REVIEW PAPER ON EFFECT OF COIR FIBRE REINFORCEMENT ON THE STRENGTH PARAMETERS AND CBR VALUE OF BLACK COTTON SOIL

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ABTRACT

In India, expansive soil makes up about 20% of the total land area. Because to the presence of clay minerals called "Montmorillonite," these soils are known to have poor qualities. Soil behaviour that is typical causes settlements, fissures, and other types of structural failure. Therefore, it is crucial to either remove the current weak soil and replace it with non-expanding soil or stabilise the weak soil to improve its qualities. One method for enhancing the engineering properties of expansive soils is soil reinforcement. It is not a new concept to use natural fibres to strengthen soil. In geotechnical engineering, randomly dispersed fibre reinforced soil has recently garnered more interest, The current dissertation attempts to investigate how various environmental factors affect the performance of coir fibres added to black cotton soil in order to increase its strength and lessen its tendency to swell. As a biodegradable substance, coir fibre is known to break down in harsh environmental circumstances, such as contaminated and polluted water, contact with leachate, alternating cycles of wetting and drying, alternating cycles of freezing and thawing, and so forth. Coir fibre in soil is typically expected to last eight to ten years. It may therefore deteriorate quickly in certain climatic conditions. It's possible to lose the increased soil strength or decreased edoema. This aspect has not yet been researched. This is why this is attempted in this study

Key Word- *Expansive Soil, Soil Stabilization, Fiber Reinforcement, Coir Fiber, CBR*

1.INTRODUCTION

The expansive soils are found all over the world. About one-third of India is covered in black cotton soil, one of the country's expansive soil types. Due to the strong potential of soil minerals to absorb water, which results in increased volume or swelling and similar drops in volume after drying, black cotton soil has a low capacity to support loads. This soil also has a high compressibility. The bearing capacity decreased together with the absorption of water. According to reports, because of its high plasticity and tendency to become soft when saturated, water can easily fill in cracks and speed up the softening process, which reduces the material's shear strength. This is because the natural state of BC lacks the necessary geotechnical properties to be used as base layers, road service layers, or building materials.

The structure is elevated as a result of shrinkage cracks caused by decreased water content during the dry season and unequal bulking up from soil swelling during the rainy season.

All over India, thousands of kilometres of highways cut through vast quantities of soil. Volumetric variations in the soil cause the pavement to become distorted, cracked, and uneven. Significant damage to roads and other infrastructure has reportedly occurred. Engineering professionals are extremely concerned about building structures on the ground as a result. Building a structure on soil deposits used for black cotton has never been easy. Large amounts of ground material are required for building roads, and in most situations, these materials need to be transported a greater distance to the large soil site because of unfavourable behaviours, which raise expenses. In the twenty-first century, developing countries need to build rural roads faster and with more energy savings. One of the major social, technological, and economic engineering issues is finding appropriate building materials.

With a population of about 125 million and a land area of 3,287,240 sq. km, India needs a huge network of buildings and roadways (Singh and Mittal, 2014). Growing urbanisation and modernity have left very little land available for construction. Everywhere land is used, structures range from a typical home to skyscrapers, bridges to airports, and village roads to highways or motorways. Because there is a shortage of suitable site for building, constructions are currently being built on land with soft or poor soil. Any structure's stability is dependent upon how the soil behaves beneath it. When building on soft soil, soil stabilisation or soil fortification is typically used as a ground improvement technique. Enhancing the soil improves its strength and stability. (Dhatrak and Chapale, 2013)Much research on the strength deformation behaviour of soft soil reinforced with fibre has been conducted during the past 25 years. It is now undeniably proven that adding fibre to the soil enhances engineering performance overall. Notable improvements include increased extensibility, minimal post-peak strength loss, strength isotropy, and the absence of planes of weakness. Many nations have recently adopted fiber-reinforced soil, and advanced research is being conducted on many of its hidden characteristics. All types of soils, including sand, silt, and clay, have been shown to benefit from the addition of fibre, whether natural or manufactured. For a very long time, natural materials like jute, coir, sisal, and bamboo have been widely employed as soil reinforcing materials in various nations, including Bangladesh, the Philippines, India, and others. These materials' affordable and readily available local supply are their main advantages. They do not cause environmental disposal issues because they are biodegradable. In 2013, Singh and Bagra

