SOIL REINFORCEMENT USING COCONUT FIBRE

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TAVANUR - 679 573, MALAPPURAM
KERALA, INDIA
2017

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PROJECT REPORT

Submitted in partial fulfilment of the requirement for the degree

BACHELOR OF TECHNOLOGY
IN
AGRICULTURAL ENGINEERING

Faculty of Agricultural Engineering and Technology

Kerala Agricultural University

Department of Irrigation and Drainage Engineering

KELAPPAJICOLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

TAVANUR - 679 573, MALAPPURAM

KERALA, INDIA

2017

DECLARATION

We hereby declare that this project report entitled "**SOIL REINFORCEMENT USING COCONUT FIBRE"** is a bonafide record of project work done by us during the course of academic programme in the Kerala Agricultural University and that the report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of any other university or society.

ATHIRAP.
(2013-02-016)

RANJAN KUMAR
(2013-02-034)

Place :Tavanur

Date :

CERTIFICATE

Certified that this project report entitled **“SOIL REINFORCEMENT USING COCONUT FIBRE”** is a bonafide record of project work jointly done by Athira, P.and Ranjan Kumar under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship, associateship, or other similar title of any other University or Society to them.

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Date:

ACKNOWLEDGEMENT

ACKNOWLEDGEMENT

We bow our heads before God Almighty for bestowing His innumerable blessing on us.

With deep sense of gratitude, indebtedness and due respect, we express our heartfelt thanks to our respected guide, **Dr. Asha Joseph**, Professor, Department of Irrigation and Drainage Engineering, KCAET, Tavanur for her valuable guidance, suggestions, abiding encouragement and acumen which served as a blessing throughout our work.

We are thankful to **Dr. M.S Hajilal**, Dean, KCAET, Faculty of Agricultural Engineering and Technology for the unfailing support for carrying out the project work.

We engrave our deep sense of gratitude to **Dr. Rema K.P**, Professor and Head, Department of Irrigation and Drainage Engineering, KCAET, Tavanur.

Nothing can deny the fact that the valuable advice and encouragement of **Dr. Sathian K.K**, Professor, Department of Land & Water Resources and Conservation Engineering rendered at critical stages which helped us in successful completion of our project.

We remain perpetually thankful to **Er. D. Sasikala**, Professor, Department of Irrigation and Drainage Engineering for her unfailing support and teaching throughout the study.

We are grateful to Shri. **Unnikrishnan,** Lab Assistant of Geotechnical Engineering Laboratory for the relentless service and cooperation with us.

We would like to express our sincere gratitude towards **Dr. Rajeev Kumar P.** Professor and Head, Department of civil engineering, MES College of Engineering and Technology for giving us permission to use the lab facilities for carrying out the project work. We are thankful to **Ms. Ambili**, and **Ms. GeethaK.G.** Asst Professors of the same department for giving us all support and guidelines. We would like to express our heartfelt thanks to **Mrs. Fazla** of the same department, who helped us a lot during the laboratory analysis.

We would also like to extend our thankfulness to all faculty members of the Department of Irrigation and Drainage Engineering, KCAET for their collective knowledge imparted to us, making us capable enough to see through the entire process.

Words do fail to acknowledge our dear friends for their support, encouragement and help which have gone a long way in making this attempt a successful one. We are greatly indebted to our parents, sisters and brothers for their blessings, prayers and support without which we could not have completed this work.

ATHIRA. P

RANJAN KUMAR

Dedicated

To Our

Beloved

Parents

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SYMBOLS AND ABBREVIATION

B R	Bearing Resistance
CBR	California Bearing Ratio
Cc	Coefficient of curvature
C“/C	Normalized Cohesion
C	Cohesion
Cu	Coefficient of uniformity
cu	Unit Cohesion
E	Compaction Energy
Ei	Initial Tangent Modulus
Es	Secant Modulus
F C	Fibre Content
F S	Failure Strain
G	Specific Gravity
KAU	Kerala Agricultural University
KCAET	Kelappaji College of Agricultural Engineering and Technology
kg /m^2	Kilogram per meter square
kg /cm^2	Kilogram per centimeter square
kg /cm^3	Kilogram per centimeter cube
kJ /m^3	Kilojoule per meter cube
kN /m^2	Kilonewton per meter square
kN /m^3	Kilonewton per meter cube
M.C	Moisture Content, %

MDD	Maximum Dry Density, kN/m3
MPa	Mega Pascal
m	Meter (s)
m^2	Square meter (s)
mm	millimeter
OMC	Optimum Moisture Content
S L	Strain Level
UCS	Unconfined Compressive Strength
&	and
°	Degree
Φ	Angle of Internal Friction
%	percentage

INTRODUCTION

Chapter 1

INTRODUCTION

Soil is highly complex, heterogeneous and unpredictable material which has been subjected to vagaries of nature, without any control. It is often regarded as a combination of four basic components: gravel, sand, silt and clay. It generally has low tensile and shear strength. Therefore, soil reinforcement is a technique to improve the engineering characteristics of soil such as shear strength, compressibility, density and hydraulic conductivity. So, the primary purpose of reinforcing soil mass is to improve its stability, increase its bearing capacity, and reduce settlement and lateral deformation.

From the beginning of construction work, the necessity of enhancing soil properties has come to the light. Ancient civilizations of the Chinese, Romans and Incas utilized various methods to improve soil strength. Some of these methods were so effective that their buildings and roads still exist. For any land-based structure, the foundation is very important and has to be strong to support the entire structure. The soil around the foundation plays a very critical role for the foundation to be strong. So, to work with soils, we need to have proper knowledge about their properties and factors which affect their behaviour and strength. Soil reinforcement (stabilization) is a process which helps to achieve the required properties in a soil.

In India, the modern era of soil stabilization began in early 1970's, with a general shortage of petroleum and aggregates, it became necessary for the engineers to look at means to improve soil, other than replacing the poor soil at the building site. Soil stabilization was used, but due to the use of obsolete methods and also due to the absence of proper technique, soil stabilization lost favour. In recent times, with the increase in the demand for infrastructure, raw materials and fuel, soil stabilization has started to take a new shape. With the availability of better research, materials and equipment, it is emerging as a popular and cost-effective method for soil improvement. Soil reinforcement is a procedure where natural or synthesized additives are used to improve the properties of soils. Soil reinforcement by fibre material is considered an effective ground improvement because of its cost effectiveness, easy adaptability and reproducibility. Use of biodegradable natural fibres as soil reinforcement materials is gaining popularity nowadays.

At this present time, there is a greater awareness to protect the environment. Hence there is a need to use "eco-composite" for soil stabilisation. The term eco-composite shows the importance of natural fibre in soil stabilisation. Coir or coconut fibre belongs to the group of natural fibres. It is an important commercial product obtained from the husk of coconut. Shorter mattress fibres are separated from the long bristle fibres which are in turn a waste in the coir fibre industry. So this coir fibre waste can be used in stabilization of soil and thus it can be effectively disposed off. The inclusion of fibres had a significant influence on the engineering behaviour of soil-coir mixtures.

Reinforcement can increase the shear strength of soil, thus improving the load bearing capacity of a sub-grade to support pavements and foundations. The most common improvements achieved through reinforcement include better soil gradation, reduction of plasticity index or swelling potential, and increases in durability and strength. Benefits of soil reinforcement are higher resistance values, reduction in plasticity, lower permeability, and reduction of pavement thickness, elimination of excavation, material hauling and handling. Use of natural /synthetic fibre in soil stabilisation has proved successful in pavement layers, retaining walls, earthquake engineering, railway embankments, protection of slopes and foundation engineering.

Sometimes soil reinforcement is also used to prevent soil erosion or formation of dust, which is very useful especially in dry and arid weather. Reinforcement is also done for soil water-proofing; this prevents water from entering into the soil and hence helps the soil from losing its strength. It helps in reducing the soil volume change due to change in temperature or moisture content. Reinforcement improves the workability and the durability of the soil.

As good soil becomes scarce and their location becomes more difficult to access and costly, the need to improve quality of soil using soil reinforcement is becoming more important. Considering all the above facts, in this project entitled “Soil reinforcement using coconut fibre”, soil stabilisation has been done with the help of randomly distributed fibre obtained from waste coconut husk. The specific objectives of the study are:

- To characterise the index and engineering properties of selected soil types.
- To explore the possibility of soil reinforcement by random inclusion of coconut fibre.
- To investigate the effect of waste coconut fibre on the engineering strength properties of soil.

REVIEW OF LITERATURE

CHAPTER 2

REVIEW OFLITERATURE

Soil reinforcement is defined as the technique to improve the engineering characteristics of soil. Much interest has been created worldwide on potential application of natural fibres for soil reinforcement in recent years. Consequently randomly distributed fibre reinforced soil has recently attracted increasing attention in geotechnical engineering. Hence this project investigated the effect of soil reinforcement using coconut fibre. According to the objectives of this study the previous studies relevant to the topic are briefly reviewed in the forgoing section under the following subtitles.

2.1 SOIL REINFORCEMENT (STABILISATION)

Soil stabilization (reinforcement) is the process of altering some soil properties by different methods, mechanical or chemical in order to produce an improved soil material which has all the desired engineering properties.

Principles of Soil Stabilization:

• Evaluating the soil properties of the area under consideration.

• Deciding the property of soil which needs to be altered to get the design value and choose the effective and economical method for stabilization.

• Designing the Stabilized soil mix sample and testing it in the lab for intended stability and durability values (Sen and Kshyap, 2012)

2.2 NEEDS AND ADVANTAGES OF SOIL REINFORCEMENT

- It improves the strength of the soil, thus, increasing the soil bearing capacity.
- It is more economical both in terms of cost and energy to increase the bearing capacity of the soil rather than going for deep foundation or raft foundation.

- It is also used to provide more stability to the soil in slopes or other such places.
- Sometimes soil reinforcement is also used to prevent soil erosion or formation of dust, which is very useful especially in dry and arid weather.
- Reinforcement is also done for soil water-proofing; this prevents water from entering into the soil and hence helps the soil from losing its strength.
- It helps in reducing the soil volume change due to change in temperature or moisture content.
- Reinforcement improves the workability and the durability of the soil.

2. 3 SOIL STABILISATION METHODS

2.3.1 Mechanical method of Stabilization

In this procedure, soils of different gradations are mixed together to obtain the desired property in the soil. This may be done at the site or at some other place from where it can be transported easily. The final mixture is then compacted by the usual methods to get the required density.

2.3.2 Additive method of stabilization

It refers to the addition of manufactured products into the soil, which in proper quantities enhances the quality of the soil. Materials such as cement, lime, bitumen, fly ash etc. are used as chemical additives. Sometimes different fibres are also used as reinforcements in the soil. The addition of these fibres takes place by two methods;

a) Oriented fibre reinforcement-

The fibres are arranged in some order and all the fibres are placed in the same orientation. The fibres are laid layer by layer in this type of orientation. Continuous fibres in the form of sheets, strips or bars etc. are used systematically in this type of arrangement.

b) Random fibre reinforcement-

This arrangement has discrete fibres distributed randomly in the soil mass. The mixing is done until the soil and the reinforcement form a more or less homogeneous mixture. Materials used in this type of reinforcements are generally derived from paper, nylon, metals or other materials having varied physical properties.

Randomly distributed fibres have some advantages over the systematically distributed fibres. Somehow this way of reinforcement is similar to addition of admixtures such as cement, lime etc. Besides being easy to add and mix, this method also offers strength isotropy, decreases chance of potential weak planes which occur in the other case and provides ductility to the soil (Sen and Kshyap, 2012).

2. 4 SOIL REINFORCEMENT USING NATURAL AND SYNTHETIC FIBRE

Hejazi*et al*. (2012) have made a brief review on the applications and benefit of natural and synthetic fiber. On the basis of review he has commented that fibers in geotechnical engineering is feasible in six fields including pavement layers ,retaining walls, railway embankment, protection of slopes ,earthquake and soil foundation engineering.

Park (2009) studied the effect of fiber reinforcement and distribution on unconfined compressive strength of fiber- reinforced cemented sand and concluded that the UCS of the fiber –reinforced cemented specimen gradually increased as the number of fiber inclusion layers increased.

Ibrahim *et al*. (2006) studied the compressive strength and swelling property of randomly distributed fiber reinforced clayey soil and concluded that UCS of the clay fiber mixture had increased with increasing the fiber content.

Lascar and pal (2013) investigated the effect of waste fiber on the compaction and consolidation behaviors of reinforced soil.

2.4.1 Natural fibres

2.4.1.1 Coconut fibre

Karthika*et al.* (2011) stabilized the soil with coir geotextile. In the field simulation test for the measurement of rut depth, a layer of geotextile was provided at a depth of 15cm and above that the soil was compacted in layers to form the subgrade and CBR of soil reinforced with geotextile is increased to 12 %. Coir fiber is a useful biodegradable waste that improves strength and stiffness of all types of soil.

Enokela and Alada (2012) investigated the strength characteristic of soil from alluvial deposit of River Benue in makurdi stabilized with coconut fibre as a stabilizer. It was used as local building material for farm structure. Processed coconut fibres were mixed with the soil at four different mix ratios of 1% fibre, 2% fibre, 3% fibre and 4% fibre by percentage weight with 0% fibre as control. Compaction test and compressive strength were carried out on the various stabilizing ratio. From the compaction test, the correlation between the maximum dry density and optimum moisture content is a second order polynomial with a coefficient of 63% obtained at 1.91kg/m^3 and 20.0% respectively while the compressive strength test showed an optimum failure load of 8.62N/mm^2 at 2%fibre:100% soil mix ratio at 2.16 maximum dry density.

Singh and Gill (2012) studied the effect of geo-grid reinforcement on maximum dry density (MDD), Optimum Moisture Content (OMC) and California Bearing Ratio (CBR) of sub-grade soil. The clayey type of soil and one type of geo--grid were selected for this study. From the study it was clear that there was a considerable improvement in California Bearing Ratio (CBR) of sub-grade due to geo-grid reinforcement. In case of without reinforcement (Geo-grid) the soaked CBR value was 2.9% and when geo-grid was placed at 0.2H from the top of the specimen, the CBR increases to 9.4%.

Chapale and Dhatrak (2013) focused on effect of coir on bearing capacity and settlement of footing with parameters such as thickness of reinforced layer (B, B/2, B/4) with 0.25%, 0.5%, 0.75% & 1.0% of coir using the laboratory model tests on square footings supported on highly compressible clayey soil reinforced with randomly distributed coir fiber. Provision of coir reinforced layer increased bearing capacity ratio up to 1.5 to 2.66. There was significant increase in bearing capacity of clayey soil with inclusion coir fibers. At 25 mm depth of fiber reinforced soil (B/4) and 0.50% fiber content the SBC was maximum.

Singh (2013) studied the influence of coir fibers on shear strength parameters (c and ϕ) and stiffness modulus (σd /ϵ) of fly ash. In this investigation, samples of fly ash compacted to its maximum dry density at the optimum moisture content were prepared without and with randomly distributed coir fiber for triaxial compression tests. The coir fiber were taken as 0.25 %, 0.5 %, 0.75 % and 1 % by dry weight of fly ash and the shear strength parameters (c and ϕ) and stiffness modulus (σd /ϵ) of reinforced fly ash for each fiber content was determined in the laboratory. Finally these strength parameters (c, ϕ and σd /ϵ) of reinforced by fly ash were compared with that of unreinforced fly ash. Tests results indicated that, on inclusion of coir fiber, the shear strength parameters and stiffness modulus of fly ash increased. It was also observed that on increasing the fiber content, the values of these strength parameters further increased and the improvement was substantial at fiber content of 1 %.Thus there was significant improvement in the strength parameters of fly ash due to inclusion of coir fiber.

Singh and Mittal (2014) conducted an experimental study on clayey soil mixed with varying percentage of coir fiber. Soil samples for unconfined compression strength (UCS) and California bearing ratio (CBR) tests were prepared at its maximum dry density corresponding to its optimum moisture content in the CBR mould without and with coir fiber. The percentage of coir fiber by dry weight of soil was taken as 0.25%, 0.50%, 0.75% and 1% and corresponding to each coir fiber content unsoaked and soaked CBR and UCS tests were conducted in the laboratory. Tests result indicated that both unsoaked and soaked CBR value of soil increased with the increase in fiber content. Soaked CBR value increases from 4.75% to 9.22% and unsoaked CBR value increased from 8.72% to 13.55% of soil mixed with 1% coir fiber. UCS of the soil increased from 2.75 kg/cm² to 6.33 kg/cm² upon addition of 1% randomly distributed coconut fiber.

Das *et al*. (2016) investigated the variation in shear strength parameters of sandy soils by the use of brown coconut fibre as reinforcing material, at a fixed length of 15 mm, using the direct shear test. It also involved the determination of optimum fibre content required for the corresponding maximum value of shear strength paramenter. The results showed that almost 21.5% enhancement in shear strength parameter could obtained on use of coconut fibre as reinforcement material.

