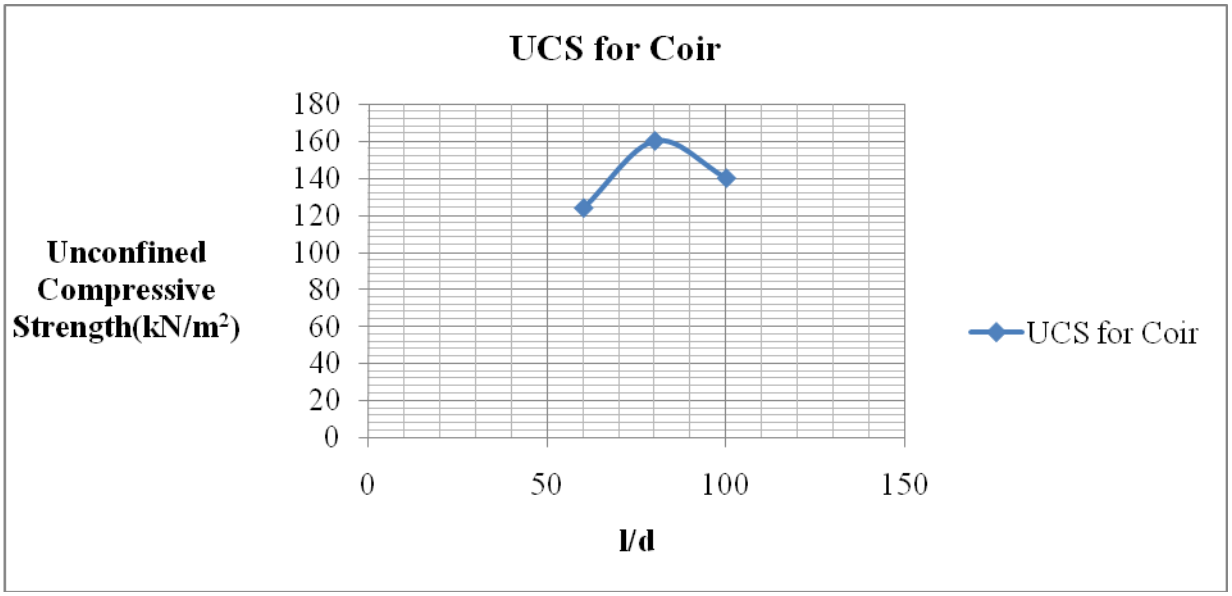
Graph 2 -Stress v/s strain graph for black soil reinforced with Jute at different l/d



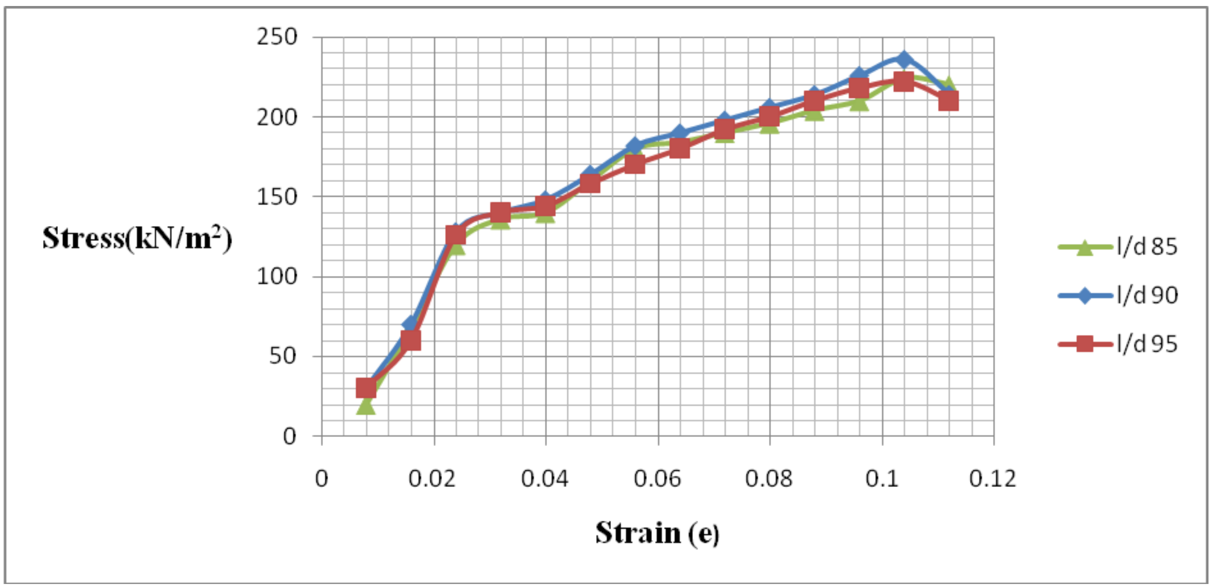
Graph 3- Unconfined Compressive Strength of soil reinforced with jute at different l/d



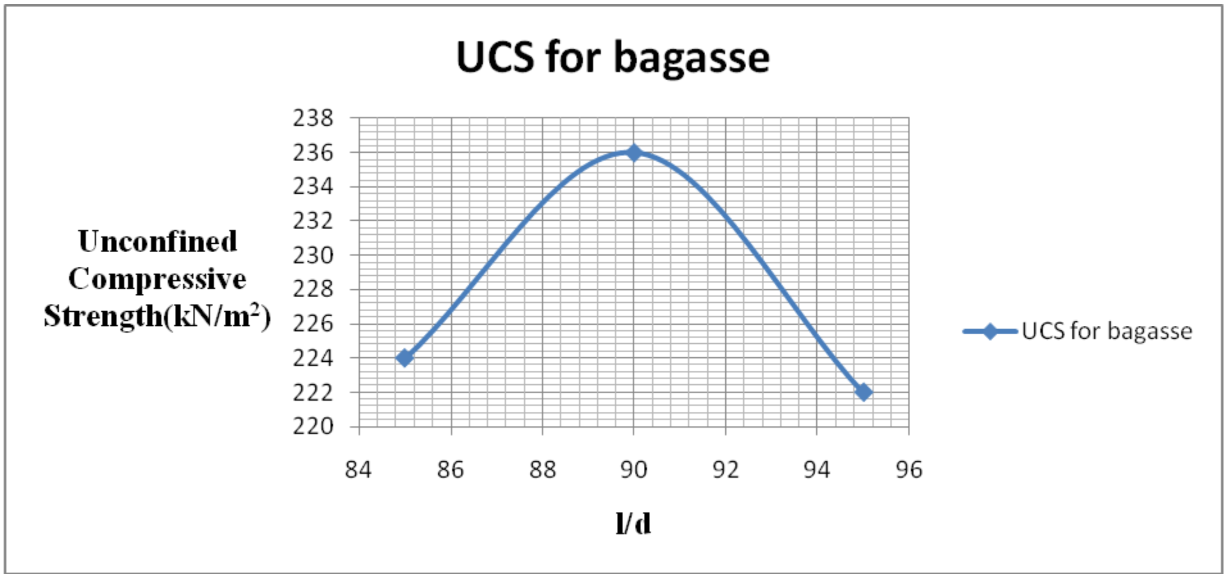
Graph 4 - Stress v/s strain graph for black soil reinforced with Coir at different l/d



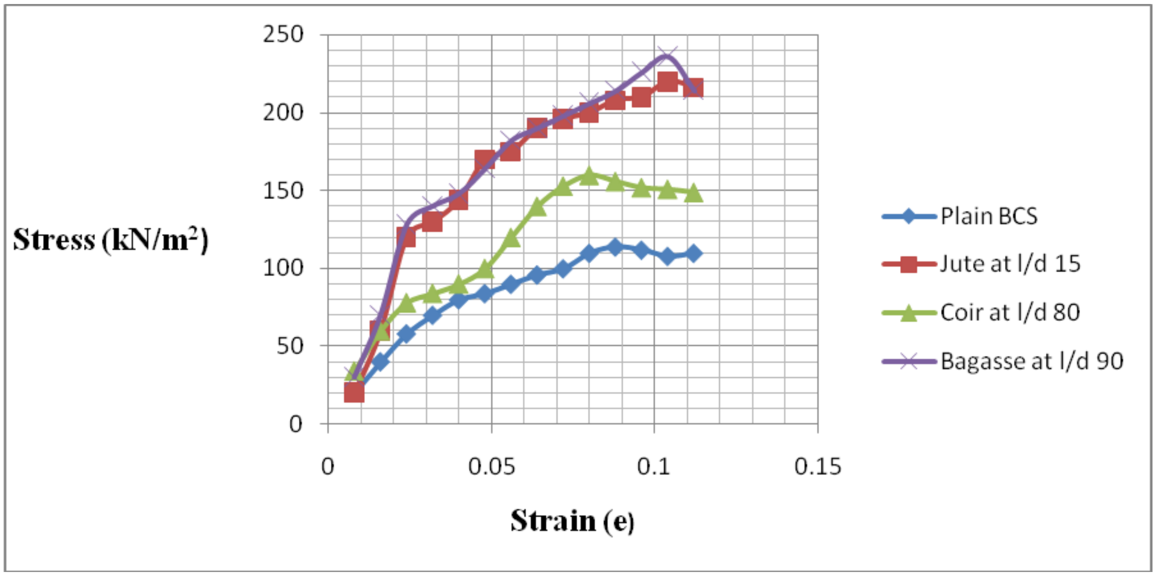
Graph 5- Unconfined Compressive Strength of soil reinforced with Coir at different l/d



