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STRENGTH BEHAVIOUR OF KEROSENE COATED COIR FIBER-REINFORCED EXPANSIVE SOIL

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Abstract. *Coir fibers are extracted from the husks surrounding the coconut. Coir fibers can be effectively used as reinforcing material but it has less durability and hence coir fiber coated with kerosene is used as reinforcement in the present study. The objective of the present investigation is to study the strength behavior of expansive soil reinforced with 5mm long randomly distributed kerosene coated coir fibers in 0% (unreinforced), 0.5%, 1% and 1.5% by dry weight of soil. Water absorption (WA) tests were conducted on uncoated and kerosene coated coir fibers. The WA tests were also conducted on kerosene coated coir fibers mellowed for a period of 1 day, 2day and 3 day. Water Absorption Capacity (WAC) of kerosene coated coir fiber reduced as compared to that of uncoated coir. It is found that 1% of coated coir fiber is the Optimum Coir Content (OCC) from view point of Unconfined Compressive (UCC) strength. Splitting tensile strength of OCC reinforced soil is increased by 50% that of unreinforced soil.*

Key words: *Expansive Soil, Coir Fiber, Kerosene coated, UCC strength.*

1. INTRODUCTION

Expansive soils, also called swelling soils, are those soils which expand during the rainy season due to intake of water and shrink during the summer season. Swelling and shrinkage of expansive soil cause differential settlements resulting in severe damage to the foundations, building, roads, retaining structures, canal lining, etc. The expansive soils occur all over the world. India has large tracts? of expansive soil known as Black Cotton soil, covering an area of 0.8 million square kilometer, which is about 20% of total area. Fibers are two types: Natural and artificial fibers. Both the types are used for civil engineering purposes. Soft silty or clayey soils can be improved with reinforcement in the

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form of randomly distributed fibers of natural and synthetic types. Use of natural fibers such as cotton, bamboo, jute, coir, etc. as soil reinforcing materials has been prevalent for a long time. The main advantage of these materials is that they are locally available and cost effective. Natural fibers are biodegradable and hence eco-friendly. Synthetic fibers such as polypropylene, polyester, polyethylene and glass fibers have also been used as reinforcing materials. There are environmental problems in the use of artificial fibers. The random inclusion of various types of fibers is a process in which the fibers act to interlock soil particles and aggregates in a unitary coherent matrix. The fiber-reinforced soil behaves as a composite material. When loaded, the fibers mobilize tensile resistance, which in turn provides greater strength to the soil. Natural or synthetic fibers in geotechnical engineering has been used in the construction of pavement layers, road and railway embankments, and retaining walls as well as in the protection of slopes. The primary purpose of reinforcing a soil mass is to improve its stability by increasing its bearing capacity, and by reducing settlement and lateral deformation.

Among the natural fibers, Coir is produced in large quantities in South Asian countries. Coir is a natural biodegradable material that is abundantly available in the state of Kerala, India. Due to high lignin content (about 46%) it is stronger than other natural materials such as jute or cotton. Coir fibers are extracted from the husks surrounding the coconut. Coir has better mechanical properties, such as tensile strength. Coir has a longer life compared to other natural fibers that degrade much faster, it is possible to use these fibers in rural roads and ground improvement [1]. Coir uses in various geotechnical engineering applications are ecologically safe. Coir geotextiles have been used in various slope stabilisation and soil erosion control projects. Addition of coir (1-2%) as randomly reinforcing material increases both strength and stiffness of clayey soil [2]. Coir fiber mixed soil can be used to increase the piping resistance and reduce seepage velocity [3]. The shear strength of marine clay increases considerably by the inclusion of the coir fibers by about four times [4]. The inclusion of coir fiber enhanced the California Bearing Ratio strength of the clayey soil significantly. For low cost embankment/rural road constructions, randomly distributed discrete natural fiber reinforced soils may result in significant cost advantages [5]. Coir fiber enhanced the liquefaction resistance of loose Saloni sand significantly [6]. Addition of coir to clayey soil improves UCC and California Bearing Ratio [7]. Coir fiber is strong fiber among all natural fibers, however it needs further treatment in order to prolong its service life as reinforcing material to soil., In general, coir fiber is a natural organic material, which absorbs huge water content and has a short life period and it is bio-degradable. Whenever the water absorption capacity of fiber reduces the longevity will be increased. Coir can be efficiently used as reinforcing material if a proper treatment is adopted. Kerosene treated/coated fiber can be used effectively as a reinforcing material for expansive soil. Coating kerosene to coir fiber will act as a thin layer which prevents water absorption. Black cotton soil reinforced by randomly distributed coir fiber coated with kerosene of 60% by weight fiber gives a better strength [8]. Hence, in the present study coir fiber coated with kerosene of 60% by weight fiber is used as reinforcing material. The main objective of the present investigation is to study the strength behaviour of cohesive soils reinforced with kerosene coated coir fiber from UCC strength tests. Strength of the reinforced soil is generally evaluated by conducting UCC. It is necessary to determine the Optimum Coir Content (OCC) in the laboratory prior to field applications.

