INVESTIGATION STUDY ON IMPROVEMENT IN CBR VALUE OF SOIL REINFORCED WITH JUTE FIBRE

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ABSTRACT

Use of natural fiber in civil engineering for improving soil properties is advantageous because they are cheap, locally available, biodegradable and eco-friendly. The natural fiber reinforcement causes significant improvement in tensile strength, shear strength, and other engineering properties of the soil. Over the last decade the use of randomly distributed natural and synthetic fiber has recorded a tremendous increase.

Keeping this in view an experimental study was conducted on locally available in India, soil reinforced with Jute fiber. In this study the soil samples were prepared at its maximum dry density corresponding to its optimum moisture content in the CBR mould with and without reinforcement. The percentage of Jute fiber by dry weight of soil was taken as 0.25%, 0.5%, 0.75% , 1% and 1.25% In the present investigation the lengths of fiber was taken as 50 mm, 75 mm, 100 mm, 125 mm and 150 mm with diameter of 2 mm were considered for each fiber length.

The laboratory CBR values of soil and soil reinforced with Jute fiber were determined. The effects of lengths and diameters of fiber on CBR value of soil were also investigated. Tests result indicates that CBR value of soil increases with the increase in fiber content. It was also observed that increasing the length and diameter of fiber further increases the CBR value of reinforced soil and this increase is substantial at fiber content of 1.25 % for 150 mm fiber length having diameter 2 mm.

1. INTRODUCTION:

FIBER:

At the present time, there is a greater awareness that landfills are filling up, resources are being used up, the planet is being polluted and that non-renewable resources will not last forever. So, there is a need to more environmentally friendly materials. That is why there have been many experimental investigations and a great deal of interest has been created worldwide on potential applications of natural fibers for soil reinforcement in recent years. The term ''eco-composite'' shows the importance role of natural fibers in the modern industry. Mainly, what part of the plant the fiber came from, the age of the plant; and how the fiber was isolated, are some of the factors which affect the performance of natural fibers in a natural fiber reinforced soil.

TYPES OF FIBERS:

It is necessary to mention that natural fibers have been used for a long time in many developing countries in cement composites and earth blocks because of their availability and low cost. At this point, some natural fibers and their features in soil projects are briefly described.

COCONUT (COIR) FIBER:

The outer covering of fibrous material of a matured coconut, termed coconut husk, is the reject of coconut fruit. The fibers are normally 50–350 mm long and consist mainly of lignin, tannin, cellulose, pectin and other watersoluble substances. However, due to its high lignin content, coir degradation takes place much more slowly than in other natural fibers. So, the fiber is also very long lasting, with infield service life of 4–10 years. The water absorption of that is about 130–180% and diameter is about 0.1–0.6 mm.

Mainly, coir fiber shows better resilient response against synthetic fibers by higher coefficient of friction. For instance, findings show that coir fiber exhibits greater enhancements (47.50%) in resilient modulus or strength of the soil than the synthetic one (40.0%). Ayyar et al. and Viswanadham have reported about the efficacy of randomly distributed coir fibers in reducing the swelling tendency of the soil. Ravi Shankar and Raghavan confirmed that for coir-stabilized lateritic soils, the maximum dry density (MDD) of the soil decreases with addition of coir and the value of optimum moisture content (OMC) of the soil increases with an increase in percentage of coir.

SISAL:

Sisal is a lingo-cellulosed fiber in which its traditional use is as reinforcement for gypsum plaster sheets in building industry with 60–70% of water absorption and diameter about 0.06–0.4 mm. Sisal fibers are extracted from the leaves of the plants, which vary in size, between 6–10 cm in width and 50–250 cm in length. In general, Brazil, Indonesia and East African countries are the world's main producers of sisal fibers. Ghavami et al. found that inclusion of 4% sisal, or coconut fiber, imparted considerable ductility and slightly increased the compressive strength.

PALM FIBERS:

The palm fibers in date production have filament textures with special properties such as low costs, plenitude in the region, durability, lightweight, tension capacity and relative strength against deterioration. Fibers extracted from decomposed palm trees are found to be brittle, having low tensile strength and modulus of elasticity and very high water absorption. Unconfined compression strength (UCS), California Bearing Ratio (CBR) and compaction tests were performed on neat and palm fiber reinforced soil samples by Marandiet al. They reported that at a constant palm fiber length, with increase in fiber inclusion (from 0% to 1%), the maximum and residual strengths were increased, while the difference between the residual and maximum strengths was decreased.

