STRENGTH AND STABILITY BEHAVIOR OF SOIL REINFORCED USING RANDOMLY DISTRIBUTED JUTE FIBER

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Abstract - *With the increase in developmental activities and the limited availability of desirable site conditions for construction, it is greatly motivating engineers to improve in-situ soil properties. In India, Soils are classified into two major types, namely Problematic soil and Non-Problematic soil based on their swell-shrink behavior. Non-Problematic soil has very higher strength due to higher shear strength parameters and hence it is less important to geotechnical engineers. However, problematic soil has very low strength due to lower shear strength parameters especially angle of internal friction. Hence an attempt is made to enhance the angle of shearing resistance of the soil by the inclusion of randomly distributed jute fibers. By optimization of soil reinforced with randomly distributed jute fibers using unconfined compressive strength test by preparing soil samples with varying percentage (0.5% to 2.5% RDJF (by weight of soil)) of randomly distributed jute fibers. The test is being conducted on 0th, 7th and 30th day of preparation of samples. From strength test it is found that soil reinforced with 1.5% randomly distributed jute fibers is found to be optimum. The effect of coating fiber with emulsifiers (kerosene, petroleum jelly, varnish) was also examined to know UCS (unconfined compressive strength). On the analysis of stability of slopes using various methods, it has also been found that more stable slopes can be possible when soil is reinforced with randomly distributed jute fibers on compared with soil alone.*

Key Words: **UCS, RDJF, Stable slopes**

1. INTRODUCTION

The term soil has various meanings and carries a different sense to different professional groups. To an engineer, soil is the unaggregated or uncemented deposits of minerals and/or organic particles or fragments covering a large portion of the earth's crust. It includes widely different materials like boulders, sand, gravel, clay and silt. The range in the particle sizes in the soil may extend from grains only to a fraction of micron (10^{-6} m) in diameter up to large size boulders. Expansive soils, also called as 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, buildings, roads, retaining structures, canal lining, etc. The clay of higher compressibility ranges in performance from excellent to poor. Sensitivity to drying and remoulding, degree of potential swell and self stabilization and presence of predominant clay minerals are the major problems experienced by civil engineer.

1.1 Soil Stabilization

Soil stabilization is the alteration of soil to enhance their physical properties. Stabilization can increase the shear strength of a soil and control the shrink-swell properties of a soil, thus improving the load bearing capacity of a sub-grade to support the pavement and foundations. Soil stabilization becomes important when it is weak in strength. There are various methods of stabilizing the soil such as mechanical method, polymer method and chemical method.

1.2 Materials and methods

Soil - The soil used for present work was collected from Bangalore by open excavation method at a depth of 1.5m from ground surface and from the Atterburg's analysis it is found that soil belongs to the classification of Clay of Higher Compressibility (CH) from plasticity chart.

Jute fiber - For the present work, Jute was collected by unthreading the used gunny bag available in one of the provision store in Bangalore. The collected jute thread was cut into smaller pieces irrespective of length and length was not more than 15 mm and was used for all the tests conducted.

- Liquid limit test
- Plastic limit test
- Shrinkage limit test
- Specific gravity tests on soil and jute fiber
- Water absorption test on coated and uncoated jute fiber
- Particle size distribution
- Mini compaction test
- Unconfined compressive strength test

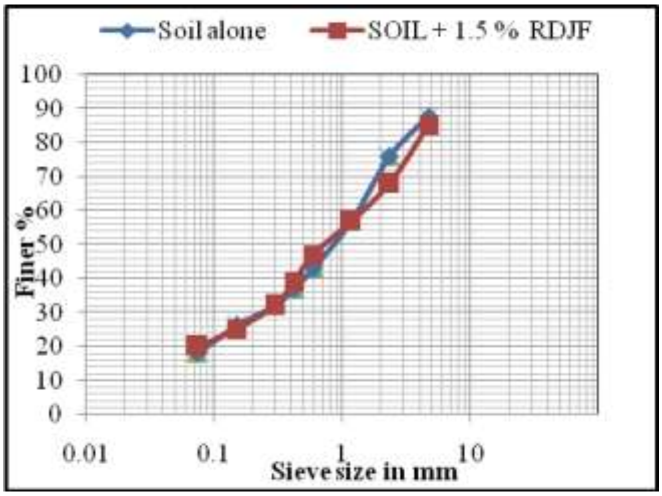
2. Analysis and results

From the basic tests conducted on soil, the following properties were observed. The properties of soil is as shown in Table -1 and Chart -1 shows the particle size distribution of soil alone and soil with 1.5% RDJF.

