# Triaxial test on saturated soil reinforced with coir products

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***Abstract*:** Coir products are proficient for low-cost applications, especially in developing countries because of its availability at low prices compared to its synthetic counterparts. They also render the advantages of ecofriendliness and biodegradability. Even though various natural products are being tried as a reinforcement material, coir gives better performance due to its high tensile strength, stiffness and durability. This Report evaluates the effectiveness of coir products in reinforcing soil. A systematic series of triaxial tests and ucc tests have been conducted to study shear strength parameters of soil reinforced with various coir products) at diferenent proportions

***Keywords:Atterbergs limits,unconfined compression test and triaxial tests.***

## INTRODUCTION

The concept of Reinforced Soil was accidentally thought about by Mr. Vidal while playing with his children on a beach.

Reinforced Soil = Soil + Reinforcement

Reinforced Soil concept is similar to that of Reinforced Concrete. The first recorded history of coconut in the country dates back to Ramayana period.In the Valmiki Ramayana there are references of coconut in the Kishkindha Kanda and Aranya Kanda. It is reported that Ramayana was written by Valmiki sometimes in 3rd Century BC. Generally it is believed that coconut was introduced in India during the post-Vedic period.

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References have been made on coconut in Raghuvamsa of Kalidasa and Sangam literatures, which proves the antiquity of the coconut in India. But its origin in India remains disputed. But Marco Polo, the famous Arab traveler who visited India in the 13th Century called coconut "Indian Nut" and the logic for such a reference needs investigation by historians. Shri. P. K. Balakrishnan, a Kerala historian argues that organised coconut cultivation started in Kerala only after the arrival of the Portugese.

Ropes and cordage, made out of coconut fibre have been in use from ancient times. Indian navigators, who sailed the seas to Malaya, Java, China and to the Gulf of Arabia centuries ago, had been using coir as their ship's cables. Arab writers of the 11th Century AD referred to the extensive use of coir as ship's cables, fenders and for rigging. Facts record that there was coir industry in UK before the 2nd half of the 19th Century. During the year 1840, Captain Widely, in co-operation with Captain Logan and Mr. Thomas Treloar, founded the well-known carpet firms of Treloar and Sons in Ludgate Hill, England for the manufacture of coir into various fabrics suitable for floor coverings.

The coir manufacturing industry producing coir mats, matting and other floor coverings, was started in India on a factory basis, over a hundred years ago when the first factory was set up in Alleppey in 1859 by the Late Mr. James Darragh, an adventurous Irish born American national. Enterprising Indians followed the trail blazed by this foreigner.

**Kerala and the Coir Industry**

The history of Coir and its association with the state of Kerala dates back to the 19th Century. Sandwiched between the Western Ghats on the east and the Arabian Sea on the west, Kerala is one of the most beautiful States in India. A tropical paradise of waving coconut palms and wide sandy beaches, this thin strip of coastal territory slopes down from the mountain ghats in a cascade of lush green vegetation and varied fauna. One of the most commonly seen tropical trees in Kerala is the Coconut tree. In fact, even the name Kerala (Kerlam in Malayalam) is derived from this tree ("Kera" in Malayalam language means Coconut and "Alam" means Land, thus Keralam = Land of Coconut). Everything from Kerala's culture to its dishes is evolved around the Coconut tree.

FIGURE 1 : Natural Coir Product

Alleppey (Alappuzha in Malayalam) is the nerve centre of Kerala's famous Coir industry. Here, one can see coconut husks being beaten into fibre for making beautiful mats and other coir products. Both men and women are actively involved in the production of Coir. The women are mainly involved in the yarn spinning sector and the men in the product-weaving sector. Coir Industry enjoys the status as the largest Cottage Industry in the State of Kerala, giving employment to over a million people. Kerala also has a very fine natural harbour located at Cochin ( Kochi). From the ancient times itself Cochin had found a place in the minds of Europeans as a trading centre because of its port and spices.

Some of the historical monuments left behind by the early travelers at Cochin are the Chinese fishing nets that were introduced during the medieval ages by traders from the Court of Kublai Khan. St. Francis Church considered as the oldest European church in India was built by the Portuguese sailor Vasco Da Gama during the period 1503 to 1524. The Jew Synagogue built by early Jewish settlers in the period 1568 is another notable historical monument.