2. MATERIALS USED

2.1. Soil

Soil used in the present study was collected from the place Enikepadu in Vijayawada, India by an open excavation from a depth of 2 meters below natural ground level. The soil collected into bags and purified from waste materials like plastics and other organic wastes. After that soil is pulverized and allowed to open atmosphere in a lab for a long period for air-dry. The property of the soil is evaluated according to ASTM D4318-10 [9] and the results are presented in Table 1. The soil is classified as Highly Compressible Clay (CH) according to Unified Soil Classification System, ASTM D2487-10 [10]. Differential Free swell index is more than 50% and hence degree of expansiveness of soil is very high [11].

Table 1 Properties of soil

Property	Value
Gravel (%)	0
Sand (%)	12.3
Silt + Clay (%)	87.7
Liquid Limit (%)	72.67
Plastic Limit (%)	34
Plasticity Index (%)	38.67
US Soil Classification	CH
Differential Free Swell Index (%)	66
Maximum Dry Density, MDD (g/cc)	1.54
Optimum Moisture Content, OMC (%)	27.61
UCC Strength (kPa)	70
Splitting Tensile strength (kPa)	64

2.2 Coir fiber

Coir is collected from locally available coconut shells which are dried. Brown colored Coir fibers extracted from the husks surrounding the coconut are presented in Fig. 1. The fibers are hard and tough. The diameter (d) and length (l) of the coir fiber used in the present study is 0.25mm and 5mm respectively. Aspect ratio (l/d) of coir fiber is 20.

(a) Coconut shell (b) Coir fiber

Fig. 1 Coir fibers extracted from the husks surrounding the Coconut

2.3 Kerosene

Blue colored kerosene is collected from locally available stores in Enikepadu, and is stored in an air tight bottle.

3. Tests Conducted

The following tests were conducted on soil with and without adding kerosene coir fiber of 0.5%, 1.0% and 1.5% of dry weight of soil: (1) Water Absorption Tests, (2) Standard Proctor tests, (3) Unconfined Compressive strength tests and (4) Splitting Tensile strength Tests.

4. Results and Discussions

4.1. Water absorption tests on coir and coated coir fiber

Water Absorption (WA) tests conducted on coir fibers are presented in Fig. 2. The weight of the uncoated coir before immersing in water is 10g and after immersing in water, the weight of the uncoated coir fiber is 63.7g for 1day immersion in water. The Water Absorption Capacity (WAC) of uncoated coir fiber is 537%. When coir coated with kerosene by 60% weight of coir, WAC is reduced to 364%. WAC of kerosene coated coir fiber reduced by 32% as that of uncoated coir. WA tests are also conducted on kerosene coated coir fibers mellowed for period of 1 day, 2 day and 3 day. Further, WAC of kerosene coated coir fiber is reduced to 298%, 223%, and 210% with mellowing time of 1 day, 2 day, and 3 day respectively. From this it can be said that 2 day mellowing of kerosene coated coir is sufficient. It is noticed that 2 day mellowed kerosene coated coir fiber reduces the WAC from 537% to 223%. WAC of 2 day mellowed kerosene coated coir fiber reduced by 58% as that of uncoated coir. Hence the WA nature of the kerosene coated coir fiber is decreased, it may be said that the longevity (durability) of kerosene coated coir fiber is increased against Biological degradation. From WA test kerosene coated fibers are used for further study because of low WAC.

Fig. 2 Water absorption tests on coir fiber

4.2. Compaction characteristics of expansive soil reinforced with coated coir fiber

Compaction tests were conducted on expansive soil without and with addition of kerosene coated coir fiber of 0.5%, 1% and 1.5% by weight of soil. Compaction tests were conducted according to ASTM D698-07e1 [12]. Compaction curves are drawn for each mix and are presented in Fig. 3. The compaction characteristics namely Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) of kerosene coated coir fiber reinforced soil are presented Table 2. From these results it can be observed that the MDD decreases and OMC increases by the addition of coir content from 0% to 1.5% to expansive soil. This is due to the fact that lighter coir fiber material replaces heavy soil mass. Similar observations were made by earlier researchers [13, 14].