Table -1: Properties of soil

Properties of Soil	**Value**
Natural Water Content (%)	10.26
Specific Gravity @ 27°C	2.461
Particle size distribution Gravel (%) Sand (%) Silt and clay size fraction (%)	 12.2 69.8 18.0
Atterburg's Limits Liquid Limit (%) Plasticity Index (%) Shrinkage Limit (%)	 62.49 34.04 18.02
Classification of soil as per Plasticity chart	CH
Compaction Test (Mini Compactor) Optimum Moisture Content (%) Maximum Dry Density (KN/m^3)	 27 15.6
Unconfined Compressive Strength (KN/m^2)	104
Safe Bearing Capacity (KN/m^2)	207.09

Chart -1: Particle size distribution curve



2.1 Compaction behavior of soil reinforced with RDJF

Compaction is the test done to compress the soil into a smaller volume, thus increasing its dry unit weight. A soil reaches maximum dry density at specific water content known as optimum moisture content. In this study, maximum dry density and optimum moisture content were found out for soil alone and thereafter varying percent of randomly distributed jute fiber (i.e., 0.5%, 1%, 1.5% (by weight of soil), 2% and 2.5%) is mixed with soil sample. The maximum dry density and optimum moisture content for individually treated soil sample is determined.

Mini compaction apparatus is used to determine the relationship between the moisture content and density of soil. Due to huge number of experiments, we have used mini compaction test apparatus instead of light compaction test apparatus as recommended by IS: 2720. According to Sridharan and Sivapulliah (2005) compaction test on soil using light compaction test apparatus as well as mini compaction test apparatus gave 98% same results. Also by using mini compaction test apparatus, conduction of test is easy and time consuming is relatively less than light compaction test apparatus, hence for our research all the compaction tests were conducted using mini compaction test apparatus only.

In this test, a standard mould of 30 mm internal diameter and an effective height of 100 mm. The mould had a detachable base plate and a removable collar of 35 mm height at its top. The soil was compacted in the mould in 3 equal layers; each layer was given 36 blows of rammer falling through a height of 195 mm. Test was conducted for varying percentages of randomly distributed jute fiber with an increment of 0.5% by weight starting from 0.5%. Fig -1 shows the mini compaction apparatus.

Fig -1: Mini compaction apparatus

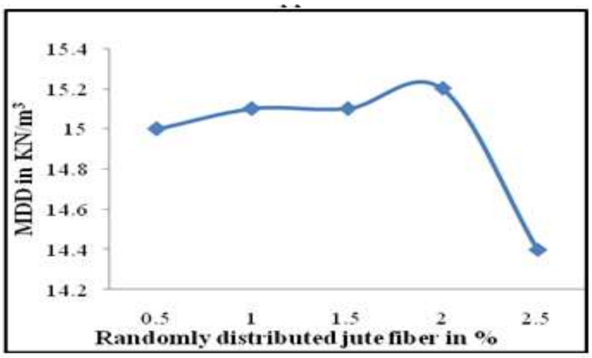


Chart -2: Variation of MDD for soil reinforced with RDJF

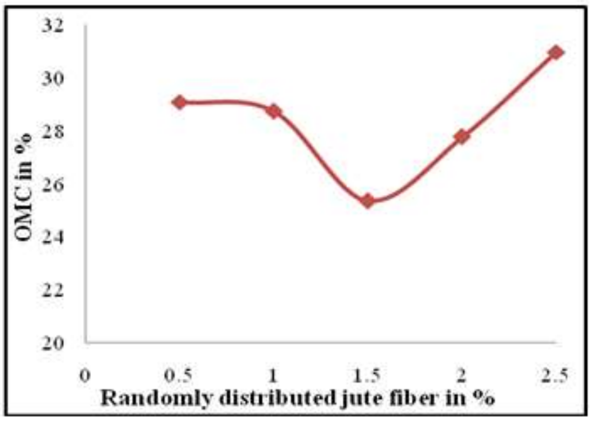


Chart -3: Variation of OMC for soil reinforced with RDJF

From Chart -2 and Chart -3 it has been found that with the addition of varying percentage of randomly distributed jute fiber to soil, maximum dry density reduces and optimum moisture content increases beyond 1.5 to 2% jute fiber in soil (by weight of soil). This may be due to replacement of high density soil by low density fiber and also due to more water observing capacity of fibers than soil alone which makes the matrix to reduce the density and increase the moisture content.

