Experimental Study on Strength Behaviour of Kuttanad Soil using Treated Coir Fibre

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***Abstract*— The Kuttanad region covering about 875 km^2 is a unique agricultural area in the world. The soil in this region is black coloured clay with high compressibility and has extremely low California bearing ratio value and shear strength. Therefore it is necessary to improve these properties. This paper presents the details and results of an experimental investigation conducted to study the effect of treated coir fibre inclusion on the strength behaviour of the Kuttanad clay. Dry, sodium hydroxide and carbon tetrachloride treated coir fibres were used in the study and coir fibre content was varied from 0.4% to1.6%. The results indicated that the unconfined compressive strength of clay and clay with dry coir fibres can be increased by treatment with carbon tetrachloride and sodium hydroxide. The increase in unconfined compressive strength was highest with carbon tetrachloride treatment. The CBR value of soil improved by reinforcing with untreated and treated coir fibre. The CBR value is higher for soil reinforced with carbon tetrachloride treated fibre. The optimum fibre content for untreated and treated fibres as per UCC and CBR is 1.2%.**

Keywords*— *Soil, Coir fibre, Treated coir fibre, OMC, MDD, UCC, CBR

I. INTRODUCTION

Soils generally have low tensile and shear strength, and their characteristics may strongly be influenced by environmental conditions . Soil reinforcement involves the incorporation of certain materials with some desired properties into soils which lack those properties. Therefore, soil reinforcement is defined as a technique to improve the engineering characteristics of soil. The primary purpose of reinforcing soil mass is to improve its stability, to increase its bearing capacity, and to reduce settlements and lateral deformations.

In the case of geotechnical engineering the idea of inserting fibrous materials in a soil mass in order to improve its mechanical behaviour has become very popular. The Soil reinforcement is an effective and reliable technique for improving strength and stability of soils. These reinforcements resists tensile stress developed within the soil mass there by restricting shear failure. Reinforcement interacts with the soil through friction and adhesion. The practicing engineers are employing this technique for stabilization of thin soil layers, repairing failed slopes, soil strengthen around the footings and earth retaining structures. Soil reinforcement is procedure where natural or synthesized materials are used to improve the properties of soil. Several reinforcement methods are available for stabilizing problematic soil. Therefore, the techniques of soil reinforcement can be classified into a number of categories with different point of view. Adding fibre into soil is considered to be an effective technique of soil reinforcement. The technique of soil reinforcement using synthetic materials and products is being widely used at present in a variety of applications and is fast replacing the conventional ground improvement techniques. These products generally have a long life and do not undergo biological degradation, but are liable to create environmental problems in the long run. In effecting this, the use of biodegradable natural materials is gaining popularity. Use of natural materials such as jute, cotton, coir, etc. as reinforcing materials in soil started in the early nineties. The main advantage of these materials is that they are locally available with practically no cost. They are biodegradable, which is an added advantage from the viewpoint of sustainable development. The ability of natural fibres to absorb water and to degrade with time is its prime property which gives them an edge over the synthetic materials. Out of all the natural fibres coir has the greatest tearing strength and retains this property even in wet conditions. India produces about 66% coir in the total world production and Kerala is the home of Indian coir industry. Hence, it can be used extensively in noncritical civil engineering applications and thereby the cost of civil engineering construction can be brought down to a great extent.

Kuttanad soil is dark brown colour medium sensitive alluvial deposits spread over the Kuttanad region in the state of Kerala in India. This area lies 0.6-2.2 m below mean sea level and a major portion of the region is in submerged condition during the monsoon season in every year. In the case of Kuttanad soil it exhibit generally undesirable engineering properties. These clays are characterized by high compressibility, low shear strength and high percentage of organic matter, which are unfavourable from the geotechnical point of view. They can be plastic and compressible and they expand when wetted and shrink when dried. A large number of embankment failures and foundation failures have been reported in this soil due to its poor shear strength and compressibility characteristics. Reinforced earth technique is considered as an effective ground improvement method because of its cost effectiveness, easy adaptability and reproducibility. Fibre selected must not be hazardous to the environment, and it should be easily available and less expensive. Here study is conducting on effect of addition of treated coir fibre on the compression behaviour of clay.

