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The Study of Strength and Durability Characteristics of Coir Fibre in Footing Resting on Black Cotton Soil using Ground Improvement Techniques

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I. INTRODUCTION

The stability, safety and durability of any structure depend entirely on the sub structural component called „Foundation". A good foundation is the one that distribute the load evenly on soil without subjecting to overstressing. Therefore for the safety of the construction to study the properties of the soil on which foundation is resting. Thus, Geotechnical & structural engineers must check for bearing capacity of soils duringfoundation design.

A. Foundation Types

Keeping depth as criteria the foundation are mainly classified as 2 types

- Shallow foundations
- Deep foundations

According to Terzaghi, The foundations whose depth of foundation Df , is less than widthB of foundation are referred to as Shallow foundations, whereas the foundations whose depth of foundation Df , is greater than its width B belongs to Deep foundations.

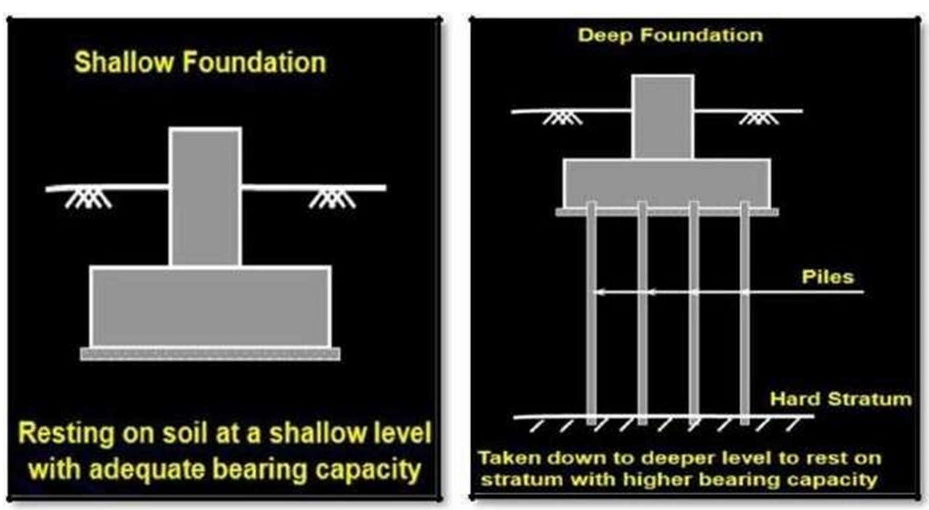

Fig 1.1: Foundation Types

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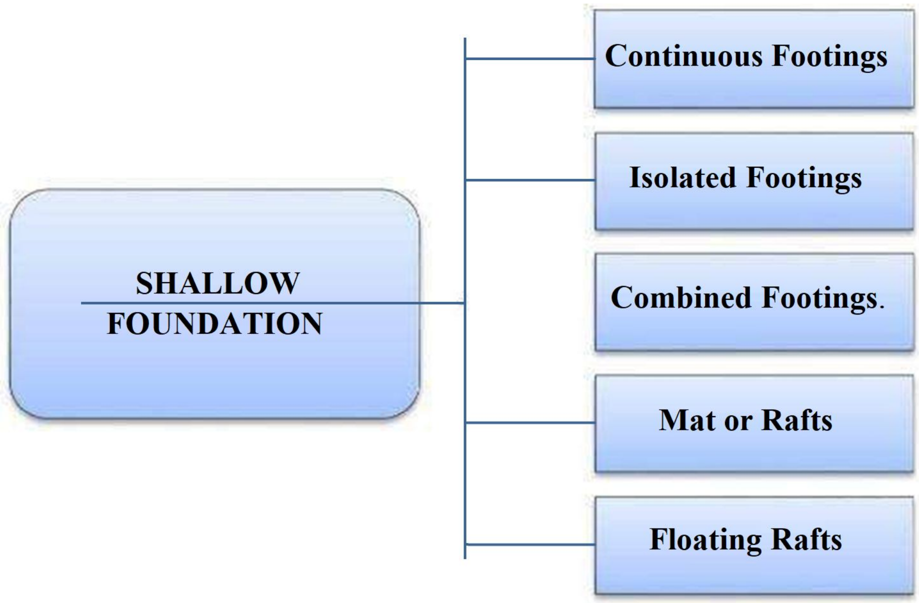
1) Shallow Foundations

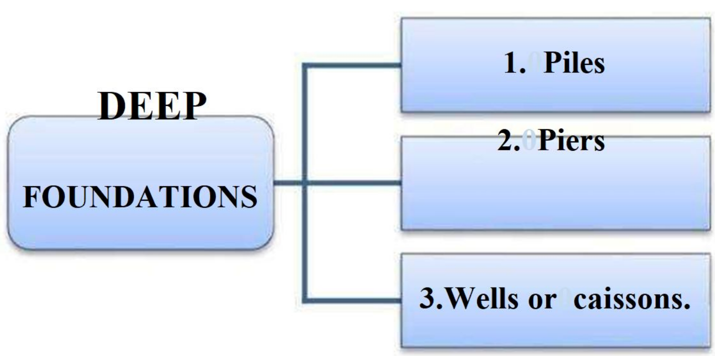
The shallow foundations are again classified into 5 types.



a) In case of Isolated or a continuous footing a pad is constructed to distribute acolumn load over a large area of soil.
b) A combined footing is a footing which takes load from two or more combinations of columns. A combined footing may be rectangular / trapezoidal in shape.
c) A raft or mat footing is preferred mainly to avoid differential settlement in the soilhaving low bearing capacity values. This footing spread the load on a concreteslab of larger area which supports number of walls andcolumns.
d) Floating rafts are constructed based on the principle of buoyancy in order toreduce the net load acting on the supporting soil by providing a hollow substructure. The depth of the hollow substructure is such that the soil weight taken away in unearthing the substructure nearly counterweighs the superstructureand substructure. These types of foundations are preferred in soils whose shear strength is very low, where other types of foundations are not effectively used.

2) Deep Foundation

The deep foundations are mainly classed under 3 groups as follows.



These deep foundations are usually preferred in case of massive structures where the super structural loads are very heavy and need to be carried to greater depths for structural stability. In places where the soil below foundation is very weak to withstand the structural load piles are preferred in order to distribute the load on hard strata or rock mass.

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B. Modes Of Bearing Capacity Failures

Several Experimental investigations stated that when a footing fails due to inadequate bearing capacity will result in the formation of 3 failure patterns as shown in figure below.

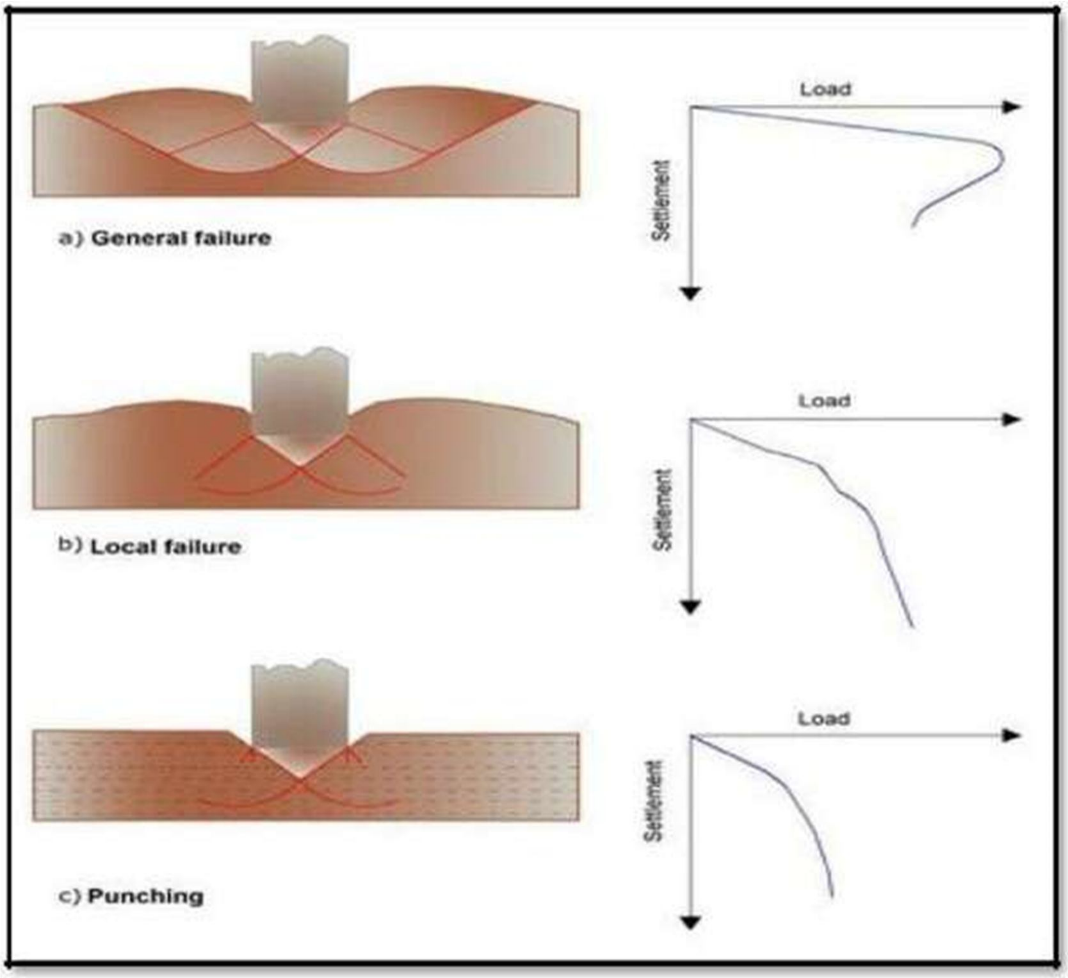

FIG 1.2: Modes Of Bearing Capacity Failures

C. Major Soil Groups Present Inindia

Indian terrain is made up of different types of soil which are listed below, there availability across different parts of India are represented in the map shown in fig 1.3.

1) Red and yellowsoil
2) Lateritessoil
3) Black cottonsoil
4) Alluvial soil
5) Saline & Alkalinesoil

a) Black Cottonsoil

It is a clayey soil most suitable for growing cotton hence they were so called as black cotton soil. Although it is good from agricultural point of view this is considered as the weakest soil from construction point of view due to its expansive characteristics. The present laboratory study mainly focuses on the design and construction of structures on this type of soil by using shallow foundations only by reducing settlements, instead of going for deep foundations.

Due to their temperature variations that is swelling and shrinking will affect the structural foundation and results in the crack formation and also in some cases the entire structure may collapse due to differential settlements.

FIG 1.3: Major Soil Groups Present In India

D. Techniques Of Ground Improvement

The process of modifying the ground soil properties in order to achieve the required desirable ground conditions for the particular use of the ground is called as Ground Improvement**.** These methods can be mainly grouped under four headings they are as follows

1) Chemical methods
2) Mechanical Methods
3) Hydraulic Methods
4) Physical Methods

The various types of ground improvement techniques which are in common use listedbelow.

a) Surface compaction
b) Pre compression and consolidation
c) Methods of vibration
d) Grouting and injection
e) Reinforced Soil Technique
f) Methods of drainage
g) Chemical stabilization
h) Other methods

E. Reinforced Soil Technique

Out of all the other techniques listed above due to easy adaptability Reinforced soil technique is considered for the present experimental work. This „soil reinforcement‟ is nothing but the introduction of any foreign material along with the soil such that the soil resists tensile stresses developed within it through friction and adhesion and consequentlyincreases its load carrying capacity.