A structure or road's foundation is essential to the efficient transfer of load to the subsurface that lies beneath it. The kind of structure and how it is designed are greatly influenced by the condition of the soil. When expansive soils—a type of weak soil—come into contact with water during the foundation engineering process for structures like embankments, roads, and buildings, they expand and alter in volume significantly. They get bigger in the rainy season and get smaller in the summer. In India, expansive soil makes up about 20% of the total land area. Because to the presence of clay minerals called "Montmorillonite," these soils are known to have poor qualities. Soil behaviour that is typical causes settlements, fissures, and other types of structural failure. Therefore, it's critical to either remove the current weak soil and replace it with non-expanding soil or stabilise the weak soil to improve its qualities (Kharade et al, 2014). One method for enhancing the engineering properties of expansive soils is soil reinforcement. It is not a new concept to use natural fibres to strengthen soil. In geotechnical engineering, randomly dispersed fibre reinforced soil has recently garnered more interest. (2012) Hejazi et al. In order to address the issue of waste disposal, attempts should also be made at stabilising soil using more waste products.

The utilisation of waste materials and materials that are readily available locally should be promoted for sustainable development in order to protect the environment for future generations. Natural fibres are widely available worldwide and are easily obtainable in many tropical places. India is home to a wide variety of natural fibres, including rice husk, sisal, coir, bagasse, jute, and oil palm. Given that soil is a good reinforcement material, efforts should be directed towards enhancing its qualities while utilising economically viable techniques. Barazesh (2012)

The amount of coir fibre produced worldwide is roughly 250,000 tonnes. Certain developing nations place a great deal of importance on the coir fibre sector. About 60% of the world's supply of white coir fibre is produced in India, primarily in the coastal region of Kerala State. Three-quarters of the world's brown fibre is produced in Sri Lanka. The nations of origin, primarily India, utilise more than half of the coir fibre produced annually worldwide. 90% of the 250,000 metric tonnes of coir produced annually is produced jointly by India and Sri Lanka. (Verma and Dixit, 2012)

2. LITERATURE SURVEY

Because of their strength, affordability, mass availability, and environmental friendliness, natural fibres are being explored in the field of soil reinforcement (Mandal et al., 1989). In addition to these benefits, it has real-world disadvantages like lack of repeatability and biodegradability. Applying chemical coatings to fibres with polymer compounds can efficiently overcome biodegradability (Khazanchi, 1990). This approach has been shown to increase the biodegradability of natural fibres. To increase specific soil engineering features, a variety of natural materials, including jute, coir, sunhemp, bamboo, wood, palm leaf, and coconut leaf, are available for use as soil reinforcing materials.

a) **Rice husk**

Utilising rice husk ash can help the local construction sector reduce the amount of garbage that must be disposed of, which would otherwise pollute the environment. The soft soil was determined to be high plasticity (CH) clay with an unconfined compressive stress of 70 KN/m2 and a very low CBR-value of 1.46, according to the IS Soil Classification System. It was necessary to stabilise the soil before starting any building projects. In their 2014 study, Roy found that treating patients with RHA plus a tiny amount of cement often reduced MDD and increased OMC as RHA concentration increased. A tiny quantity of cement and varying percentages of rice husk ash are used to stabilise the soil. Additionally, the unsoaked CBR (106% at 10% RHA content) showed improvement above the natural soil's CBR. For UCS, a similar pattern was found. At 10% RHA, the UCS value peaked (enhanced by 90.6%). The most feasible amount for soil stabilisation was suggested to be 10% RHA content with 6% cement for maximum strength increase. (Roy, 2014)

b) **Palm Fibres**

The filamentous textures of palm fibers in date production exhibit distinct properties, including cost-effectiveness, durability, resistance to deterioration, tensile strength, and lightweight characteristics. It has been observed that fibers obtained from decomposing palm trees tend to be brittle, with high water absorption capacity, poor tensile strength, and elastic modulus. Marandi et al. (2008) conducted unconfined compression strength tests on soil samples reinforced with palm fibers, examining factors such as bearing ratio and compaction. They noted an increase in both maximum and residual strengths as the percentage of fiber inclusion rose from 0% to 1%, while maintaining a fixed palm fiber length. However, the difference between the two strengths decreased.