Graph 6 - Stress v/s strain graph for black soil reinforced with Bagasse at different l/d



Graph 7- Unconfined Compressive Strength of soil reinforced with Bagasse at different l/d



Graph 8– Stress v/s strain graph for black soil reinforced with different fibres

The stress strain graphs of black soil samples reinforced with different proportions of jute, coir,bagasse fibres are given in annexture 2.1

Result

Unconfined compressive strength of soil =q_u= 114 kN/m^2

Unconfined compressive strength of reinforced soil (jute fibre l/d=7.5)=220 kN/m^2

Unconfined compressive strength of reinforced soil (coir fibre = cm)=160 kN/m^2

Unconfined compressive strength of reinforced soil (bagasse fibre l/d=90)=236 kN/m^2

The % increase in UCS of black cotton soil (on addition of jute fibre) **= 92.9 %**

The % increase in UCS of black cotton soil (on addition of coir fibre) = **40.350%**

The % increase in UCS of black cotton soil (on addition of bagasse fibre) = **97 %**

Inference:

Among the soil reinforced with different fibres, the unconfined compressive strength (kN/m2) of soil was found to be maximum in Bagasse reinforced soil which was 236 kN/m^2 . Hence there was 97% increase in the unconfined compressive strength of BCS.

7.2 Water Content

Calculation

The water content of soil is calculated using the following equation

W_1=Empty weight of container

W_2=Weight of container + wet soil

W_3=Weight of container + oven dry soil

Water content of soil = W = Weight of natural water present / Weight of dry soil

$$= (W_2 - W_3)/ (W_3 - W_1)*100$$

Sample	W_1(g)	W_2(g)	W_3(g)	W%
1	20.9	39.9	35.5	30.13
2	18.6	36.6	32.7	27.659
3	19.3	39.3	35	27.388

Table 5 – Values of water content determined

The average Water content of black cotton soil is found out to be 28.39 **%**

7.3 Specific Gravity Test

Calculation

The specific gravity of soil solids (GS) is calculated using the following equation

W_1 = Weight of Empty Density bottle

W_2 = Weight of Density bottle + oven dry soil

W_3 = Weight of Density bottle + oven dry soil + water

W_4 = Weight of Density bottle + water full

Specific Gravity of soil = Density of water at 27°C / Weight of water of equal volume

$$= (W_2-W_1) / [(W_2-W_1) - (W_3 - W_4)]$$

Sample	W_1 (g)	W_2 (g)	W_3 (g)	W_4 (g)	Specific Gravity
1	30	38	84.2	79.4	2.64
2	28.6	36.5	84.5	79.7	2.75

Table 6 – Values of different samples of Specific gravity

Result

The range of specific gravity for different soils is given in Table:

Soil	Specific Gravity
Sand	2.63 – 2.67
Silt	2.5 – 2.7
Clay and Silty Clay	2.67 – 2.9
Organic Soils	< 2.45

Table 7– Range of specific gravity for different soils

Specific gravity of soil sample was found to be **2.69** and hence the soil is clayey.

7.4 Liquid Limit Test

Calculation

- Initially a **'flow curve'** is to be plotted on a semi-logarithmic graph representing water content in arithmetic scale and number of drops on the logarithmic scale.
- The flow curve is a straight line drawn as nearly as possible through all four points.
- The moisture content corresponding to 25 blows as read from curve is the liquid limit of that soil
- .

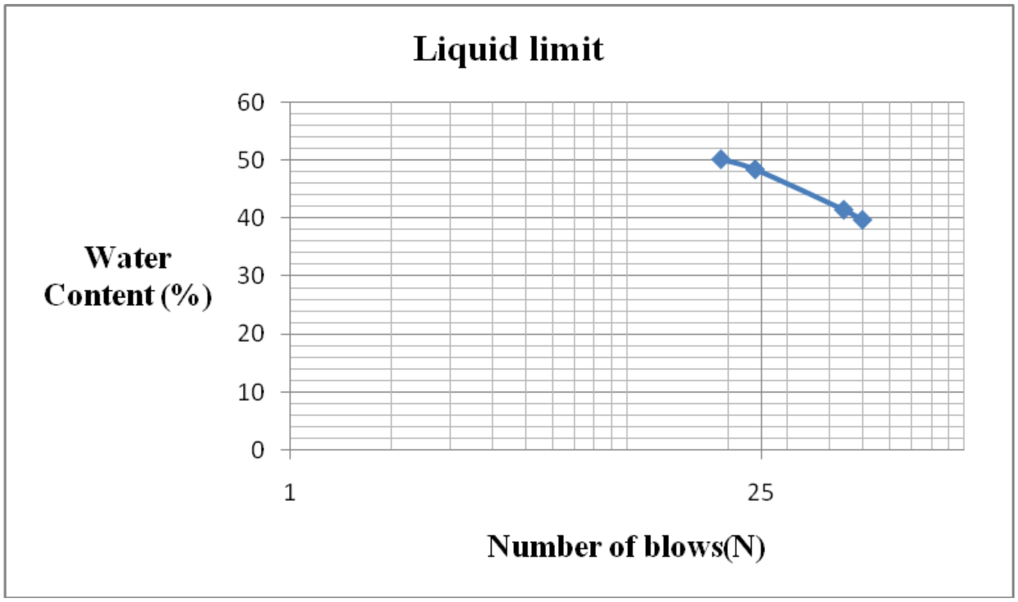
Observations

Serial Number	1	2	3	4
Container number	37	12	5	6
Weight of container(g)	28.6	27.6	25.8	27
Weight of container + wet soil (g)	56.8	45.9	47.6	40.6
Weight of container + dry soil (g)	48.7	40.3	41.3	36.3
Weight of water (g)	8.1	5.6	6.3	4.3
Weight of dry soil (g)	20.1	12.7	15.5	9.3
Moisture content (%)	41.5	48.38	50.1	39.8
No. of blows	44	24	19	50

Table 8 – Different values of water content at different blows

Computation

A graph is drawn which shows the relationship between water content (y- axis) and number of blows done (x – axis) on semi-log graph. The curve which is then obtained is called flow curve . The moisture content which corresponds to 25 drops (blows) as read from the graph represents the liquid limit. (Refer to Graph)



Graph 9 – Liquid Limit on plain soil

Result

The liquid limit of black soil is found to be **49.6 %**

Inference

Since the liquid limit comes out to be < 50%, therefore the soil is medium to high plastic.

7.5 Plastic Limit Test

Observation and Reporting

At regular intervals of rolling the soil sample , the diameter of thread was compared with the rod. When the diameter reduced up to 3mm, the cracks on the surface of thread were noted.

Observation Table

Sample No.	1	2	3
Container No.	11	5	42
Wt. of container+lid,W_1(g)	29.3	28.1	27.5
Wt. of container + lid + wet sample , W_2 (g)	31	51.8	30.6
Wt. of container + lid +dry sample , W_3 (g)	30.66	47.180	29.606
Wt. of dry sample(g) =W_3-W_1	1.36	19.08	2.106
Wt. of water in the soil (g) =W_3-W_2	0.34	4.62	0.994
Water content(%) = (W_3-W_2)/(W_3-W_1)*100	24.8	24.21	25.03

Table 9– Different values of plastic limit obtained.

Result

The average plastic limit of black soil was found to be **24.68%**

Plastic Index (PI) = Liquid Limit(W_{LL}) –Plastic Limit (W_{PL}) = 49.6-24.68 =24.92%

Inference

Since plasticity index of black cotton soil is 24.92%, therefore the soil is medium to high plastic.

7.6 Shrinkage Limit Test

Observation & Reporting

As soon as the shrinkage dish containing the dry soil pat was taken out of the oven , it was immediately weighed and the procedure for the shrinkage limit experiment was performed.

Shrinkage limit (W_{SL}) = W_1-{[(V_1-V_2)γ_w]/ Ws}*100

W_{SL}= Shrinkage limit in % soil pat

γ_w = Mass density of water in g/cc

Observation Table :

Shrinkage dish	1	2	3
Initial water content of wet soil pat W_1(g)	48.1	48.99	46.8
Mass of oven dry soil pat in gm W_s (g)	26.66	24.9	25.4
Volume of wet soil pat in cc (V_1)	23.84	22.25	22.25
Volume of dry soil in cc (V_2)	13.18	12.51	12.44
Shrinkage limit W_{SL} (%)	8.1	9.89	8.2

Table 10 – Different values of shrinkage limit of soil

Result

The average shrinkage limit of black cotton soil was found to be **8.73%**

7.7 Particle Size Distribution

Total weight of soil taken for sieve analysis = 600g

Percentage of soil retained on 75 µ sieve = 37%

Percentage of soil passes through 75 µ sieve = 63%

Dry sieve is performed on soil retained on 75 µ sieve

Observation table of dry sieve

Sieve (mm)	Retained wt(g)	Cumulative Retained (g)	Cumulative retained%	%Finer (100-cumulative %)
4.75	0	0	0	0
2.36	34.32	34.72	5.72	94.28
1.18	10.32	44.64	7.44	92.56
0.6	83.76	128.4	21.4	78.6
0.425	25.68	154.08	25.68	74.32
0.3	24.08	178.56	29.76	70.24
0.15	22.08	200.64	33.44	66.56
0.075	21.06	222	37	63