Gbenga*et al.* (2016) used coconut coir fibre as an additive material to improve the strength properties of soils such as the maximum dry density, the cohesion, angle of internal friction and the California bearing ratio CBR. Three different soil samples were sourced and mixed with different percentage proportions of coconut fibre (0.1%, 0.3%, 0.5%, 0.7%, 0.9%, 1.0%, 1.2% and 1.5%). Results of the experimental study revealed that all the soil parameters tested attained highest values at 1.2% coconut coir fibre addition. Addition of about 1.2% coconut fibre to the soil enhanced its strength.

2.4.1.2 Jute fibre

Singh and Bagra (2013) studied the improvement in CBR value of soil reinforced with jute fibre. The natural fibre reinforcement causes significant improvement in tensile strength, shear strength, and other engineering properties of the soil. In this study the soil samples were prepared at its maximum dry density corresponding to its optimum moisture content in the CBR mould with and without reinforcement. The percentage of Jute fibre by dry weight of soil was taken as 0.25%, 0.5%, 0.75% and

1%. In the present investigation the lengths of fibre was taken as 30 mm, 60 mm and 90 mm and two different diameters, 1 mm and 2 mm were considered for each fibre length. The laboratory CBR values of soil and soil reinforced with Jute fibre were determined. The effects of lengths and diameters of fibre on CBR value of soil were also investigated. Tests result indicates that CBR value of soil increases with the increase in fibre content. It was also observed that increasing the length and diameter of fibre further increases the CBR value of reinforced soil and this increase is substantial at fibre content of 1 % for 90 mm fibre length having diameter 2 mm. Thus there is significant increase in CBR value of soil reinforced with Jute fibre and this increase in CBR value will substantially reduce the thickness of pavement subgrade.

Hamid and Shafiq (2017) carried out an experimental study on subgrade soil stabilization using Jute fibre as a reinforcing material. In order to stabilize the subgrade soil, jute fibres in different lengths (30mm, 60mm and 90mm) and proportions of 0.25%, 0.5%, 0.75% and 1% were used as the reinforcing agents in the present study. The California Bearing Ratio test was conducted on all the samples and the results have been presented in the paper.

Sonthwal and Sahni study the effect of subgrade soil improvement using jute fibre. In this study a series of Proctor Compaction tests and California Bearing Ratio (CBR) tests were carried out on locally available soil reinforced with jute fibre. The percentage of Jute fibre by dry weight of soil was taken as 0.25%, 0.5%, 0.75% and 1%. In the present investigation the lengths of fibre was taken as 10 mm and 25 mm and two various diameters, 4 mm and 8 mm had been considered for each fibre length to find out the optimal quantity.

2.4.1.3 Bamboo fibre

Mohammed (2008) done a laboratory trial on bamboo as a soil reinforcement. In this trial a lateritic soil was reinforced with 0, 1, 2 and 3 bamboo specimens at laboratory trial level to evaluate its unconfined compressive strength (UCS) and modulus of rigidity. The soil specimens were molded in cylindrical form of 38mm diameter and 76mm height while the bamboo specimens were trimmed in to circular plates of 34mm diameter and 3mm thickness. The trial soil specimens are: soil specimen without bamboo specimen (0 bamboo), soil specimen with one bamboo specimen in the center (1 bamboo), soil specimen with one bamboo specimen on top and one at the bottom (2 bamboos) and soil specimen with one bamboo specimen on top, center and bottom (3 bamboos). Though, the dry density of the molded soil specimen decreased from 1.638Mg/m3 at 0 bamboo to 1.470Mg/m2 at 3 bamboos, the UCS increased from 226KN/m2 at 0 bamboo to 621KN/m2 at 3 bamboos. Also, for each of the 3 percentage strains (0.5, 1.0 and 1.5%) considered, the modulus of rigidity increased with bamboo specimens.

Asaduzzaman and Iftiarul (2014) conducted a study on soil improvement by using bamboo reinforcement. This paper described a new soil improvement method with a minimum cost solution by using bamboo reinforcement having a length of 12 inch and 0.5 inch in diameter distributed in uniform medium dense soil at different depths (0.75 inch, 1.5 inch and 2.25 inch) below the footings. Three square footings have been used (3x3 inch, 3.5x3.5 inch, 4x4 inch) to carry the above investigation for such purposes. It was found that the initial vertical settlement of footing was highly affected in the early stage of loading in unreinforced soil with compared to bamboo reinforced soil. The failure load value for proposed model in any case of loading increased compared with the un-reinforced soil by increasing the depth of improving below the footing. The load carrying capacity of single layer reinforced soil is increased up to 1.77 times and 2.02 times for multiple reinforced soil system than the load carrying capacity of unreinforced condition of soil. Improvement in load carrying capacity was observed considerable in reinforced soil over the unreinforced soil. For single layer system, load carrying capacity is maximum and settlement is minimum when the reinforcement layer placed at 0.30B. For multilayer system, BCR increases with increasing number of reinforcing layer. One of which is highlighted in the paper, facilitates the improvement of load bearing capacity of soil and spreading the techniques on soft ground.

2.4.1.4 Cane fibre

Danso *et. al.* (2015) studied the effect of sugarcane bagasse fibre on the strength properties of soil blocks. In this paper the effects of sugarcane bagasse fibres on the strength properties of soil blocks have been investigated. Laboratory experiments including density, water absorption, compressive strength, splitting tensile strength and erosion tests were conducted on soil blocks reinforced with 0.25-1% mass of fibres. It was determined that by utilisation of an optimum (0.5%) of sugarcane bagasse fibres in the soil matrix improved the strength properties of the soil blocks. Furthermore, the study shows that although the reinforced soil blocks were of lower density and higher water absorption, they had a better resistance against erosion. In addition, it was found that high clayey soil achieved better strength and durability properties. This research therefore recommends the use of 0.5% fibre content and high clayey soil for production soil blocks reinforced with sugarcane.

2.4.2 Synthetic fibres

2.4.2.1 Plastic fibre

Chandrakaran (2004) carried out laboratory experimental study to utilize waste plastics (in the form of strips) obtained from milk pouches in the pavement construction. Results of the study indicated that by adding plastic strips in the soil, shear strength, tensile strength and CBR values of the soil increased. In this study, plastic or polythene sheets having thickness of 0.5mm and made up of high density were used. These plastic strips have innumerable advantageous properties like high tensile strength, low permeability etc. These plastic strips also acted as a good barrier to gases and liquids and are unaffected by cycles of wetting and drying.

Gill *et al*. (2010) demonstrated the potential of HDPE as soil reinforcement by improving engineering properties of sub grade soil. From waste plastic, HDPE strips were obtained and mixed randomly with the soil and by varying percentage of HDPE strips length and proportions a series of CBR tests were carried out on reinforced soil. There results of CBR tests proved that inclusion of strip cut from reclaimed HDPE was useful as soil reinforcement in highway application.

Nsaif *et al.* (2013) conducted experiments by mixing plastic waste pieces with two types of soil (clayey soil and sandy soil) at different mixing ratios (0,2,4,6,and 8%) by weight. There was significant improvement in the strength of soils because of increase in internal friction. The percentage of increase in the angle of internal friction for sandy soil was slightly more than that in clayey soil, but there was no significant increase in cohesion for the two types of soils. Also, it was concluded that due to low specific gravity of plastic pieces, there was a decrease in MDD and OMC of the soil.

Poweth *et al.* (2013) investigated the safe and productive disposal of quarry dust, tyre waste and was teplastic by using them in the pavements sub grade. In their study a series of CBR and SPT test were carried out for finding the optimum percentages of waste plastics, and quarry dust in soil sample. The results showed only quarry dust should be mixed with the soil plastic mix, to increase its maximum dry density and was suitable for pavement sub grade. Tyres alone were not suitable for sub grade. They concluded that soil plastic mixed with quarry dust maintained the CBR value within the required limit. Soil tyre mixed with quarry dust gave lesser CBR value than soil plastic quarry dust mix but it could be used for pavement sub grade.

Ghasemain *et al.* (2014) studied the effect of HDPE plastic waste on the UCS of soil. In a proportion of 1.5%, 3%, 4.5% and 6% of the weight of dry soil, HDPE plastic (40 micron) waste was added. They concluded that the UCS of black cotton soil increased on addition of plastic waste. When 4.5 % plastic waste mixed with soil strength obtained was 287.32KN/m^2 which was maximum, because for natural soil it was 71.35KN/m^2.

Nagle *et al*. (2014) performed CBR studies for improving engineering performance of sub grade soil. They mixed polyethylene, bottles, food packaging and shopping bags etc as reinforcement with black cotton soil, yellow soil and sandy soil. Their study showed that MDD and CBR value increased with increase in plastic waste. Load bearing capacity and settlement characteristics of selected soil material were also improved.

Dhatrak *et al.* (2015) after reviewing performance of plastic waste mixed soil as a geotechnical material, it was observed that for construction of flexible pavement to improve the sub grade soil of pavement using waste plastic bottles chips was an alternative method. In study a series of experiments were done on soil mixed with different percentage of plastic (0.5%, 1%, 1.5%, 2 % & 2.5%) to calculate CBR. On the basis of experiment she concluded that plastic waste strips would improve the soil strength and could be used as a sub grade. It is an economical and eco-friendly method to dispose waste plastic because there is a scarcity of good quality soil for embankments and fills.

Fauzi *et al*. (2016) studied the engineering properties by mixing waste plastic high density polyethylene (HDPE) and waste crushed glass as reinforcement for sub grade improvement. The chemical element was investigated by integrated electron microscope and energy-dispersive X-ray Spectroscopy (SEM-EDS). The engineering properties like PI, C, and OMC values were decreased while ϕ, MDD, CBR values were increased when content of waste HDPE and Glass were increased.

2.4.2.2. Nylon fibre

Estabragh *et al.* (2011) investigated the mechanical behavior of a clay soil reinforced with nylon fibers. This paper presents the results of an investigation into the effects of fiber on the consolidation and shear strength behavior of a clay soil reinforced with nylon fibers. A series of one dimensional consolidation and triaxial tests were conducted on samples of unreinforced and reinforced clay with different percentages of randomly distributed nylon fibers. The results show that the pre consolidation pressure decreases and the coefficient of swelling and compression generally increase with increasing the fiber content. Furthermore, the addition of the fiber leads to a significant increase in shear strength and friction angle of the natural soil.

2.4.3 Applications of soil reinforcement

Maheshwari *et al.*, (2011) had done research on application and modeling of fiber reinforced soil. In this study a series of model footing tests were conducted to check the feasibility of using polypropylene fibers as a reinforcing material below footing with the idea of upgrading the engineering behaviour of clayey soil as a subsoil for the foundation. Total nine model footing tests on fiber reinforced soil with three different fiber content (0.25%, 0.50%, 1.00%) and three depths of placement of fiber reinforced soil (b/4, b/2, b, where b is width of footing). The actual full scale load tests with the optimum fiber content (0.50%) and optimum depth of placement of fiber reinforced soil (b/4) were conducted to verify small scale laboratory results. The bearing capacity of un reinforced soil was found to be 64 kN/m2 , which increased to 250 kN/m2 with the inclusion of polypropylene fibers. Also modeling of footing resting on fiber reinforced soil was done using the finite element software Plaxis 2D.

MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHOS

The Project entitled 'Soil reinforcement using coconut fibre' was made an attempt to investigate the effect of random inclusion of waste coconut coir fibre on strength properties of soil. The soil strength properties were analysed mainly by carrying out direct shear test and unconfined compression tests. The results obtained were compared and inferences were drawn towards the usability and effectiveness of fibre reinforcement for improving the stability of soil. The various materials and experimental investigations needed for the research have been elaborated in this chapter.

3.1 GENERAL

3.1.1 Location and climate

The experiment was conducted in the KCAET campus at Tavanur in Malappuram district of Kerala. It is situated at 10.8521° N latitude and 75.985° E longitude.

Kerala, which lies in the tropic region, is mostly subject to the type of humid tropical wet climate experienced by most of Earth's rainforests. Meanwhile, its extreme eastern fringes experience a drier tropical wet and dry climate. Kerala receives an average annual rainfall of 3107 mm – some 7,030 crore m^3 of water.

3.2 MATERIALS

Two soil samples were used to reinforce the soil. They are identified as soil sample- 1 and soil sample- 2.

Soil sample -1: Soil sample-1 was taken from locations at Manasasarovar project site of KCAET, Tavanur (Plate3.1). This area was dominated by soil of laterite type.

Soil sample-2: Soil sample -2 was taken from locations at low lying area of KCAET Instructional farm (Plate3.2). This area was constituted by sandy loam type soil.

Reinforcement: Randomly oriented waste coconut coir fibre was selected. The diameter and length of coconut fibre (Plate 3.3) pieces used for mixing the soil were approximately 10 to 15 µm and 1 cm respectively. The index and strength property of coconut fibre is given in Table 3.1.

Table 3. 1 Index and strength properties of coconut fibre

Length in inches	6-8
Density (g/cm^3)	1.40
Tenacity (g/Tex)	10
Breaking elongation%	30
Diameter in mm	0.1 to 1.5
Rigidity of Modulus dyne/cm2.	1.8924
Swelling in water (diameter)	5mm
Moisture at 65% RH	10.50%

Plate 3.1 Location at Manasasarovar **Plate 3.2 Location at paddy field**

Plate 3.3 Soil sample-1 **Plate 3.4 Soil sample-2**

Plate 3.5 Coconut coir fiber

3.3 EXPERIMENTAL INVESTIGATIONS

Several standard experimental tests are being carried out well before the reinforcement is added to properly determine the properties of soil. These tests are used to find out the various characteristics of the soil such as size of soil, specific gravity, cohesiveness, Atterberg's limit etc. The strength tests were again conducted after the addition of reimbursement for comparison. The following were the various laboratory experiments conducted, to determine

1. Specific gravity of soil
2. Index properties (Atterberg Limits) of soil
   i) Liquid limit by Casagrande's apparatus and
   ii) Plastic limit
3. Particle size distribution by sieve analysis
4. Maximum dry density (MDD) and the corresponding optimum moisture content (OMC) of the soil by Proctor compaction test
5. Determination of the shear strength by:
   i) Direct shear test (DST) and
   ii) Unconfined compression strength (UCS) test
6. Preparation of reinforced soil samples.

3. 4 BRIEF STEPS INVOLVED IN THE ABOVE EXPERIMENTS

3.4.1 Specific gravity of the soil

Specific gravity of a substance denotes the number of times that substance is heavier than water. In simpler words we can define it as the ratio between the mass of any substance of a definite volume divided by mass of equal volume of water. In case of soils, specific gravity is the number of times the soil solids are heavier than equal volume of water.

The specific gravity of soil is the ratio between the weight of the soil solids and weight of equal volume of water. It is measured by the help of a volumetric flask (Pyconometer) in a very simple experimental setup(Plate 3.6) where the volume of the soil is found out and its weight is divided by the weight of equal volume of water.

$$\text{Specific Gravity } G = \frac{w2-w1}{[(w2-w1)-(w3-w4)]}$$

Where,

W1- Weight of bottle (g)

W2- Weight of bottle + Dry soil (g)

W3- Weight of bottle + Soil + Water

W4- Weight of bottle + Water

3.4.2 Index properties (Atterberg limits)

1) Liquid Limit:

It is the water content of the soil between the liquid state and plastic state of the soil. It can be defined as the minimum water content at which the soil, though in liquid state, shows small shearing strength against flowing. It is measured by the Casagrande's apparatus and is denoted by wL.

The Casagrande's tool (Plate 3.7) cuts a groove of size 2mm wide at the bottom and 11mm wide at the top and 8 mm high. The number of blows used for the two soil samples to come in contact is noted down. Graph is plotted taking number of blows on a logarithmic scale on the abscissa and water content on the ordinate. Liquid limit corresponds to 25 blows from the graph.

2) Plastic Limit:

This limit lies between the plastic and semi-solid state of the soil. It is determined by rolling out a thread of the soil on a flat surface which is non- porous. It is the minimum water content at which the soil just begins to crumble while rolling into a thread of approximately 3mm diameter. Plastic limit is denoted by *wP*.This is determined by rolling out soil till its diameter reaches approximately3 mm and measuring water content for the soil which crumbles on reaching this diameter.