II.LITERATURE REVIEW

From ancient time onwards soil is reinforced using fibrous materials. Natural and synthetic fibres are the two types of fibres used in stabilization of soil. This chapter is devoted to bring about the salient points of published literatures and other reported works using various fibres mainly coir fibre for strength improvement of soil and various chemical treatments used to improve the tensile strength of coir.

Sivakumar Babu et al (2008) reports the results of comprehensive experimental investigations using tri-axial shear tests, swelling, and consolidation tests to quantify the improvement of strength, swelling and compressibility characteristics of black cotton soil reinforced with coir fibres in a random manner. The study facilitates the use of combination of black cotton soil and coir fibres for sustainable development purposes.

Ramesh.H et al.(2010) conducted study on effect of lime-coir fibre on geotechnical properties of black cotton soil .A series of Compaction and Unconfined Compressive Strength tests were conducted to study the effects of Randomly Distributed Coir fibre inclusions and lime on the geotechnical properties of BC of Black Cotton soil as one combination and effect of bitumen coating on coir fibre reinforced BC soil as another combination. These UCS tests were conducted up to 180 days of curing. Indian brown colour coir fiber was mixed with optimum percentage of lime to BC Soil in different proportions. The strength increases up to 30 days linearly with curing period, with further curing the increase in the strength is marginal. Optimum fibre of 1.0 % by weight with 0.5 centimetre length was identified for improving the strength of BC Soil. From UCS test with 180 days of curing it is found that addition of bitumen coated coir fibre in BC soil is less beneficial.

Karthika et.al (2011) have stabilized the soil with coir geotextile. For performing the CBR test, the geotextile was placed at a mid depth of the mould while compacting. 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 %. CBR of soil stabilized with 5 percent fly ash and 2.5 percent cement and reinforced with geotextile is found to be excellent and comes to 28 percent.

Rakesh Kumar Dutta et al. (2012), studied the effective use of treated coir fibres on unconfined compressive strength of clay. Test is conducted with NaOH treated coir and CC treated coir fibre. The results indicate that the fibre reinforced clay was able to bear higher strains and increase in the unconfined compressive strength was higher with CC treatment.

Savita Dixit and Preeti Verma (2012) studied the influence of some treatments like alkali treatment, acetylation, permanganate treatment and heat treatment on the moisture absorption tendency of coconut coir fibre has been investigated. The result showed that these chemical treatments have successfully modified the structure of coconut coir and also reduces water absorption tendency of coconut coir.

H.P. Singh (2013) studied the influence of coir fibres on shear strength parameters (c and ϕ) and stiffness modulus (σd /ϵ) of fly ash. In the present investigation, samples of fly ash compacted to its maximum dry density at the optimum moisture content were prepared without and with randomly distributed coir fibre for triaxial compression tests. The coir fibre 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 fibre content was determined in the laboratory. Finally these strength parameters (c, ϕ and σd /ϵ) of reinforced fly ash were compared with that of unreinforced fly ash. Tests results indicate that on inclusion of coir fibre, the shear strength parameters and stiffness modulus of fly ash increases. It was also observed that on increasing the fibre content, the values of these strength parameters further increases and the improvement is substantial at fibre content of 1 %.Thus there is a significant improvement in the strength parameters of fly ash due to inclusion of coir fibre.

Maliakal and Thiyyakkandi, (2013) discusses the shear strength of clay reinforced with randomly distributed coir fibres based on a series of consolidated undrained triaxial compression tests. Test results show that major principal stress at failure for clay-coir fibre matrix increases with increase in fibre content and fibre aspect ratio. In general, the study identifies that the inclusion of discrete coir fibres in random fashion significantly improves the shear strength of clay.

R. Hari Setyanto,et al (2013) research was conducted to analyze the alkali treatment in improving the quality of coir fibre. Study coir fibre done by specifying the physical characteristics and methods of making specimen, mechanical treatment and testing the tensile strength of single fibre. Determine the characteristics physical of the fibre is done by observing and measuring the diameter of the fibre directly, testing the density and moisture content testing. Chemical treatment is done by the method of alkali. Single coir fibres for the treatment carried out using NaOH 5%. Alkali solution set with a variation of the submersion of 0, 1, 2, 3, and 4 hours. Single fibre tensile strength testing is done according to standard ASTM C1557-2003. Tensile tests showed that an alkali treatment can increase the tensile strength of single fibre of 27.9% in immersion lye for 2 hours compared without soaking and increase the elongation of over 20% compared without soaking.