Table 11-Different values for % finer and sieve size for dry sieve

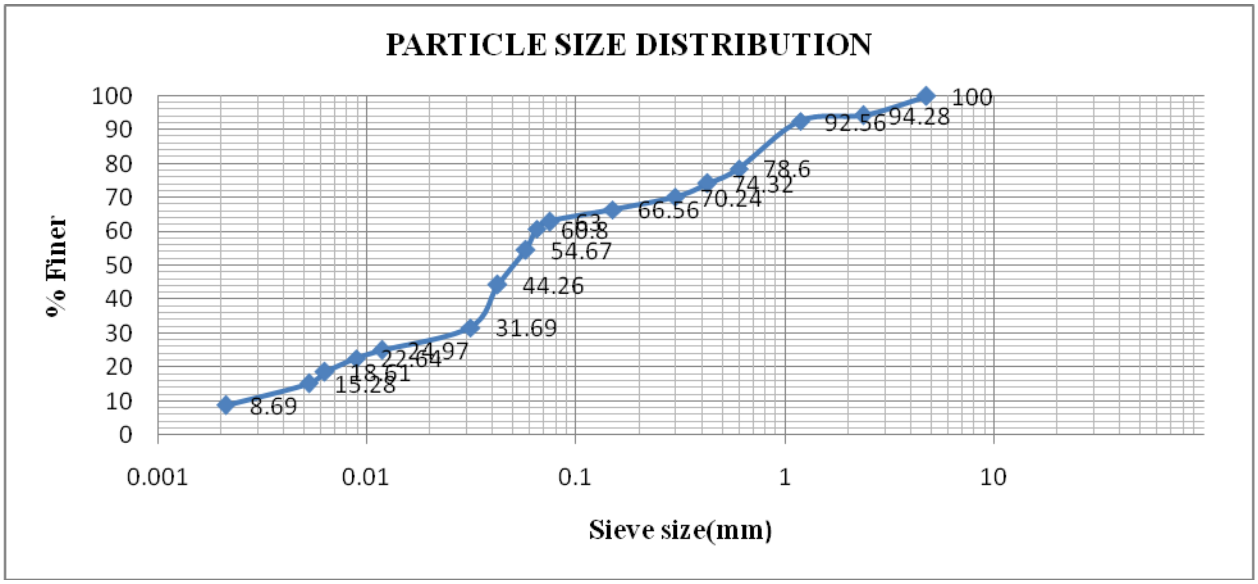
Hydrometer analysis is done on the percentage of soil passing through 75 micron sieve

Observation Table

Sieve size (mm)	% Finer
0.065	60.8
0.0574	54.67
0.0423	44.26
0.0313	31.69
0.0118	24.97
0.0089	22.64
0.0063	18.61
0.0053	15.28
0.00221	8.69

Table 12- Hydrometer analysis for % finer sieve size

Graph



Graph 10 – Particle size distribution graph for BCS

Result

D_{60} = 0.065

D_{30} = 0.028

D_{10} = 0.0029

C_U = 0.065 / 0.0029 = 22.41

$C_C = (0.028)^2 / (0.065*0.0029) = 4.16$

7.8 Permeability Test

Calculations

Area of stand pipe , a = 1.13 square cm

Cross sectional area of soil specimen , A = 78.5 square cm

Length of soil specimen , L = 12.78cm

Initial reading of stand pipe , h_1= 100 cm

Final reading of stand pipe,h_2 = 92 cm

Time after which drainage occurs , t = 350280 sec

Coefficient of permeability (K_t) = $2.303(al/At)\log_{10}(h_1/h_2)$

= 0.044 µ cm/sec

Result

Coefficient of permeability (Kt) of the soil specimen is **0.044** µ cm/sec

Inference

As the permeability of soil specimen came out to be 0.044 µ cm/sec , it is a clayey soil.

7.9 Light Weight Standard Proctor Test

Cylinder Specifications

- Diameter & Height = 10cm &11.7cm
- Volume = 918.45 cc
- Weight = 4316.6g

The values for water content and dry density is calculated in table no provided in annexure 1.1

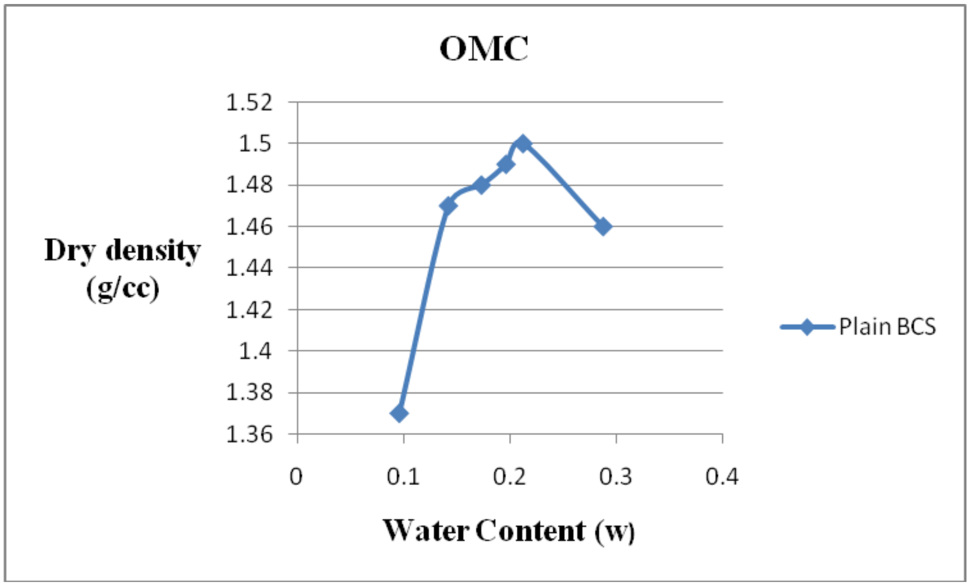
Calculation

Dry density = Bulk density/(1+w)

Where ‘w’ is the moisture content of soil.

Graph is plotted between dry density and moisture content .

From the graph maximum dry density and optimum moisture content of the given soil sample is determined.



Graph 11 – Determination of Optimum moisture content

Result

The maximum dry density of the soil specimen calculated from graph is 1.5 g/cc and optimum moisture content is 21.2 %.

7.10 Unconfined Compression Test

Calculations

Specific gravity (G_s) of black soil used is 2.52

Water content of soil sample used is 28.39%

Diameter (D_0) of the sample is 3.4 cm

Initial length (L_0) of the sample is 75 mm.

Analysis

1) The readings of load and displacement were noted digitally.
2) The sample cross sectional area is computed as $A_0 = \pi*(d^2)/4$
3) The deformation (ΔL) were noted.
4) Strain (e)= $\Delta L/L_0$
   Where, L_0 is original specimen length
5) Corrected area is given as $A_c=A_0(1-e)$
6) Using the area , the stress is computed as $S_c=P/Ac$
7) The stress v/s strain graph was then plotted.