## LITERATURE REVIEW

Many small-scale laboratory investigations have been carried out to understand the effect addition of discrete randomly distributed synthetic fiber(polypropylene or polyester) on the compressive stress-strain behavior,peak compressive strength, ductility, splitting tensile strength, ând flexu-ral toughness of fine-grained soils, and it is observed that fiber-reinforcedsoil performs better in all the above aspects compared to that without reinforcement (Freitag 1986, Maher and Ho 1994, Ranjan et al. 1996, Kudo et al.2001, Kumar et al. 2005, Sung-Sik 2009). Influence of aspect ratio and dosageof fibers on the flexural and permeability characteristics of a cohesive soil has been studied by Viswanadham et al. (2008), and concluded that an increase in friction angle and decrease in adhesion were observed withthe increase in fiber content On similar lines, many researchers studied he influence of discrete synthetic fiber on the shear strength and stiffnes properties of natural or artificially cemented cohesionless sand (Maher and Gray 1990; Consoli et al. 2010) and the triaxial results clearly demonstrate that the peak strength and ultimate strength have increased with fiber reinforcement whereas the initial stiffness is apparently unchanged It was also observed that the contribution of the fibers to the composite strength is the largest when they are placed in the direction of the largest extension of the composite (Michalowski and Cermark 2003), and fibers performed under their elastic limit when deviator stress is applied, and no breakage or plastic behavior of the fiber is observed even at the end of the tests (Diambra et al.2010)

Studies have also been conducted to understand the influence of natural fiber in the form of coconut on the shear strength, ductil-Mnit otne tric shrinkage, piping characteristics of various fine-grainedsoils (Ranjan et al 1996, Ghavami et al, 1999, Puppala and Musanda 2000Sivakumar Babu and Vasudevan 2008, Viswanadham et al. 2009a, 2009b),and the results show that shear strength and ductility were increased considerably with the addition of fibers to soil; also, a substantial decreaseinvolumetric shrinkage was observed when fibers are mixed with expansivesoils (Puppala and Musanda 2000, Viswanadham et al. 2009b).Zornberg (2002) derived equations for finding the shear strength param-eters of fiber-reinforced soils when the failure is governed by pullout of the fiber. The equations are given below:

$$\acute{C}_{eq,p} = \acute{C}\,(1+ \alpha\eta\chi Ci,\acute{c})$$

$$(\tan\phi')_{eq,p} = (1+ \alpha\eta\chi Ci,\phi')\tan\phi',$$

where, $\acute{C}_{eq,p}$ is the equivalent cohesive component of fiber-reinforced soil when the failure is occurring by fiber pullout, C' is the cohesion intercept of un-reinforced soil, $\alpha$ is the empirical coefficient accounting for the effect of fiber orientation and mobilization of fiber-induced tension $\alpha$ = 1 for randomly distributed fibers), $\eta$ is the aspect ratio of the fiber, $\chi$ is the gravimetric fiber content, Ci,ć is the interaction coefficient of the frictional component of interface shear strength, and Ci,$\phi$' is the interaction coefficient of the frictional component of interface shear strength.

Sivakumar Babu and Vasudevan (2008) proposed analytical models for finding out the major principal stress at failure and shear strength parameters of fine grained red soil.How ever the analytical models proposed by them is soil specific

On the basis of the available literature, it can be concluded that there are not many studics available that observes the influence of natural fiber on the shear strength characteristics of cohesive soils. As the natural fiber is abundantly available in many parts of the world, their bulk use in geotechnical applications can only be justified with the availability of more research studies on the performance of natural fiber-reinforced soils. Hence, the following

**Main objectives have been identified for the present work**

**1** To obtain the unconfined compressive strength of fine-grained soil specimens of size 38 mm x 76 mm, randomly reinforced with various quantities of coir fiber.

**2**.To obain the stress-strain behavior of coir fiber-reinforced fine grained soil by conducting unconsolidated undrained triaxial compression tests on 38-mm x 76-mm soil specimens.