1) Types Of Reinforcement Used In Reinforced SoilTechnique

The various types of materials used as soil reinforcements are grouped as follows

- Natural geo-synthetics
- Artificial geo-synthetics
- Steel reinforcements
- Reinforcements by waste materials

2) Natural Geo-Synthetics

The various types of natural fibers such as coir, jute, sisal, Babar, hemp, bamboo, munja and banana are available in India. In addition coir fiber is more rigid, stronger and tensile in its nature. Further to decrease its degradation properties coir fibers are chemically treated there by increasing its durability.

The production of coconut all over the world is represented graphically through pie chartin the Fig 1.4. India stands 3rd place of which about 22% of total production of world. Thecoir fibers are originated from the husk of coconut fruits.

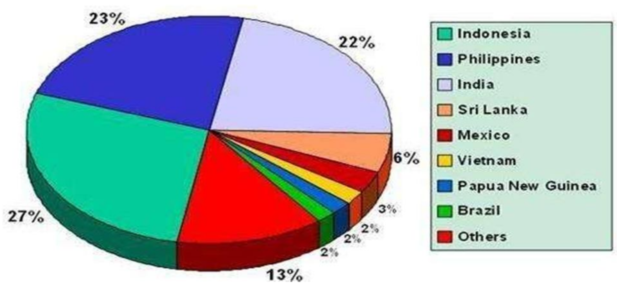

FIG 1.4: Pie Chart Showing Worldwide Coconut Production

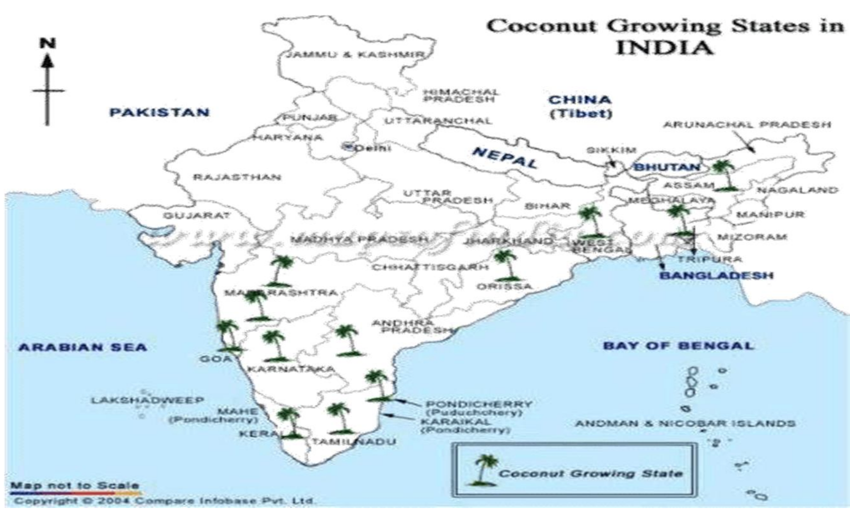

FIG 1.5: Major Coconut Growing States In India

The major states which grow coconut are represented in the map shown in fig 1.5. Historically the first coir production industry developed in Kerala and then continuing with Karnataka, Tamil Nadu, Assam, Orissa, Tripura and Andhra Pradesh etc.

Many states in India produce coir fibers but out of which less than 25% of the produced coir fibers are effectively utilized in industries and the remaining is getting wasted in the form of garbage or they dried and burnt for fuel. Therefore in order to utilize these natural waste materials effectively there is a need for investigating and developing new ideas in the field of construction industry.

F. Basic Mechanism of Reinforced Soil

This mechanism is schematically represented in the fig 1.6 where two individual soilparticles are tied together to yield Pseudo-cohesion.

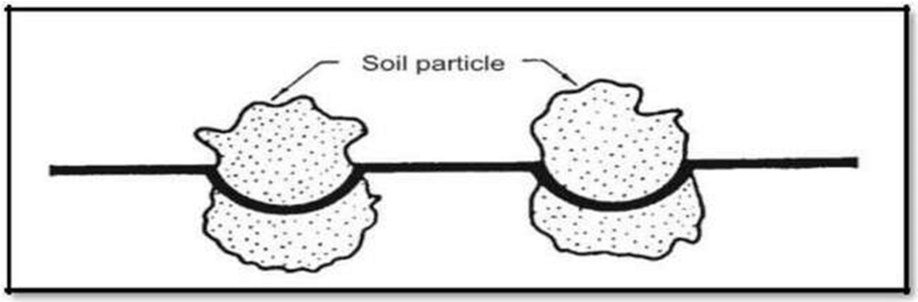

FIG 1.6: Individual Soil Particles Tied With Reinforcement

This mechanism can be explained in simpler way by using Rankine state.

1) If a 2D-element of cohesion less soil is subjected to uniaxial stress as the Mohr‘s circle of stress cut strength envelop of the soil which is shown in fig 1.7(a)
2) The element will undergo uniform compression when uniaxial stress is replaced with equal biaxial stresses, which is shown in fig 1.7(b)
3) If any one of the stresses, let's consider σ1 is increased by maintaining the other constant, a compression of the element takes place in the direction σ1& expansion takes place in the other direction σ3.
4) When lateral strains exceed critical proportions, results in failure of the element, the failure is similar to the failure of sample in triaxial compression test. At this stage σ1&σ3 are related as σ3=Kaσ1
5) At this stage, the Mohr's circle of stresses is tangential to the strength envelop.
6) In order to hold the element without failure there is a need of increasing the lateral stresses.
7) When the reinforcement is provided in 3 directions, the interaction betweenthe soil & reinforcement will generate frictional forces along the interface.
8) Additional lateral pressure developed due to the reinforcement will move the Mohr's circle towards right side which is as shown in fig 1.7 (c)

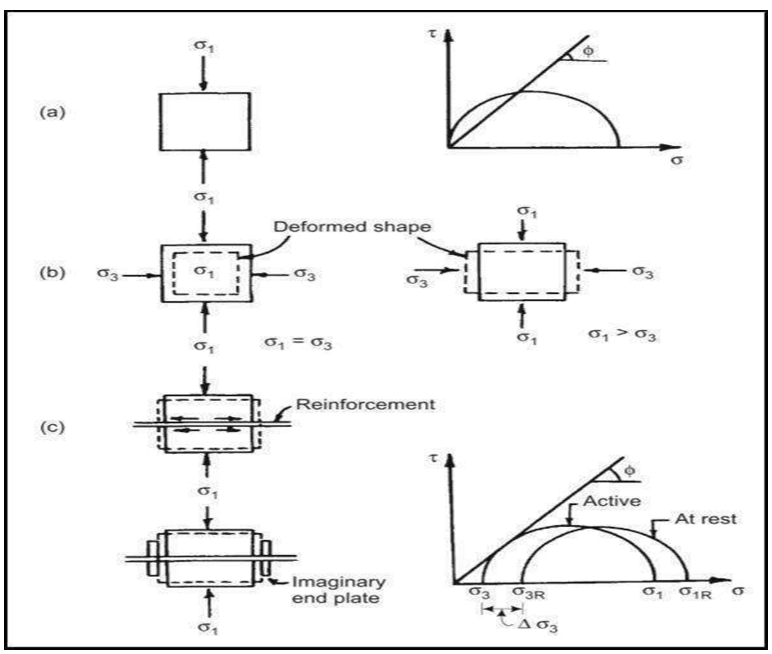

FIG 1.7: Basic Mechanism Of Reinforced Earth

G. Methods Of Placing Soil Reinforcement

There are mainly two ways in which the reinforcement is placed along with the soiltheyare

1) Layer By Layer Distribution Offibers

As the name indicates in this method the reinforcement say coir fiber is arranged in layer by layer that is they are provided in horizontal layers throughout the height of soil layer. In this method the effect of reinforcement is not uniform, so chances of development of voids and gap is more hence this method has got less importance when compared to other one.

2) Randomly Distributed Fibers (RDFS)

In this method the reinforcing element say coir fibers are distributed in a random fashion. In the present work we are incorporated RDFS method for analyzing the strengthbehavior of BC soil for different conditions.

Comparatively this method has more advantageous when compared to layer by layer distribution. The inclusion of fibers in randomly fashion has shown considerable rise in shear strength & stiffness of BC soil as the curing period passes. The concept of RDFS is new in the geotechnical field and many researches are going on to explore the hidden aspects of RDFS. The composite material so formed due to the inclusion of fibers along with the soil is also called as **Ply soil'**. In case of layer method the reinforcement is provided in specific direction which will make the soil weak in the other directionwhereas in case of ply soil the isotropy in strength is maintained uniform throughout. Thus preparation method is similar to the conventional stabilization technique. Generally the random reinforcement can be provided to various soil types in the form of discrete fibers, mesh elements, waste plastic strips continuous yarn or filament, metallic powes, waste tire chipsetc.

H. Advantages Of Fibre Reinforcedsoil

The main advantages of the randomly distributed fiber reinforced soil are as follows

1) Increased shear strength by maintaining uniform isotropy throughout.
2) Post peak strength losses are reduced.
3) It provides erosion control and facilitates the vegetation growth.
4) Increased ductility and seismic performance are obtained.
5) In case of soils of expansive behavior the swelling and shrinkage rates arereduced.
6) No appreciable changes when comes to permeability.
7) This method is not much affected due to weather conditions unlike other chemicalstabilization methods, cement, lime stabilization etc.

I. Practical Applications Of Reinforced soil

They can be effectively used in many engineering practical applications few of them arelisted below

1) In railway embankment
2) In reinforced earth dams
3) In construction of quay walls
4) In bridge abutment
5) For providing horizontal platforms in case of sloping ground
6) Used as foundation slab
7) For providing sharp differences of level between two horizontal platforms
8) In underground mining system
9) In reinforced earth arches

II. LITERATURE REVIEW

The review of various literatures referred in order to have a thorough knowledge; Implementing new ideas and point of reference with respect to present experimental investigations are as follows.