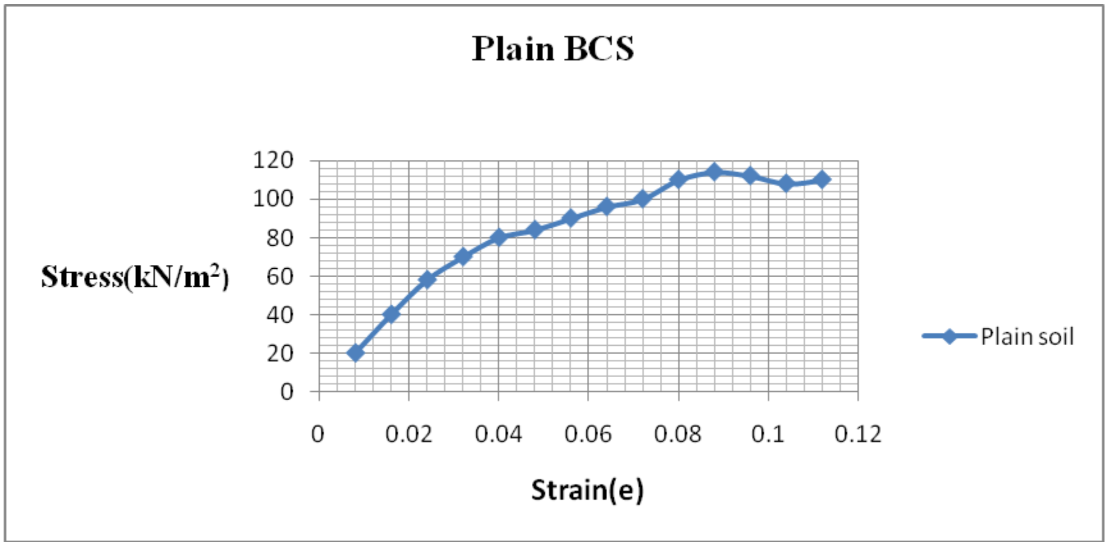
Mentioned in Annexure 1.2

Graph

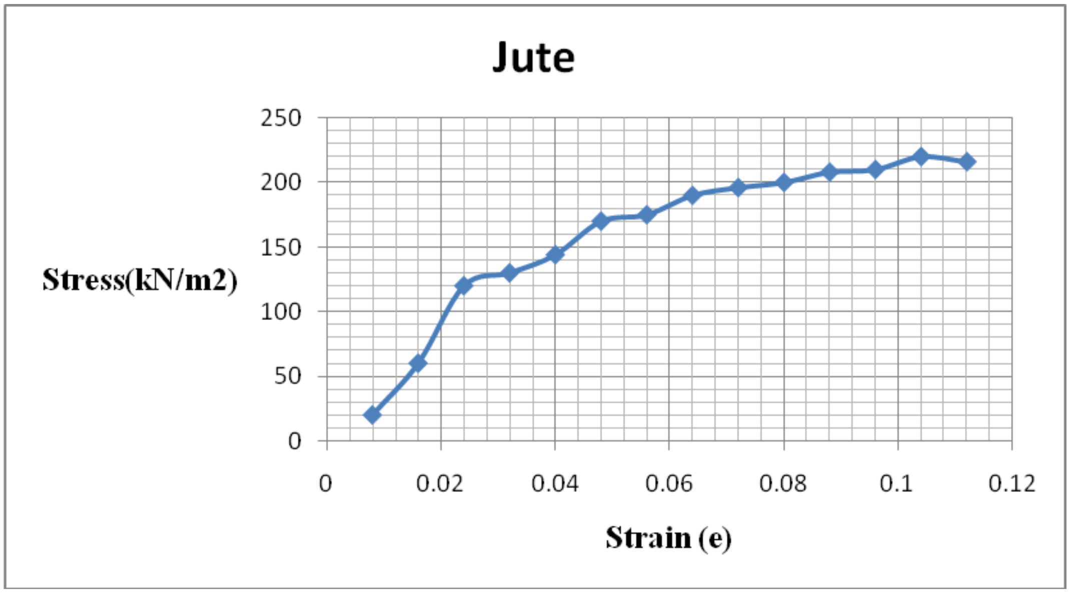
Mentioned in Annexure 2.1a

Result

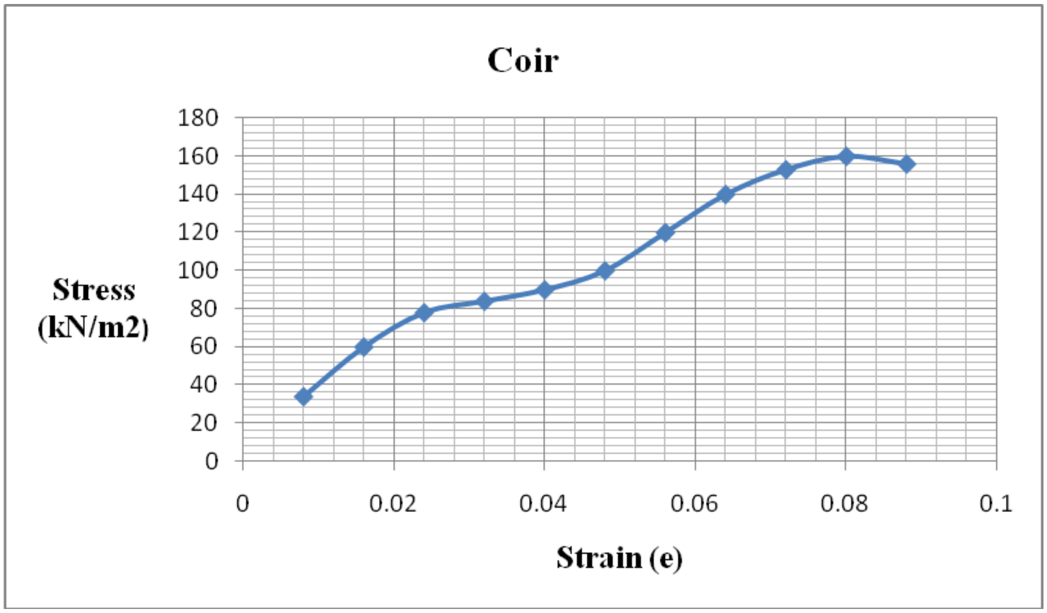
Unconfined compressive strength of soil =q_u= **114 kN/m^2**



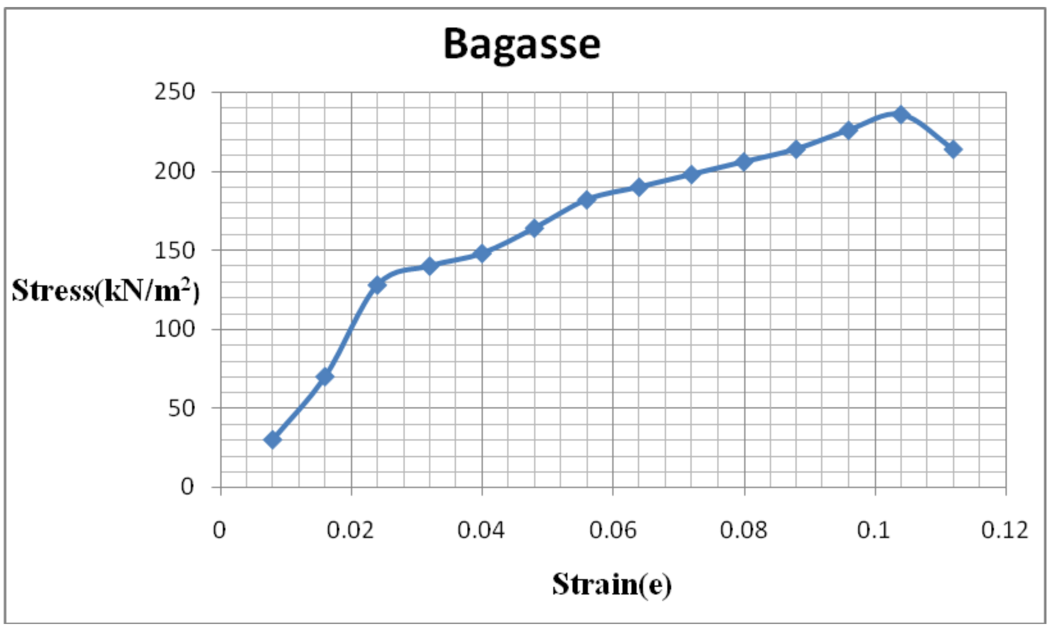
Graph 12 – Stress v/s strain graph for Plain BCS



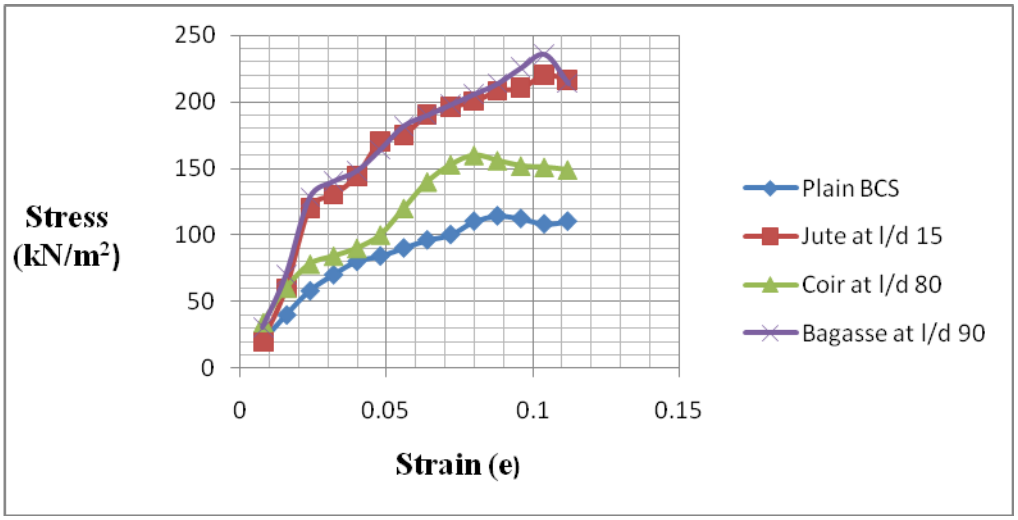
Graph 13- Stress v/s strain graph for soil reinforced with Jute



Graph 14- Stress v/s strain graph for soil reinforced with Coir



Graph 15 - Stress v/s strain graph for soil reinforced with Bagasse



Graph 16 - Stress v/s strain graph for plain BCS reinforced with different fibres

7.11 California Bearing Ratio Test

Observation & Reporting

7.11.1

The values for CBR was calculated at 2.5mm and 5mm penetration.