Amit Tiwari, (2014) focused the properties of soil such as Atterbergs limits, compaction curve (Optimum moisture content and Maximum dry density), shrinkage limit, California bearing ratio, swelling pressure, permeability, direct shear test. He found the effect of fly ash, coir fibre & crushed glass with various percentages along with black cotton soil as a combination. To achieve this goal experimental study on 48 trial samples test were carried in two phase such as in first phase, the physical properties of soil such as hygroscopic moisture content, grain size distribution, specific gravity, Atterberg's limits, direct shear test, swelling pressure, MDD-OMC, CBR, permeability test values are determined. In second phase, various test investigation performed on black cotton soil using different percentages of fly ash at 10%, 15%, 20%, 25%, coir fibre at

0.25%, 0.5%, 0.75%, 1% & crushed glass at 3%, 5%, 7% which improved engineering properties and CBR value.

Singh and Mittal (2014) conducted an experimental study on clayey soil mixed with varying percentage of coir fibre. Soil samples for unconfined compression strength (UCS) and California bearing ratio (CBR) tests are prepared at its maximum dry density corresponding to its optimum moisture content in the CBR mould without and with coir fibre. The percentage of coir fibre by dry weight of soil is taken as 0.25%, 0.50%, 0.75% and 1% and corresponding to each coir fibre content unsoaked and soaked CBR and UCS tests are conducted in the laboratory. Tests result indicates that both unsoaked and soaked CBR value of soil increases with the increase in fiber content. Soaked CBR value increases from 4.75% to 9.22% and unsoaked CBR value increases from 8.72% to 13.55% of soil mixed with 1% coir fibre. UCS of the soil increases from 2.75 kg/cm² to 6.33 kg/cm² upon addition of 1% randomly distributed coconut fibre. Adding of coconut coir fibre results in less thickness of pavement due to increase in CBR of mix and reduce the cost of construction and hence economy of the construction of highway will be achieved. This is because of composite effect of natural fibre changes the brittle behaviour of the soil to ductile behaviour.

M.Deivanai and P.D.Arumairaj (2015) studied the effect of natural fibres on soil subgrade. In this study used four type of natural fibres in different percentages and conducted soaked and unsoaked CBR test. coir, jute, bamboo and sisal fibres are used for study. This paper deals with the effectiveness of solutions using Natural fibres for strengthening the subgrade and for designing the pavement. In this study, Proctor's compaction tests, UCS tests and CBR tests are conducted on locally available soil reinforced with natural fibres. The soil identified for this study has a CBR value of only 1.5%. The behaviour of this soil with the addition of natural fibre is studied. A series of laboratory soaked and un-soaked CBR tests are conducted on randomly oriented natural fibre reinforced and un-reinforced soil specimens compacted at OMC and MDD. Test results indicate that Unsoaked and Soaked CBR value of soil increases with increase in fibre content. It is also observed that increase in CBR value of reinforced soil is substantial at fibre content of 1 % for coir fibre and at 0.75% for jute and sisal fibre and at 1.25% for bamboo fibre. The significant increase in CBR value of soil due to natural fibre reinforcement will thus substantially reduce the thickness of pavement subgrade

Vishwas N. Khatri et al.(2015) studied the shear strength behaviour of clay reinforced with treated coir. coir was treated with NaOH and CCl_4 solution.0.4%, 8% and 1.6% of coir was used for experiments. compaction and triaxial test with different deviated stress was conducted. maximum dry density of clay was decreases with increase in percentage of treated/untreated coir and OMC was increase with increase in percentage of treated/ untreated coir. Shear strength of clay was improved by treating with chemicals.

III.OBJECTIVES OF STUDY

- To determine the basic properties of Kuttanad soil.
- To study the strength behaviour of Kuttanad soil reinforced with coir fibre.
- To study the variation in strength behaviour of Kuttanad soil reinforced with treated coir fibre.
- To reduce construction cost by the best use of locally available material.