BINQUET AND LEE (1975): They have studied the strength & deformation characteristics of footings resting on reinforced sand layer. They concluded the Bearing capacity ratio (BCR), at some particular settlement, will not increase due to the increase in reinforcement proportions i.e. they are not proportional. The graphical curve of BCR &Number of layers of reinforcement almost becomes straight line after six to seven layers of reinforcement.[1]

MC GOWN et al. (1978): They outlined the differences between high & low modulus reinforcements and divided in 2 major groups as ideally inextensible& ideally extensibleinclusions. The metal strips & bars will come in inextensible whereas natural fibers, synthetic fibers, polymeric fabrics & plant roots belong to extensible category. Heimdahl& Drescher in 1999 justified that the placement of reinforcement in any particular direction will leads to development of weak planes causing anisotropy which in turn results in reduction of directional strength. [2]

YETIMOGLU T SALBAS O (2003): They performed direct shear tests to analyze the strength behaviour of reinforced sand by using RDFs technique. From the test results it is found that adding fibers won"t affect peak shear strength & initial stiffness to greater extent. [3]

HUANG GU (2009): Using NaOH solution of which the concentrations varied from 2% to 10% the brown coir fibers was treated. Then the alkali-treated fibers tensile strength was measured. The fibre tensile strength is reducing and increasing in NaOH density, so severe fibre deterioration was found in 10% NaOH solution. The composite tensile strength difference among the cases of 2%, 4%, 6% & 8% of NaOH were insignificant. This confirmed the coir fibers was found due to alkali treatment for up to a max of 8% of NaOH.[4]

MAMATHA, H.V (2010): They studied the effects of randomly distributed coir fibers &lime on the strength properties of BC soil and also the effects of bitumen coated coir fibers separately. They conducted a cycle of compaction & unconfined compressive strength testsby using different proportions of coir along with optimum lime. The UCS samples areallowed for a curing period of 180 days. From graphical representation it as showing more in strength of soil up to 30 days linearly with curing period, after 30 days of curing period the improvement in strength was found to be marginal. Through test results it is found that 4% lime & 1% coir fiber of 0.5cms length were found to be optimum resulting in the improvement of soil strength and bitumen coating is not much effective in compare with the uncoated coir as for as strength is concerned. [5]

H. N.RAMESH (2011): They investigated on the water absorption and durability conditions of Coir fibers for the effective use in reinforcement. They conducted water absorption tests for both uncoated & kerosene coated coir fibers by considering 100% submerged condition. The weights of both are taken at suitable intervals of time and they are compared with unsoaked weights of uncoat or coat.[6]

SAYYED MAHDI HEJAZI ET AL. (2011): The introduction of fibers in discrete RDFs form results in the improvement of Stiffness characteristics & strength of soil. The improvement in strength due to fiber inclusions was mainly depends on properties like aspect ratio, skin friction & modulus of elasticity. [7]

AMIN CHEGENIZADEH (2011): CBR test was conducted on a geosynthetic fiber reinforced clayey soil. During pavement design the CBR results are very essential, the reinforcing of subgrade soil of pavement leads to improves the clayey soil strength. They concluded that the uses of short RDFs in clay are practicable. [8]

M.T. PRATHAP KUMAR & R.SRIDHAR (2012): Coir fibers were used to reinforce the sand, the behaviour of mat foundation resting on this reinforced sand was investigated. Load tests were carried out by considering different lengths of fiber of coir. Through load tests it is found that the inclusions of fibers considerably increase the strength in the soil. From model footing strength &settlement aspects, the optimum depth of coir fibre reinforcement zone is found to be 0.8b below the base of the footing, where b is width of the footing. [9]

PREETI VERMA (2012): They concentrated on the durability and degradability of the natural coir fibers for the effective use in geotechnical applications. They treated the coir fibers by using different treatment methods like alkali treatment, acetylation, permanganate treatment & heat treatment to investigate the moisture absorption capacity of particular treated coir fibers and there moisture absorption characteristics were studied. Through test results it is found that chemically treated coir have successfully modified its structure & also minimized moisture absorption tendency.[10]

PARAG M. CHAPLE & A.I. DHATRAK (2012): They conducted model footing tests by considering square footing resting on highly compressible clayey soil reinforced using RDCFs to study the bearing capacity & settlement characteristics. They have considered reinforced soil layer thickness of B, 0.25B & 0.5B along with varying percentage of coir fibers such as 0.25%, 0.5%, 0.75% & 1.0%. It is observed that the BCR increases up to 1.5to 2.66 due to reinforcement. The maximum SBC is found for 0.5% fiber proportion at 25 mm depth of reinforced soil (B/4).

They suggested that the soil is affected to a significant depth of 2 to 2.5 times the width of the footing, so it is not necessary to put reinforcement for the entire depth of the soil. The provision of coir reinforcement minimizes the settlement there by improving the bearing capacity.[11]

H.P. SINGH (2013): In this study, number of tests is conducted on RDCF reinforcedsoil. The soil samples were prepared at its MDD & OMC for both conditions that is with and without RDCF. The coir fibers proportions 0.25%, 0.5%, 0.75%, 1% by dry weight of the soil were used and for each fiber content separate CBR tests were conducted for both soaked & unsoaked condition. Due to the inclusion of coir fibers the CBR value of soil increases significantly which reduces the pavement subgrade thickness substantially.[12]

Dr. M.T PRATHAP KUMAR AND JAIRAJ .C (2014): They studied the effect of limetreatment & length of coir fiber on peak deviator stress & shear parameters by conductingundrained triaxial tests on reinforced BC soil. From the test results they observed that addition of lime to BC soil results in increase in peak deviator stress. The shear parameters angle of internal friction & cohesion increases with increase in coir fiber lengths up to 20mm above which causes marginal reduction in shear parameters causing mixing difficulty.[13]

GODAVARTHI VENKATA RAMASUBBARAO (2014): Kerosene coated Coir fibers are used as reinforcement along with the expansive soil in the present case. 5mm long kerosene coated coir fibers in various proportions of 0%, 0.5%, 1%, and 1.5% are distributed randomly along with the soil. Water absorption tests, and Standard Proctortests study the strength behaviour of coir fibers and soil. Both uncoated& kerosene coated fibers are tested to check water absorption capacity. The result shows that there is a considerable reducing the water absorption of kerosene coated coir fiber with that of uncoated coir. Out of all proportions 1% of coated coir fiber is found to be the optimum coir content from UCC strength point of view. The Split tensile strength of reinforced soil using 1% coated fiber was found to be increased by 50% that of the unreinforced soil. [14]

PRIYANKA GOYAL et al. (2015): Coconut coir fibers were used to minimize the swelling behaviour of black cotton soil. They conducted the unconfined compressive strength and swelling tests on BC soil with inclusion of 2% fiber content. The results shows that there is a significant increase in shrinkage limit, compressive strength & optimum moisture content due to blending of 2% coir fibers along with the BC soil. [15]

STUTI MAURYA, Dr. A.K.SHARMA et al. (2015): They concluded that the coir fiber can used as effective reinforcing material which improves strength & stiffness of soil. The coir fibers with different length & proportions affect the soil properties; there is a need of further research on degradation of coir fibers.[16]

III. MAIN OBJECTIVES AND SCOPE

A. Main Objectives of Present Investigation

The prime objectives of the current experimental work are as follows

1) To study the basic properties of the BC soil and basic properties of coir fiber.
2) To reducing construction cost by using naturally available coir fibers andindustrial waste products.
3) For to find the strength of BCS is reinforcing to TCF resting on loose stratumthrough different size of model footings i.e. 0.05 m& 0.025 m.
4) A comparative study on BC soil reinforced with TCF& unreinforced BC soil byconsidering static load conditions.
5) Influence of various criteria like width of model footings, depth of fiber reinforcedBC soil layers and settlement characteristics.

B. Scope Ofwork

1) A standard chemical treatment procedure to make coir fiber water repellent to decrease its biodegradability.
2) Effective usage of many industrial wastes as fiber reinforcement along with soil.
3) Behavior of compaction characteristics of BC soil along with TCF reinforcement
4) The work can also be further experimented by blending with TCF for different proportions for different densities and trying with new chemicals or materialswhich makes coir fiber more water repellent.

IV. TREATMENT OF COIR FIBRE

The primary purpose of this modification of coir fibers by the treatment is to minimize itswater absorption properties & to make it as a water proof material. Many researchershave been attempted and developed various methods for the treatment of fiber of coir & the yare

- Chemical treatment
- Graftco-polymerization
- Coating polymeric solutions

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Out of above the chemical treatment was performed in the current study**.** The most commonly used methods for treating natural fibers by chemical means are as follows.

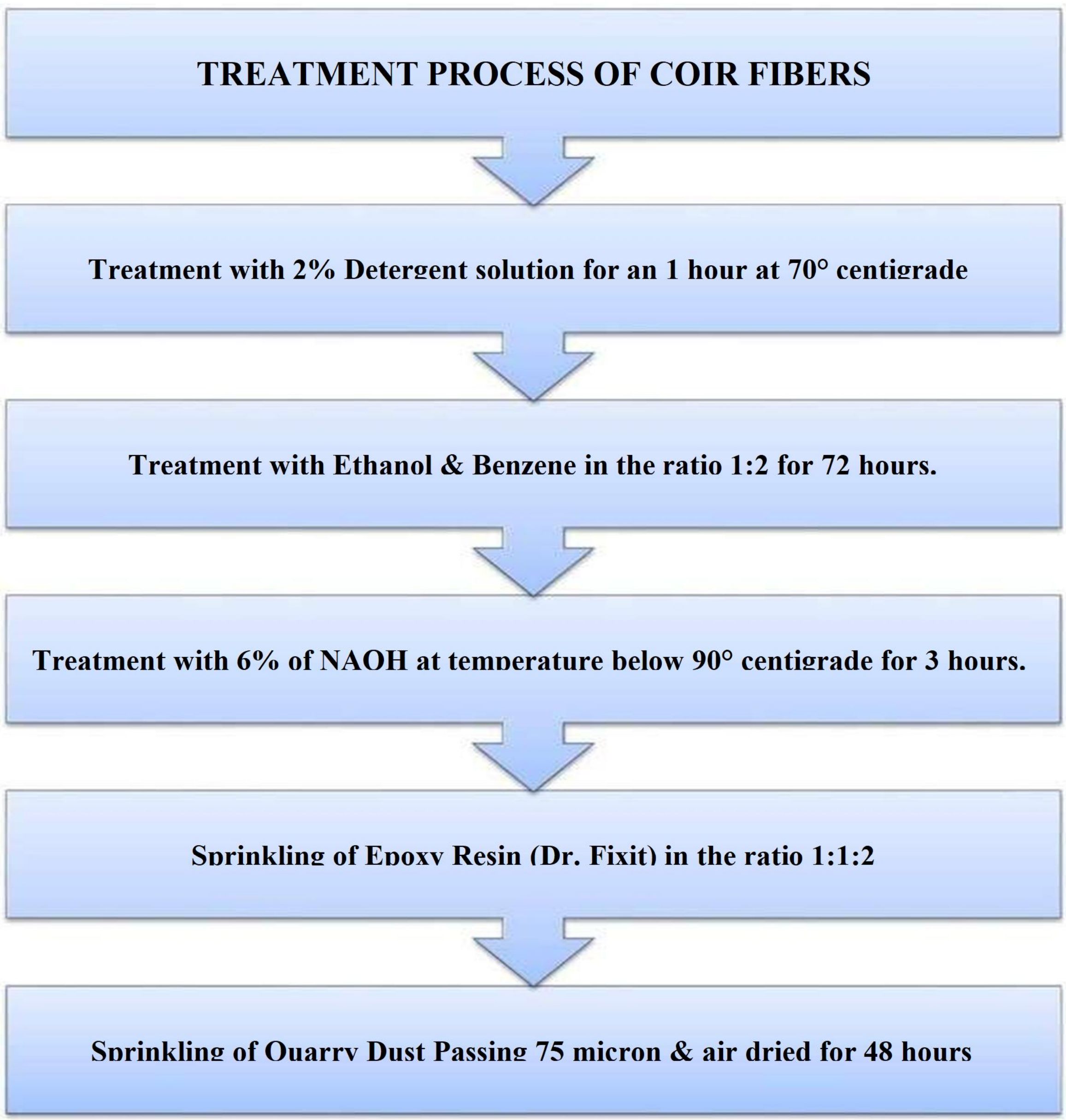
- Alkali treatment
- Acetylated treatment
- Heat treatment
- Permanganate treatment

A. Alkali Treatment

The Alkali treatment also called as mercerization is one of the best suited chemical treatment method for treating natural fibers. In this process partially amorphous constituents such as lignin, hemicellulose, waxes, & oils soluble in alkaline solution are eliminated & therefore it reduces the level of fiber aggregation, making the surface materialrougher.