CBR at 2.5 mm = (value / 1370 kg)*100

CBR at 5mm = (value / 2055 kg)*100

Observation Table mentioned in Annexure 1.3.1

CBR at 2.5 mm = (399.9/1370)*100 = 29.189

CBR at 5mm = (506.54/2055)*100 = 24.65

7.11.2

Calculation of CBR for soil reinforced with Jute fibre of l/d = 15 (d=0.5)

Observation Table mentioned in Annexure 1.3.2

CBR at 2.5 mm = (430.2/1370)*100 = 31.401%

CBR at 5 mm = (550.57/2055)*100 = 26.791%

7.11.3

Calculation of CBR for soil reinforced with Coir fibre of l/d = 80 (d=0.125)

Observation Table mentioned is given in Annexure 1.3.3

CBR at 2.5 mm = (424.7/1370)*100 = 31 %

CBR at 5 mm = (540.1/2055)*100 = 26.282 %

7.12.4

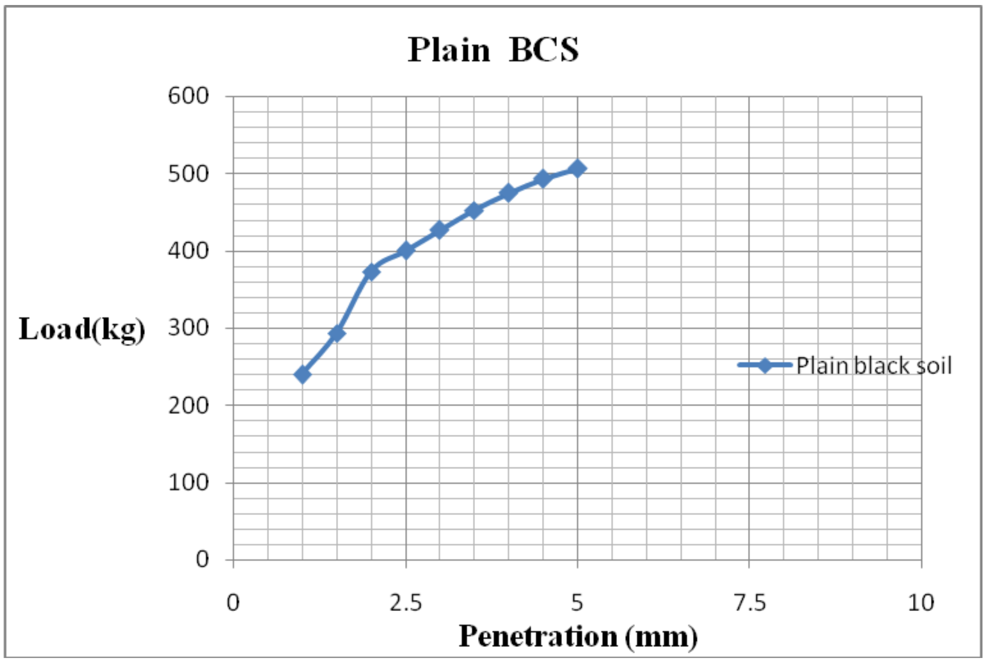
Calculation of CBR for soil reinforced with Bagasse fibre of l/d = 90 (d=0.02)

Table mentioned is given in Annexure 1.3.4

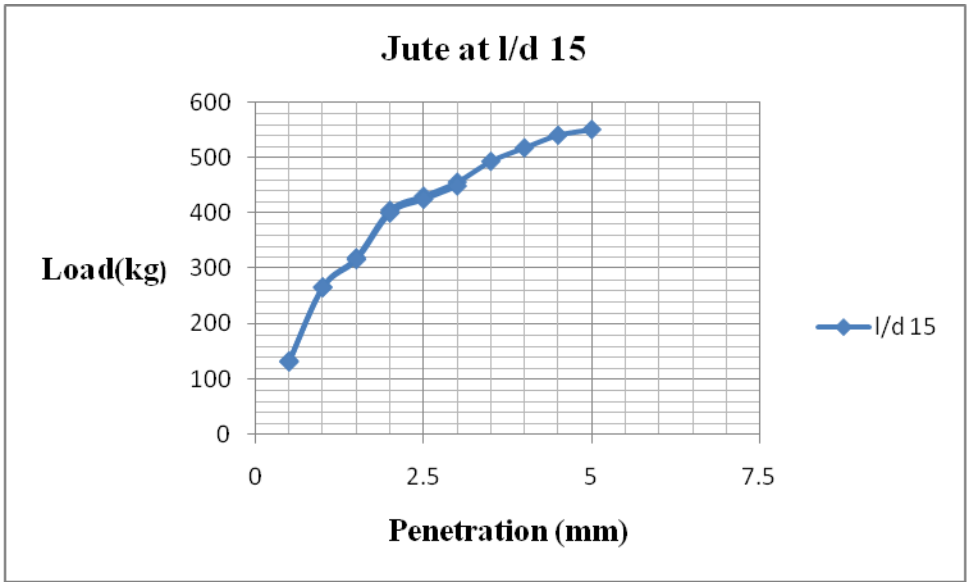
CBR at 2.5 mm = (449.7/1370)*100 = 32.824 %

CBR at 5 mm = (569.9/2055)*100 = 27.732%

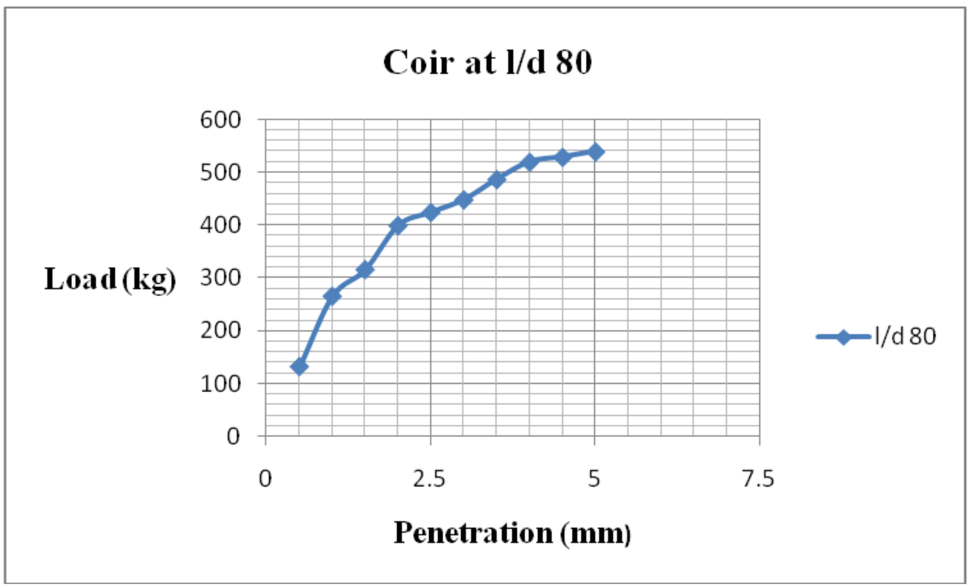
Graph



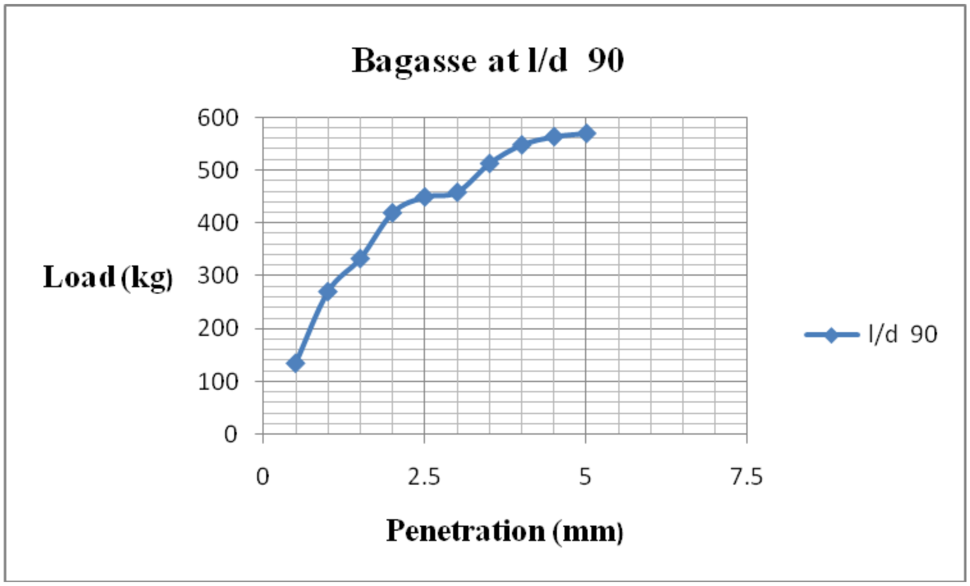
Graph 17 – California Bearing Ratio on plain BCS



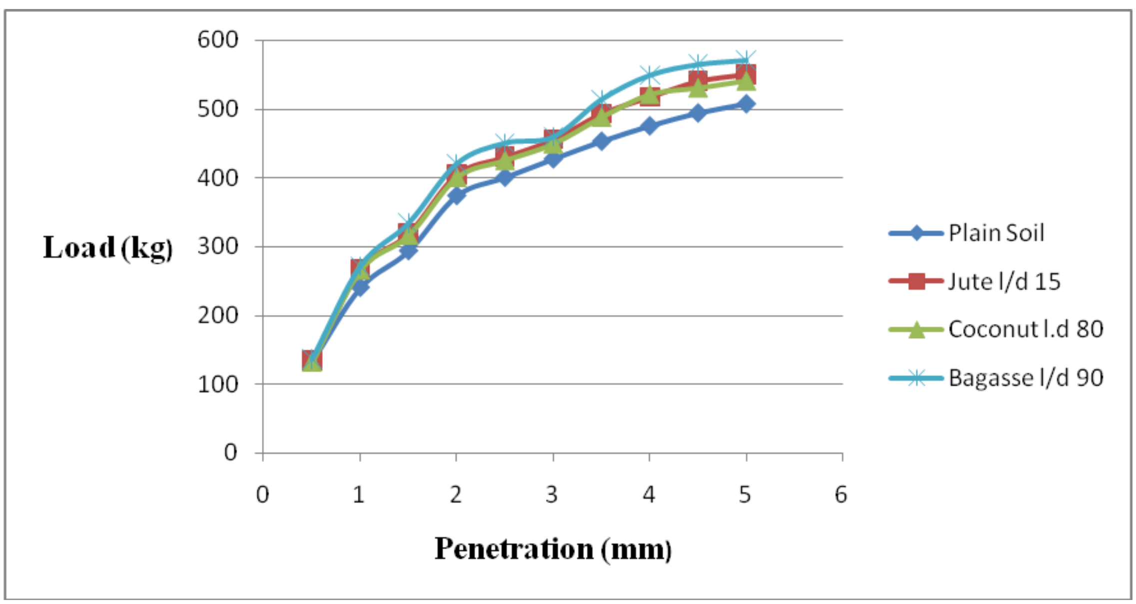
Graph 18 - CBR values when soil is reinforced with jute (l/d 15)



Graph 19 - CBR values when soil is reinforced with Coir (l/d 80)



Graph 20 –CBR values when soil is reinforced with Bagasse (l/d 90)



Graph 21- CBR values for different fibers reinforced in soil

Result

The CBR value for the given soil sample is **29.189%**.