Similarly, maintaining constant palm fiber inclusion and increasing the length of palm fibers (from 20 mm to 40 mm) exhibited a comparable trend. Jamellodin et al. (2010) reported significant improvements in failure deviator stress and shear strength parameters (C and υ) when soft soil was reinforced with palm fibers. The fibers played a role in interlocking particles, forming a cohesive matrix that enhanced the soil's strength characteristics.

In a study by Ahmad et al. (2010), palm fibers were combined with silty sand soil to investigate the increase in shear strength through triaxial compression. Testing included concentrations of 0.5% and 0.25% palm fibers at lengths of 15 mm, 30 mm, and 45 mm. Reinforced sand with 0.5% coated fibers of 30 mm length showed approximately a 25% increase in friction angle and a 35% increase in cohesiveness compared to unreinforced silty sand.

According to Sallehan and Yaacob's research in 2011, the addition of 3% palm fibers to composite bricks increased their compressive strength. The water absorption test indicated a slight increase in water absorption with the rise in palm fiber content.

D)**Cane**

Cane, a member of the grass family, grows up to 6m in height with a diameter reaching up to 6cm. Bagasse, the fibrous residue obtained from sugarcane production after extracting juice from the cane stalk, has a fiber diameter ranging from 0.2 to 0.4 mm. The utilization of waste cane fiber is constrained due to the presence of residual sugars and limited structural properties. However, these residual sugars can have a detrimental impact on final products, leading to the formation of a stiffer bonding phase in composite structures.

To address this, a novel product known as 'Cement Board' has been recently introduced to the market, utilizing sugar cane waste. This innovation aims to mitigate the challenges posed by residual sugars, offering a potential solution for creating composite structures. The authors suggest exploring the application of these fibers in soil reinforcement, identifying it as an unexplored research area

c) **Sisal**

Sisal is a naturally occurring hard fiber, predominantly composed of hemicelluloses, cellulose, and lignin. The failure strength, elastic modulus, and rupture lengthening of sisal fiber are influenced by the quantity of cellulose and the orientation of micro-fibers. Due to its natural origin, each sisal plant possesses distinctive qualities. Commercially, sisal fibers are accessible in various forms such as rolls, cloth, strips, cords, and wire. Table 1 presents details on the properties of sisal fiber.

Table.1. Properties of Sisal fibre

Specific gravity	1370
Water absorption (%)	110
Tensile strength(M Pa)	347-378
Modulus of elasticity(G Pa)	15

The advantages of sisal fibre are as follows:

- - They exhibit excellent resistance to moisture.
- - They possess strong tension resistance or tensile strength.
- - These fibers display impressive resistance to heat.
- - Sisal short fibers effectively slow down restrained plastic shrinkage, thereby managing crack development during early stages.
- Sisal fibres conditioned in sodium hydroxide solution retained respectively 72.7% and 60.9% of their initial strength.

d) The breakdown of sisal fibre in alkaline conditions or under biological attack are drawbacks. It is utilised in many different products, including cement reinforcement, ropes, carpets, and mats. (Reddy and Sen, 2011)

e) Sisal is a lingo-cellulose fibre that has historically been used in the building industry as reinforcement for gypsum plaster sheets. Its diameter ranges from 0.06 to 0.4 mm, and it absorbs 60-70% of water. Sisal fibres are taken from plant leaves, which range in size from 50 to 250 cm in length and 6 to 10 cm in breadth. The top three countries in the world for sisal fibre production are Brazil, Indonesia, and East African nations. According to Ghavami et al., adding 4% sisal, or coconut fibre, significantly improved the material's ductility and marginally raised its compressive strength. Additionally, it was shown that bitumen emulsion greatly increased soil durability without enhancing the link between soil and fibre. To strengthen a local problematic soil, Prabakar and Siridihar employed 0.25%, 0.5%, 0.75%, and 1% of sisal fibres by weight of raw soil with four varied lengths of 10, 15, 20, and 25 mm, respectively. They came to the conclusion that sisal fibres decreased the soil's dry density. A rise in the length and content of fibres also lowers the soil's dry density. Additionally, it was discovered that, up to 20 mm and beyond, the shear stress rose nonlinearly with increasing fibre length and decreased with increasing length. The shear strength was also enhanced by the fibre content percentage. However, the shear stress decreased when the fibre content increased over 0.75%.