Many investigators are experimented and studied the moisture absorption of surface TCF& they were found that there is a reduction of about 30% of water absorption by TCF. Hence in the present work alkali treatment was used.

The step by step procedure used in the present chemical treatment of Coir Fiber isrepresented in the form of flow chart as below.



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B. Chemical Treatment Pocedure For Coirfiber

The detailed procedure for treating coir fibers along with diagrams are explained in various steps as follows. Initially before starting the treatment process the coir fibersare cut in to required length ranging from 1cm to 2 cm. The fig.4.1 shows the coir fibers before subjected to treatment.

FIG 4.1: Coir Fibers Before Treatment

1) *Step 1:* The Coir Fibers which are cut to required length are then scoured with hot Detergent solution of 2% for about 1 hour at 70° centigrade. Once the coir fibers are properly scoured with detergent solution they are thoroughly washed with a Distilled Water and it allowing for air dry about 24 hours. The process is shown in fig 4.2.

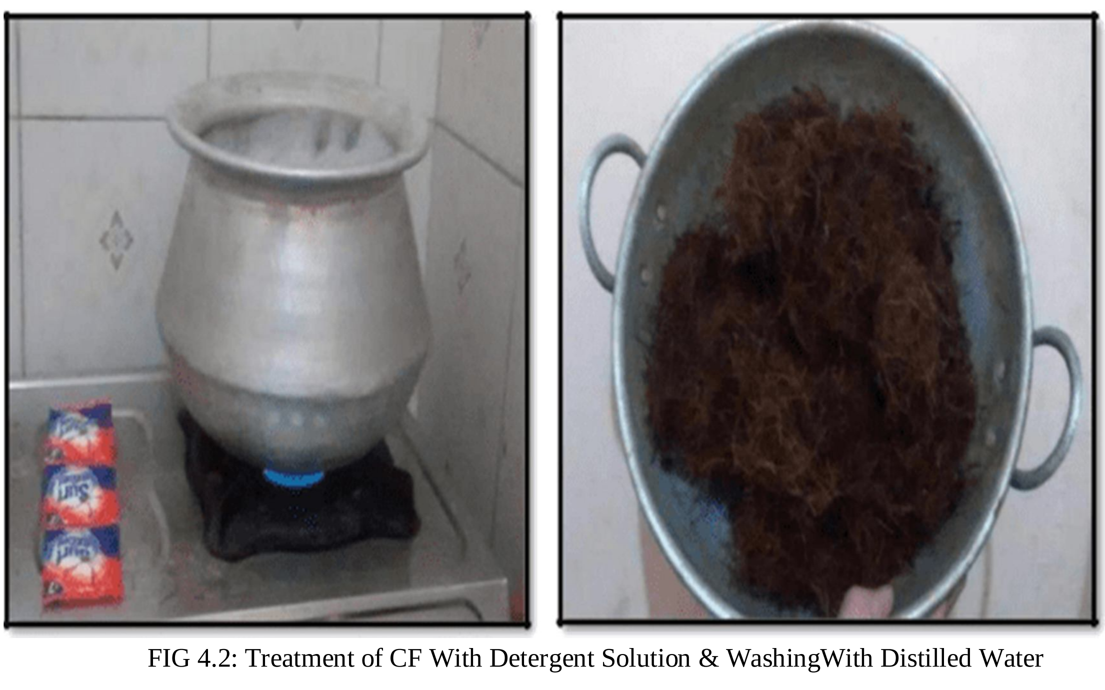

FIG 4.2: Treatment of CF With Detergent Solution & WashingWith Distilled Water

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2) *Step 2:* The air dried Coir Fibers are then immersed in an air tight box containing a mixture of Ethanol & Benzene in the ratio 1:2 for a period of about 72 hours After completing the required immersion period coir fibers are taken out followed by thorough washing using distilled water & allowed for air dry for about 24 hours. The process is shown below in fig 4.3.

FIG 4.3: Immersion in Ethanol: Benzene (1:2)

3) *Step 3:* The de-waxed Coir Fibers so obtained are treated with 6% of NAOH by maintaining the temperature below 90° centigrade by using thermometer for about 3hours. After 3 hrs, take out the fibers followed by thorough water wash for several times and allowing the fibers for 24 hours air dry. This entire process is represented in fig 4.4& 4.5 respectively.

FIG 4.4: Treatment Of Detergent Scoured Cf Using NaohSolution

FIG 4.5: Drying After Washing With Distilled Water

4) *Step 4:* The NAOH treated air dried fibers are then sprayed with water based Epoxy Resin which is available as Dampguard [104] manufactured by Dr. Fixit. The Dampguard consists of two components Base and Hardener which is shown in fig 4.6 these components are mixed thoroughly of the ratio 0.5:0.5:1 & sprayed over the CoirFiber.

FIG 4.6: Epoxy Resin (DR. Fixit) Coating on Coir Fibers

5) *Step 5:* As soon as the fibers are sprayed with water based epoxy resin, the Quarry Dust Passing through 75µ is sprinkled immediately over the coir fibers and allowed for air dry for about 48 hours before they are used as soil reinforcement.

FIG 4.7: Quarry Dust Passing -75µ used IN Present Work

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The finally obtained treated coir fibers after all the process which are used in the present laboratory investigation as reinforcement for analyzing the strength characteristics of BC soil for different footing sizes are shown in fig 4.8

Fig 4.8: Final Treated Coir Fiber Obtained After AllTreatment

V. MATERIALS AND METHODOLOGY

A. Introduction

In this research work Black cotton soil were taken as a problematic soil. Whereas sawdust is used as a loose stratum.

B. Materials Used

1) Black Cottonsoil

The soil used in this project has been obtained from Challakere Taluk Chithradurgadistrict Karnataka state, from a depth of 1.5 meter below natural ground level.

FIG 5.1: BC Soil Shrinkage Cracks after testing

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Basic Properties	Values
Water Content (%)	29.84
L.L (%)	80
P.L (%)	32
P.I (%)	48
Specific Gravity (G)	2.67
O M C (%)	30.70
M D D (gm./cc)	1.413
Silt & Clay (%)	81.43
Sand (%)	18.57

TABLE5.1: Basic test Results of BC Soil

2) Treated Coir Fiber

In the present experimental study naturally occurring coir fibers are cut into a length varying from 2cm to 3 cm and then they which chemically treated in more proofing water & develop more stiff in its layer. The TCF were used as an effective natural geo-synthetic reinforcing material along with the BCS.

The Coirs are used in the present research work were collected from coir board THIPPTUR Karnataka state. The chemical composition and various physical andmechanical properties of coir are mentioned in tables 5.2, 5.3&5.4 respectively. Fig 5.2 shows typical CF before treatment & after treatment.

FIG 5.2: COIR Fibers Before Treatment And After Treatment

Coir Fibre Properties

Young's modulus	4000-5000 Mpa
Tensile strength	140-150 Mpa
Elongation index	15-17.3 %

TABLE 5.2: Mechanical Properties

Thermal conductivity	0.0470 - 0.0476 W/m k
Density	1.15-1.33 kg/m^3
Water absorption	0-10%

TABLE 5.3: Physical Properties

Total water soluble	26.00 %
Pectin etc. soluble in boiling water	14.25 %
Hemi-celluloses	8.51 %
Lignin	29.23 %
Cellulose	23.81 %

Table 5.4: Chemical Composition

3) Brick Waste

The brick waste is in this present experimental project is taken from a saw mill at Yelahanka in Bangalore. For the safer design of any foundation it is very necessary to consider safety factor against worst possible conditions.

FIG 5.3: Brick Waste

C. Methodology

1) Determination Of Index Properties

This section explains the important laboratory tests performed as per Indian Standards forthe determination of Index properties of soil.

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a) Water Content Test

Oven drying method is used in the present work for the determination of water content According to **IS: 2720 – Part 2- 1973.**

b) Specific Gravity Test

The specific gravity of the BC soil is determined by using 50ml density bottle which is shown below. Kerosene is used in the present work for the proper removal of air voids to ge accurate results.

FIG 5.4: 50 ML Density Bottle ALONG With LID

Atterberg (1911) proposed a series of tests for deciding consistency and plasticproperties in soil.

c) Liquid Limit test

The test is conducted according to IS: 2720, Part 5, 1985. The Casagrande apparatus used isas shown below.

FIG 5.5: Liquid Limit Apparatus

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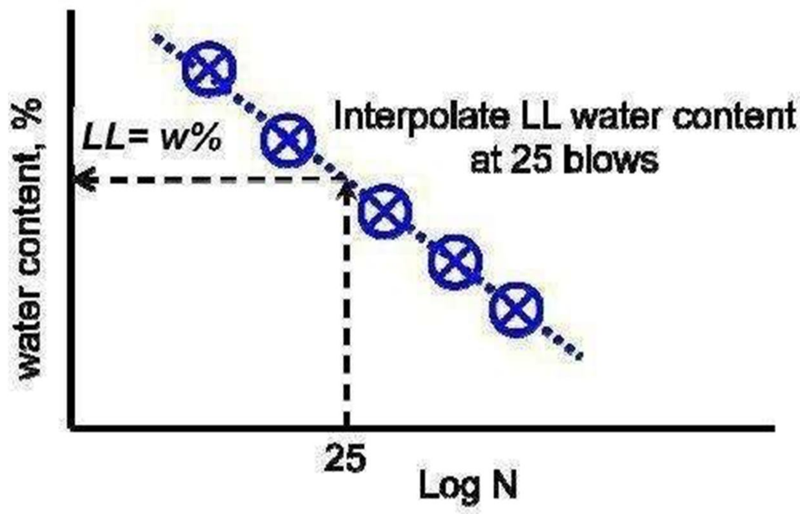

d) Plastic Limittest

This test is to study the difference in moisture content giving the plasticity index. Thetest is conducted according to IS: 2720, Part 5, 1985.

FIG 5.6: Plastic Limit Test

e) Grain Size Analysisis

Grain size analysis is conducted as per IS: 2720 Part 4 – 1985. Using mechanical sieve shaker the test is conducted for duration of about 10 minutes. The soil passed weight is determine using weighing machine and it tabulate in respective tabular column and represent the distribution curves and find the various percentages of particles present in sample.

f) Hydrometer Analysis

The test is conducted according to IS: 2720, Part 4, 1985.Initially a blank solution is prepared using Sodium hexametaphosphate & Sodium carbonate. Around 50g of soil passing through 75µ is taken and mixed thoroughly along with distilled water and 100 ml blank solution using mixer as shown below. The suspended soil particles settles graduallyalong with time, Hence the hydrometer reading is noted at suitable time intervals. By applying suitable corrections the particle size & percentage finer is determined and they are represented graphically to determine the percentage of clay & silt.

FIG 5.7: Initial Preparation During Hydrometeranalysis

FIG 5.8: Final Stage Of Hydrometer Analysis After 24hrs.