**3**.To find the effect of fiber inclusion on the peak deviator stress, major principal stress at failure, shear strength parameters, and stiffness characteristics of the soil, under the influence of confining pressure

## METHODOLOGY

The two soil samples are used in the study and Black cotton soil collected from the Nandyal (Kurnool t) and Red soil collected from the Panyam (Kurnool Dt).For these Soil samples the Engineering and Index properties are determined are tabulated in the Table.1and Table.2.The Black cotton soil is collected from the trial pits at a depth of 4.0m from ground level.The soil lumps were broken into pieces and sieved through 4.75mm sieve and then dried in oven atb $105^0$c for 24 hours. The soil are classified as I.S Classification system(IS 1498-1970).

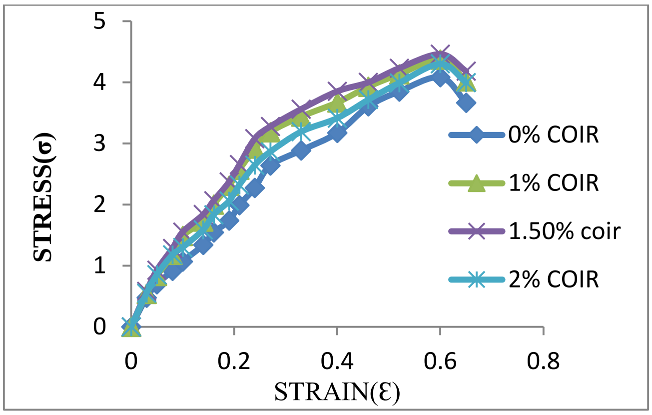
**Table:1 properies of soils**

| Descriptopn | Sample A | Sample B |
|---|---|---|
| % Gravel | 2.0 | 4.56 |
| % Sand | 23.0 | 47.12 |
| %Silt + Clay | 75.43 | 48.32 |
| Liquid limit | 52 | 57.08 |
| Plasticityindex(plasticitychart) | 34 | 34.05 |
| Free swell index | 130 | 90 |
| Specific gravity | 2.52 | 2.63 |
| MaximumDryDensity(KN/$m^3$) | 17.3 | 18.45 |
| Optimum MoistureContent(%) | 18.62 | 19.50 |
| Classification of soil | **CH** | **CH** |

**UNCONFINED COMPRESSION TESTS ON SOIL**

In order to understand the effect of addition of coir fiber on the unconfined compressive stress, a number of unconfined compression tests are conducted on un-reinforced and randomly reinforced soil. Fibers of 15-mm length are added to the soil at a dosage of 0.1% of dry weight of the soil, and the results are shown in Figure. Based on the analysis of test results with various dosages of fiber, it is believed that the failure in the soil specimen would be taking, and it is noticed from Figure that when soil is reinforced with fiber, the unconfined compressive strength increases with increase of fiber dosage, and the soil shows a ductile behavior with addition of fiber, which are in line with previous research findings. Hence, fiber length of 15 mm is used for further studies. The peak compressive strength increases with increase in fiber dosage up to 1.5%, and thereafter the compressive strength does not increase considerably with further increase in fiber dosage. As the fiber content increases, the failure would take place slowly and the sample behaves like a ductile material. Well-defined failure surfaces could not be seen due to the increased ductile behavior. It can be seen from the figure that the peak compressive strength at 1.5% fiber dosage is about twice that for soil without fiber reinforcement.

**Comparitive Study on UCC values of Black soil reinforced with coir**




| Descriptions Sample A | UCCvalues | Shear Strength values |
|---|---|---|
| 0% coir | 3.72 kg/cm$^2$ | 1.86 kg/cm$^2$ |
| 1% coir | 4.33 kg/cm$^2$ | 2.165 kg/cm$^2$ |
| 1.5% coir | 4.45 kg/cm$^2$ | 2.225 kg/cm$^2$ |
| 2% coir | 4.23 kg/cm$^2$ | 2.115 kg/cm$^2$ |

**Comparitive Study on UCC values of Red soil reinforced with coir**

| Descriptions Sample A | Cell pressure (kg/cm$^2$) | | |
|---|---|---|---|
| | 0 | 0.5 | 1 |
| 0% coir | 0.7013 | 0.8299 | 0.9761 |
| 1% coir | 0.8709 | 0.9791 | 1.0196 |
| 1.5% coir | 0.9832 | 1.0341 | 1.1697 |
| 2% coir | 1.0467 | 1.0524 | 1.2523 |