JUTE:

Jute is abundantly grown in Bangladesh, China, India and Thailand. Jute fibers are extracted from the fibrous bark of jute plants which grow as tall as 2.5 m with the base stem diameter of around 25 mm. There are different varieties of jute fibers with varying properties. Jute is mainly environmental-friendly fiber that is used for producing porous textiles which are widely used for filtration, drainage, and soil stabilization. For instance, GEOJUTE is the commercial name of a product woven from jute fibers used for soil stabilization in pavement engineering. Aggarwal and Sharma used different lengths (5–20 mm) of jute fibers in different percentages (0.2–1.0%) to reinforce soil.

Bitumen was used for coating fibers to protect them from microbial attack and degradation. They concluded that jute fiber reduces the MDD while increases the OMC.

Maximum CBR value is observed with 10 mm long and 0.8% jute fiber, an increase of more than 2.5 times of the plain soil CBR value. Islam and Ivashita showed that jute fibers are effective for improving the mortar strength as well as coherence between block and mortar.

FLAX:

Flax is probably the oldest textile fiber known to mankind. It has been used for the production of linen cloth since ancient times. Flax is a slender, blue flowered plant grown for its fibers and seeds in many parts of the world. In an effort, Segetin et al. improved the ductility of the soil–cement composite with the addition of flax fibers. An enamel paint coating was applied to the fiber surface to increase its interfacial bond strength with the soil.

BARELY STRAW:

Barley straw is widely cultivated and harvested once or twice annually in almost all rural areas in all over the world and could be used in producing composite soil blocks with better characteristics, but relatively few published data is available on its performance as reinforcement to soil or earth blocks.

It is important to know that during the Egyptian times, straws or horsehairs were added to mud bricks, while straw mats were used as reinforcements in early Chinese and Japanese housing construction. From the late 1800s, straw was also used in the United States as bearing wall elements.

BAMBOO:

Bamboo fiber is a regenerated cellulose fiber. It is a common fact that bamboo can thrive naturally without using any pesticide. The fiber is seldom eaten by pests or infected by pathogens. So, scientists found that bamboo owns a unique anti-bacteria and bacterio static bio-agent named ''Bamboo Kun''. It is important to know that the root rhizomes of bamboo are excellent soil binders which can prevent erosion.

CANE:

Cane or sugarcane belongs to grass family and grows up to 6 m high and has a diameter up to 6 cm and bagasse is the fibrous residue which is obtained in sugarcane production after extraction of the juice from the cane stalk. The fiber diameter is up to 0.2– 0.4 mm. However, waste cane fiber has limited use in most typical waste fiber applications because of the residual sugars and limited structural properties within the fiber.

JUTE FIBER:

Jute is one of the world's most important natural fibers second only to cotton in production. It is a bast fiber obtained from two species namely White Jute (Corchoruscapsularis) and Tossa Jute (Corchorusolitorius). Every part of jute from leaves to root sis utilized in different forms such as packaging material, furnishing fabrics, vegetables, cooking fuel etc.

As it is a coarse textile fibre it is mainly used as a raw material for the production of packaging material. Properly retted and washed jute fibre is fairly lustrous. The color of the fibre varies from creamy white to brown. Jute and jute products are bio degradable, photodegradable, thermal degradable, non-toxic, hydrophilic, droppable and less extensible with high moisture and UV absorbing capacity. It has the similarity with cotton and wood simultaneously due to the presence of cellulose and lignin respectively. Based on its properties a large number of traditional and diversified jute products are now being produced.

Fig. 1.1 represents the jute field

Fig. 1.2 represents the extraction of jute


Fig. 1.3 represents the jute

Fig. 1.4 represents the view of jute fiber

PROPERTIES OF JUTE:

- High strength and modulus-Low extensibility
- Moisture absorbing ability
- High abrasion resistance
- Good thermal stability
- Insulation against sound
- Anti-static property
- Surface morphology

APPLICATIONS OF JUTE:

- Traditionally jute has been used to manufacture packaging materials like hessian, sacking, ropes, twines, carpet backing cloth etc.
- Yarns/Twines/Cordages
- A wide range of yarns / twines / cordages (3lbs-500lbs) are manufactured in different counts and diameter. These are used for the purpose of tying, knotting, and binding etc Jute yarns of various dimensions are plied together to make twines as per requirement and use.