The CBR value for black cotton soil reinforced with jute fibre (l/d=15) is **31.401%**

The CBR value for black cotton soil reinforced with coir fibre (l/d=80) is **31 %**

The CBR value for black cotton soil reinforced with bagasse fibre (l/d=90) is **32.824**

CBR	**Jute**	**Coir**	**Bagasse**
At 2.5 mm Penetration	31.401 %	31%	32.824%
At 5 mm Penetration	26.791%	26.282%	27.732%

Table 13 - CBR values for different fibers reinforced in soil

Inference

Since the CBR values of Plain BCS is low therefore modification of soil is required or the development of patholes etc. can be seen.

CHAPTER 8 : COMPARISON OF RESULTS

The comparison of strength between black cotton soil and reinforced black cotton soil is given in following table

Properties	Black soil	Jute fibre	Coir fibre	Bagasse fibre
Unconfined compressive strength(kN/m^2)	114	220	160	236

Table 14 – Comparison of unconfined compressive strength of BCS with inclusion of different fibre

The percentage increase in Unconfined Compressive Strength of BCS with the reinforcement of different fibre into soil by weight is given in Table 15

Natural Fibres	% Increase in UCS
Jute fibre	92.9
Coir fibre	40.35
Bagasse fibre	97

Table 15 – Percentage increase in UCS with reinforcement of Natural Fibres in plain BCS

The comparison of California bearing ratio between black cotton soil and reinforced black cotton soil is given in Table 16

Properties	Black soil	Jute fibre	Coir fibre	Bagasse fibre
CBR (%)	29.189	31.401	31	32.824

Table 16 – Comparison of CBR value between plain BCS and reinforced BCS

CHAPTER 9 : CONCLUSION

- Improvement in strength properties of black cotton soil like shear strength and unconfined compressive strength were obtained from the reinforcement of natural fibre.
- The increase in strength was observed with the increase in aspect ratio of different fibre upto l/d 15 in jute , l/d 80 in coir , l/d 90 in bagasse and beyond that the strength decreased.
- The increase in CBR was also observed with the inclusion of different fibre.
- The maximum strength was developed by inclusion of bagasse fibre into black cotton soil whereas the minimum strength was observed from inclusion of coir fibre. Jute fibre gives the intermediate increase in strength.
- As the bagasse fibre is more costly and coir fibre gives the minimum of strength among these fibres, the inclusion of jute fiber is recommended as it provides economic soil modification as well as only marginal decrease in strength as compared to bagasse fiber.

CHAPTER 10: FUTURE SCOPE

From the above experimental result and literature review, it can be concluded that the soil reinforcement with natural fibres is one of the efficient soil improvement technique. It is a smart approach in improving the black cotton soil properties such as bearing capacity , decreased volume changes under the impact of water, shear strength and California bearing ratio .It is also beneficial in efficient management of biodegradable wastes like bagasse, coconut fibre ,rise husk etc.

It can also pave way for the production of new geo composite products that are effective and eco-friendly. Natural fibres have a great potential to be used as cost effective solutions to several engineering problems. Research can be done on development of methods of improving the durability and strength of natural fibres. By proper implementation of this technique of soil reinforcement technique, the land mass can be effectively utilized for various construction purpose.

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ANNEXURE 1

Annexure 1.1

Density (g/cc)	1.72	1.85	1.86	1.88	1.84	1.83
Serial No.	1	2	3	4	5	6
Water to be added(percent)	10	15	17.5	20	22.5	29
Weight of water to be added(g)	400	600	700	800	900	1000
Weight of cylinder+compacted soil(g)	5893	6019.9	6032.2	6043.2	6003.2	6001.4
Weight of compacted soil(g)	1576.4	1703.3	1715.6	1726.6	1686.6	1684.8
Average moisture content(%)	25.6	25.6	25.6	25.6	25.6	25.6
Density of water (g/cc)	1000	1000	1000	1000	1000	1000
Dry density(g/cc)	1.3	1.47	1.48	1.50	1.46	1.45
Water content(%)	9.6	14.2	17.3	19.6	21.2	28.7
Container No.	1	2	3	4	5	6
Wt . of container + wet soil(g)	60	49.2	31.9	46.8	46.1	48.2
Wt. of container + dry soil(g)	56.8	46.1	30.6	43.2	42.2	44.2
Wt. of container alone(g)	19.1	19.1	20.4	18.8	19.3	19.3
Wt. of water (g)	3.2	3.1	1.3	3.6	3.9	4
Wt. of dry soil (g)	37.7	27	10.2	24.4	22.9	24.9
Water content (%)	9.6	14.2	17.3	19.6	21.2	28.7

Table 17 – Light weight Standard Proctor Test

Annexure 1.2

Annexure 1.2.1

Displacement(ΔL)	Strain ($e= \Delta L/L_0$)	Corrected area[$A_c=A_0(1-e)$]	Load (kN)	Stress(kN/m^2)
0.6	0.008	9.14	0.01828	20
1.2	0.016	9.22	0.05532	60
1.8	0.024	9.29	0.11148	120
2.4	0.032	9.37	0.12181	130
3	0.04	9.45	0.136	144
3.6	0.048	9.53	0.1620	170
4.2	0.056	9.61	0.1681	175
4.8	0.064	9.69	0.1841	190
5.4	0.072	9.77	0.1914	196
6	0.08	9.86	0.1972	200
6.6	0.088	9.945	0.2068	208
7.2	0.096	10.033	0.2106	210
7.8	0.104	10.122	0.2226	220
8.4	0.112	10.21	0.2205	216

Table 18- Values of stress and strain on plain soil calculated using UCS

Annexure 1.2.2

Displacement(ΔL)	Strain ($e= \Delta L/L_0$)	Corrected area[$A_c=A_0(1-e)$]	Load (kN)	Stress(kN/m^2)
0.6	0.008	9.14	0.01828	20
1.2	0.016	9.22	0.0497	54
1.8	0.024	9.29	0.0929	100
2.4	0.032	9.37	0.11244	120
3	0.04	9.45	0.1323	140
3.6	0.048	9.53	0.15248	160
4.2	0.056	9.61	0.16337	170
4.8	0.064	9.69	0.1744	180
5.4	0.072	9.77	0.17586	180
6	0.08	9.86	0.17748	180
6.6	0.088	9.945	0.188955	190
7.2	0.096	10.033	0.190627	190
7.8	0.104	10.122	0.192318	190
8.4	0.112	10.21	0.19399	190

Table 19- Values of stress and strain on soil with jute (l/d=12.5) calculated using UCS

Annexure 1.2.3

Displacement(ΔL)	Strain (e= $\Delta L/L_0$)	Corrected area[$A_c=A_0(1-e)$]	Load (kN)	Stress(kN/m^2)
0.6	0.008	9.14	0.01828	20
1.2	0.016	9.22	0.05532	60
1.8	0.024	9.29	0.11148	120
2.4	0.032	9.37	0.12181	130
3	0.04	9.45	0.136	144
3.6	0.048	9.53	0.1620	170
4.2	0.056	9.61	0.1681	175
4.8	0.064	9.69	0.1841	190
5.4	0.072	9.77	0.1914	196
6	0.08	9.86	0.1972	200
6.6	0.088	9.945	0.2068	208
7.2	0.096	10.033	0.2106	210
7.8	0.104	10.122	0.2226	220
8.4	0.112	10.21	0.2205	216

Table 20 - Values of stress and strain on soil with jute (l/d=15) calculated using UCS

Annexure 1.2.4

Displacement(ΔL)	Strain (e= $\Delta L/L_0$)	Corrected area[$A_c=A_0(1-e)$]	Load (kN)	Stress(kN/m^2)
0.6	0.008	9.14	0.0182	20
1.2	0.016	9.22	0.05071	55
1.8	0.024	9.29	0.0845	91
2.4	0.032	9.37	0.10307	110
3	0.04	9.45	0.1275	135
3.6	0.048	9.53	0.1467	154
4.2	0.056	9.61	0.15664	163
4.8	0.064	9.69	0.1666	172
5.4	0.072	9.77	0.1787	183
6	0.08	9.86	0.185368	188
6.6	0.088	9.945	0.1929	194
7.2	0.096	10.033	0.2006	200
7.8	0.104	10.122	0.2004	198
8.4	0.112	10.21	0.2001	196