**EXPERIMENTAL PROGRAMME AND DICUSSION**

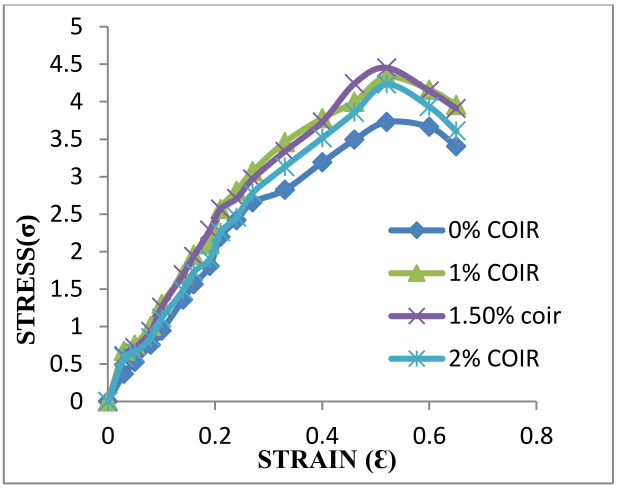
The following tests are conducted in this investigations as per standard specifications

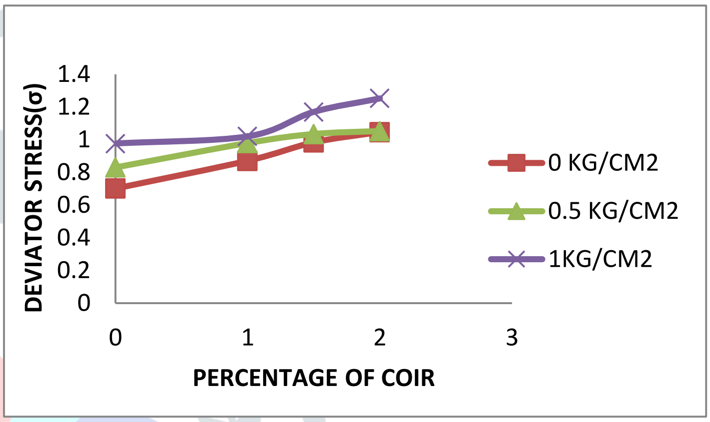
1. INDEXPROPERTIES
2. SPECIFIC GRAVITY
3. COMPACTION CHARACTERISTICS
4. SHEAR STRENGTH

**Mixing proportion details**

Here the Natural coir fiber is used as a Reinforcement mateial added at different proportios by the weight of soil the quantity of reinforcement computed corresponding to the above is directly placed to the soil in order to obtain even distribution of thecoir fiber.

**TRIAXIAL COMPRESSION TESTS ON COIR REINFORCED SOIL**

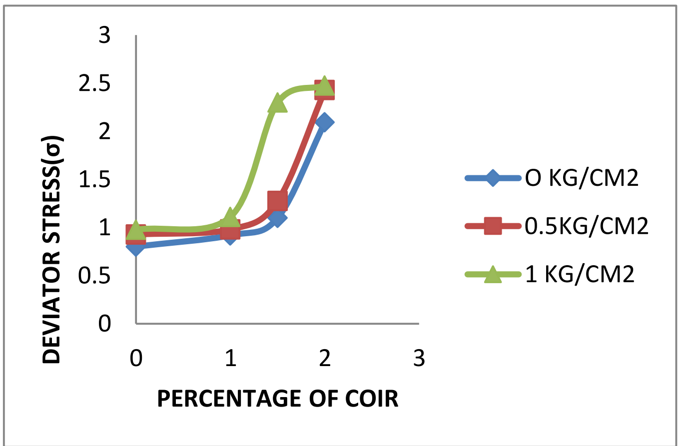



Graph shows major deviator stresses versus percentage of coir at different cell pressures.