2) Determination Of Compaction Properties

Compaction is the process of densification of soil mass by removing air voids by mechanical means. The density of a soil depends on its moisture content. An "Optimum Moisture Content" exists at which soil is having maximum density. The soil can be densified by removing air voids. During this compaction test only air content reduces not the water content. If the compaction density obtained is of greater value generally implies that the soil is stiff, strong &durable.

The process of consolidation & compaction are different even though consolidation isalso a densification process it is due to static load acting over long duration. The degree of compaction and the soil is measured in terms of drydensity.

The degree of compaction is mainly governed by its water content, compactive effort& soil type. In the current investigation, light compaction test was performed in accordance with IS: 2720 (PART 7) – 1980 using following apparatus.

a) Cylindrical mould of capacity1000 cc with an internal ϕ of 100 mm & height 127.3 mm.
b) The mould is fitted with a detachable base plate & removable collar or expansionof about 60 mm high.
c) For light compaction, a metal rammer having 50 mm dia & weight of 2.6kg isused which is set to a height of face310mm.
d) Steel straight edge having beveled edge for trimming top of the specimen.
e) Other accessories include moisture containers, balances of capacity 10 kg and200g oven, sieves & mixing tools.

FIG 5.9: Compaction Test

Procedure

a) The mould along with base plate is weighed. Soil & water is mixed uniformly andgrouped as 8 equalparts.

b) To the compaction test the mixed soil in 3 equal layers by the rammer of mass 2.6 kg & height of 310 mm with a 25blows.

c) After compacting remove the collar of the mould and cut the outer soil and ejecting outside. Care should be taken while removing the collar by twist and turn it is removed such that the soil is leveled exactly to the surface.

d) Clean properly the outside & base of the mould later weigh the mould along with its baseplate.

e) After noting the weight take out the representative soil in small quantity from top, middle & bottom portions to check water content.

f) The moisture content containers along with soil samples are weighed and afterwards it is kept in oven for about 24 hrs by maintaining a temperature rangingfrom 105^0 to 110^0C.

g) From results a graph of water content versus dry density is drawn to find out MDD &OMC.

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3) Determination Of Density Of Sawdust

In the present work the approximate value of density of saw dust was determined byusing soil raining technique. The procedure is as follows

a) Weigh the empty weight of the cup and note down asW1.
b) The cup was then filled by using saw dust and weighed again. While filling, the saw dust should be poured to the cup from a constant height and filled at the constant rate in order to achieve uniform filling, finally the surface is leveled and weighed it asW2.
c) The weight of saw dust filling the cup can be found i.e. WS=W2-W1
d) The volume of the cup filling the saw dust was determined by filling the water andmeasuring it asVC.
e) The density of the saw dust was determined by using the formula γ =WS/VC
f) 0.639g/cc is the density of the soil isestimated.

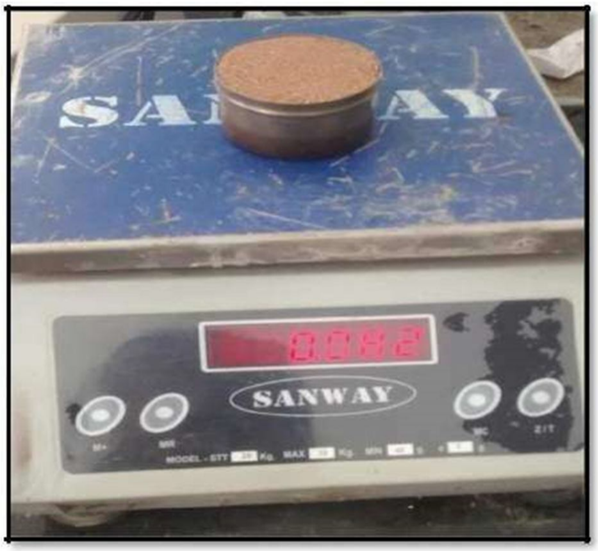

FIG 5.10: Determination Of Saw Dustdensity By Soil RainingTechnique

4) Model Footingtest

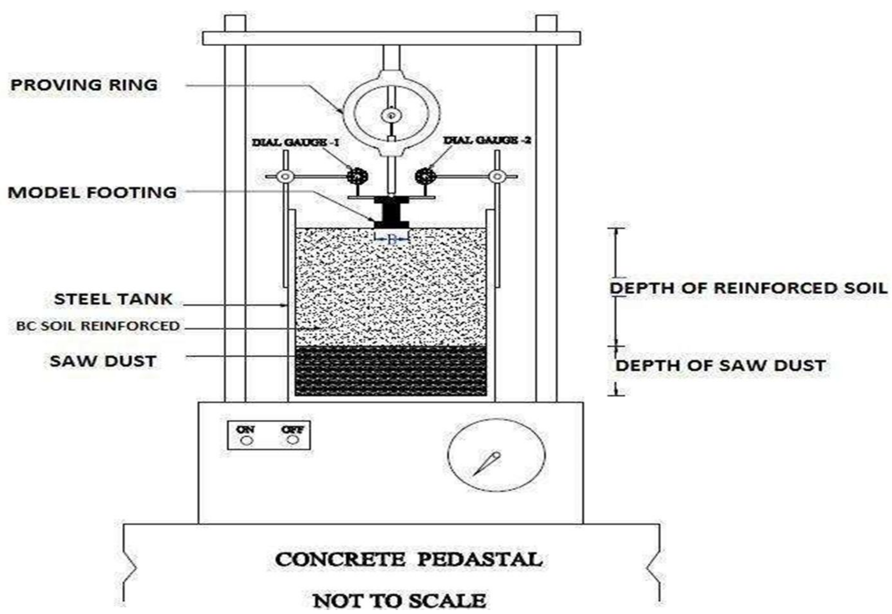

FIG 5.11: Typical Model Footing Test Arrangement

a) A square steel tank of size 300mm X 300mm and height of 380mm is used in thepresent work.
b) In order to avoid boundary effects the side walls of the steel tank was madesmooth by the application of lubricating gel.
c) Initially the saw dust is poured in to the steel tank in such a way that the density found through soil raining technique i.e. 0.64 g/cc is maintained and it is kept constant throughout the experiment.
d) The reinforced or unreinforced BC soil is compacted to required thickness using OMC and MDD. The soil layer so prepared is then placed over the saw dust insidethe steel tank.

FIG 5.12: Bottom Saw Dust Layer Acting As Loose Soil Stratum

FIG 5.13: Steel Mould & Tamper Used For Preparing Bc SoilLayer

FIG 5.14: BC Soil Layer Compacted for PRE Determined Depth

Fig 5.15: Placing Of Compacted BC Soil Layer Over Saw Dust

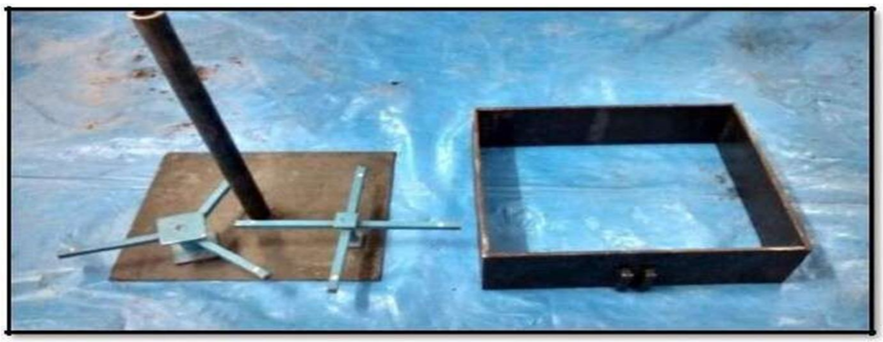

FIG 5.16: Different Sizes Of Model Footings Used

FIG 5.17: Model Footing Test Apparatus

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VI. RESULTS AND DISCUSSIONS

A. Introduction

One of the real difficulties for Geotechnical Engineers is in the construction of any structures on exceptionally risky soils, for example, BC soil and in the soil having loose stratum. Because of excessive settlement or compression of such soils will result in the failure of the structure as a whole. Therefore it is very essential to take precautions duringthe design and construction stage itself in order to avoid any future damage to thebuilding foundation. The following precautions or alternatives are recommended for the construction on black cotton soil.

1) For distributing load over large area & to avoid differential settlements in case ofrelatively important structures mat or raft foundation is provided.
2) For heavy structural loads pile foundation is preferred to transfer loads to thegreater depth until the hard soil or rock bed is available to take loads safely.
3) If the depth of loose soil stratum present is less, it is removed totally andsupplanting the hard soil.

At the point when the structure covers a littler zone, the last alternative may turn out to beefficient and practicable when contrasted with other three.

a) Surface treating coir fibers are using to reinforcement in BC soil layer, to investigate the beneficial effects and practical feasibility.
b) The OMC & MDD was determined separately for both BCS only and BCS along 0.5% TCF by conducting light compaction test.
c) The experiments were carried out on model footings resting upon compacted BC soil beds under laid by loose stratum and they are subjected to static loading.
d) Two different widths of model footings (0.05m, 0.025m), is used for different depths of reinforcing layers ranging from 0.2B to 2B and the readings are tabulated separately
e) With respect to literature studies, the optimum percentage of coir fiber to be used as reinforcements was found to be 0.5% and optimum length of fibers was 10 to 20mm same standards are implemented in the current study.
f) The saw dust is compacted to the predetermined density also the BC soil layer is compacted to the predetermined depths ranging from 0.2B to 2B using OMC and MDD which was found before.
g) The Load vs. Settlement curves was plotted and the BCR is determined. The graphical results are represented and discussed in this section.

B. Results Of Compaction Test

The test of compaction is carried by separately for BCS only and BCS along 0.5% TCF. The moisture content and density determined for each trial. Graphical representation was corresponding to dry density v/s water content in order to determine the maximum dry density in g/cc & optimum moisture content in percentage. Figure 6.1 shows typical compaction curves found for BCS along 0.5 % TCF and BC soil alone. From this test gives maximum dry density & optimum moisture content were plotted. The Maximum MDD & minimum OMC have been obtained for the BC soil along with 0.5% randomly distributed treated coir fibers. As shown in table6.1

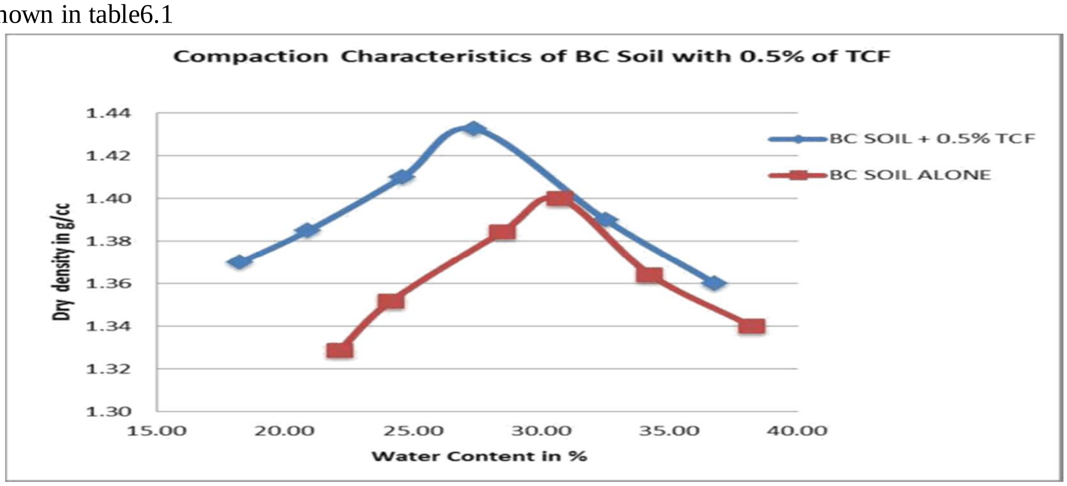

FIG 6.1: Graphical Representation Of Compaction Curves

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From Compaction curves it is found that the Treated coir fiber reinforced soil have greater value of MDD with Minimum OMC when compared to unreinforced BC soil.