Table 21- Values of stress and strain on soil with jute (l/d=17.5) calculated using UCS

Annexure 1.2.5

Displacement(ΔL)	Strain ($e = \Delta L/L_0$)	Corrected area[$A_c=A_0(1-e)$]	Load (kN)	Stress(kN/m^2)
0.6	0.008	9.14	0.02742	30
1.2	0.016	9.22	0.0461	50
1.8	0.024	9.29	0.05202	56
2.4	0.032	9.37	0.0637	68
3	0.04	9.45	0.0756	80
3.6	0.048	9.53	0.0829	87
4.2	0.056	9.61	0.0903	94
4.8	0.064	9.69	0.1065	110
5.4	0.072	9.77	0.1270	130
6	0.08	9.86	0.1222	124
6.6	0.088	9.945	0.1193	120

Table 22 Values of stress and strain on soil with coconut (l/d=60) calculated using UCS

Annexure 1.2.6

Displacement(ΔL)	Strain ($e = \Delta L/L_0$)	Corrected area[$A_c=A_0(1-e)$]	Load (kN)	Stress(kN/m^2)
0.6	0.008	9.14	0.031076	34
1.2	0.016	9.22	0.05532	60
1.8	0.024	9.29	0.072462	78
2.4	0.032	9.37	0.0787	84
3	0.04	9.45	0.0850.5	90
3.6	0.048	9.53	0.0953	100
4.2	0.056	9.61	0.1153	120
4.8	0.064	9.69	0.13566	140
5.4	0.072	9.77	0.14948	153
6	0.08	9.86	0.1577	160
6.6	0.088	9.945	0.15514	156

Table 23- Values of stress and strain on soil with coconut (l/d=80) calculated using UCS

Annexure 1.2.7

Displacement(ΔL)	Strain ($e = \Delta L/L_0$)	Corrected area[$A_c=A_0(1-e)$]	Load (kN)	Stress(kN/m^2)
0.6	0.008	9.14	0.03199	35
1.2	0.016	9.22	0.05532	60
1.8	0.024	9.29	0.07432	80
2.4	0.032	9.37	0.07496	80
3	0.04	9.45	0.080325	85
3.6	0.048	9.53	0.08577	90
4.2	0.056	9.61	0.10571	110
4.8	0.064	9.69	0.121125	125
5.4	0.072	9.77	0.12701	130
6	0.08	9.86	0.1380	140
6.6	0.088	9.945	0.13525	136

Table 24- Values of stress and strain on soil with coconut (l/d=100) calculated using UCS

Annexure 1.2.8

Displacement(ΔL)	Strain ($e = \Delta L/L_0$)	Corrected area[$A_c=A_0(1-e)$]	Load (kN)	Stress(kN/m^2)
0.6	0.008	9.14	0.0182	20
1.2	0.016	9.22	0.06269	68
1.8	0.024	9.29	0.1114	120
2.4	0.032	9.37	0.12743	136
3	0.04	9.45	0.1323	140
3.6	0.048	9.53	0.15248	160
4.2	0.056	9.61	0.17298	180
4.8	0.064	9.69	0.17829	184
5.4	0.072	9.77	0.18563	190
6	0.08	9.86	0.1932	196
6.6	0.088	9.945	0.20287	204
7.2	0.096	10.033	0.21069	210
7.8	0.104	10.122	0.226732	224
8.4	0.112	10.21	0.22462	220

Table 25- Values of stress and strain on soil with bagasse (l/d=85) calculated using UCS

Annexure 1.2.9

Displacement(ΔL)	Strain ($e = \Delta L/L_0$)	Corrected area[$A_c = A_0(1-e)$]	Load (kN)	Stress(kN/m^2)
0.6	0.008	9.14	0.02742	30
1.2	0.016	9.22	0.06454	70
1.8	0.024	9.29	0.118912	128
2.4	0.032	9.37	0.13118	140
3	0.04	9.45	0.13986	148
3.6	0.048	9.53	0.15629	164
4.2	0.056	9.61	0.17490	182
4.8	0.064	9.69	0.18411	190
5.4	0.072	9.77	0.19344	198
6	0.08	9.86	0.2031	206
6.6	0.088	9.945	0.2128	214
7.2	0.096	10.033	0.2267	226
7.8	0.104	10.122	0.2388	236
8.4	0.112	10.21	0.2184	214

Table 26- Values of stress and strain on soil with bagasse (l/d=90) calculated using UCS

Annexure 1.2.10

Displacement(ΔL)	Strain ($e = \Delta L/L_0$)	Corrected area[$A_c = A_0(1-e)$]	Load (kN)	Stress(kN/m^2)
0.6	0.008	9.14	0.02742	30
1.2	0.016	9.22	0.05532	60
1.8	0.024	9.29	0.1170	126
2.4	0.032	9.37	0.1311	140
3	0.04	9.45	0.1360	144
3.6	0.048	9.53	0.1505	158
4.2	0.056	9.61	0.16337	170
4.8	0.064	9.69	0.17442	180
5.4	0.072	9.77	0.1875	192
6	0.08	9.86	0.1972	200
6.6	0.088	9.945	0.2088	210
7.2	0.096	10.033	0.2187	218
7.8	0.104	10.122	0.2247	222
8.4	0.112	10.21	0.21441	210

Table 27- Values of stress and strain on soil with bagasse (l/d=95) calculated using UCS

Annexure 1.3

Annexure 1.3.1

Penetration dial	Load dial	
Penetration (mm)	Proving ring reading	Load (kg)
0.5	5	133.3
1	9	239.94
1.5	11	293.26
2	14	373.24
2.5	15	399.9
3	16	426.56
3.5	17	452.22
4	17.8	474.55
4.5	18.5	493.21
5	19	506.54

Table 28 – Different values of penetration and loads on plain soil obtained

Annexure 1.3.2

Penetration dial	Load dial
Penetration (mm)	Load (kg)
0.5	133.3
1	266.6
1.5	319.2
2	404.8
2.5	430.2
3	455.6
3.5	493.2
4	517.5
4.5	540.3
5	550.57

Table 29 – Different values of penetration and loads on jute with (l/d 15)

Annexure 1.3.3

Penetration dial	**Load dial**
Penetration (mm)	Load (kg)
0.5	131.2
1	265.3
1.5	315.8
2	399.7
2.5	424.7
3	448.7
3.5	487.2
4	520.3
4.5	529.7
5	540.1

Table 30– Different values of penetration and loads on soil with coir (l/d 80)

Annexure 1.3.4

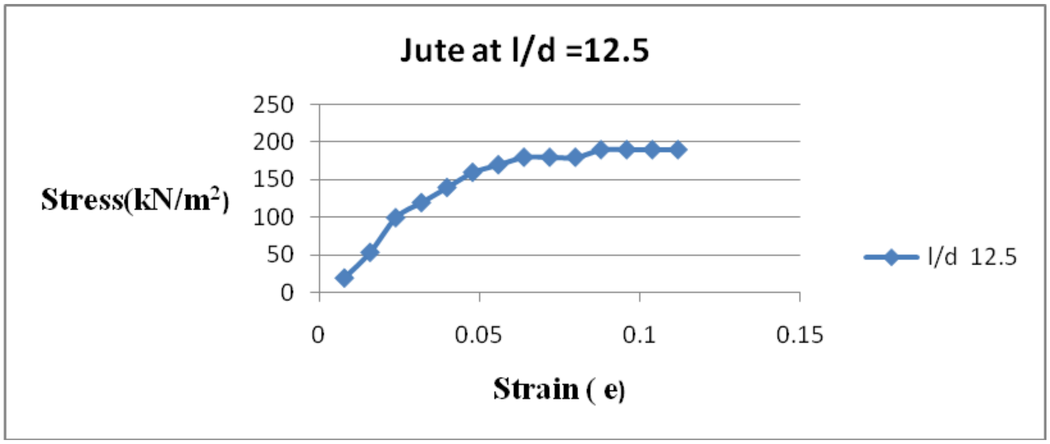
Penetration dial	**Load dial**
Penetration (mm)	Load (kg)
0.5	135.4
1	270.8
1.5	333.4
2	419.8
2.5	449.7
3	458.6
3.5	513.1
4	548.2
4.5	563.8
5	569.9

Table 31– Different values of penetration

and loads on soil with bagasse (l/d=90)