IV.MATERIALS USED

A.SOIL

Soil used in this study was collected from Kuttanad region in Alappuzha district. The soil sample was collected in polythene gunny bags and then air-dried before starting the experiment. The sample was collected from a depth of about 1.5m below the ground level by open excavation. The soil is classified as MH as per Unified Classification System.Initial properties of soil were determined by standard test procedure as per IS code practice .

Table I. properties of soil

Properties	Values
Specific gravity	2.22
Sand content (%)	8
Silt content (%)	52
Clay content (%)	40
Liquid limit (%)	75
Plastic limit (%)	36
Shrinkage limit (%)	12
Plasticity index (%)	39
Maximum dry density (kN/m³)	13.6
Optimum moisture content (%)	33
Unconfined compressive strength (kN/m²)	20.9
CBR value (%)	1.9

B.COIR FIBRE

The use of natural fibres was widely adopted in ancient period due to the eco-friendly behaviour of natural fibre. Now a days proper use of natural fibres like coconut coir fibre can give strength along with elasticity. The use of natural fibres such as coir for soil improvement is highly attractive in countries like India where such materials are locally and economically obtainable, in view of the preservation of natural environment and cost effectiveness. The coir fibre is one of the hardest natural fibre available because of its high content of lignin.

Table II. properties of coir fibre

Properties	Values
Specific gravity	1.2
Cut length	15 mm
Diameter	0.20
Aspect ratio (l/d)	75
Colour	Brown

Table III. Chemical properties of coir fibre

Lignin	45.84%
Cellulose	43.44%
Hemi- Cellulose	0.25%
Pectin's and related compounds	3.0%
Water soluble	5.25%
Ash	2.22%

C. TREATED COIR FIBRE

In this study coir fibre was cut in the length of 15mm and coir fibre was treated with sodium hydroxide solution and carbon tetra chloride solution. For chemical treatment the coir fibres used were dipped in NaOH and CCl_4 solution for 24 hours in order to remove the impurities on the surface of coir fibres. After 24 hours, the fibres were removed from the beaker and allowed to dry at room temperature for a week. The concentration and composition of chemicals used for the treatment of coir fibre given below.

Table IV.

Carbon tetra chloride	Sodium hydroxide
Assay(GCL)=99% Wt per ml at 20° = 1.590gm Boiling range (95%) = 76- 77° C N. V. M - 0.003% max	Carbonate 2% Chloride 0.01% Sulphate 0.05% Potassium 0.1% Silicate 0.05% Zinc 0.02% N/10 solution

V. METHODOLOGY

A. STANDARD PROCTOR COMPACTION TEST

Standard Proctor compaction test is done to assess the amount of compaction and water content required for the sample. The test is conducted as per IS 2720 (Part 7). The Proctor compaction test is a laboratory method of determining the optimum moisture content at which a given soil will become most dense and achieve its maximum dry density. In this study compaction test were conducted with unreinforced soil and soil reinforced with untreated and treated coir fibres at varying contents. Coir fibre were cut in the length of 15mm and compaction test was conducted with 0.4%, 0.8%, 1.2% and 1.6% of coir fibre by using untreated and treated coir fibre and optimum moisture content and dry density for each sample was determined.

B. UNCONFINED COMPRESSION TEST

The Unconfined Compressive Strength and Cohesion is obtained by conducting Unconfined Compressive Strength test. The test is conducted as per IS 2720(Part 10): 1991. The Unconfined Compression Strength tests were conducted on the unreinforced soil and soil reinforced with the untreated and treated coir fibres at varying content. All the specimens were prepared corresponding to optimum moisture content and maximum dry unit weight values. For reinforced soil specimens, untreated and treated coir fibres were added as a percentage of dry weight of soil. The specimens were prepared with fibre content of 0.4 %, 0.8 %,1.2% and1.6 % and stress- strain curve were plotted and undrained shear strength was determined.

C. CALIFORNIA BEARING RATIO TEST

The California Bearing Ratio (CBR) is a penetration test for evaluation of the mechanical strength of road subgrades and base courses. The CBR tests are conducted as per IS 2720(Part 16) -1987. It was developed by the California Department of transportation before world war II. The soil samples of unreinforced and reinforced soil for CBR test were prepared as per standard procedure. The desired amount of soil was taken and mixed thoroughly with water corresponding to its optimum moisture content (OMC) in the CBR mould. The soil was then compacted to its maximum dry density obtained by laboratory standard Proctor test. For the preparation of soil samples of reinforced soil the desired amount of fibre was mixed in dry state before the addition of water and then compacted to same Proctor density. CBR test was conducted with 0.4%, 0.8%, 1.2% and 1.6% of untreated and treated coir fibre reinforced soil.