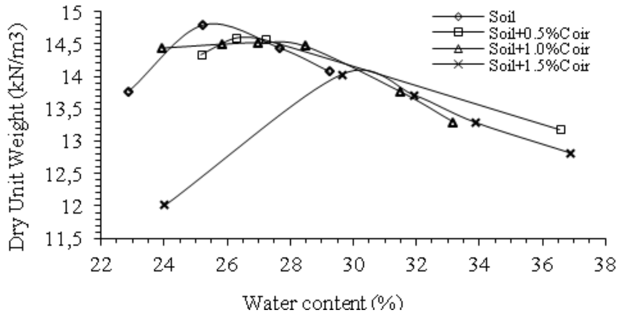

Fig. 3 Compaction curves for Coir fiber reinforced soil

Table 2 Compaction characteristics of coir fiber reinforced expansive soil

Mix	Compaction characteristics	
	MDD (kN/m^3)	OMC (%)
Soil alone	14.80	25.21
Soil+0.5%Coir	14.60	26.27
Soil+1.0%Coir	14.52	26.97
Soil+1.5%Coir	14.03	29.63

4.3. Unconfined compressive strength of expansive soil reinforced with coated coir fiber

Unconfined Compressive Strength (UCC) tests were conducted on samples which were prepared by kerosene coated coir fibers of 0.5%, 1% and 3% (by weight of soil). UCC strength tests were conducted according to ASTM D2166–06 [15]. UCC strength tests were conducted on coir fiber reinforced soil samples prepared at OMC & MDD. Fibers are randomly mixed in soil to form a homogeneous mixture. Stress-stain plots are drawn for different percentages of coir fiber reinforced soil are depicted in Fig. 4. The results of UCC strength are presented in Table 3. When expansive soil reinforced with 1% Coir fiber UCC strength increases and with further increasing of percentage of coir reduces UCC strength, this is due to addition of coir fiber leading to domination of fiber-to-fiber interaction rather than soil-to-fiber interaction. The Optimum Coir Content (OCC) is 1% (by weight of kerosene coated coir) from view point of UCC strength. To express the improvement in UCC strength in dimensionless terms, the parameter named "Strength Ratio (SR)" is used. SR is defined as the ratio of UCC strength of reinforced soil to that of unreinforced soil. SR of soil reinforced with 1% of kerosene coated coir fiber is 2.44. UCC strength of 1% kerosene coated coir fiber reinforced soil increased about 2.5 times in comparison to that of unreinforced soil. The Relative Strength Gain Number (RSGN) as suggested by [14] has been used in the present study to know the effect of coir fiber inclusion in expansive soil. RSGN is given by Eq. (1) as below:

$$\text{RSGN} = \frac{Q_{fo} - Q_o}{Q_o} \quad (1)$$

where, Q_{fo} = UCS of fiber-reinforced specimen, and
Q_o = UCS of unreinforced specimen.

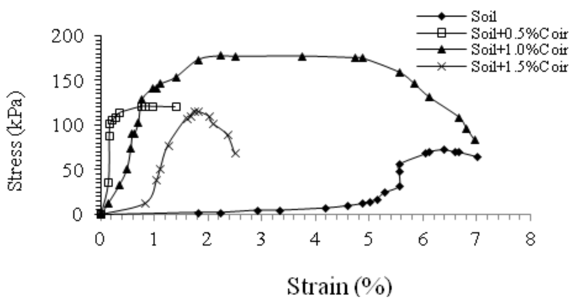

Fig. 4 Stress-stain plots for coir fiber reinforced expansive soil

Table 3 Unconfined compressive strength of coir fiber reinforced expansive soil

Mix	UCC strength (kPa)	Strength Ratio (SR)	RSGN
Soil alone	73	1	0
Soil+0.5%Coir	121	1.66	0.66
Soil+1.0%Coir	178	2.44	1.44
Soil+1.5%Coir	115	1.58	0.58

The RSGN of the composite specimen obtained in the present investigation using coir fibers to that of unreinforced expansive soil specimen is 0.66, 1.44 and 0.58 respectively for fiber content 0.5, 1.0 and 1.5% for aspect ratio of 20. It is observed that at optimum coir content of 1%, the highest RSGN is 1.44. Variation of UCC strength with percentage of coir added is depicted in Fig. 5. A regression model was developed below to predict the UCC strength (q_{uf}) of kerosene coated coir fiber reinforced expansive soil in terms of % of fiber content (f) for coir fiber of diameter 0.25mm and length 5mm.

$$q_{uf} = -172*f^3 + 276*f^2 + 1*f + 73$$

Coefficient of determination (R^2) is 1.