Plasticity index (Ip) was also calculated with the help of liquid limit and plastic limit;

Ip = wL – Wp

wL- Liquid limit

wP- Plastic limit

3.4.3 Particle size distribution by sieve analysis

Sieve analysis is the name given to the operation of dividing a sample of aggregate into various fractions each consisting of particles of the same size. The sieve analysis is conducted to determine the particle size distribution in a sample of aggregate, which we call gradation. The sieve analysis gives us a detailed idea regarding the type, consistency and components of the soil. The sieve analysis experiment shown in Plate 3.8

Soil at any place is composed of particles of a variety of sizes and shapes, sizes ranging from a few microns to a few centimetres are present some times in the same soil sample. The distribution of particles of different sizes determines many physical properties of the soil such as its strength, permeability, density etc. Particle size distribution is found out by two methods, first is sieve analysis which is done for coarse grained soils only and the other method is sedimentation analysis used for fine grained soil sample (Hydrometer analysis). Both are followed by plotting the results on a semi-log graph. The percentage finer *N* as the ordinate and the particle diameter i.e. sieve size as the abscissa on a logarithmic scale. The curve generated from the result gives us an idea of the type and gradation of the soil. If the curve is higher up or is more towards the left, it means that the soil has more representation from the finer particles; if it is towards the right, we can deduce that the soil has more of the coarse grained particles.

A typical sieve analysis involves a nested column of sieves with wire mesh cloth (screen). A representative weighed sample is poured into the top sieve which has the largest screen openings. Each lower sieve in the column has smaller openings than the one above. At the base is round pan, called the receiver. The column is typically placed in a mechanical shaker. The shaker shakes the column, usually for some fixed amount of time. After the shaking is complete the material on each sieve is weighed. The weight of the sample of each sieve is then divided by the total weight to give a percentage retained on each sieve is then analysed to get a cut-off point or specific size range, which is then captured on a screen.

3.4.4 Proctor compaction test

This experiment gives a clear relationship between the dry density of the soil and the moisture content of the soil. The experimental setup (Plate 3.9) consists of (i)cylindrical metal mould (internal diameter- 10.15 cm and internal height-11.7cm), (ii) detachable base plate, (iii) collar (5 cm effective height), (iv) rammer (2.5kg). Compaction process helps in increasing the bulk density by driving out the air from the voids. The theory used in the experiment is that for any compactive effort, the dry density depends upon the moisture content in the soil. The maximum dry density (MDD) is achieved when the soil is compacted at relatively high moisture content and almost all the air is driven out, this moisture content is called optimum moisture content (OMC). After plotting the data from the experiment with water content as the abscissa and dry density as the ordinate, we can obtain the OMC and MDD. The equations used in this experiment are as follows:

$$\text{Wet Density} = \frac{\text{Weight of wet soil in mould (g)}}{\text{Volume of Mould (cm}^3\text{)}}$$

$$\text{Moisture \%} = \frac{\text{Weight of water (g)} \times 100}{\text{Weight of dry soil (g)}}$$

$$\text{Dry density } \gamma d \text{ (g/cm}^3\text{)} = \frac{\text{Wet density}}{1 + \frac{\text{(Moisture Content)}}{100}}$$

3.4.5 Direct shear test

This test is used to find out the cohesion (c) and the angle of internal friction (φ) of the soil, these are the soil shear strength parameters. The shear strength is one of the most important soil properties and it is required whenever any structure depends on the soil shearing resistance. The test is conducted by putting the soil at OMC and MDD inside the shear box which is made up of two independent parts. A constant normal load (σ) is applied to obtain one value of c and φ. Horizontal load (shearing load) is increased at a constant rate and is applied till the failure point is reached. This load when divided with the area gives the shear strength 'τ' for that particular normal load. The equation goes as follows:

$$\tau = c + \sigma * \tan(\varphi)$$

After repeating the experiment for different normal loads (σ) we obtain a plot which is a straight line with slope equal to angle of internal friction (φ) and intercept equal to the cohesion (c). Direct shear test is the easiest and the quickest way to determine the shear strength parameters of a soil sample. The apparatus used for the test in this study is shown in Plate 3.10 and plate 3.11

3.4.6 Unconfined compression test

This experiment is used to determine the unconfined compressive strength of the soil sample which in turn is used to calculate the unconsolidated, un-drained shear strength of unconfined soil shown in plate 3.12 and plate 3.13. The unconfined compressive strength (q_u) is the compressive stress at which the unconfined cylindrical soil sample fails under simple compressive test. The experimental setup constitutes of the compression device and dial gauges for load and deformation. The load was taken for different readings of strain dial gauge starting from $\varepsilon = 0.005$ and increasing by 0.005 at each step. The corrected cross-sectional area was calculated by dividing the area by (1- ε) and then the compressive stress for each step was calculated by dividing the load with the corrected area.

q_u= load/corrected area (A')

Where,

q_u - compressive stress

A'= cross-sectional area/ (1- ε)

3.4.7 Preparations of reinforced soil samples

Following steps were carried out while mixing the fibre to the soil,

- All the soil samples were compacted at their respective maximum dry density (MDD) and optimum moisture content (OMC), corresponding to the standard proctor compaction tests
- The content of fibre to be added in the soil is decided by the following equation

$$\rho_f = \frac{W_f}{W}$$

Where, ρf= ratio of fibre content

W_f = weight of the fibre

W = weight of the air-dried soil

- In the preparation of sample if fibre is not used, then air dried soil was mixed with an amount of water that depends on the OMC of soil.
- The different values adopted in the present study for the percentage of fibre reinforcement are 0.00, 0.25, 0.35, and 0.45.

If fibre reinforcement was used, the adopted content of fibre was first mixed into the air-dried soil in small increments by hand, making sure that all the fibres were mixed thoroughly, so that a fairly homogenous mixture is obtained, and then the required water was added. The soil sample mixed with coconut fibre is shown in Plate3.14.

Plate 3.6 Pyconometer apparatus

Plate 3.7 Liquid Limit using Casagrande Apparatus

Plate 3.8 Sieve analysis set

Plate 3.9 Standard procter apparatus

Plate 3.10 Direct shear apparatus

Plate 3.11 Direct shear moulds

Plate 3.12 UCS apparatus

Plate 3.13 UCS Mould

Plate 3.14 A view of soil sample-1 before and after addition coconut fiber

RESULTS AND DISCUSSION

Chapter 4

RESULTS AND DISCUSSION

A study was conducted to find the effect of soil reinforcement using coconut fibre. The benefits included the increment of soil strength which could support the industrial building which promotes the future development of the country. The results of various experiments and investigation pertaining to the study have been explained and discussed in this chapter.

4.1 SPECIFIC GRAVITY

4.1.1 Soil sample- 1

The results of specific gravity of soil sample-1 for three repetitions as determined by pyconometer were given in Table 4.1.

Table 4.1 Specific gravity of soil sample -1

Sample number	**1**	**2**	**3**
Wt. of Pyconometer (W1)g	626.5	626.5	626.5
Wt. of Pyconometer+Soil(W2) g	1018	1018	1018
Wt. of Pyconometer+Soil+Water (W3) g	1741	1738	1742
Wt. of Pyconometer+Water(W4) g	1503	1500	1500
Average Specific Gravity of Soil	2.58		

The average specific gravity of soil sample -1 was obtained as 2.58. This indicated that soil sample-1 is of coarse grain texture.

4.1.2 Soil sample-2

The results of specific gravity of soil sampl-2 determined by pyconometer were given in Table4.2.

Table 4.2 Specific gravity of soil sample -2

Sample number	1	2	3
Wt. of Pyconometer (W1) g	660	660	660
Wt. of Pyconometer+Soil (W2) g	1009.5	1009.5	1009.5
Wt. of Pyconometer+Soil+ Water (W3) g	1722	1720	1717
Wt. of Pyconometer+Water(W4) g	1532	1530	1528
Average Specific Gravity of Soil	2.18		

The average specific gravity of soil sample -2 was obtained as 2.18. This indicated that soil sample-2 is of coarse grain texture.

4.2 SOIL INDEX PROPERTIES

4.2.1 Liquid limit

4.2.1.1Soil sample-1

The results obtained from Casagrande tool for soil sample-1 is given in Table 4.3

Table 4.3 Liquid limit of soil sample-1

Sample Number	1	2	3	4
Mass of empty can g	25.0	16.5	30.5	25.0
Mass of can+ wet soil in g	29.5	20.5	39.5	31.5
Mass of can+ dry soil in g	28.5	19.5	37.0	29.5
Mass of soil solids g	3.5	3.0	6.5	4.5
Mass of pore water g	1.0	1.0	2.5	2.0
Water content (%)	28.5	33.34	38.4	44.45
No of blows	80.0	65.0	42.0	20.0

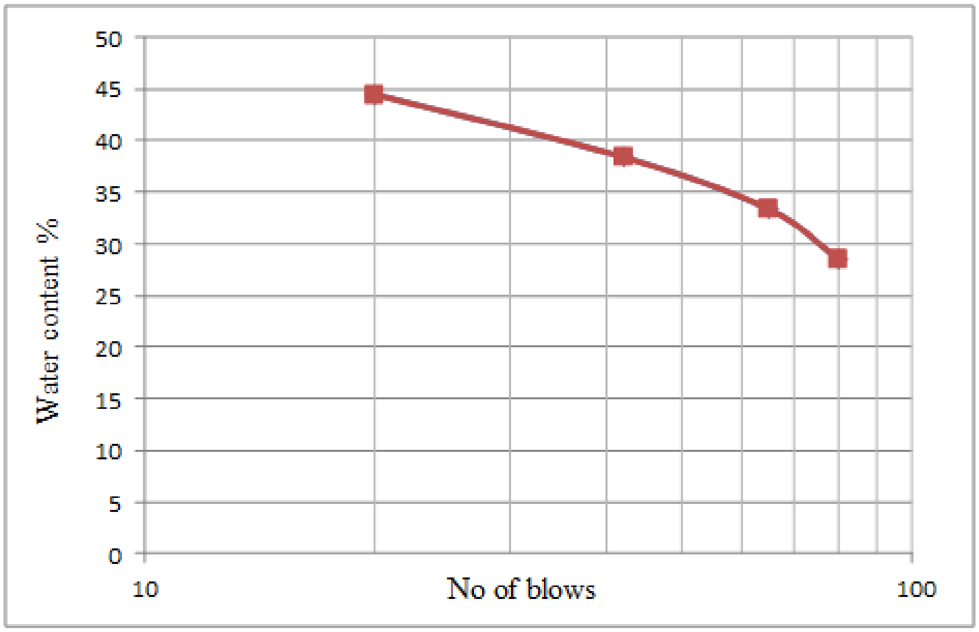

Fig. 4.1 No of blows vs. Water content (soil sample -1)

The liquid limit as obtained from Fig.4.1 was 43.07(corresponding to 25 blows)

4.2.1.2 Soil sample- 2

The results of liquid limit experiment for soil sample-2 is shown in Table 4.4

Table 4.4 Liquid limit of soil sample-2

Sample No	**1**	**2**	**3**	**4**
Mass of empty can g	31	16.5	16.5	29.5
Mass of can+ wet soil in g	49.5	32.5	40	53
Mass of can+ dry soil in g	45	28.5	34	46.5
Mass of soil solids g	14	12	17.5	17
Mass of pore water g	4.5	4	6	6.5
Water content (%)	32.14	33.34	34.2	38.23
No of blows	56	30	20	12

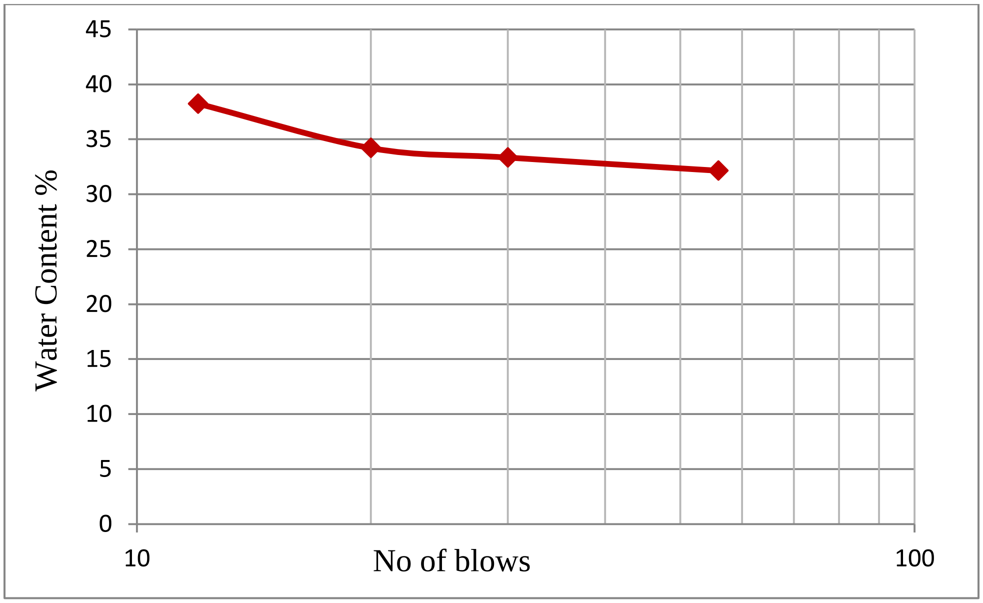

Fig.4.2 No of blows vs. Water content (soil sample-2)

From Fig. 4.2 Liquid limit was obtained as34.63 **(**corresponding to 25 blows)

4.2.2 Plastic limit

4.2.2.1 Soil sample- 1

The results of the experiment conducted for finding the plastic limit for soil sample-1 is given in Table 4.5.

Table 4.5 Plastic Limit of soil sample-1

Sample No	**1**	**2**	**3**
Mass of empty can g	19	22	18
Mass of can+ wet soil in g	37	35	28
Mass of can+ dry soil in g	33	32	26
Mass of soil solids g	14	10	8
Mass of pore water g	4	3	2
Water content (%)	28.5	30	25
Average Plastic limit	27.83		

The plastic limit value of soil sample-1 was obtained as 27.83 which indicated low plasticity.

4.2.2.2 Soil sample-2

The results of the experiment conducted for finding the plastic limit for soil sample-2 is given in Table 4.6.

Table 4.6 Plastic Limit of soil sample-2

Sample No	**1**	**2**	**3**
Mass of empty can g	24	25	18
Mass of can+ wet soil in g	49	45	37
Mass of can+ dry soil in g	45	42	34
Mass of soil solids g	21	17	16
Mass of pore water g	4	3	3
Water content (%)	19.04	17.64	18.75
Average Plastic limit	18.47		

The plastic limit value of soil sample-2 was obtained as 18.47 which indicated low plasticity.

4.2.3 Plasticity Index

After obtaining value of liquid limit and plastic limit for soil sample-1 and soil sample-2 The plasticity index was calculated as follows:

4.2.3.1 Soil sample- 1

$I_p = w_L – w_P = 43.05 – 27.83 = 15.22\%$ (Low plasticity)

4.2.3.2 Soil sample- 2

$I_p = w_L – w_P = 34.63 – 18.47 = 16.16\%$ (Low plasticity)

This showed that both the soil had low plasticity which indicates that composition of silt and sand is more as compared to clay.

4.2.4 Particle Size Distribution

Particle size distribution of soil was done with the help of sieve analysis and the results were shown for soil sample-1 (Table 4.7) and soil sample-2 (Table 4.8).

4.2.4.1 Soil sample- 1

Table 4.7 Particle size distribution of soil sample-1

Sieve Size (mm)	**Retained (g)**	**Retained (%)**	**Cumulative Retained (%)**	**Cumulative Finer (%)**
2	770	38.5	38.5	61.5
1	264.5	13.22	51.72	48.28
0.60	248	12.4	64.12	35.88
0.425	140.5	7.02	71.14	28.86
0.30	135	6.75	77.89	22.11
0.212	221.5	11.07	88.96	11.04
0.150	59	2.95	91.91	8.09
0.075	99.5	4.9	96.81	3.19
<0.075	57	2.8	99.61	0.39

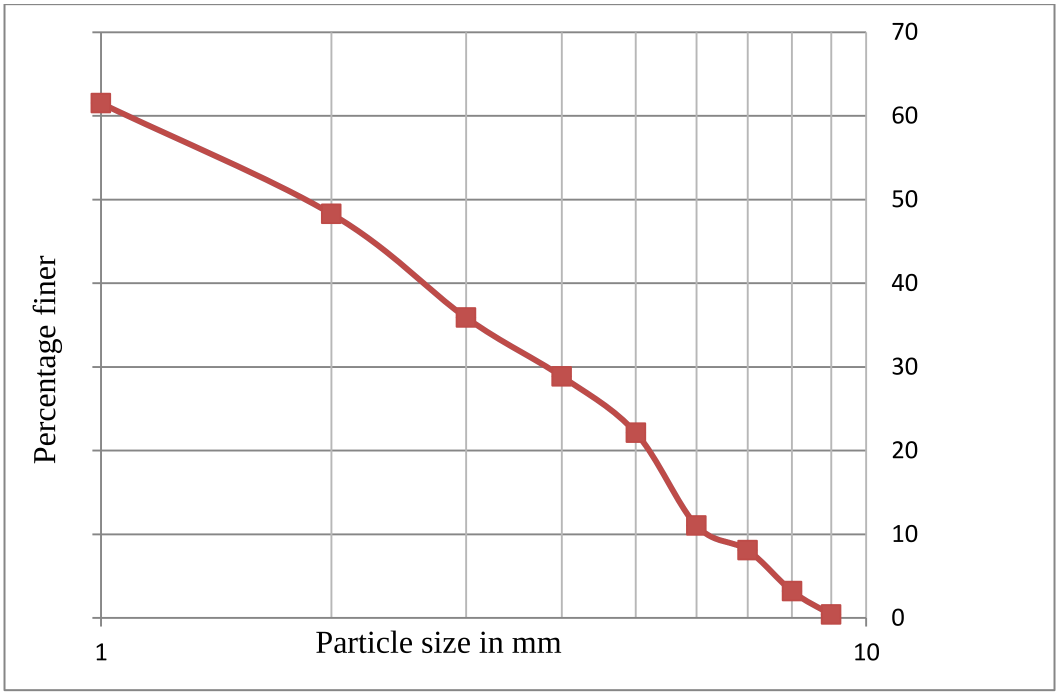

Fig. 4.3 Particle size distribution curve (soil sample-1)

From Table 4.7 and Fig.4.3 it is concluded that percentage of soil particles is maximum in 2mm size sieve for soil sample-1, which comes under fine gravel as per British soil classification system tables.