MIX DESIGNATION	MDD(g/cc)	OMC(%)
BC SOIL WITHOUT TCF		
BCS	1.40	30.70
BC SOIL WITH TCF		
0.5%TCF + BCS	1.43	27.39

Table 6.1 Compaction Characterstics of BC Soil With & WithoutTCF

C. Model Footing Test Results

1) Load V/S Settlment Characteristics OffootingSize 0.05 M For Different D/Bratios

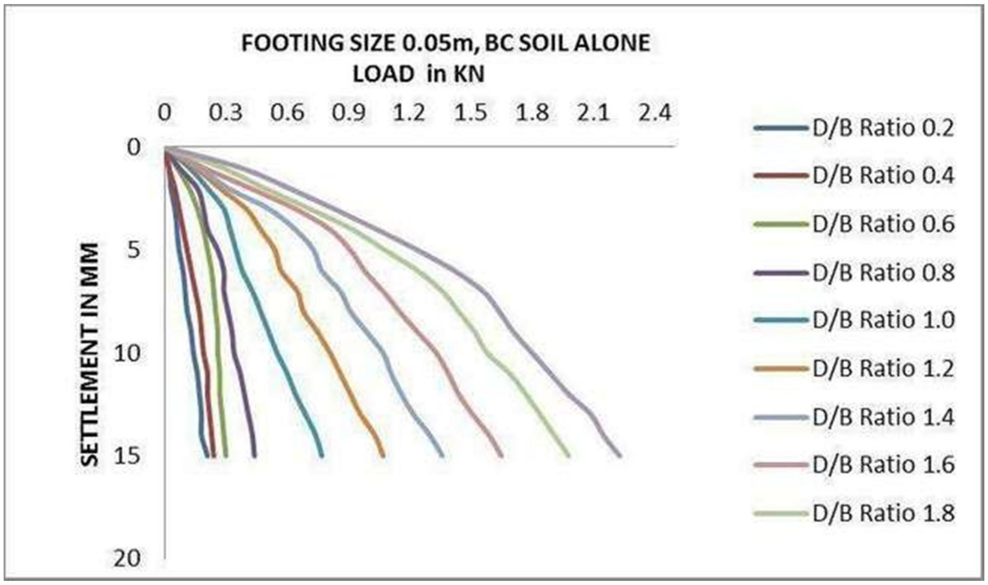

FIG 6.2: LOAD-SETTLEMENT FOR FOOTING SIZE 0.05M FOR ALL D/BRATIOS FOR UNREINFORCED SOIL

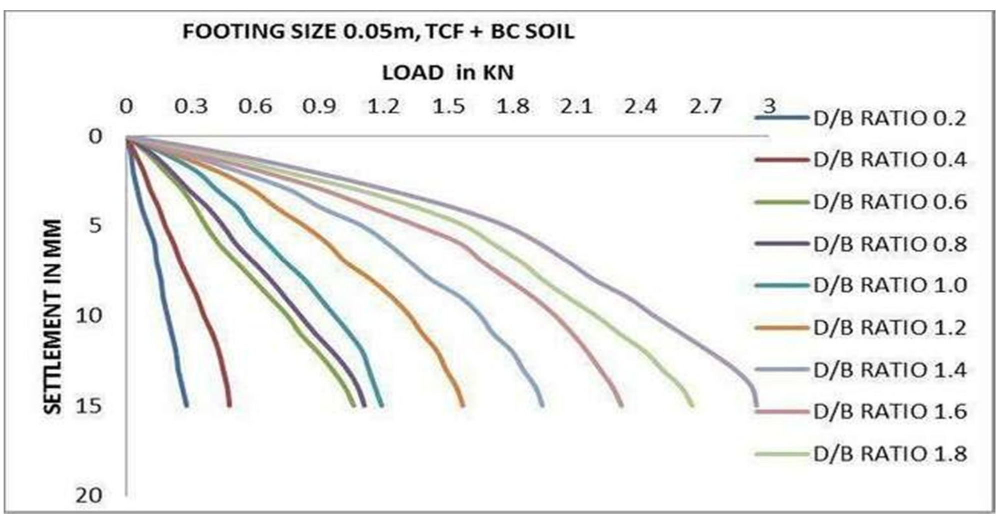

FIG 6.3: LOAD-SETTLEMENT FOR FOOTING SIZE 0.05M FOR ALL D/B RATIOSFOR TREATED COIR FIBER REINFORCED SOIL

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The graphs 6.2 & 6.3 represents Load vs. Settlement characteristic curves of 0.05 m size model footing for all D/B ratios which is resting on both the conditions reinforced as well as unreinforced. The results outlined from curves are tabulated below.

Footing size in m	Settlement in mm	Load in KN	Load in KN	Value of BCR
0.05		BCS withTCF	BCS Only	
D/B=0.2	05	0.09	0.07	01.43
	10	0.19	0.14	1.36
	15	0.28	0.21	1.33
D/B=0.4	5	0.18	0.11	1.64
	10	0.36	0.19	1.89
	15	0.48	0.24	2.00
D/B=0.6	5	0.37	0.21	1.76
	10	0.75	0.26	2.88
	15	1.06	0.3	3.53
D/B=0.8	5	0.45	0.26	1.73
	10	0.81	0.34	2.38
	15	1.11	0.44	2.52
D/B=1	5	0.58	0.35	1.66
	10	0.97	0.55	1.76
	15	1.19	0.77	1.55
D/B=1.2	5	0.83	0.54	1.54
	10	1.32	0.81	1.63
	15	1.57	1.07	1.47
D/B=1.4	5	1.1	0.73	1.51
	10	1.65	1.07	1.54
	15	1.94	1.36	1.43
D/B=1.6	5	1.36	0.91	1.49
	10	2	1.33	1.50
	15	2.31	1.65	1.40
D/B=1.8	5	1.58	1.08	1.46
	10	2.19	1.58	1.39
	15	2.64	1.98	1.33
D/B=2	5	1.77	1.24	1.43
	10	2.46	1.8	1.37
	15	2.94	2.23	1.32

Table 6.2: Load and Value Of BCR OF An Footing Size 0.05m

The table results 6.2 shows that the load carried by treated coir fiber reinforced soil layer is higher than unreinforced soil for all 5mm, 10mm and for 15mm settlements of model footing of 0.05 m size.

2) Load V/S Settlment Characteristics OffootingSize 0.025 M For Different D/Bratios

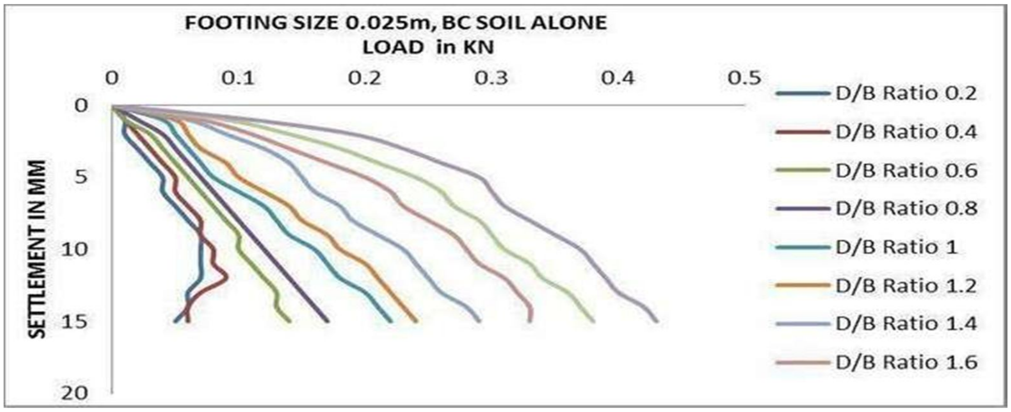

Fig 6.4: Load-Settlement For Footing Size 0.025m For All D/BRatios For Unreinforced Soil

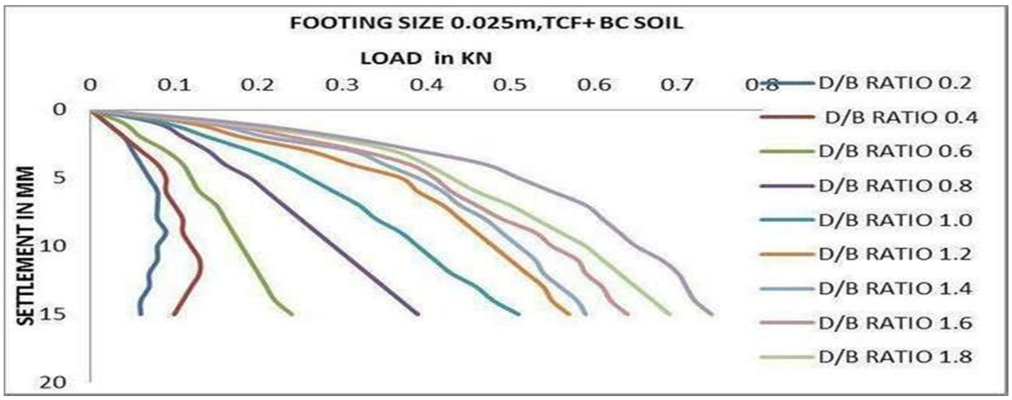

FIG 6.5: Load-Settlement for Footing Size 0.025M for ALL D/B Ratiosfor Treated COIR Fiber Reinforced Soil

The graphs 6.4 & 6.5 represents Load vs. Settlement characteristic curves of 0.025 m sizemodel footing for all D/B ratios which is resting on both the conditions reinforced as wellas unreinforced. The results outlined from curves are tabulated below.

Footing size in m	Settlement in mm	Load in KN	Load in KN	Value of BCR
0.025		BCS with TCF	BCS ONLY	
D/B=0.2	05	0.06	0.05	1.73
	10	0.08	0.07	1.14
	15	0.06	0.05	1.20
D/B=0.4	5	0.09	0.05	1.80
	10	0.12	0.08	1.50
	15	0.1	0.06	1.67
D/B=0.6	5	0.12	0.06	2.00
	10	0.18	0.1	1.80
	15	0.24	0.14	1.71
D/B=0.8	5	0.19	0.07	2.71
	10	0.29	0.12	2.42
	15	0.39	0.17	2.29
	5	0.26	0.08	3.25

D/B=1	10	0.39	0.16	2.44
	15	0.51	0.22	2.32
D/B=1.2	5	0.37	0.1	3.70
	10	0.48	0.18	2.67
	15	0.57	0.24	2.38
D/B=1.4	5	0.39	0.15	2.60
	10	0.51	0.23	2.22
	15	0.59	0.29	2.03
D/B=1.6	5	0.41	0.2	2.05
	10	0.55	0.28	1.96
	15	0.64	0.33	1.94
D/B=1.8	5	0.43	0.24	1.79
	10	0.59	0.31	1.90
	15	0.69	0.38	1.82
D/B=2	5	0.51	0.29	1.76
	10	0.65	0.37	1.76
	15	0.74	0.43	1.72

TABLE 6.3: Load And Value of BCR Of An Footing Size 0.025M

The table results 6.3 shows that the load carried by treated coir fiber reinforced soil layer is higher than unreinforced soil for all 5mm, 10mm and for 15mm settlements of model footing of 0.025 m size.