VI.RESULTS AND DISCUSSION

A. COMPACTION CHARACTERISTICS

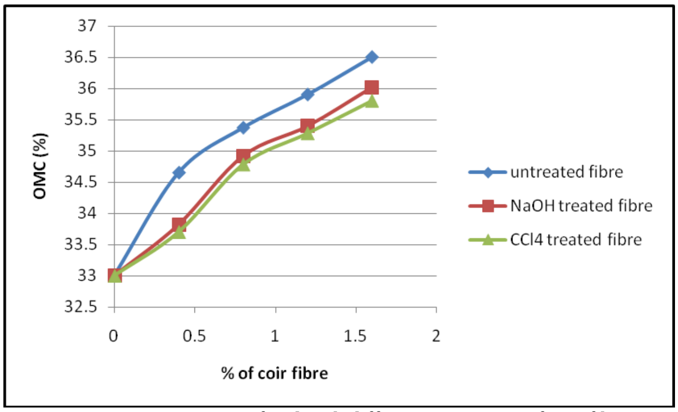

Fig.1.variation in OMC of soil with different percentage of coir fibre

The optimum moisture content of soil was 33% which increased to 34.65%, 33.82% and 33.7%, respectively when it was reinforced with 0.4% of untreated, 0.4% of NaOH treated and 0.4% of CCl_4 treated coir fibres. The optimum moisture content further increased to 36.5%, 36.02%, 35.8% respectively when the soil reinforced with 1.6% of untreated, 1.6% of NaOH treated, 1.6% of CCl_4 treated coir fibres. The optimum moisture content value constantly increase in percentage of treated and untreated coir fibres. The increase in the optimum moisture content of specimen of soil reinforced with untreated and treated coir fibre may be due to the high water absorption tendency of coir fibres. Fig 4.1 further reveals that the optimum moisture content of soil specimen reinforced with NaOH and CCl_4 treated coir fibre is marginally smaller than soil reinforced with untreated coir fibres. This is due to the treatment with sodium hydroxide and carbon tetra chloride decreases the tendency of coir fibre to absorb water.

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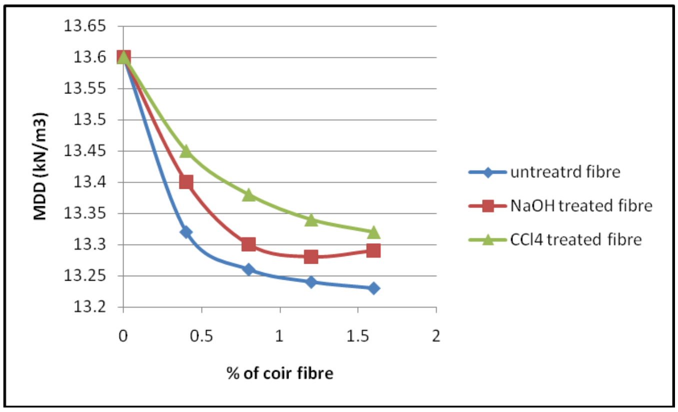

Fig 2:variation in MDD with different percentage of coir

The maximum dry density of soil was 13.6kN/m^3 which decreased to 13.32kN/m^3, 13.4kN/m^3 and 13.45kN/m^3 respectively, when it was reinforced with 0.4% of untreated, 0.4% of NaOH treated and 0.4% of CCl_4 treated coir fibre. The maximum dry density further decreased to 13.23kN/m^3, 13.29kN/m^3, 13.32kN/m^3 respectively when the soil was reinforced with 1.6% of untreated, 1.6% of NaOH treated and 1.6% of CCl4 treated coir fibres. This is mainly due to the lower value of specific gravity of coir fibre as compared to the higher value of specific gravity of soil and lighter coir fibre material replaces heavy soil mass. The maximum dry density of soil reinforced with a given percentage of treated coir fibre is higher than untreated coir fibre. This is due to the chemical treatment may useful to increase adhesion between fibres and soils. Further it should be noted from fig 4.2 that at a given fibre percentage, the maximum dry density of soil reinforced with CCl_4 treated fibre specimen is marginally higher than the respective value for the soil specimen reinforced with NaOH treated coir fibre. The reason for slight increase in maximum dry density of soil reinforced with CCl_4 treated coir fibre specimen can be provide better interaction of clay with fibre as the surface cleaning of CCl_4 treated fibres are better as compared to NaOH treated fibre.