4.2.4.2 Soil sample- 2

Table 4.8 Particle size distribution of soil sample-2

Sieve Size (mm)	**Retained (g)**	**Retained (%)**	**Cumulative Retained (%)**	**Cumulative Finer (%)**
2	921	46.05	46.05	53.95
1	55	2.75	48.8	51.2
0.60	890.5	44.528	93.325	6.675
0.425	7	0.35	93.675	6.325
0.30	17	0.85	94.525	5.475

0.212	68	3.4	97.925	2.075
0.150	8.5	0.425	98.35	1.65
0.075	22.5	1.125	99.375	0.625
<0 .075	6.5	0.325	99.8	0.2

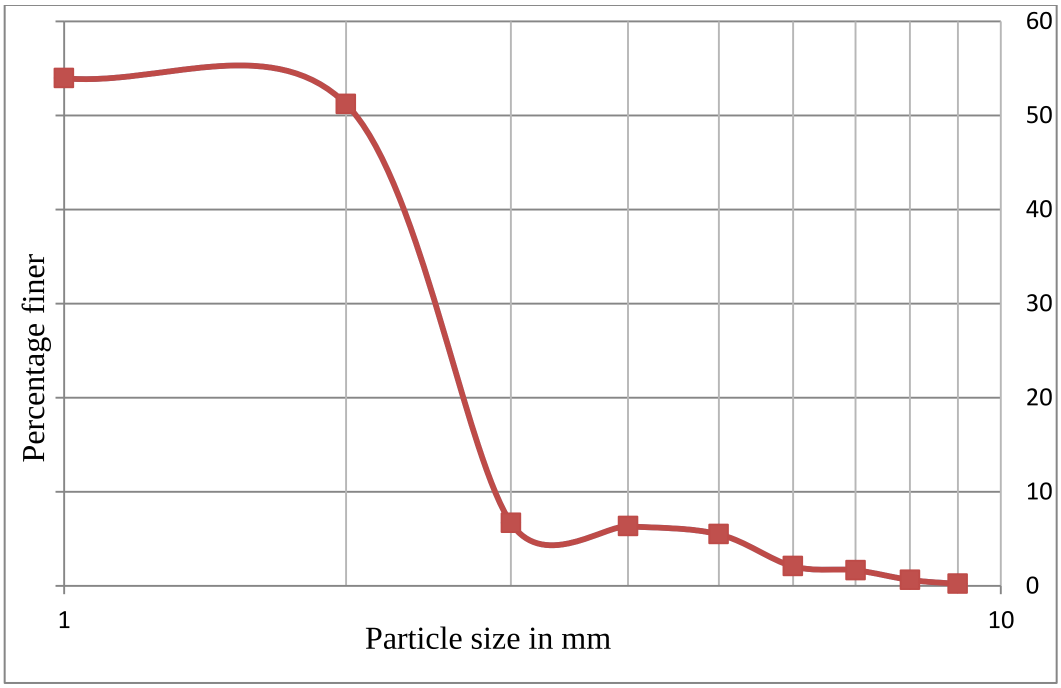

Fig.4.4 Particlesize distributioncurve of soil sample 2

For soil sample-2 (Table 4.8 and Fig.4.4) it is concluded that percentage of soil particles is maximum in the range 1 to 2mm size.

4.2.5 Standard Proctor Compaction Test

4.2.5.1 Soil sample- 1

The proctor compaction test was done for finding the optimum moisture content (OMC) and maximum dry density (MDD).The results for soil sample-1 and soil sample-2 is given in Table 4.9 and Table 4.10 respectively.

Table 4.9 Standard proctor compaction test data (soil sample-1).

Test No	**1**	**2**	**3**	**4**	**5**
Internal diameter of mould (d) cm	10	10	10	10	10
Height of mould (h) cm	12.5	12.5	12.5	12.5	12.5
Volume of mould (V)	981.747	981.747	981.747	981.747	981.747
Weight of empty mould + base plate	4578	4578	4578	4578	4578
Weight of mould +compacted soil + Base plate (g)	6147	6395.5	6461	6576	6482.5
Weight of Compacted Soil (W)g	1569	1821.5	1883	1998	1884.5
Container no.	1	2	3	4	5
Weight of Container (X1) g	22.5	27	22.5	28.5	24.5
Weight of Container + Wet Soil (X2) g	50	50	46	59.5	58.5
Weight of Container + dry soil (X3) g	47.5	47	41.5	51.5	46.5
Weight of dry soil (X3-X1) g	25	20	19	23	22
Weight of water (X2-X3) g	2.5	3	4.5	8	12
Wet Density of Soil (W/V)	1.598	1.85	1.918	2.035	1.919
Water content w= X2-X3/X3-1	10%	15%	23.6%	34.7%	54.5%
Dry Density (wet/(1+w))	1.452	1.608	1.55	1.510	1.242

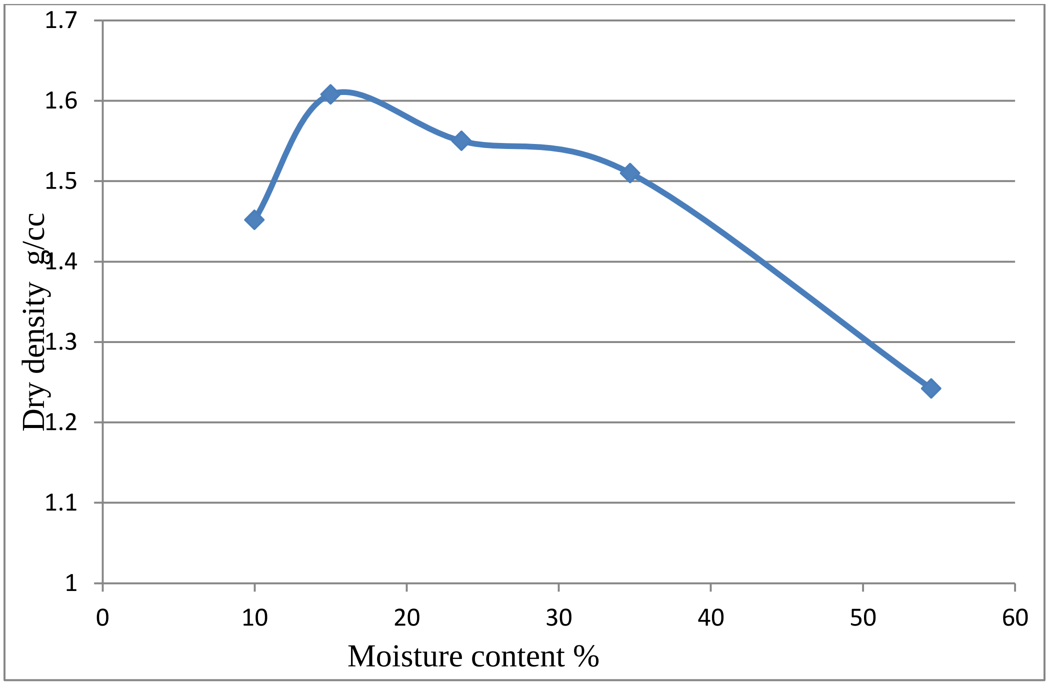

Fig.4.5 Moisture content vs. Dry density (Soil sample-1)

From Table 4.9 and Fig.4.5theoptimum moisture content and corresponding maximum dry density was obtained as 15% and 1.608g/cm³ respectively for soil sample-1.

4.2.5.2 Soil sample- 2

The results of standard proctor compaction test data for soil sample-2 were given in Table 4.10.

Table 4.10 Standard proctor compaction test data (soil sample-2)

Test No	**1**	**2**	**3**	**4**	**5**
Internal diameter of mould (d) cm	10	10	10	10	10
Height of mould (h) cm	13	13	13	13	13
Volume of mould (V) cm^3	1000	1000	1000	1000	1000
Weight of empty mould + base plate	4133	4133	4133	4133	4133

Weight of mould +compacted soil + Base plate (g)	6174	6261	6427	6347	6348
Weight of Compacted Soil (W)g	2041	2128	2294	2214	2215
Container no.	1	2	3	4	5
Weight of Container (X1) g	19.49	21.6	21.14	20.19	21.55
Weight of Container + Wet Soil (X2) g	90.21	122.57	113.12	125.00	119.28
Weight of Container + dry soil (X3) g	82.51	110.04	99.74	108.94	102.32
Weight of dry soil (X3-X1) g	63.02	88.87	78.6	88.75	80.77
Weight of water (X2-X3) g	7.70	12.53	13.38	16.06	16.96
Wet Density of Soil (W/V)	2.041	2.128	2.294	2.214	2.275
Water content w= X2-X3/X3-1	12.18%	14.4%	17.02%	18.1%	21%
Dry Density (wet/(1+w))	1.81	1.86	1.96	1.875	1.83

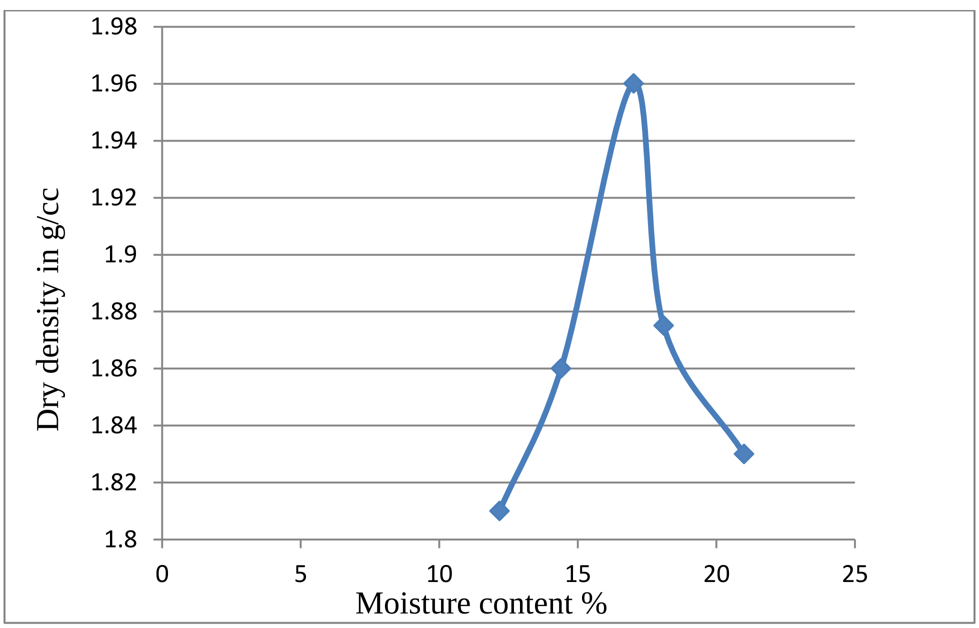

Fig.4.6 Moisture content vs. Dry density (Soil sample-2)

From Table 4.10 andFig.4.6the optimum moisture content and corresponding maximum dry density was obtained as 17.02% and 1.96g/cm^3 respectively for soil sample-2.

4.2.6 Direct shear test (DST)

Direct shear test is conducted for finding the value of shear stress and cohesion of soil for assessing its stability. This test was conducted with and without reinforcement for soil sample-1 and soil sample-2.

4.2.6.1. Soil sample- 1

The Initial data of DST test and the results for soil sample-1(without reinforcement) is given in Table 4.11 and 4.12 respectively.

Table 4.11 Initial data of DST experiment

Volume of shear Box	90 cm^3
Maximum dry density of soil	1.608 gm/cm^3
Optimum moisture content of soil	15%
Weight of the soil to be filled in the shear box	1.608*90 = 144.72 g
Weight of water to be added	(15/100)*144.72 = 21.708 g

Table 4.12 Results of DST on soil sample-1 (without reinforcement)

Sample No.	**Normal Stress(kg/cm ^{2})**	**Proving ring reading**	**Shear Load (kg)**	**Shear Stress (kg/cm^2)**
1	0.2	51	12.158	0.3655
2	0.4	75	19.35	0.5375
3	0.6	85	21.93	0.609

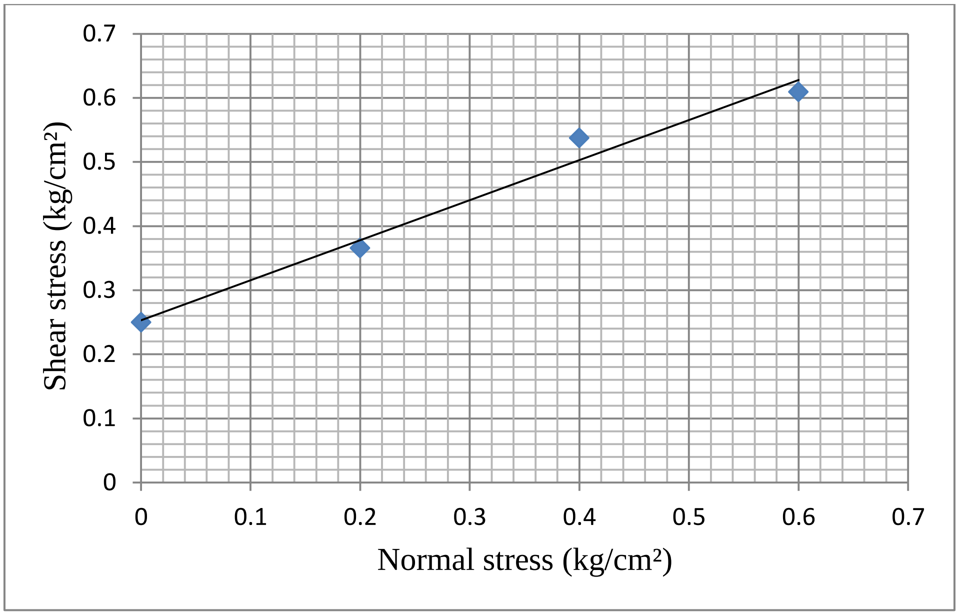

Fig.4.7 Shear stress vs. Normal stress for unreinforced soil (soil sample-1)

From Fig.4.6 the following strength parameters were obtained

i) Cohesion(c) = 0.25 kg/cm² ii) Angle (φ) = 32°

2. Soil sample-1 with reinforcement 0.15%

The same results for 0.15%, 0.25% and 0.35% reinforcement were presented in Table 4.13, 4.14, 4.15 and Fig.4.7, 4.8 and 4.9 respectively.