SOIL REINFORCEMENT:

Soil has been used as a construction material from time immortal. Being poor in mechanical properties, it has been putting challenges to civil engineers to improve its properties depending upon the requirement which varies from site to site. During last 25 years, much work has been done on strength deformation behaviour of fiber reinforced soil and it has been established beyond doubt that addition of fibre in soil improves the overall engineering performance of soil. Among the notable properties that improved are greater extensibility, small loss of post peak strength, isotropy in strength and absence of planes of weakness. Fiber reinforced soil has been used in many countries in the recent past and further research is in progress for many hidden aspects of it.

FIBER-REINFORCED SOIL:

The standard fiber-reinforced soil is defined as a soil mass that contains randomly distributed, discrete elements, i.e. fibers, which provide an improvement in the mechanical behavior of the soil composite. Fiber reinforced soil behaves as a composite material in which fibers of relatively high tensile strength are embedded in a matrix of soil. Shear stresses in the soil mobilize tensile resistance in the fibers, which in turn imparts greater strength to the soil. Mainly, the use of random discrete flexible fibers mimics the behavior of plant roots and contributes to the stability of soil mass by adding strength to the near-surface soils in which the effective stress is low. In this way, laboratory and some in situ pilot test results have led to encouraging conclusions proving the potential use of fibers for the reinforcement of soil mass providing an artificial replication of the effects of vegetation.

CLASSIFICATION OF FIBER-REINFORCED SOIL:

A comprehensive literature review shows that short fiber soil composite can be considered as a coin with two sides. One side includes the randomly direct inclusion of fibers into the matrix, i.e. soil mass.

Another side comprises the oriented fibrous materials, e.g. Geo-Synthetics family.

It is emphasized that the former concept is not as well-known as the second, not only in optimizing fiber properties, fiber diameter, length, surface texture, etc., but also in reinforcing mechanism. McGown et al. classified soil reinforcement into two major categories including ideally inextensible versus ideally extensible inclusions. The former includes high modulus metal strips that strengthens soil and inhibits both internal and boundary deformations.

2. LITERATURE REVIEW

- Zafar Iqbal Ahanger, Abhishek Bawa [2018], explained that CBR mould with and without reinforcement. Standard size of moulds has been used. From the laboratory tests the effect of jute fiber content on density of soil (optimum moisture content and maximum dry density) was observed for each length and diameter of jute fiber. The California Bearing Ratio test was conducted on all the samples and the results have been presented.
- Anzar Hamid [2017] stated that now-a-days, many techniques are used to stabilize the subgrade soil, use of natural fibres being one of them. Natural fibres are cheap, easily available and eco friendly. In order to stabilize the subgrade soil, jute fibres in different lengths (30mm, 60mm and 90mm) and proportions of 0.25%, 0.5%, 0.75% and 1% were used as the reinforcing agents in the present study.
- Amit Kumar Singh [2016] invented that metal strips, synthetic geotextiles, geogrid sheets, natural geotextiles, randomly distributed, synthetic and natural fibers are being used as reinforcing materials to soil. Further, the soil reinforcement causes significant improvement in unconfined compressive strength, maximum dry density, bearing capacity as well as economy. Use of natural fiber in civil engineering for improving soil properties is advantageous because they are cheap, locally available and environmental friendly.
- Dharmendra Kumar [2015] stated that five soil samples were prepared at its maximum dry density corresponding to its optimum moisture content. The Jute and Coir fibers were reinforced in different percentage in the soil samples.

3. MATERIALS

JUTE:

Jute is a very strong natural fiber with a wide variety of uses. Second only to cotton in its amount of yearly production, jute is a component in a number of industrial, culinary and manufacturing processes. In home decor, jute is often found woven into carpets, drapes, upholstery and rugs as well as textiles such as accent pillows and throws. Jute is also biodegradable, which is why it's often used to wrap young plants outdoors. Known as the Golden Fiber, jute, in it's finished forms, is more commonly known as Burlap or Hessian.

Jute is produced in many areas around the world. The fiber is derived from plants in the Corchorus genus, specifically Corchoruscapsularis, which is used to produce White Jute and Corchorusolitorius, from which Tossa Jute is derived. These fibers are made from the skin of the plant's stem, while the leaves have a number of culinary uses, particularly in Nigeria where the leaves of the Tossa Jute plant are used to make soup.