B. UCC CHARACTREISTICS

A careful study of fig 3 reveals that the unconfined compressive strength of clay increases with increase in dry fibre content upto 1.2%. The unconfined compressive strength is 20.9kN/m^2 for pure clay increased to 38.65kN/m^2 when the clay specimen was reinforced with 0.4% of dry fibre. The unconfined compressive strength further increased to 53.5kN/m^2 when content of dry fibre was raised to 1.2%. An increase of about 2.55 times improvement with respect to unreinforced soil is seen in the unconfined compressive strength of the reinforced soil when 1.2% of untreated coir fibre were added to the soil. Further the unconfined compressive strength value decreased to 49.5kN/m^2 when fibre content reached to 1.6% this is due to addition of coir fibre leading to domination of fibre-to-fibre interaction rather than soil-to-fibre interaction. So the optimum coir fibre content is 1.2% from the view point of unconfined compressive strength.

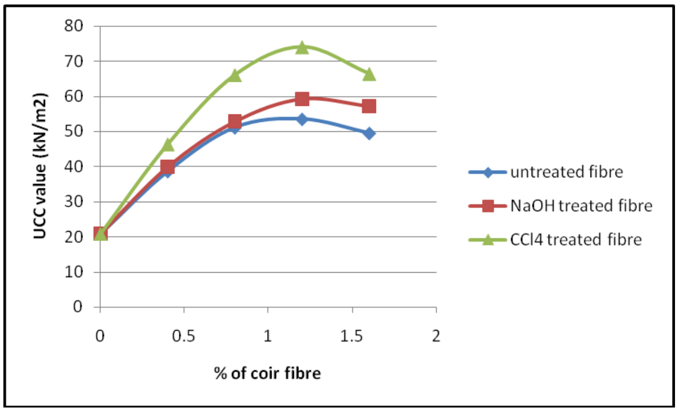

Fig 3. variation in UCC value with different percentage of coir

In the case of soil reinforced with NaOH and CCl_4 treated coir fibre shows a considerable increase in the unconfined compressive strength with increase in treated coir fibre content upto 1.2%. The unconfined compressive strength of soil reinforced with 0.4% NaOH treated fibre was 39.98kN/m^2 which increased to 59.32kN/m^2 when the fibre content was increased to 1.2% then unconfined compressive strength was decreased to 57.26kN/m^2 when the fibre content increased to 1.6%. The unconfined compressive strength of soil reinforced with 1.2% of NaOH treated coir fibre was 2.84 times that of unreinforced soil. This implies that the soil reinforced with NaOH treated coir fibre can sustain higher load at large deformation. In the case of soil reinforced with CCl_4 treated coir fibre the unconfined compressive strength is increased to 46.4kN/m^2 for 0.4% fibre and 74.11kN/m^2 for 1.2% of fibre when the content of CCl_4 treated coir fibre reached to 1.6% the unconfined compressive strength decreased to 66.5kN/m^2. A close examination of fig 4.3 further reveals that among the untreated and treated coir fibres improvement brought about by CCl_4 treated coir fibre was highest. The unconfined compressive strength of soil reinforced with 1.2% of CCl_4 treated fibre was 3.54 times that of unreinforced soil.

C. CBR CHARACTERISTICS

the CBR of clay reinforced with both treated and untreated coir fibres increases with the increase in fibre content upto 1.2%. The CBR of clay was 1.9 % which increased to 2.68 %, 3.38% and 3.81 % respectively when it was reinforced with 0.4% untreated, NaOH and CCl_4 treated coir fibres. The CBR further increased to 4.55 %, 5.12 % and 5.94 % respectively when the clay was reinforced with 1.2 % untreated, NaOH and CCl_4 treated coir fibres after that the CBR value decreases with increase in percentage of untreated and treated coir fibre. So the optimum percentage of coir fibre is 1.2%.