Table 4.13 Results of DST on soil sample-1 (0.15% reinforcement)

Sample No.	**Normal Stress(kg/cm ²)**	**Proving ring reading**	**Shear Load (kg)**	**Shear Stress (kg/cm²)**
1	0.2	57	14.76	0.41
2	0.4	79	20.52	0.57
3	0.6	93	24.12	0.67

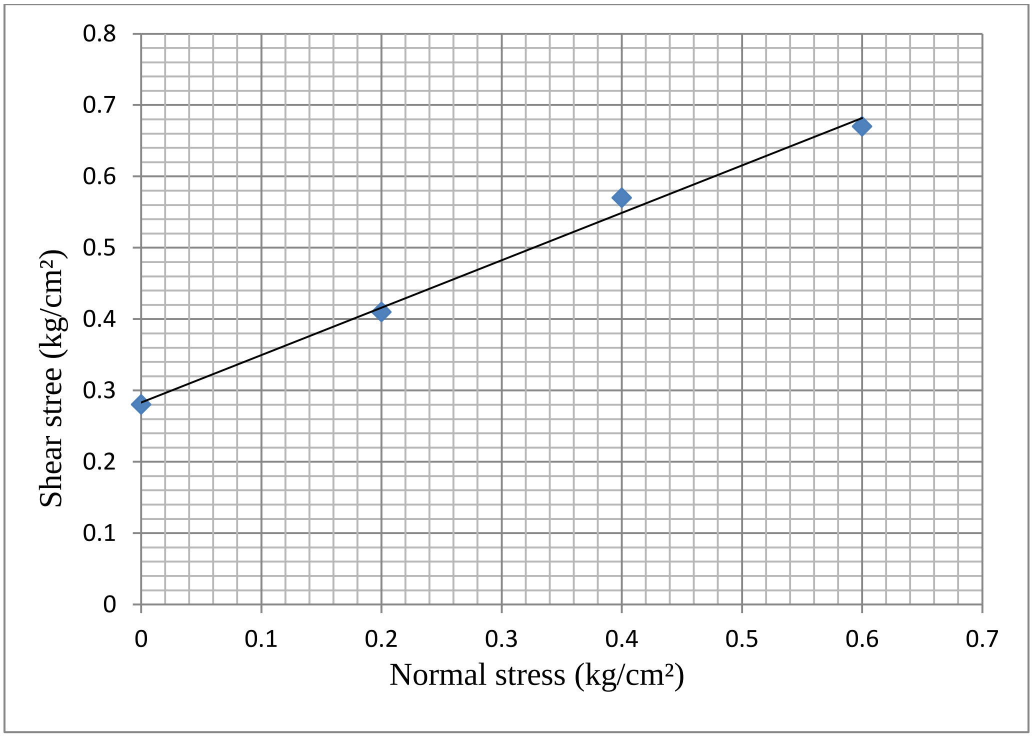

Fig.4.8 Shear Stress vs. Normal stress for reinforced soil (0.15%)

The results obtained from Fig.4.7 were

i) Cohesion(c) = 0.28 kg/cm² ii) Angle (φ) =33.42°

3. With reinforcement 0.25%

Results of DST on soil sample-1 (0.25% reinforcement) is given in Table 4.14

Table 4.14 Results of DST on soil sample-1 (0.25% reinforcement)

Sample No.	**Normal Stress(kg/cm ²)**	**Proving ring reading**	**Shear Load (kg)**	**Shear Stress (kg/cm²)**
1	0.2	59	15.22	0.422
2	0.4	81	20.89	0.58
3	0.6	96	24.76	0.68

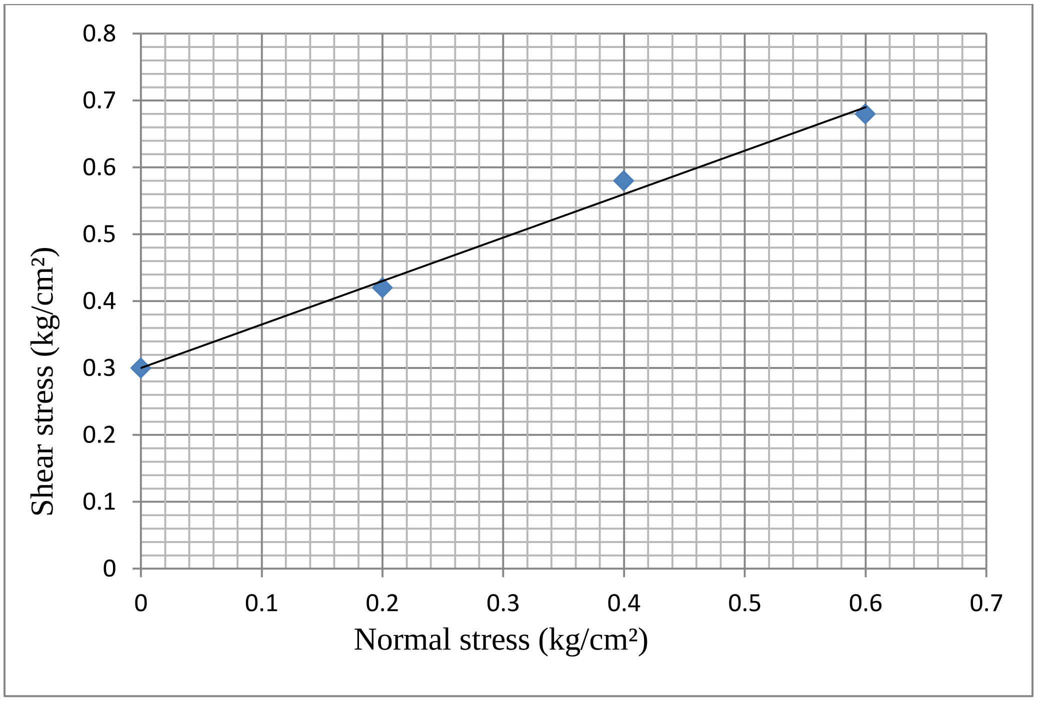

Fig.4.9 Shear tress vs. Normal stress for reinforced soil (0.25%)

The cohesion and angle of internal friction obtained from Fig. 4.8 were

i) Cohesion(c) = 0.30 kg/cm² ii) Angle (φ) = 35.2°

4. With reinforcement 0.35%

Results of DST on soil sample-1 (0.35% reinforcement) is given in Table 4.15

Table 4.15 Results of DST on soil sample-1 (0.35% reinforcement)

Sample No.	**Normal Stress(kg/cm ²)**	**Proving ring reading**	**Shear Load (kg)**	**Shear Stress (kg/cm²)**
1	0.2	64	16.512	0.45
2	0.4	85	21.93	0.609
3	0.6	102	26.31	0.731

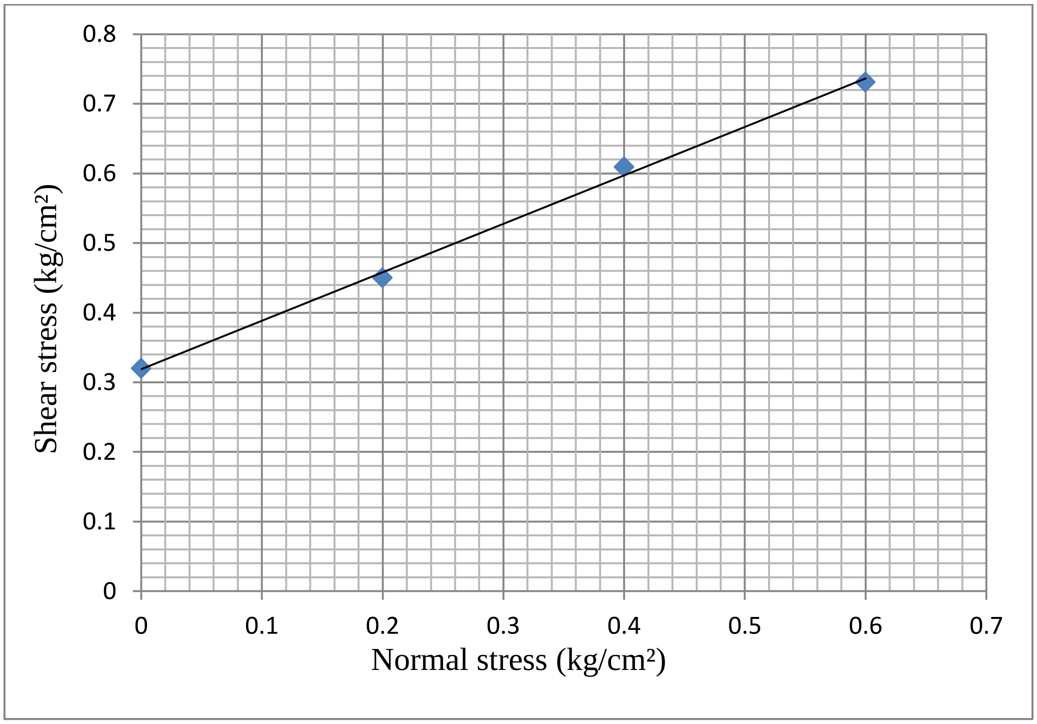

Fig. 4.10 Shear stress vs. Normal stress for reinforced soil (0.35%)

From Fig. 4.9 the following strength parameters were obtained

i) Cohesion(c) = 0.32 kg/cm² ii) Angle (φ) = 35.5°

The above results with and without reinforcement indicated that the ccohesion value increased from 0.25 kg/cm^2 to 0.32 kg/cm².which means a net increment of 28% while reinforcing the soil with coconut fiber. The percentage increase is represented in Fig.4.10.

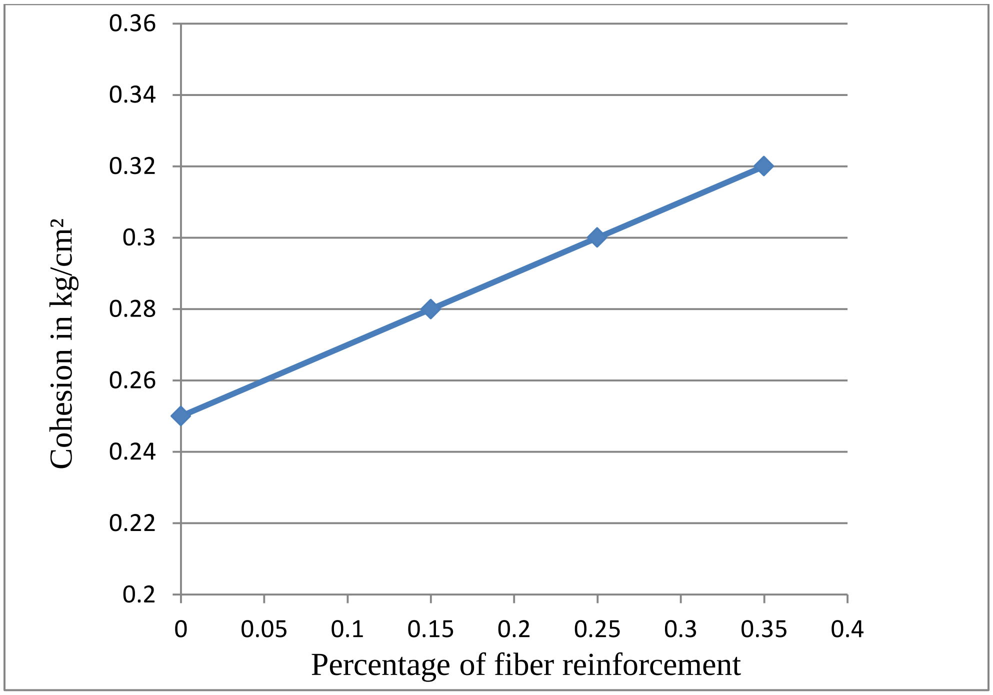

Fig.4.11 Percentage of fiber reinforcement vs. Cohesion (soil sample-1)

The following conclusions were from drawn DST on soil sample-1 (Fig.4.10 and 4.11).

- Graph showed a gradual increase in cohesion as we could observe from the above graph.
- The angle of internal friction increases from 32 to 35.5 degrees which showed a net increment of 10.9%.
- Increment in shear strength of soil sample-1 due to reinforcement was found marginal

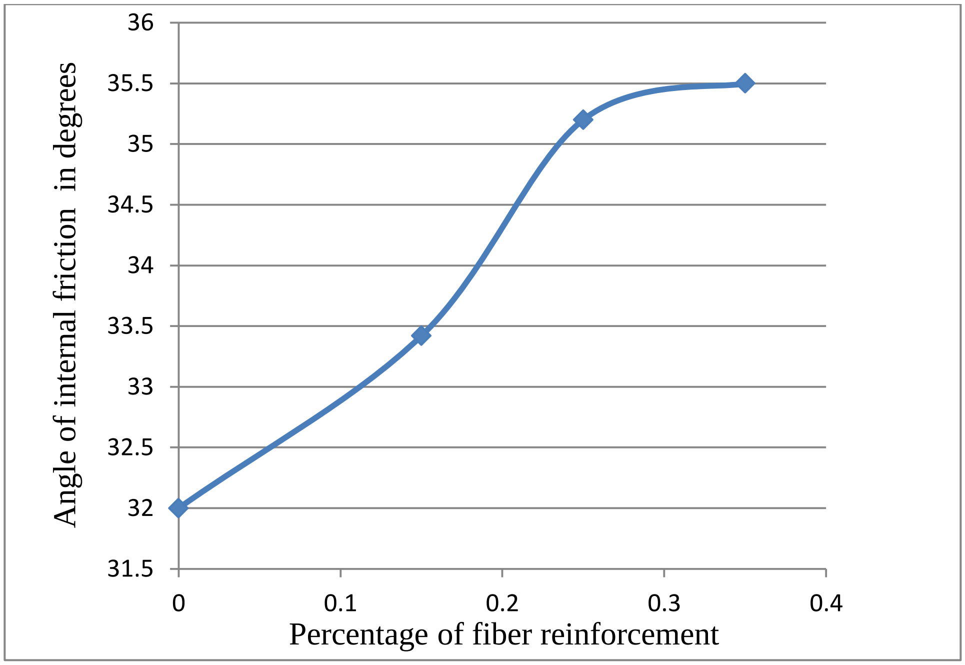

Fig.4.12 Percentage of fiber reinforcement vs. Angle of internal friction (soil sample-1)

4.2.6.2 Soil sample- 2

1. Soil sample-2 (without reinforcement).

The same experiments were conducted for soil sample- 2 and the results were presented in Table 4.16, 4.17, 4.18, 4.19 and 4.20 and Fig.4.12, 4.13, 4.14, 4.15 and 4.16

Table 4.16 Initial data of DST experiment

Volume of shear Box	90 cm^3
Maximum dry density of soil	1.96gm/cm^3
Optimum moisture content of soil	17.02%
Weight of the soil to be filled in the shear box	1.96*90 = 176.4g
Weight of water to be added	(17.02/100)*176.4 = 30.028

Table 4.17 Results of DST on soil sample-2 (without reinforcement)

Sample No.	**Normal Stress(kg/cm ²)**	**Proving ring reading**	**Shear Load (kg)**	**Shear Stress (kg/cm²)**
1	0.2	80	20.70	0.58
2	0.4	113	29.26	0.82
3	0.6	145	37.47	1.05

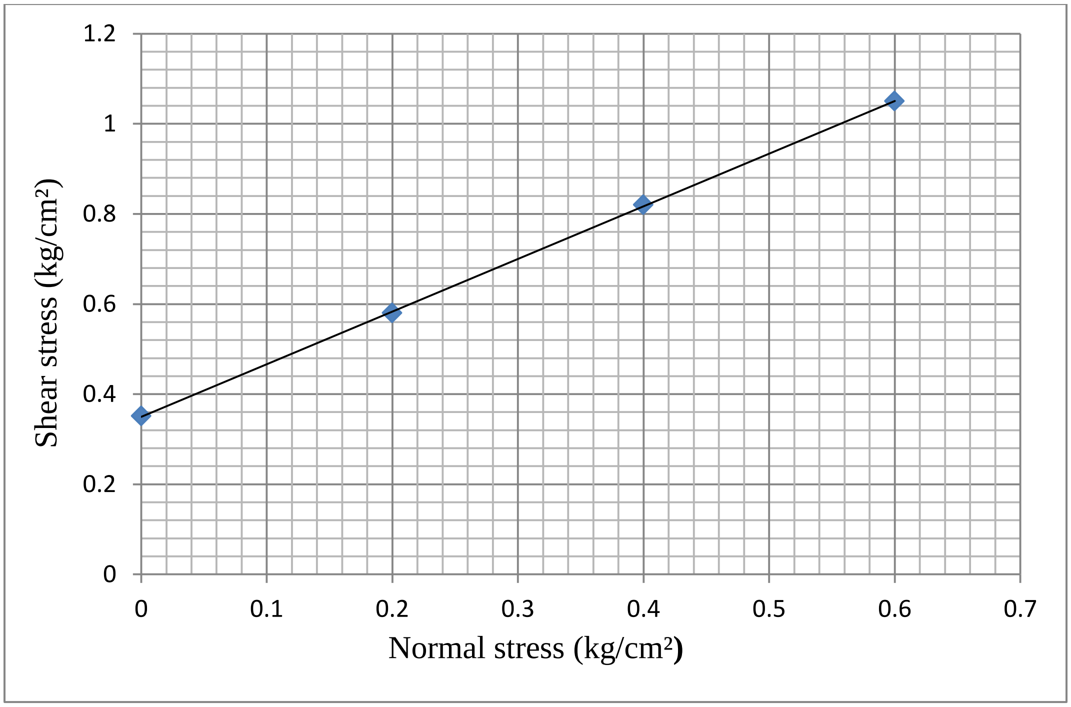

Fig.4.13 Shear stress vs. Normal stress for unreinforced soil (Soil sample-2)