f) Reduction of free plastic shrinkage is achieved by using 25mm sisal fibre with a 0.2% volume percentage. After being conditioned for 420 days in a sodium hydroxide solution, sisal fibres maintained 72.7% and 60.9% of their initial strength, respectively. When fibres were submerged in a calcium hydroxide solution, the initial strength was lost entirely after 300 days. The authors suggest that the increased attack by $Ca(OH)_2$ may have its origins in the crystallisation of lime within the pore structure of the fibre.

g) **Bamboo**

A cellulose fibre that has been renewed is bamboo fibre. It's well knowledge that bamboo can grow organically without the need for pesticides, and that diseases or pests rarely consume the fibre. Bamboo is known to possess a special bioagent known as "Bamboo Kun" that has antibacterial and bacteriostatic properties. It is crucial to understand that bamboo's root rhizomes are good soil binders that stop soil erosion. Bamboo fibres have a high water absorption rate of 40–45% and a low modulus of elasticity in the range of 33–40 KN/mm2. Despite this, they are exceptionally strong in tension. The results of Coutts' studies show that bamboo fibre is a suitable fibre to incorporate into the cement matrix. The behaviour of concrete reinforced with bamboo fibres was examined by Ramaswamy et al. The outcomes demonstrated that, like other fibres, these fibres can be advantageously incorporated into concrete. Table 2.2 lists this fiber's properties.

Table.2. Properties of Bamboo fibre

Specific gravity	1158
Water absorption (%)	145
Tensile strength(M Pa)	73-505
Modulus of elasticity(G Pa)	10-40

The advantages of bamboo fibre are:

- Demonstrates elevated mechanical strength.

- Possesses a low specific weight.

- Exhibits high tensile strength.

- Shows a superior modulus of elasticity compared to other natural materials.

- Readily available locally.

However, bamboo fiber has its drawbacks:

- It exhibits poor performance in torsion as it matures.

- There is a likelihood of decomposition under biological attacks.

The various applications of bamboo fibre are:

- Bamboo segments find application as reinforcement in various concrete elements such as beams, circular columns, and pillars with quadratic concrete forms. Additionally, they are utilized in plane truss bamboo structures, double-layer spatial configurations, and special joints between bamboo elements, suitable for both plane and double-layer spatial structures

- Local communities commonly employ bamboo frame structures to enhance concrete permanent bamboo shutter slabs and reinforce concrete beams or columns.

h) **Jute fibre**

In 2013, Singh and Bagra determined the percentage of Jute fibre by dry weight of soil to be 0.25%, 0.5%, 0.75%, and 1%. They also determined the length of the fibre to be 30 mm, 60 mm, and 90 mm, taking into account two distinct diameters (1 mm and 2 mm) for each fibre length. It was discovered what the CBR values of soil and soil reinforced with jute fibre were. Additionally, the impact of fibre sizes and lengths on the soil's CBR value was examined. The results of the tests showed that the CBR value of the soil rose as the fibre content did. It was also observed that increasing the fiber's length and diameter raised the reinforced soil's CBR value. This increase was significant at 1% fibre content for 90 mm of fibre with a 2 mm diameter. As a result, the CBR value of soil reinforced with jute fibre increased significantly, and this increase will cause the pavement subgrade's thickness to decrease significantly. Table 3. lists the fiber's properties.

Table.3. Properties of Jute Fibre

Specific gravity	1460
Water absorption (%)	13
Tensile strength(M Pa)	400-800
Stiffness(KN/mm^2)	10-30

Advantages of jute fibre are:

• It resists decaying readily.