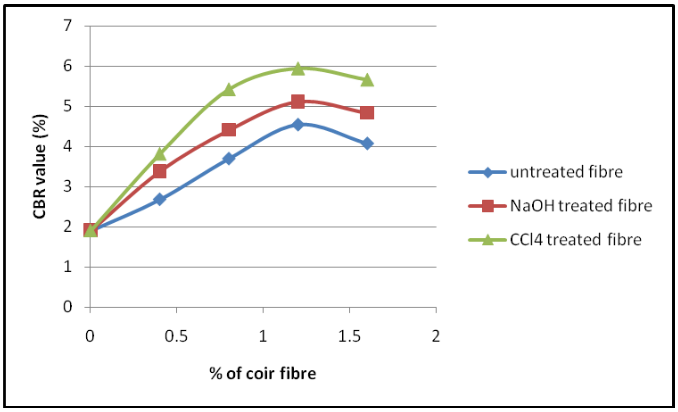

Fig 4.variation in CBR value with different percentage of coir

The increase in CBR of clay reinforced with 1.2 % untreated, NaOH and CCl_4 treated coir fibre content in comparison to unreinforced case was about 139 %, 169 % and 212 %. Further study of Fig: 4.4 reveals that the CBR of clay reinforced with NaOH and CCl_4 treated coir fibres is higher than clay reinforced with untreated fibres. This is due to the fact that treatment with sodium hydroxide and carbon tetra chloride removes the impurities present on the surface of untreated coir fibres and surface irregularities becomes quite visible. These surface irregularities help in improving the interaction between treated coir fibres and clay which results in the increase in CBR. It is further evident from Fig:4.4 that CCl_4 treated coir fibres improves the CBR of clay better in comparison to NaOH treated coir fibres. This may be perhaps due to the fact that CCl_4 is a better cleaning agent in comparison to NaOH.

VII.CONCLUSIONS

The conclusions drawdown from above studies are stated below:

- The result have been shows that the maximum dry density of soil decreases with increase in percentage of untreated and treated coir fibre. This is mainly due to the lower value of specific gravity of coir fibre as compared to the higher value of specific gravity of soil and lighter coir fibre material replaces heavy soil mass.
- The maximum dry density of soil reinforced with a given percentage of treated coir fibre is higher than untreated coir fibre. This is due to the chemical treatment may useful to increase adhesion between fibres and soils.
- The maximum dry density of soil reinforced with CCl_4 treated fibre specimen is higher than the respective value for the soil specimen reinforced with NaOH treated coir fibre. The reason for slight increase in maximum dry density of soil reinforced with CCl_4 treated coir fibre specimen can be provide better interaction of clay with fibre as the surface cleaning of CCl_4 treated fibres are better as compared to NaOH treated fibre.
- The optimum moisture content value constantly increases with increase in percentage of treated and untreated coir fibres. The increase in the optimum moisture content of specimen of soil reinforced with untreated and treated coir fibre may be due to the high water absorption tendency of coir fibres. The optimum moisture content of soil specimen reinforced with treated coir fibre is smaller than soil reinforced with untreated coir fibres. This is due to the chemical treatment decreases the tendency of coir fibre to absorb water.
- The unconfined compressive strength of soil reinforced with coir fibre can be significantly improved by treatment with NaOH and CCl_4. The increase in unconfined compressive strength highest with the treatment with CCl_4.The unconfined compressive strength soil reinforced with CCl4 treated fibre is about 3.55 times that of untreated fibre for optimum percentage of fibre. Soil reinforced with treated fibres was able to bear high strain at failure as compared to the dry fibre.
- The CBR of clay reinforced with NaOH and CCl_4 treated coir fibres is higher than clay reinforced with untreated fibres. This is due to the fact that treatment with sodium hydroxide and carbon tetra chloride removes the impurities present on the surface of untreated coir fibres and surface irregularities becomes quite visible. These surface irregularities help in improving the interaction between treated coir fibres and clay which results in the increase in CBR. CCl_4 treated coir fibres improve the CBR value of reinforced soil better than NaOH treated coir fibres.

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