From Fig4.12, the following values were obtained for the soil sample -2 (without reinforcement)

i) Cohesion(c) = 0.3513 kg/cm² ii) Angle of internal friction (φ) = 27.82°

2. With reinforcement 0.15%

Table 4.18 Results of DST on soil sample-2 (0.15% reinforcement)

Sample No.	Normal Stress(kg/cm^2)	Proving ring reading	Shear Load (kg)	Shear Stress (kg/cm^2)
1	0.2	100	25.70	0.72
2	0.4	133	34.26	0.96
3	0.6	169	43.54	1.22

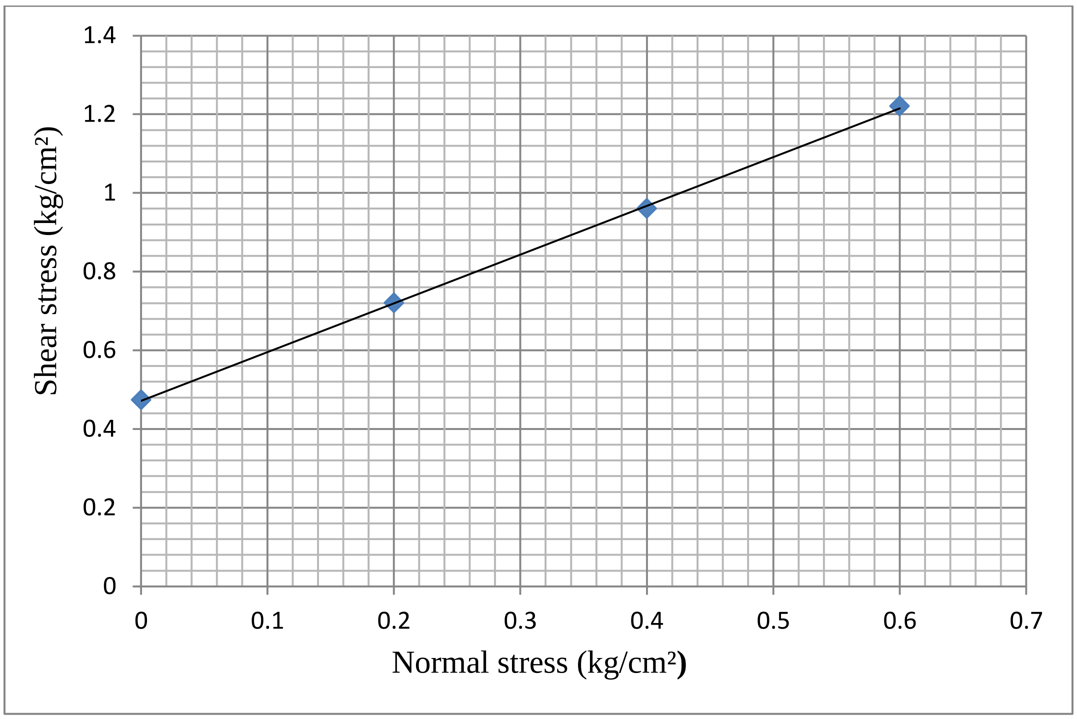

Fig.4.14 Shear stress vs. Normal stress for reinforced Soil sample-2 (0.15% reinforcement)

From Fig.4.13 the following strength parameters were obtained for soil sample-2

i) Cohesion(c) = 0.4732 kg/cm^2 ii) Angle (φ) = 29.02°

3. With reinforcement 0.25%

Table 4.19 Results of DST on soil sample-1 (0.25% reinforcement)

Sample No.	Normal Stress (kg/cm^2)	Proving ring reading	Shear Load (kg)	Shear Stress (kg/cm^2)
1	0.2	109	28.11	0.788
2	0.4	150	38.65	1.083
3	0.6	190	49.19	1.378

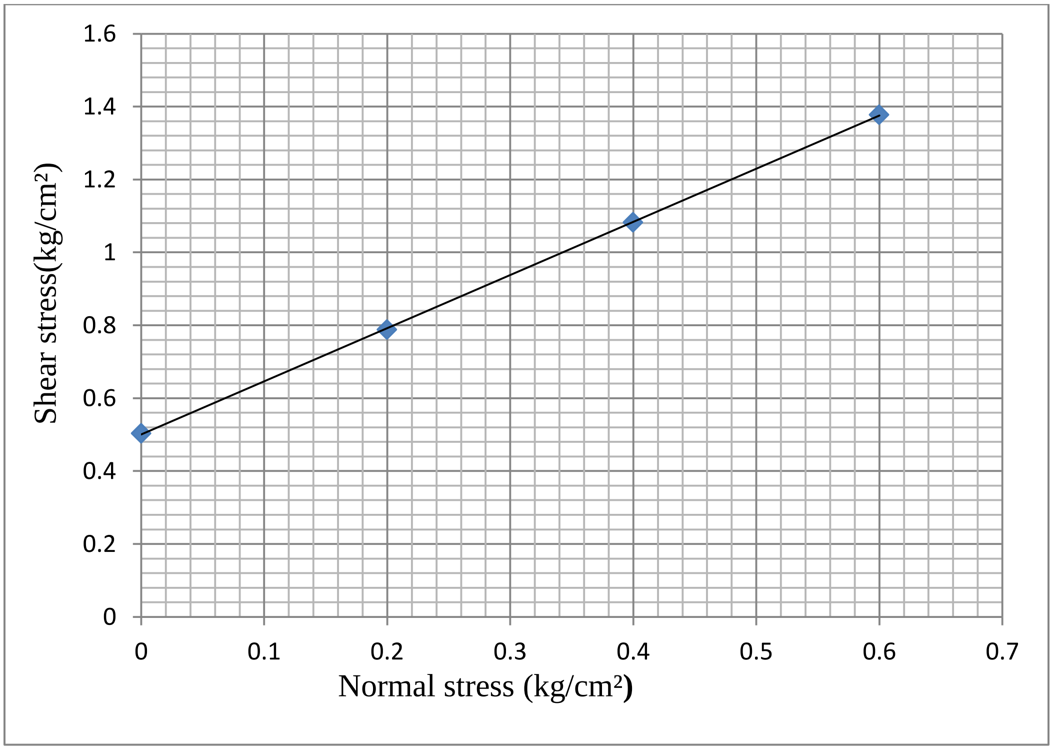

Fig. 4.15 Shear stress vs. Normal stress for reinforced Soil sample-2 (0.25%)

From Fig.4.14, the following values were obtained for 0.25% reinforcement:

i) Cohesion(c)= 0.504 kg/cm^2 ii) Angle (φ) = 29.95°

4. With reinforcement 0.35%

Table 4.20 Results of DST on soil sample-1 (0.35% reinforcement)

Sample No.	**Normal Stress (kg/cm^2)**	**Proving ring reading**	**Shear Load (kg)**	**Shear Stress (kg/cm^2)**
1	0.2	118.02	30.45	0.85
2	0.4	161	41.77	1.17
3	0.6	207	53.54	1.5

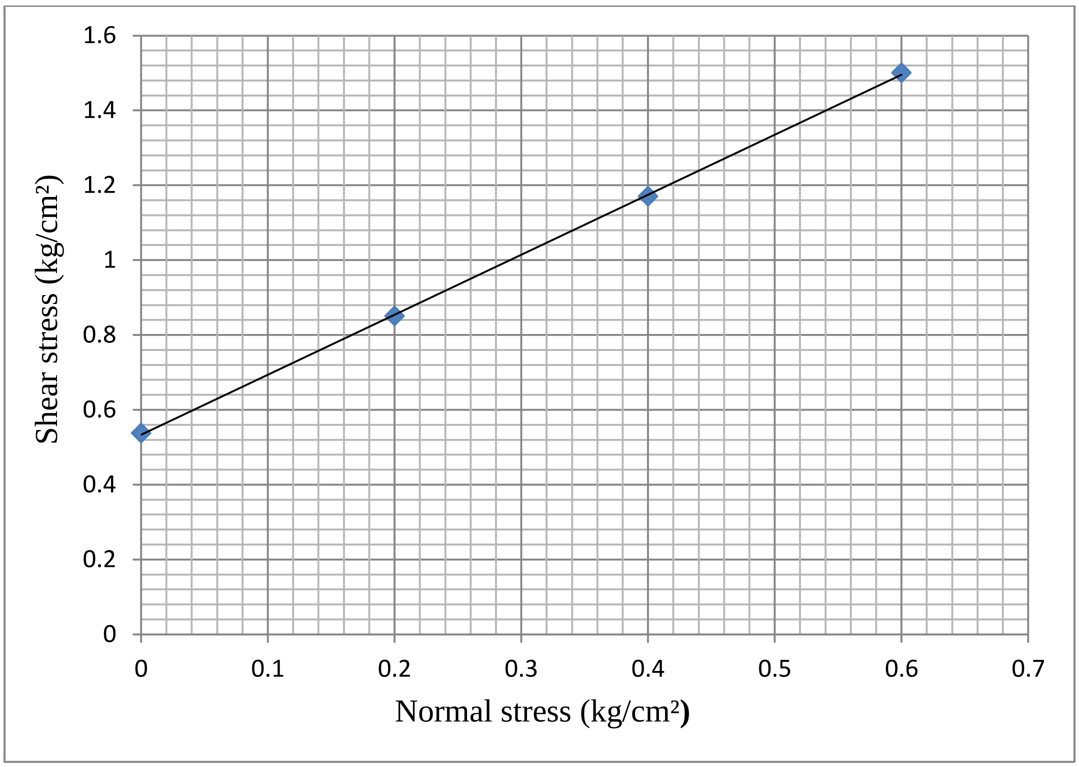

Fig.4.16 Shear stress vs. Normal stress for reinforced Soil sample-2 (0.35%)

From Fig. 4.15, the obtained values were:

i) Cohesion(c): 0.5375 kg/cm^2 ii) Angle (φ) = 32°

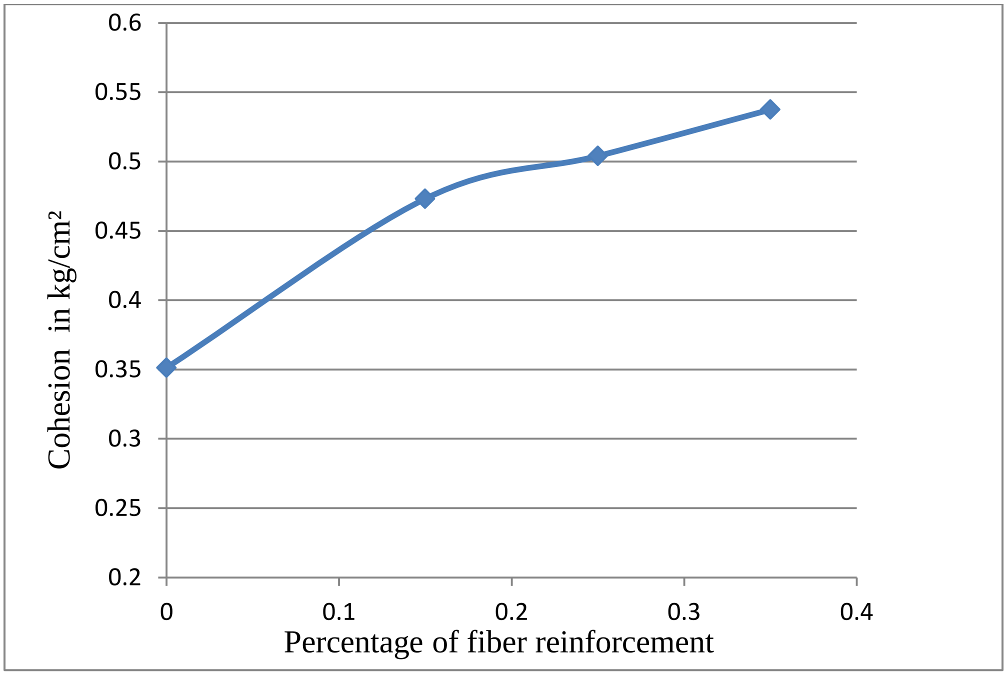

Fig. 4.17 Percentage of fiber reinforcement vs. Cohesion (soil sample 2)

The following conclusions were arrived at, from DST conducted on soil sample-2

- Cohesion value increased from 0.3513 to 0.5375kg/cm² with a net increment of 53% (Fig.4.16).
- The increment graph showed gradual decline in slope (Fig. 4.16).
- Angle of internal friction increased from 27.82 to 29.95 degrees which showed a net increment of 7.66%(Fig. 4.17)
- The increment in shear strength of soil due to reinforcement for soil sample-2was substantial.

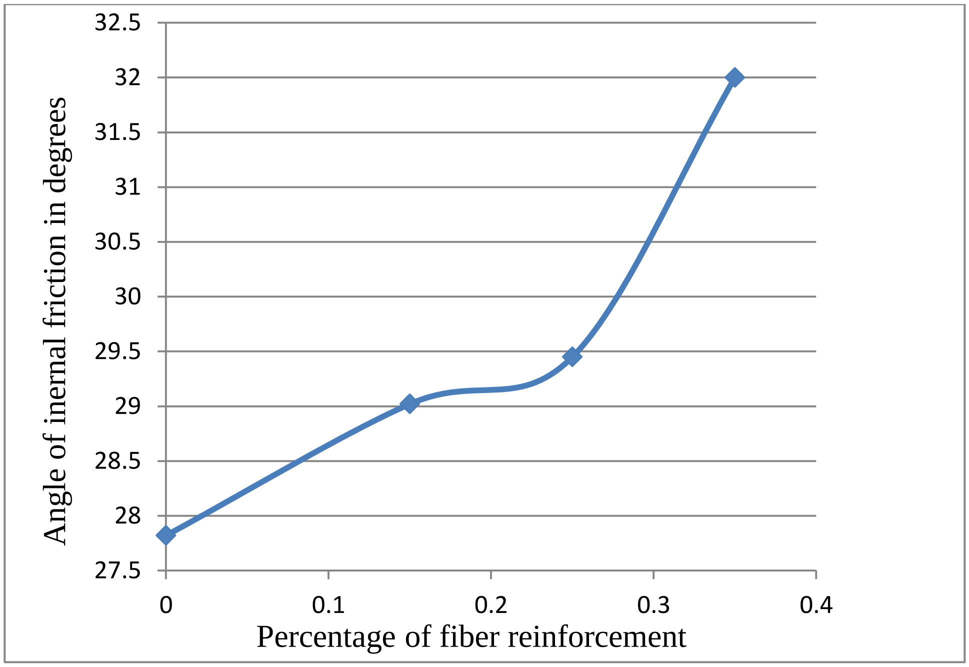

Fig. 4.18 Percent of fiber reinforcement vs. Angle of internal friction (soil sample 2)

4.2.7 Unconfined compression strength (UCS) test

4.2.7.1 Soil sample-1 (without reinforcement)

The slump and results obtained from UCS for soil sample-1 is shown in Plate 4.1 and Table 4.21.

Plate 4.1 UCS soil sample-1from the mould (without reinforcement)

Table 4.21 Observations of UCS test on soil sample-1 (without reinforcement)

Dial gauge reading	**Strain(ϵ)**	**Proving ring reading**	**corrected area**	**load (N)**	**Axial Stress (Mpa)**
50	0.0033	35	19.72	40.81	0.0207
100	0.0076	62	19.82	69.19	0.0349
150	0.0100	79	19.92	92.11	0.0462
200	0.0133	91	20.03	106.12	0.0530
250	0.0167	98	20.13	114.27	0.0567
300	0.0200	93	20.4	908.44	0.0536
350	0.0233	85	20.34	99.11	0.0487

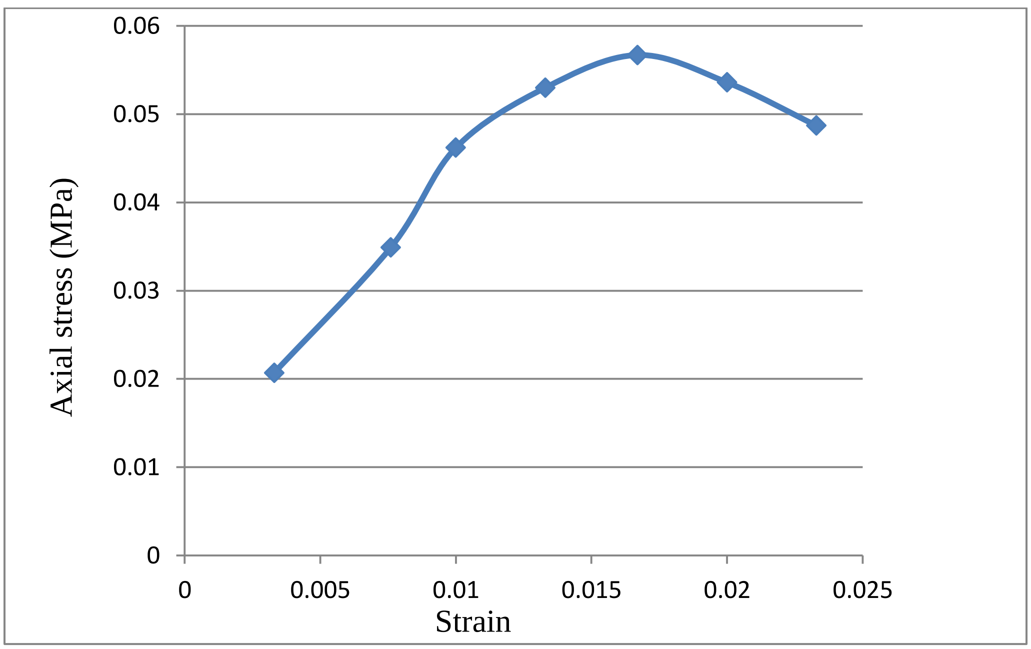

Fig. 4.19 Axial stress vs. Strain for unreinfoced (soil sample-1)

From Fig.4.18 the unconfined compressive strength of soil sample-1 without reinforcement was obtained as 0.0562 MPa.