PHYSICAL PROPERTIES OF JUTE:

- Ultimate length: 1.5 – 4 mm
- Ultimate diameter: 0.015 – 0.020 mm
- No. of ultimate in X-section: 6 – 10
- Fibers length: 5 – 12 ft
- Color: White, Off White, Yellow, Brown, Grey, Golden
- Strength (Tenacity): 3 – 4 gm/den
- Elongation: 1.7% at the break
- Specific Gravity: 1.5
- Moisture Regain(mr%):13.75%
- Dimensional stability : good
- Abrasion resistance : average
- Effect of light and heat: average

USES OF JUTE:

Jute is the second most important vegetable fiber after cotton, not only for cultivation but also for various uses:

- Jute is used chiefly to make cloth for wrapping bales of raw cotton, and to make sacks and coarse cloths.
- The fibers are also woven into curtains, chair coverings, carpets, area rugs, hessian cloth, and backing for linoleum.
- While jute is being replaced by synthetic materials by many of these uses, some uses take advantage of jutes bio degradable nature, where synthetics would be unsuitable.
- Jute butts, the coarse ends of the plants are used to make inexpensive cloth.

Color	**Brown**
Natural Water Content (%)	6.25
Liquid Limit (%)	29.95
Plastic Limit (%)	22.85
Consistency Index (%)	3.33
Maximum Dry Density (γd) (gm/cc)	1.98
Optimum Moisture Content (%)	13.0
Specific Gravity (GS)	2.70
C B R (at 2.5mm) (%)	1.82

Table 3.1 represents the index properties of soil

SOIL PROFILE:

There are different types of soil, each with its own set of characteristics. Dig down deep into any soil, and you'll see that it is made of layers, or horizons (O, A, E, B, C, R). Put the horizons together, and they form a soil profile. Like a biography, each profile tells a story about the life of a soil. Most soils have three major horizons (A, B, C) and some have an organic horizon (O).

SOIL SELECTION:

The plants and plant communities which grow on a site are to a large extent governed by the characteristics and location of the site and soil in which they are rooted. Plant species have evolved strategies to exploit different combinations of climate, soil conditions and disturbance by animals or man: some species have specialized to thrive in particular conditions such as occur on chalk soils, other species are more generalist. For any set of conditions there will be species that thrive and survive, and others which do less well or fail; through this process a natural balance between species is established. Recognizing and understanding the characteristics of your site and soil is clearly useful in deciding which species are most likely to do well.

WORK WITH NATURE:

The most rewarding approach to using wild seeds is to work with nature. If you aim to sow a selection of species that are naturally suited to your soil and site conditions, and if you manage the resulting plant community sympathetically allowing natural selection to determine the balance of species appropriate to your site, you have the best chance of attaining the maximum potential from your site and with the least effort. The alternative gardening approach by comparison requires a struggle for control with nature to impose a specific idea of aesthetic and balance that may have no basis in nature.

ARRANGEMENT OF PROPORTIONS:

In order to stablize the subgarde soil the jute fiber in different lengths of 25mm , 50mm,75mm,100mm and 125mm and proportions of 0.25%,05%,0.75% ,1% and 1.25%.

With the diameter of 2mm of jute fiber

Length of jute fiber	**Diameter of jute fiber**	**Jute fiber percentage**
50mm	2 mm	0.25, 0.5, 0.75, 1, 1.25
75mm		0.25, 0.5, 0.75, 1, 1.25
100mm		0.25, 0.5, 0.75, 1, 1.25
125mm		0.25, 0.5, 0.75, 1, 1.25
150mm		0.25, 0.5, 0.75, 1, 1.25

Table 3.2 represents the length, diameter and percentage of jute fiber

4. EXPERIMENTAL TESTS

MOISTURE CONTENT:

Moisture content (m)or water content(w) is the quantity of water contained in a material such as soil. And it is defined as the ratio of weight of water to the Weight of the solids in a given mass of soil. This ratio is usually expressed as percentage. In almost all soil tests natural moisture content of the soil is to be determined. The knowledge of the natural moisture content is essential in all studies of soil mechanics. For example, natural moisture content is used in determining the bearing capacity and settlement.

Box no.	Weight of the box(w_1)	Weight of the box+ wet soil (w_2)	Weight of the box+ dry soil (w_3)	Moisture content (w_2- w_3)	Weight of dry soil (w_3 - w_1)
1	4.65gm	38.70 gm	36.90 gm	1.80gm	31.95 gm
2	4.90gm	40.00 gm	38.40 gm	1.60gm	33.50 gm
3	5.00gm	42.60 gm	40.85 gm	1.75gm	35.85 gm
Average				w_w= 1.72gm	w_s= 33.7gm

Table 4.1 represents moisture content of soil sample A

Water content / moisture content m_c = $\frac{weight\ of\ water}{weight\ of\ solid} \times 100 = \frac{1.72}{33.77} \times 100$ = 5.09