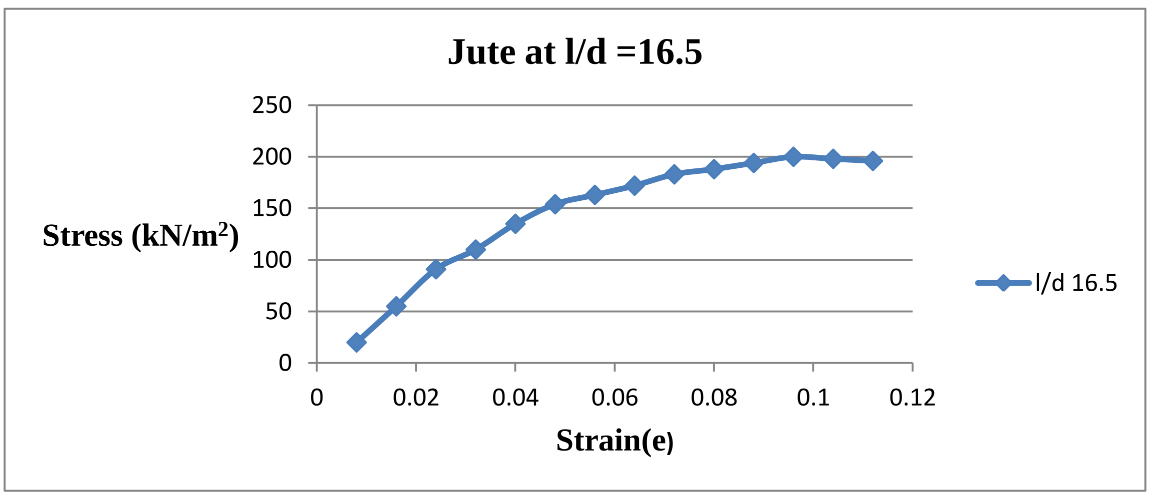
Annexure 2

Annexure 2.1



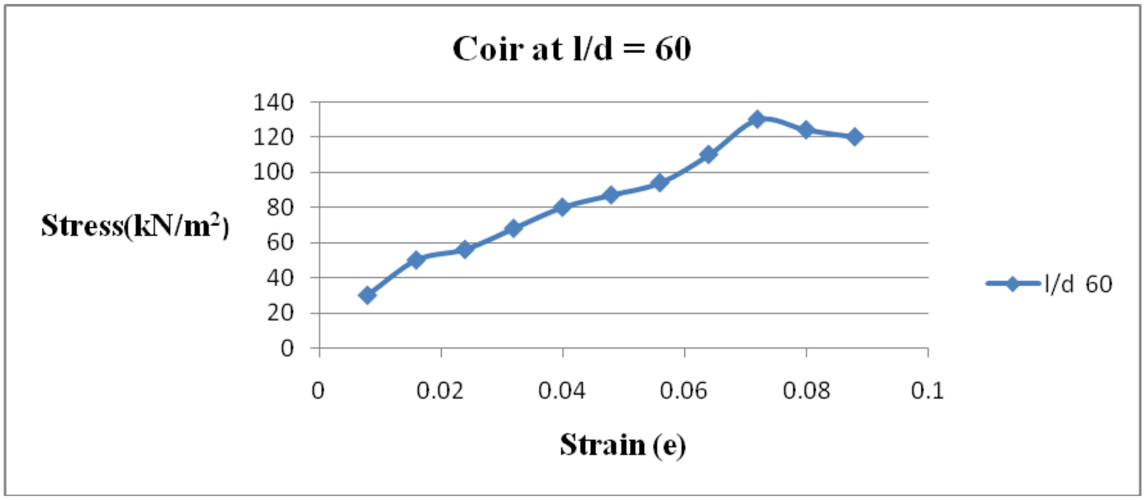
Graph 22 – Stress v/s Strain graph for black soil reinforced with jute (l/d 12.5)

Annexure 2.2



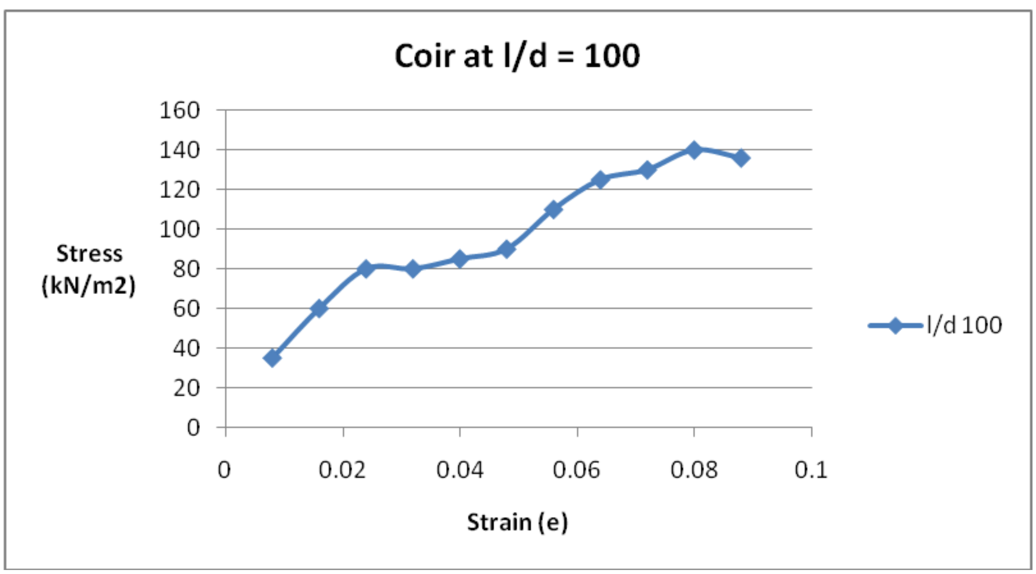
Graph 23 – Stress v/s strain graph for black soil reinforced with jute (l/d 16.5)

Annexure 2.3



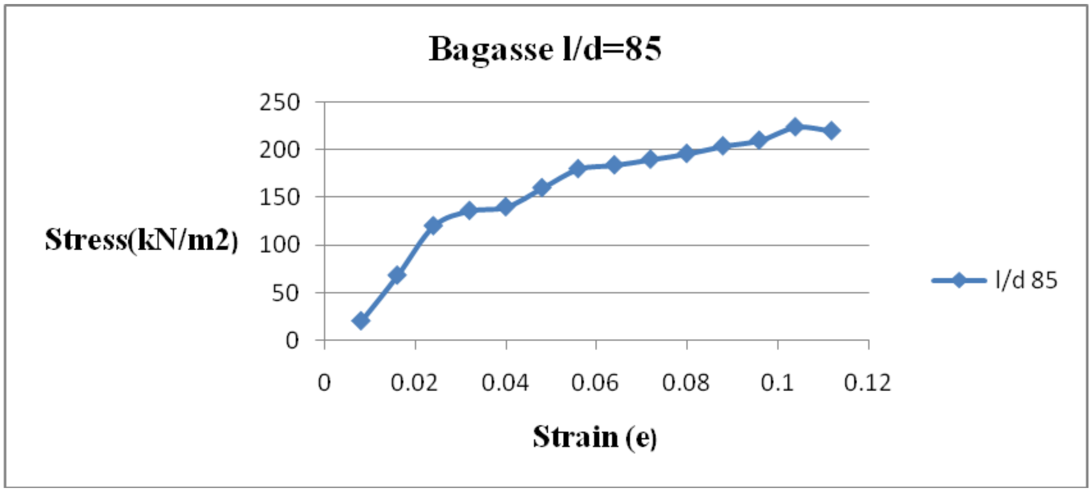
Graph 24– Stress v/s strain graph for black soil reinforced with coir (l/d 60)

Annexure 2.4



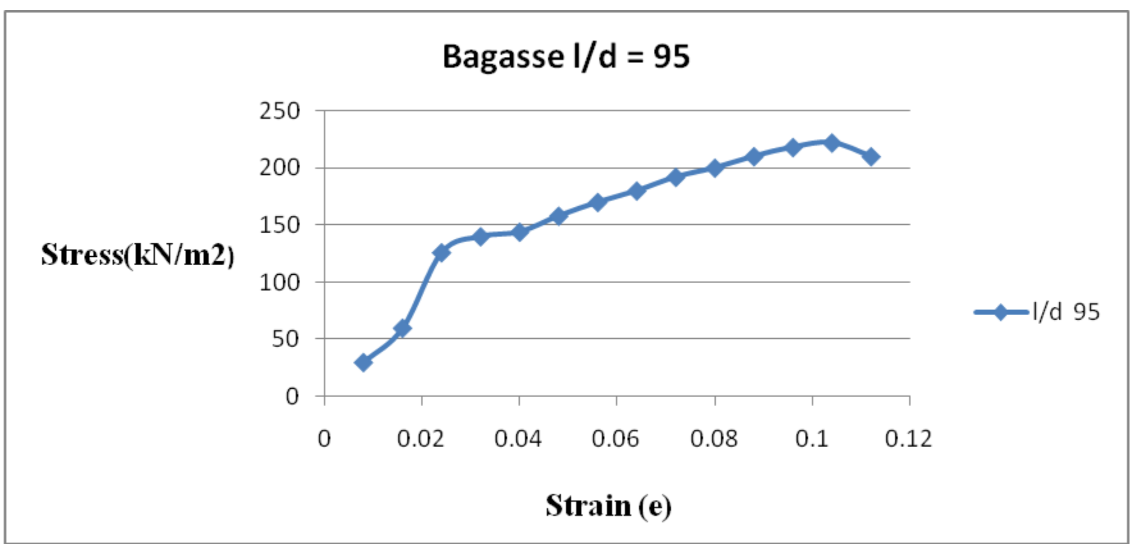
Graph 25– Stress v/s strain graph for black soil reinforced with coir (l/d 100)

Annexure 2.5



Graph 26 – Stress v/s strain graph for black soil reinforced with Bagasse (l/d 85)

Annexure 2.6



Graph 27 – Stress v/s strain graph for black soil reinforced with Bagasse (l/d 95)