3) Bearing Pressure V/S D/B Ratio CharacteristicsAt Various settlements

The Bearing Pressure is nothing but the ratio of load to particular footing area. The variation of both footing sizes for reinforced as well as unreinforced soil layers for all D/B ratios are represented in tables 6.4, 6.5 & 6.6 & respective graphs are shown in fig 6.6, 6.7 & 6.8 for various levels ofsettlements.

D/B RATIO	Bearing Pressure Value (KN/m^2)		BearingPressureValue(KN/m^2)	
	BCS with TCF		BCS only	
	Footings in m		Footings in m	
	0.025	0.05	0.025	0.05
0.2	112	40	64	28
0.4	144	72	80	44
0.6	192	148	96	84
0.8	304	180	112	104
1	416	232	128	140
1.2	592	332	160	216
1.4	624	440	240	292
1.6	656	544	320	364
1.8	688	632	384	432
2	816	708	464	496

TABLE 6.4: Bearing Pressure Values for 5mm Settlement

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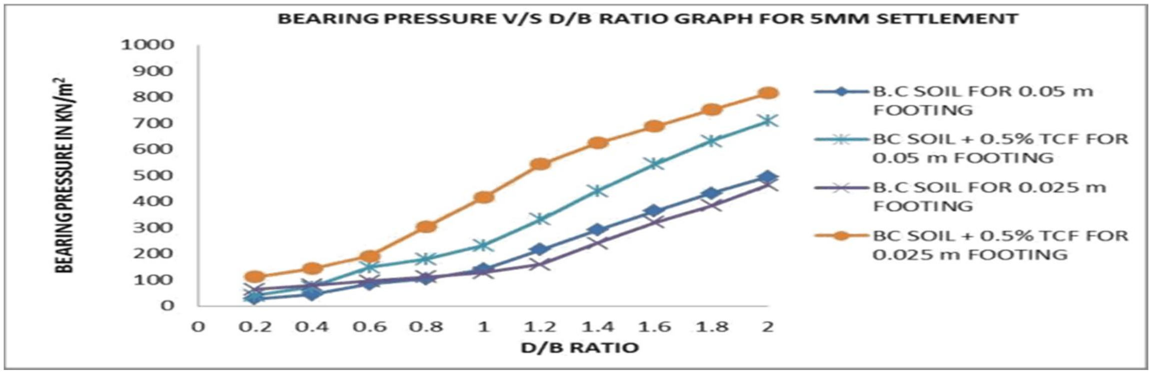

FIG 6.6: Bearing Pressure Values For 5mmsettlement

D/B RATIO	Bearing Pressure Value(KN/m^2)		Bearing Pressure Value(KN/m^2)	
	BCS with TCF		BCS only	
	Footings in m		Footings in m	
	0.025	0.05	0.025	0.05
0.2	126	75	110	54
0.4	193	147	127	78
0.6	286	299	163	102
0.8	465	326	191	138
1	627	387	255	221
1.2	766	529	289	323
1.4	817	659	370	427
1.6	881	799	445	529
1.8	943	877	497	631
2	1042	983	591	717

TABLE6.5: Bearing Pressure Values For 10mmsettlement

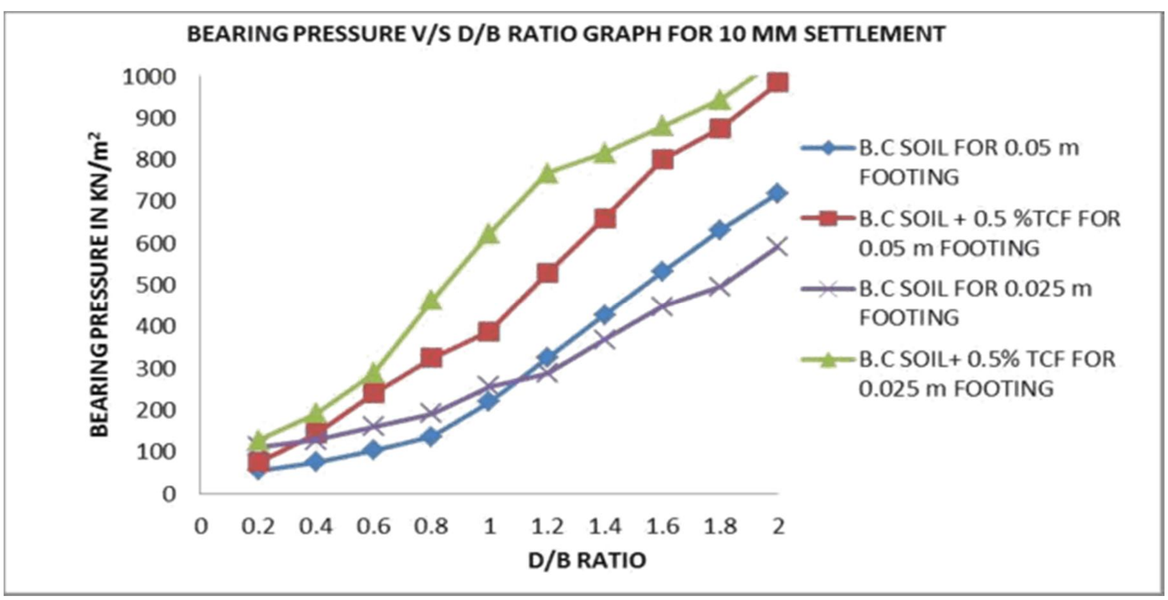

FIG 6.7: Bearing Pressure Values For 10mm Settlement

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D/B RATIO	Bearing Pressure Value(KN/m^2)		Bearing Pressure Value(KN/m^2)	
	BCS with TCF		BCS only	
	Footings in m		Footings in m	
	0.025	0.05	0.025	0.05
0.2	96	112	80	84
0.4	160	192	96	96
0.6	384	424	224	120
0.8	624	444	272	176
1	816	476	352	308
1.2	912	628	384	428
1.4	944	776	464	544
1.6	1024	924	528	660
1.8	1104	1056	608	792
2	1184	1176	688	892

TABLE 6.6: Bearing Pressure Values For 15MM Settlement

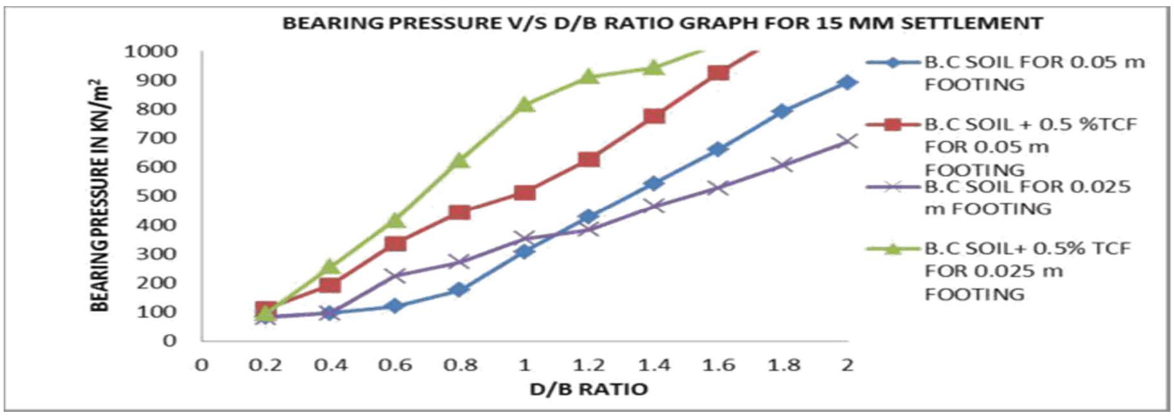


FIG 6.8: Bearing Pressure Values For 15mm Settlement

The Variation of Bearing pressure is increases the reinforced fiber of an particular D andB ratios & for size of footings. These values are increases along increasing the ratios. The bearing pressure values observed for footing of smaller size i.e. 0.025 m is higher thanthat the footing of larger dimension (0.05m).

4) BCR Characteristics of Different Footing Size at Various Settlements

D/B RATIO	LOAD Values (KN) BCS with TCF		LOAD Values(KN) BCS only		BCR	
	Footings in m		Footings in m		Footings in m	
	0.025	0.05	0.025	0.05	0.025	0.05
0.2	0.07	0.1	0.04	0.07	1.75	1.43
0.4	0.09	0.18	0.05	0.11	1.8	1.64
0.6	0.12	0.37	0.06	0.21	2	1.76
0.8	0.19	0.45	0.07	0.26	2.71	1.73
1	0.26	0.58	0.08	0.35	3.25	1.66
1.2	0.37	0.83	0.1	0.54	3.7	1.54
1.4	0.39	1.1	0.15	0.73	2.6	1.51
1.6	0.41	1.36	0.2	0.91	2.05	1.49
1.8	0.43	1.58	0.24	1.08	1.79	1.46
2	0.51	1.77	0.29	1.24	1.76	1.43

TABLE 6.7: BCR Values for 5MM Settlement

D/B RATIO	LOAD Values(KN) BCS with TCF		LOAD Values(KN) BCS only		BCR	
	Footings in m		Footings in m		Footings in m	
	0.025	0.05	0.025	0.05	0.025	0.05
0.2	0.08	0.19	0.07	0.14	1.14	1.36
0.4	0.12	0.36	0.08	0.19	1.50	1.89
0.6	0.18	0.75	0.1	0.26	1.80	2.88
0.8	0.29	0.81	0.12	0.34	2.42	2.38
1	0.39	0.97	0.16	0.55	2.44	1.76
1.2	0.48	1.32	0.18	0.81	2.67	1.63
1.4	0.51	1.65	0.23	1.07	2.22	1.54
1.6	0.55	2	0.28	1.33	1.96	1.50
1.8	0.59	2.19	0.31	1.58	1.90	1.39
2	0.65	2.46	0.37	1.8	1.76	1.37

TABLE6.8: BCR Values For 10mm Settlement

D/B RATIO	LOAD Values (KN) BCS with TCF		LOAD Values (KN) BCS only		BCR	
	Footings in m		Footings in m		Footings in m	
	0.025	0.05	0.025	0.05	0.025	0.05
0.2	0.06	0.28	0.05	0.21	1.20	1.33
0.4	0.1	0.48	0.06	0.24	1.67	2.00
0.6	0.24	1.06	0.14	0.3	1.71	3.53
0.8	0.39	1.11	0.17	0.44	2.29	2.52
1	0.51	1.19	0.22	0.77	2.32	1.55
1.2	0.57	1.57	0.24	1.07	2.38	1.47
1.4	0.59	1.94	0.29	1.36	2.03	1.43
1.6	0.64	2.31	0.33	1.65	1.94	1.40
1.8	0.69	2.64	0.38	1.98	1.82	1.33
2	0.74	2.94	0.43	2.23	1.72	1.32

TABLE 6.9: BCR Values for 15MM Settlement.