Box no.	Weight of the box(w_1)	Weight of the box+ wet soil with	Weight of the box + dry soil with jute	Moisture content (w_2- w_3)	Weight of dry soil with jute (w_3 - w_1)

		jute fiber (w_2)	fiber (w_3)		
1	4.85gm	51.85gm	49.95gm	1.90gm	45.10gm
2	4.90gm	49.40gm	47.80gm	1.60gm	42.90gm
3	4.80gm	41.60gm	40.25gm	1.35gm	35.40gm
Average				w_w= 1.62gm	w_s= 41.13gm

Table 4.2 represents moisture content of soil sample B

Water content / moisture content m_c = $\frac{weight\ of\ water}{weight\ of\ solid} \times 100 = \frac{1.62}{41.13} \times 100$ = 3.94

LIQUID LIMIT:

N	$\left(\frac{N}{25}\right)^{0.12}$	N	$\left(\frac{N}{25}\right)^{0.12}$
15	0.941	23	0.990
16	0.948	24	0.995
17	0.955	25	1.000
18	0.961	26	1.005
19	0.967	27	1.009
20	0.974	28	1.014
21	0.979	29	1.018
22	0.985	30	1.022

Table 4.3 represents the Values of (N/25)

Sample no.	A	B	C
Box no.	1	2	3
Number of blows	17	25	34
Mass of empty box(M_1)	44.9	46	44.6
Mass of empty box+ wet soil (M_2)	78.3	81.3	76.8
Mass of empty box+ dry soil (M_3)	70	75.30	74.10
Water content = (M_2- M_3/ M_3- M_1) ×100	33.07	20.30	10.00

Table 4.4 represents the liquid limit of soil sample.

PLASTIC LIMIT:

Box No.	1	2
Weight Of Empty Box (W_1)	45.7	44.5
Weight Of Empty Box + Wet Soil (W_2)	50.6	49.5
Weight Of Empty Box + Dry Soil (W_3)	48	46
Water content = (W_2- W_3/ W_3- W_1) ×100	1.13	1.17
Average	1.15	

Table 4.5 represents the plastic limit of soil sample

Penetration (mm) of plunger	Standard load (kg)
2.5	1370
5.0	2055
7.5	2630
10.0	3180
12.5	3600

Table 4.6 represents the penetration and standard load

Moisture content		Dry density	
box	A	Weight of the mould(gm)	7383
Weight of the box(gm)	95.5	Weight of the mould + compacted soil (gm)	11842
Weight of the box + wet soil(gm)	888.6	Volume of the mould (cc)	2110
Weight of the box + dry soil(gm)	832.4	Bulk unit weight (gm/cc)	2.11
Moisture content %	7.63	Dry unit weight (gm/cc)	1.96

5. RESULTS AND DISCUSSION

5.1 CBR FOR UNREINFORCED SOIL:

Penetration (mm)	Load dial readings (divisions)	Load (kg)
0.0	0	0
0.5	0.7620	5
1.0	1.5004	10
1.5	2.1007	14
2.0	2.6999	18
3.0	3.4498	23
4.0	4.1997	28
5.0	4.6579	31
7.5	5.6997	38
10.0	6.7508	45
12.5	7.4996	50

Table 5.1 Represents CBR Test Data Of Unreinforced Soil Sample

Table 5.2 represents CBR Test Data Of Reinforced Soil Sample (fibre length=50mm)

Fibre Content	CBR at 2.5 mm penetration	CBR at 5 mm penetration
0%	1.496%	1.508%
0.25%	2.627%	2.822%
0.5%	3.138%	3.163%
0.75%	3.275%	3.288%
1.0%	3.300%	3.357%
1.25%	3.470%	3.521%

Table 5.3 Represents CBR values at different fibre contents and fibre length of 50

6. CONCLUSION

Based on the present investigation it is concluded that CBR value of soil increases with the inclusion of Jute fiber.

When the Jute fiber content is increases, the CBR value of soil is further increases and this increase is substantial at fiber content of 1.25 %. It was also found that preparation of identical soil samples for CBR test beyond 1.25 % of fiber content is not possible and optimum fiber content was found to be 1.25 % by dry weight of soil.

It is also concluded that there is significant effects of length and diameter of fiber on the CBR value of soil. The CBR value of soil increases with the increase in length and diameter of fiber. The maximum increase in CBR value was found to be more than 200 % over that of plain soil at fiber content of 1.25 % for fiber having diameter 2 mm and length 150 mm.

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