2. With 0.15% reinforcement

The same tests were also conducted for 0.15, 0.25 and 0.35% reinforcement and results were tabulated in Table 4.22, 4.23, 4.24 and Fig.4.19, 4.20, 4.21 respectively.

Table 4.22: Observations of UCS test on soil sample-1 (with 0.15% reinforcement)

Dial gauge reading	**Strain(ϵ)**	**Proving ring reading**	**corrected area**	**load (N)**	**Axial Stress (Mpa)**
50	0.0033	48	19.72	55.97	0.0284
100	0.0076	65	19.82	75.79	0.0302
150	0.0100	93	19.92	108.44	0.0544
200	0.0133	102	20.03	118.93	0.0594
250	0.0167	109	20.13	127.09	0.0631
300	0.0200	105	20.4	122.43	0.0605
350	0.0233	96	20.34	111.94	0.0551

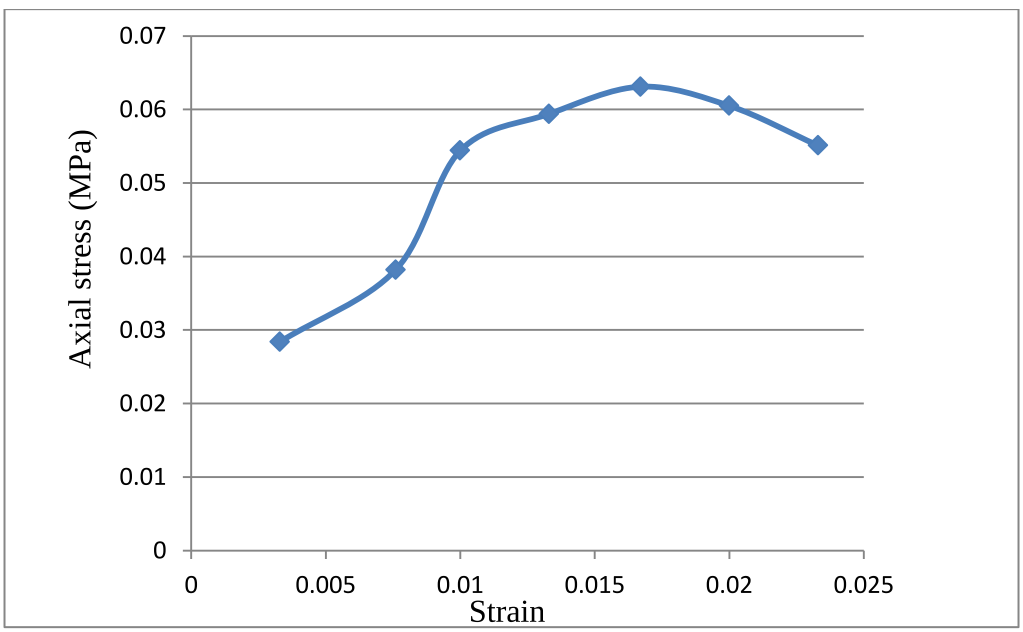

Fig. 4.20 Axial stress vs. Strain for reinforced soil sample-1 (0.15%)

From Fig.4.19 the value of unconfined compressive strength of soil sample-1 with.15% reinforcement was obtained as 0.0631MPa.

3. Soil with reinforcement 0.25%

Table 4.23: Observations of UCS test on soil sample-1 (with 0.25% reinforcement)

Dial gauge reading	**Strain(ϵ)**	**Proving ring reading**	**corrected area**	**load (N)**	**Axial Stress (Mpa)**
50	0.0033	47	19.72	54.8	0.0277
100	0.0076	71	19.82	82.79	0.0417
150	0.0100	94	19.92	109.6	0.0550
200	0.0133	105	20.03	122.43	0.0612
250	0.0167	110	20.13	128.26	0.0639
300	0.0200	103	20.4	120.1	0.0593
350	0.0233	92	20.34	107.27	0.0527

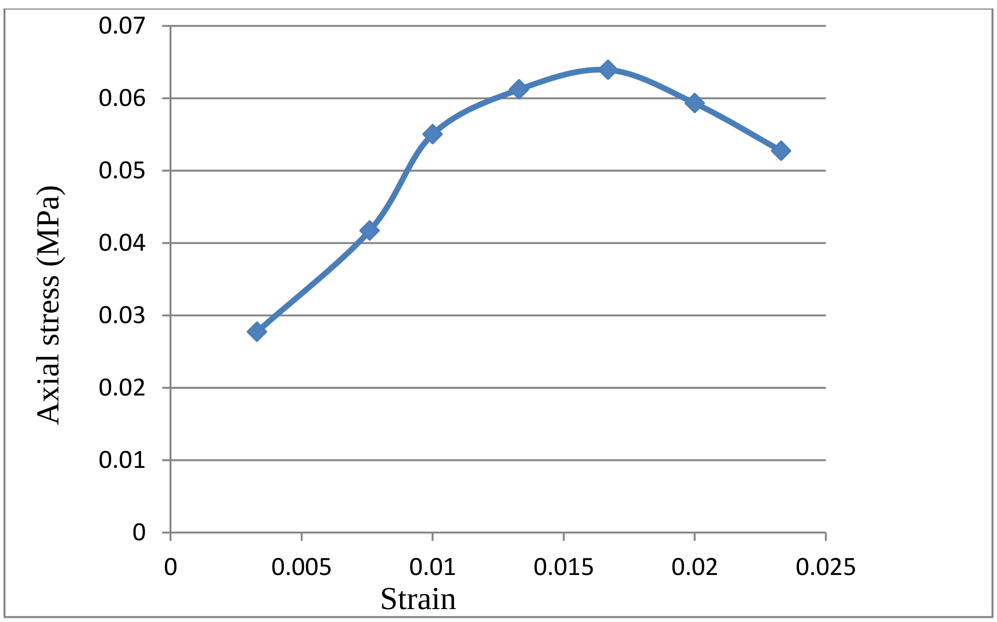

Fig.4.21 Axial stress vs. Strain for reinforced Soil sample-1 (0.25%)

The unconfined compressive strength of soil sample-1reinforced with0.25% was obtained as 0.0637MPa (Fig.4.20).

4. Soil with reinforcement 0.35%

Table 4.24: Observations of UCS test on soil sample-1 (with 0.35% reinforcement)

Dial gauge reading	**Strain(ϵ)**	**Proving ring reading**	**corrected area**	**load (N)**	**Axial Stress (Mpa)**
50	0.0033	51	19.72	59.47	0.0302
100	0.0076	69	19.82	80.45	0.0406
150	0.0100	94	19.92	109.6	0.0550
200	0.0133	105	20.03	122.43	0.0612
250	0.0167	111	20.13	129.43	0.0643
300	0.0200	106	20.4	123.1	0.0611
350	0.0233	93	20.34	108.44	0.0533

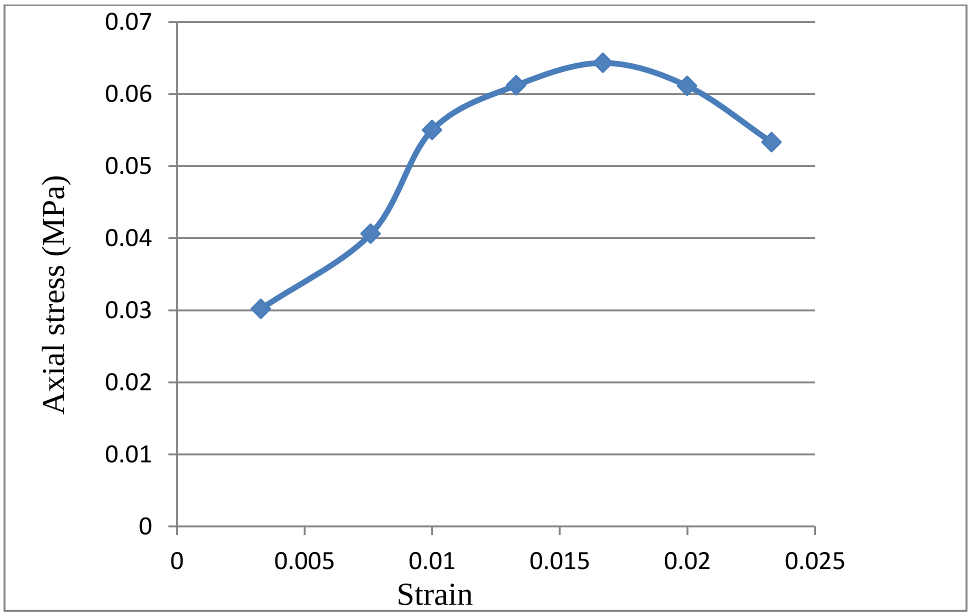

Fig. 4.22 Axial stress vs. Strain for reinforced soil sample-1 (0.35%)

The unconfined compressive strength of soil sample-1reinforced with 0.35% was obtained as 0.0643MPa(Fig. 4.21). A view of the soil sample-1 moulded for UCS is shown in Plate 4.2.

Plate 4.2 Soil sample moulded for UCS Test (sample-1)

From the above experimental observations on Soil sample-1 under unconfined compressive strength test the following conclusions were drawn.

- UCS values increased from 0.0562 to 0.0643Mpa that showed a net increment of 14.4% (Fig. 4.22).
- Slope of graph is continuously decreasing with initially steep slope.
- Values showed very marginal change in soil sample-1 by reinforcement.

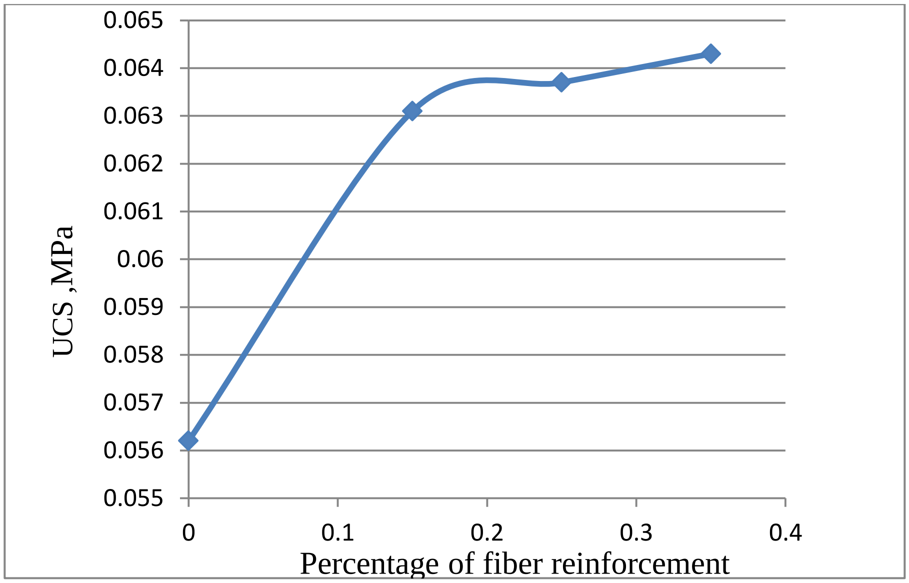

Fig. 4.23 Percentage of fiber reinforcement vs. UCS (soil sample-1)

4.2.7.2 Soil sample- 2

1. Soil sample-2 (without reinforcement)

The same experiment was conducted.

Table 4.25: Observations of UCS test on soil sample-1 (without reinforcement)

Dial gauge reading	**Strain(ϵ)**	**Proving ring reading**	**corrected area**	**load (N)**	**Axial Stress (Mpa)**
50	0.0033	42	19.72	48.97	0.0248
100	0.0076	78	19.82	90.95	0.0459
150	0.0100	102	19.92	118.93	0.0597
200	0.0133	114	20.03	113.92	0.0663
250	0.0167	119	20.13	138.75	0.0689
300	0.0200	115	20.4	134.09	0.0662
350	0.0233	107	20.34	124.76	0.0613

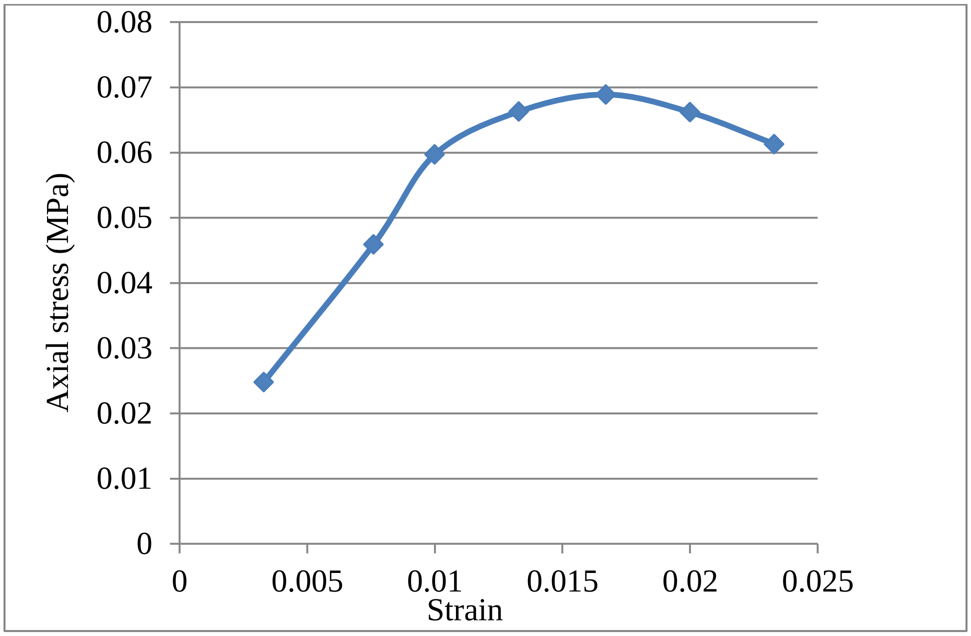

Fig. 4.24 Axial stress vs. Strain for unreinforced soil (soil sample-2)

From Table 4.25 and Fig.4.23, the unconfined compressive strength of soil sample-2 (without reinforcement) was obtained as 0.0692MPa.

2. With reinforcement 0.15%

The results of UCS test on soil sample-2 with reinforcement 0.15, 0.25 and 0.35%were represented in Table 4.26, 4.27, 4.28 and Fig.4.24, 4.25, 4.26 respectively.