Table shows major deviator stresses versus percentage of coir at different cell pressures for Black cotton soil.

| Description Sample B | UCC values | Shear Strength values |
|---|---|---|
| **0% coir** | 4.08 kg/cm$^2$ | 2.04 kg/cm$^2$ |
| **1% coir** | 4.37 kg/cm$^2$ | 2.185 kg/cm$^2$ |
| **1.5% coir** | 4.60 kg/cm$^2$ | 2.3 kg/cm$^2$ |
| **2% coir** | 4.30 kg/cm$^2$ | 2.15 kg/cm$^2$ |

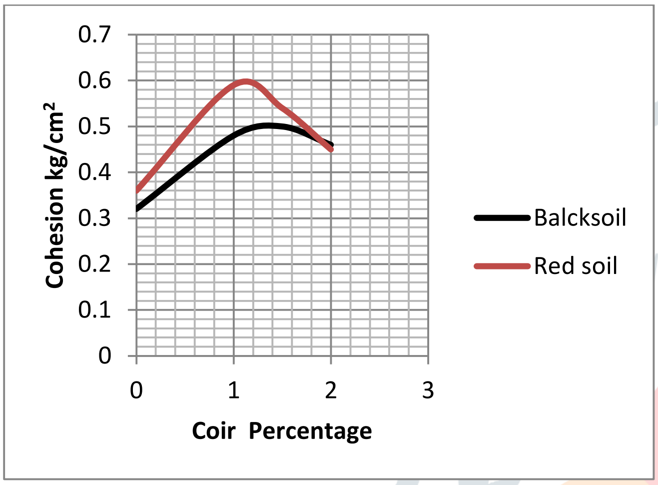



Graph shows Major deviator stresses versus percentage of coir at different cell pressures for Black cotton soil.

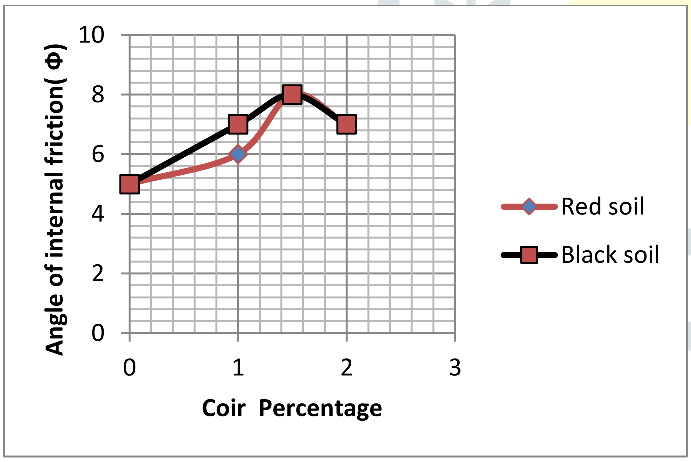
| Descriptions Sample B | Cell pressure (kg/cm$^2$) | | |
|---|---|---|---|
| | 0 | 0.5 | 1 |
| 0% coir | 0.8003 | 0.927 | 0.9761 |
| 1% coir | 0.9167 | 0.9791 | 1.1103 |
| 1.5% coir | 1.1001 | 1.2768 | 1.2768 |
| 2% coir | 2.0918 | 2.428 | 2.4742 |

Table shows major deviator stresses versus percentage of coir at different cell pressures for Red soil.

**SHEAR STRENGTH PARAMETERS**




**Variation in cohesion of soil with various fiber dosages**




**Variation in friction angle of soil with various fiber dosages**

## CONCLUSIONS

In order to understand the effect of addition of coir fiber on the unconfined compressive stress, a number of unconfined compression tests are conducted on un-reinforced and randomly reinforced soil. Fibers of 15-mm length are added to the soil at a dosage of 0.1% of dry weight of the soil, and the results are shown in Figure. Based on the analysis of test results with various dosages of fiber, it is believed that the failure in the soil specimen would be taking, and it is noticed from Figure that when soil is reinforced with fiber, the unconfined compressive strength increases with increase of fiber dosage, and the soil shows a ductile behavior with addition of fiber, which are in line with previous research findings. Hence, fiber length of 15 mm is used for further studies. The peak compressive strength increases with increase in fiber dosage up to 1.5%, and thereafter the compressive strength does not increase considerably with further increase in fiber dosage. As the fiber content increases, the failure would take place slowly and the sample behaves like a ductile material. Well-defined failure surfaces could not be seen due to the increased ductile behavior. It can be seen from the figure that the peak compressive strength at 1.5% fiber dosage is about twice that for soil without fiber reinforcement.

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