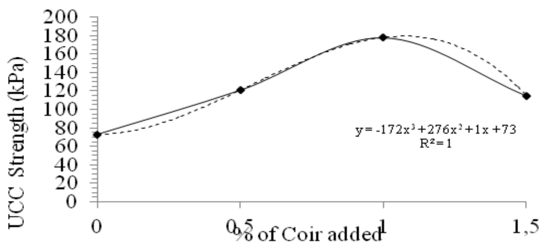

Fig. 5 Variation of UCC strength with addition of Coir

4.4. Splitting tensile strength of expansive soil reinforced with coir fiber

The tensile strength is one of the basic and important properties of the soil. The soil is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. However, the determination of tensile strength of soil is necessary to determine the load at which the soil members may crack. The cracking is a form of tension failure. Splitting Tensile Strength tests are conducted on expansive soil, soil+1% coir. The splitting tests are well known indirect tests used for determining the tensile strength of soil sometimes referred to as split tensile strength of concrete. In this study, the split-tensile strength test equipment was modified from unconfined compressive strength test apparatus. The setup of the test is shown in Fig. 6. The split tensile strength is calculated according to [16], as follows:

$$T = \frac{2P_{max}}{\pi DL}$$

where, T is split tensile strength; p_{max} is applied maximum load; l and d are length and diameter of the specimen respectively. The splitting tensile strength of unreinforced expansive soil is 64 kPa and that of kerosene coated 1% coir reinforced soil is 96kPa. Splitting tensile strength of OCC reinforced soil is increased by 50% that of unreinforced soil. The addition of kerosene coated coir fibers enhanced the tensile strength of the expansive soil due to 'bridge' effect of fiber reinforcement.

Fig. 6 Splitting tensile strength test set up

5. Conclusions

The following conclusions can be drawn from the present study:

1. Water Absorption Capacity (WAC) of kerosene coated coir fiber reduced by 32% as that of uncoated coir. It is understood that 2day mellowing of kerosene coated coir is sufficient.WAC of 2day mellowed kerosene coated coir fiber reduced by 58% as that of uncoated coir.
2. The compaction characteristics namely MDD and OMC are changed with addition of coir reinforced. The addition of kerosene coated coir fiber decreased MDD and increased OMC. The reason may be the addition of lesser weight material like coir to expansive soil.
3. A coir content of 1% by dry weight of expansive soil gives higher strength. It can be said that UCC strength of 1% kerosene coated coir fiber reinforced soil increased to about 2.5 times in comparison to that of unreinforced soil UCC strength value. Therefore, Optimum Coir Content (OCC) is 1% by dry weight of soil.
4. Splitting tensile strength of OCC reinforced soil is increased by 50% in comparison to that of unreinforced soil. With addition of fibers the tensile strength of the expansive soil is enhanced and it is owing to 'bridge' effect of fiber reinforcement.

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PONAŠANJE ČVRSTOĆE TLA OJAČANOG KOKOSOVIM VLAKNIMA OBLOŽENIM PETROLEJOM

Vlakna kokosovih oraha se izdvajaju iz ljuski kokosovih oraha. Vlakna se mogu efikasno koristiti kao material za ojačanje, ali imaju malu trajnost zbog čega se se vlakna obložena petrolejom koriste u ovom istraživanju. Cilj ovog istraživanja je da se ispita ponašanje bubrenja tla ojačanog nasumično raspoređenim kokosovim vlaknima obloženim petrolejom dužine 5 mm u masi od 0% (neojačano tlo), 0.5%, 1% i 1.5% težine suvog tla. Ispitivanja upijanja vode (WA) su obavljena kako na vlaknima koja su bila potapana u petrolej tako i na onima koja nisu bila. WA ispitivanja su takođe obavljena na vlaknima obloženim petrolejom koja su bila potapana u petrolej na 1, 2 i 3 dana. Moć upijanja tla (WAC) vlakana obloženih petrolejom je manja od onih koja nisu obložena petrolejom. Utvrđeno je da je optimalni sadržaj kokosovih vlakana obloženih petrolejom (OCC) 1%, sa aspekta jednoaksijalne čvrstoće. Zatezna čvrstoća kidanjem tla ojačanog optimalnim sadržajem vlakana je za 50% veća od neojačanog tla

Ključne reči: *bubrenje tla, vlakna kokosovih oraha*