• For improved water resistance, phenolic resin is a preferred bond for lignocellulosic fibres.

• Fibres are heat-resistant with ease.

• Tensile strength is high.Disadvantages of jute fibre are:

- The jute fibre based composites involve reactions with acetic anhydride (acetylation).
- Fibres are biodegradable.

The Applications of jute fibre are:

- • Used as packaging material (bags). • Used as carpet backing, ropes, yarns. • Used for wall decorating.

i) **Coir Fibre**

The rejected portion of coconut fruit is the fibrous outer layer, or coconut husk, of a fully grown coconut. Typically ranging in length from 50 to 350 mm, fibres are mostly composed of cellulose, tannin, pectin, lignin, and other compounds soluble in water. (2012) Hejazi et al. The coconut palm, which is mostly grown in tropical regions of the world, yields a commodity that is used in both food and non-food items, supporting people's livelihoods everywhere. The white meat of the coconut palm, which has a total weight percentage of 28, is encased in a protective shell and husk, which have respective weight percentages of 12 and 35. 30% of the weight of the coconut palm's husk is made up of fibre, while 70% is made up of pith material. Several techniques are used to extract the fibre from the husk, including the traditional method of retting, the use of fungi and bacteria in decortications, mechanical and chemical processes, and more. The fibre is then used to make building and packaging materials, brushes, mattress padding, ropes and yarns, and other products (Pillai, 2003). Coir is a hard structural fibre that is flexible enough to twist without breaking and maintain a curl that appears to be waved indefinitely. The engineering behaviour of soil-coir mixes is greatly impacted by the addition of fibres. The addition of randomly arranged polypropylene fibres significantly decreased the clayey soil's consolidation settlement. The properties of soil are largely determined by the contents of the fibre, not by the length of the fibre. Hydraulic conductivity increased and plasticity decreased with the addition of fibre. As a result, interest in soil-fibre reinforcement has grown. The study focused on the strength-deformation behaviour of fiber-reinforced soil, and it was generally accepted that adding fibre to soil enhanced its overall engineering performance. Many nations have recently adopted fiber-mixed soil, and advanced study is being conducted to uncover many of its hidden benefits. Fiber-mixed soil works well in all kinds of soil, including clay, silt, and sand. Coir fiber's high lignin content makes it one of the hardest natural fibres on the market. Coir is favoured over other natural fibres because it offers greater benefits in various applications for soil stabilisation, erosion control, and strengthening. (Mittal and Singh, 2014) Because coir has a high lignin content, it degrades much more slowly than other natural fibres. As a result, the fibre has an infield service life of 4–10 years, making it incredibly durable. About 130–180% of it absorbs water, and its diameter is between 0.1 and 0.6 mm.When wet, coir seems to maintain most of its tensile strength. They are significantly more elongated but have less toughness. Coir deterioration is dependent on the embedment medium and climate; however, it is shown that after six months in clay, coir retains 80% of its tensile strength. With a higher coefficient of friction than synthetic fibres, coir fibre responds more robustly. Increases in the proportion of coir lead to increases in the percentage of water absorbed and in the tensile strength of coir-reinforced soil. Hejazi and others (2012) Tables 4 and 5 list the coir fiber's physical and chemical characteristics, respectively.

Table.4. Physical properties of coir fibre

(Source: Ravi Shankar et al, 2012)

Length in inches	6-8
Density (g/cc)	1.40
Tenacity(g/Tex)	10.0
Breaking Elongation%	30%
Diameter in mm	0.1 to 0.5
Rigidity of Modulus	1.8924 dyne/cm^2

3. CONCLUSION

The in-depth experimental study revealed that the soil samples geotechnical parameters reached peak values when the percentage of coir fiber added reached 1.2%. This showed that enough quantity of fiber is in the soil to hold its particles together to supplement the resistance of soil against external load. . Thus the combination of environmental wastes with coir fibres was attributable to higher standards of soil treatment than the environmental wastes alone.

Thus the locally available materials like eggshell powder and coir fibres could be used as a standard stabilizer which brings about economy and a good replacement for the traditional stabilizers.

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