Table 4.26: Observations of UCS test on soil sample-1 (with reinforcement 0.15%)

Dial gauge reading	**Strain(ϵ)**	**Proving ring reading**	**corrected area**	**load (N)**	**Axial Stress (Mpa)**
50	0.0033	63	19.72	73.4	0.0372
100	0.0076	105	19.82	122.43	0.0612
150	0.0100	130	19.92	151.58	0.0760
200	0.0133	154	20.03	179.56	0.0897
250	0.0167	162	20.13	188.89	0.0938
300	0.0200	155	20.4	180.73	0.0893
350	0.0233	142	20.34	165.57	0.0814

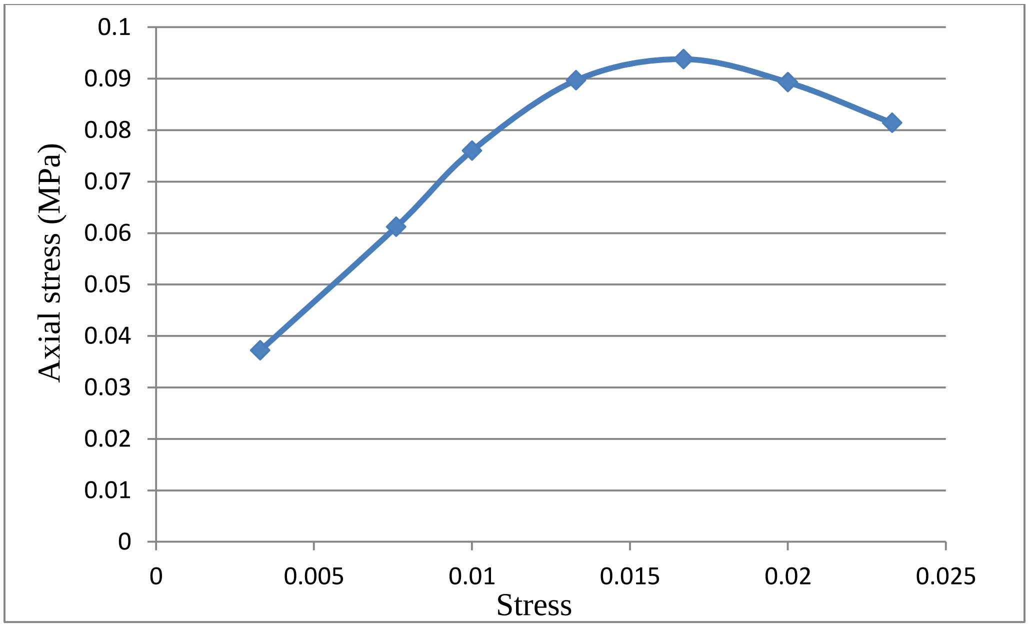

Fig.4.25 Axial stress vs. Strain for reinforced soil sample-2 (0.15%)

The unconfined compressive strength of soil sample-2 reinforced with 0.15% is obtained as 0.0938MPa (Fig.4.25).

3. Soil reinforced with 0.25%

Table 4.27: Observations of UCS test on soil sample-1 (with reinforcement 0.25%)

Dial gauge reading	**Strain(ϵ)**	**Proving ring reading**	**corrected area**	**load (N)**	**Axial Stress (Mpa)**
50	0.0033	69	19.72	80.45	0.0408
100	0.0076	108	19.82	125.93	0.0635
150	0.0100	145	19.92	169.07	0.0849
200	0.0133	158	20.03	184.23	0.0919
250	0.0167	166	20.13	193.56	0.0961
300	0.0200	161	20.4	187.73	0.0927
350	0.0233	1152	20.34	177.23	0.0871

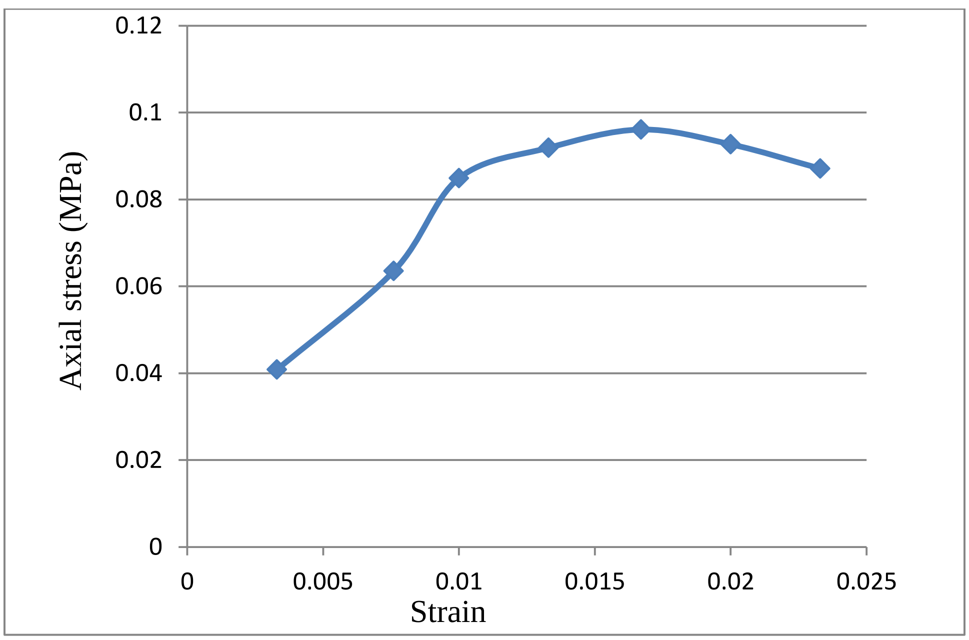

Fig. 4.26 Axial stress vs. Strain for reinforced Soil sample-2 (0.25%)

From Fig.4.25 the Unconfined compressive strength of soil sample-2 reinforced with 0.25% was obtained as 0.0965MPa.

4. Soil reinforced with 0.35%

Table 4.28: Observations of UCS test on soil sample-1 (with reinforcement 0.35%)

Dial gauge reading	**Strain(ϵ)**	**Proving ring reading**	**corrected area**	**load (N)**	**Axial Stress (Mpa)**
50	0.0033	76	19.72	88.62	0.0449
100	0.0076	112	19.82	130.59	0.0659
150	0.0100	151	19.92	176.07	0.0884
200	0.0133	167	20.03	197.72	0.0972
250	0.0167	179	20.13	208.71	0.1037
300	0.0200	170	20.4	198.22	0.0979
350	0.0233	157	20.34	183.06	0.0900

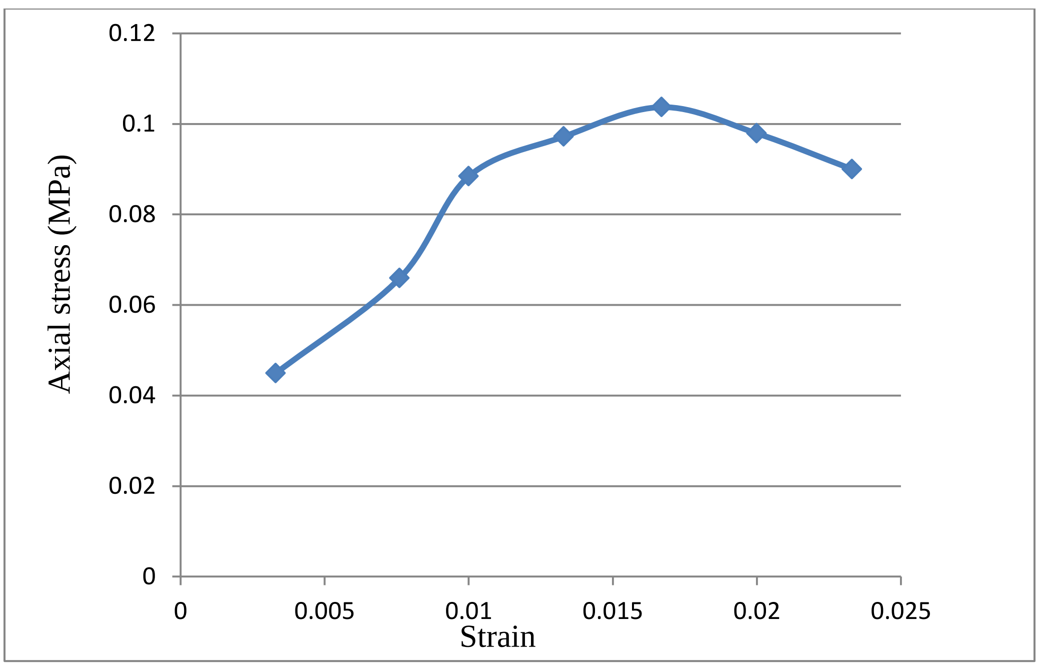

Fig.4.27 Axial Stress vs. Strain for reinforced Soil sample-2 (0.35%)

The unconfined compressive strength of soil sample-2 reinforced with 0.35% was found 0.1037MPa (Fig.4.26). A view of soil sample moulded for UCS was shown in Plate 4.2.

Plate 4.3 Soil sample moulded for UCS Test (sample-2)

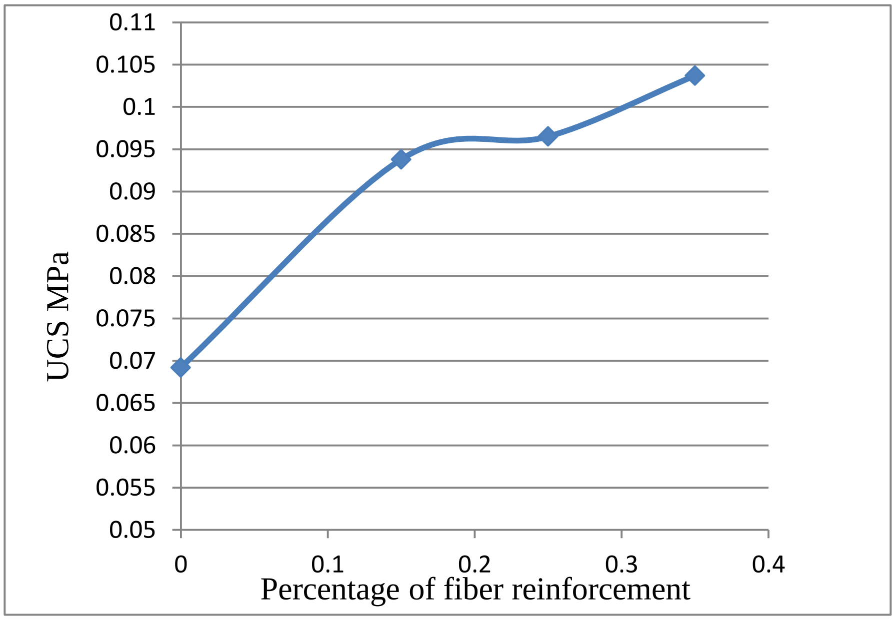

Fig. 4.28 Percentage of fiber reinforcement vs. Cohesion (soil sample 2)

From the UCS test on Soil sample-2 test on soil sample -2 it is concluded that:

- UCS value increases from 0.0692 to 0.1037 MPa, which showed a net increment of 49.85% (Fig.4.27)
- Slope of graph varies with alternate rise and fall
- These values showed that soil sample-2 is preferable for reinforcement with coconut coir fibre

On the basis of experimental investigations conducted to study the effect of soil reinforcement using coconut fibre the following conclusions were drawn.

According to direct shear test (DST) on soil sample-1 with fibre reinforcement of 0.15%, 0.25% and 0.35% , the increase in the cohesion value was found to be 12%, 7.1%, 6.6% respectively. Similarly the increase in internal angle of friction was found to be 4.4%, 5.3%, 0.85% respectively. The net increase in the value of cohesion and angle of internal friction were observed to be 28% (from 0.25 to 0.32kg/cm^2) and 10.9% (from 32to 35.5°) respectively. This increase was found to be substantial. But as per unconfined compressive strength (UCS) test for soil sample-1, with fibre reinforcement of 0.15%, 0.25% and 0.35%, the increment in the compressive strength were found to be 12.2%, 0.95% and 0.90% respectively. As this increment is not considerably significant, reinforcing soil sample-1 with coconut fibre is not recommended.

According to DST on soil sample 2, with fibre reinforcement of 0.15%,0.25% and 0.35% the increment in the cohesion value were found to be 34.69%, 6.5%, 6.6% respectively. The increase in internal angle of friction was found to be 4.3%, 3.1%, 6.8% respectively. The net increase in the value of cohesion and angle of internal friction were observed to be 53.0% (from 0.3513 to 0.5375kg/cm^2) and 13.06% (from 27.82-32°) respectively. The result from UCS test for soil sample-2, with fibre reinforcement of 0.15%, 0.25% and 0.35%, the increment in the compressive strength were found to be 35.5%, 2.8%and 7.4% respectively. This increment is significant compared to soil sample-1.Hence reinforcing soil sample-2 with coconut fibre is much effective than soil sample-1.

SUMMARY AND CONCLUSIONS

Chapter 5

Summary and Conclusions

Soil reinforcement is a technique to improve the engineering characteristics of soil such as shear strength, compressibility, density and hydraulic conductivity. The primary purpose of reinforcing soil mass is to improve its stability, increase its bearing capacity, and reduce settlement and lateral deformation. In this Study soil stabilisation has been done with the help of randomly distributed fibre obtained from waste coconut husk. The effect of coconut fibre in reinforcing the soil was studied by carrying out direct shear test and unconfined compressive strength test. The results obtained were compared for two different soil samples taken from different locations in KCAET campus. One soil sample from the area dominated by laterite (soil sample-1) and the second from sandy loam area (soil sample-2).

According to direct shear test (DST) on soil sample-1 with fibre reinforcement of 0.15%, 0.25% and 0.35% , the increase in the cohesion value was found to be 12%, 7.1%, 6.6% respectively. Similarly the increase in internal angle of friction was found to be 4.4%, 5.3%, 0.85% respectively. The net increase in the value of cohesion and angle of internal friction were observed to be 28% (from 0.25 to 0.32kg/cm^2) and 10.9% (from 32to 35.5°) respectively. This increase was found to be substantial. But as per unconfined compressive strength (UCS) test for soil sample-1, with fibre reinforcement of 0.15%, 0.25% and 0.35%, the increment in the compressive strength were found to be 12.2%, 0.95% and 0.90% respectively. As this increment is not considerably significant, reinforcing soil sample-1 with coconut fibre is not recommended.

According to DST on soil sample 2, with fibre reinforcement of 0.15%, 0.25% and 0.35% the increment in the cohesion value were found to be 34.69%, 6.5%, 6.6% respectively. The increase in internal angle of friction was found to be 4.3%, 3.1%, 6.8% respectively. The net increase in the value of cohesion and angle of internal friction were observed to be 53.0% (from 0.3513 to 0.5375kg/cm^2) and 13.06% (from 27.82-32°) respectively. The result from UCS test for soil sample-2, with fibre reinforcement of 0.15%, 0.25% and 0.35%, the increment in the compressive strength were found to be 35.5%, 2.8%and 7.4% respectively. This increment is significant compared to soil sample-1.Hence reinforcing soil sample-2 with coconut fibre is much effective than soil sample-1.

The further scopes of this study are

- To assess the possibility of other types of natural and synthetic fibres for reinforcing the soil
- To compare the strength properties and economics while using natural and synthetic fibres for soil reinforcement
- To find the optimum relative proportions of fibre addition to soil for effective reinforcement
- To test the applicability of soil reinforcement in slope stabilization, pavement lying, retaining wall and embankment construction etc.

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SOIL REINFORCEMENT USING
COCONUT FIBRE

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ABSTRACT REPORT

Submitted in partial fulfilment of the requirement for the degree

BACHELOR OF TECHNOLOGY
IN
AGRICULTURAL ENGINEERING

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2017

ABSTRACT

Soil reinforcement is a technique to improve the engineering characteristics of soil such as shear strength, compressibility, density and hydraulic conductivity. The primary purpose of reinforcing soil mass is to improve its stability, increase its bearing capacity, and reduce settlement and lateral deformation. In this Study, the effect of waste coconut fibre in reinforcing the soil was studied by carrying out direct shear test and unconfined compressive strength test. The results obtained were compared for two different soil samples taken from two different locations in KCAET campus. One soil sample from the area dominated by laterite (soil sample-1) and the second from sandy loam area (soil sample-2).

According to direct shear test (DST) on soil sample-1 with fibre reinforcement of 0.15%, 0.25% and 0.35% , the increase in the cohesion value was found to be 12%, 7.1%, 6.6% respectively. Similarly the increase in internal angle of friction was found to be 4.4%, 5.3%, 0.85% respectively. The net increase in the value of cohesion and angle of internal friction were observed to be 28% (from 0.25 to 0.32kg/cm^2) and 10.9% (from 32to 35.5°) respectively. This increase was found to be substantial. But as per unconfined compressive strength (UCS) test for soil sample-1, with fibre reinforcement of 0.15%, 0.25% and 0.35%, the increment in the compressive strength were found to be 12.2%, 0.95% and 0.90% respectively. As this increment is not considerably significant, reinforcing soil sample-1 with coconut fibre is not recommended.

According to DST on soil sample 2, with fibre reinforcement of 0.15%,0.25% and 0.35% the increment in the cohesion value were found to be 34.69%, 6.5%, 6.6% respectively. The increase in internal angle of friction was found to be 4.3%, 3.1%, 6.8% respectively. The net increase in the value of cohesion and angle of internal friction were observed to be 53.0% (from 0.3513 to 0.5375kg/cm^2) and 13.06% (from 27.82-32°) respectively. The result from UCS test for soil sample-2, with fibre reinforcement of 0.15%, 0.25% and 0.35%, the increment in the compressive strength

were found to be 35.5%, 2.8%and 7.4% respectively. This increment is significant compared to soil sample-1.Hence reinforcing soil sample-2 with coconut fibre is much effective than soil sample-1.