From Load vs. Settlement variations the bearing capacity ratio [BCR] values are calculated for both footing sizes and the values are tabulated above for all D/B ratios at different settlement levels. “The Bearing Capacity Ratio is the ratio of load on reinforced soil layer to the load on unreinforced soil layer at a particular settlement”. Through BCR values the variation of D/B ratio & BCR values are plotted for different widths of footing for selected settlements of 5mm, 10mm, and 15mm.The variations of D/B ratio & BCR values are shown graphically in fig 6.9 & 6.10.

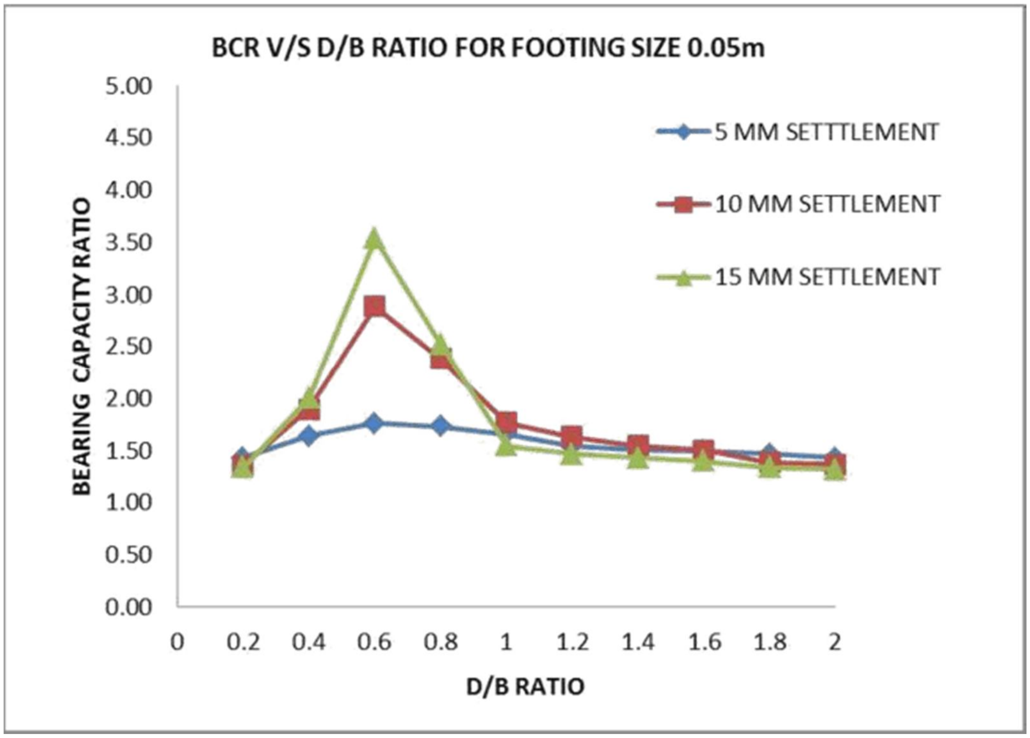


Fig 6.9: Variation For Bearing Capacity And D/B Ratios For FootingSize 0.05 M

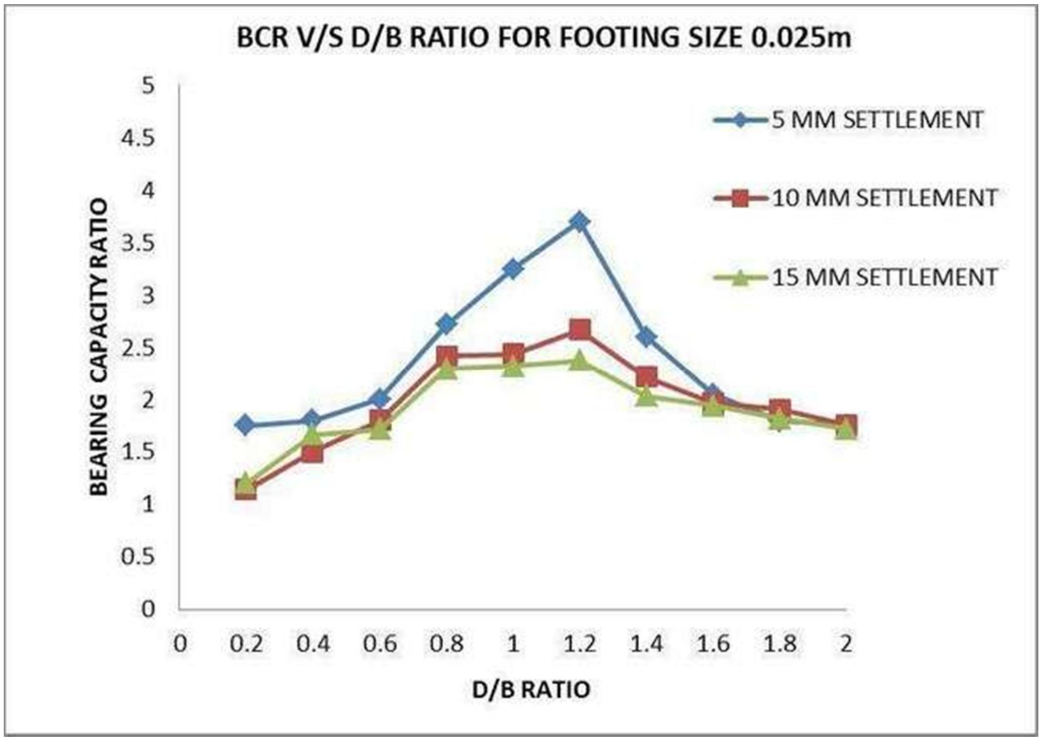


Fig 6.10: Variation Bearing Capacity And D/B Ratios ForFooting SIZE 0.025 M

From the curves 6.9 & 6.10 it is observed that D/B ratio versus BCR values for a 5mm, 10mm & 15mm settlements indicates that the soil is affected to a depth of 2 - 2.5 times the width of footing, appreciable increase in BCR occurs only till the depth equal 30mm.

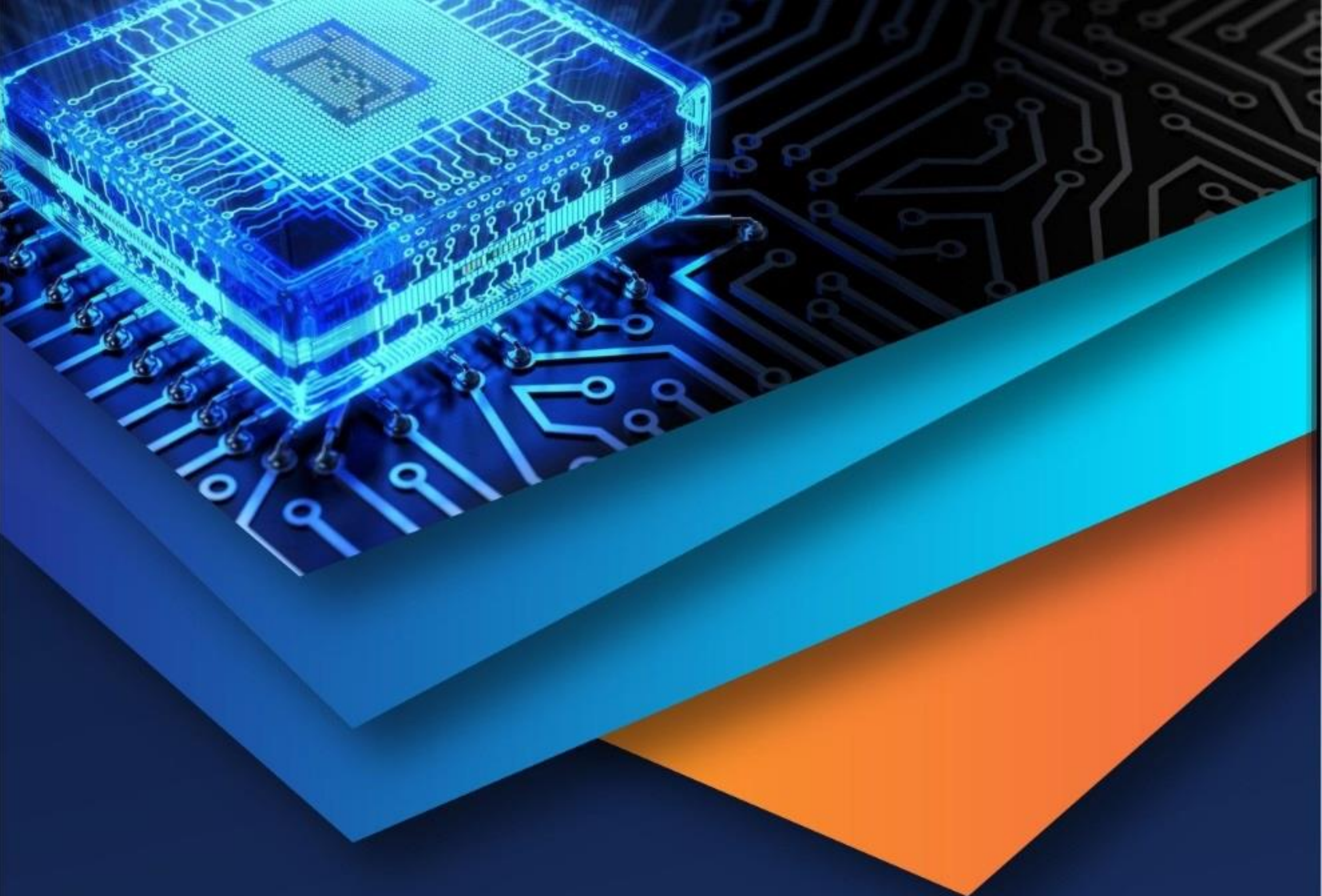
At a particular settlement the load carried by reinforced soil is considerably greater than unreinforced soil. The BCR value greater than 1 implies that there is an improvement in strength of BC soil due to treated coir fiber reinforcement

The experiment results indicate that the BCR values gradually decreases as the thickness of soil layers increases.

VII. CONCLUSION

Depending on the laboratory experiment results & observations obtained due tothe addition of TCF to BC soil, the entire results are concluded as below.

1) For different settlements of footings load carried by RDCFsre in forced soil was relatively more for reinforcing depths of0.2B, 0.4B, 0.6B, 0.8B, 1B, 1.2B, 1.4B, 1.6B, 1.8B and 2B. WhereB-footing width.
2) The load bearing capacity increasing along increasing the footing width for theequal settlement. But higher BCR values are observed for the smaller footing.
3) The differences in the specified settlements for a graph of BCR ratios and D/B ratios was showed that the values of BCR is more for 0.025m footing of 1.2 D/Band 0.05m footing of 0.6
4) The soil is affected to a depth of 2 to 2.5 times the width of footing.
5) As the size of footing is increasing, The reinforced and unreinforced soil of anloose stratum overlied is increasing considerably.



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