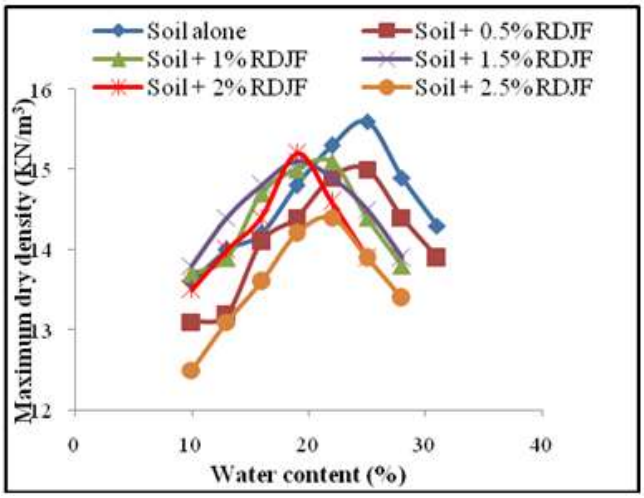


Chart -4: Variation of MDD of soil reinforced using RDJF with water content

Dry density tends to increase up to certain percentage of water then it was found to reduce. The water content at which maximum dry density was achieved is taken as optimum moisture content of the mixture. As water is added to soil at low moisture content, it becomes easier for the particles to move past one another during the application of compacting force. As the particles come closer, the voids are reduced and this causes the dry density to increase. As the water content increases, the soil particles develop larger water films around them. This increase in dry density continues till a stage is reached where water starts occupying the space that could have been occupied by the soil grains. Thus the water at this stage hinders the close packing of grains and reduces the dry unit weight. Chart -4 indicates that soil alone has maximum dry density of 15.6KN/m^3 at optimum moisture content of 27.3%. Soil reinforced with 2.5% randomly distributed jute fiber has minimum dry density of 14.4KN/m^3 at optimum moisture content of 30.96%.

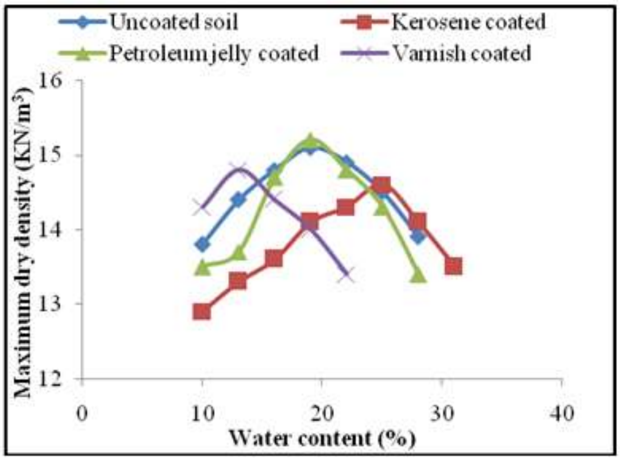


Chart -5: Variation of MDD of soil reinforced using emulsifier coated RDJF with water content

Further, compaction test was conducted by mixing soil with 1.5% (by weight of soil) randomly distributed jute fiber coated with emulsifier like kerosene, petroleum jelly and varnish. From Chart -5, it has been found that the optimum moisture content was maximum for kerosene and minimum for petroleum jelly. Whereas petroleum jelly has maximum dry density than other emulsifiers. This may be because of petroleum jelly is more water repellant.

2.2 Strength behavior of soil reinforced with RDJF

The unconfined compressive strength samples were prepared for soil alone and soil reinforced with randomly distributed jute fibers with varying percentages from 0.5% to 2.5% with an increment of 0.5%. The test was conducted on 0, 7 and 30 days. For 0 day, immediately prepared moulds were tested but for 7 and 30 days test the moulds were prepared and kept for curing in manually prepared desiccators

Fig -2: Moulds placed in desiccator

Fig -3: Unconfined strength test under process

Table -2: Variation of shear strength behavior of soil reinforced with RDJF

Mixture	Unconfined compressive strength (KN/m²)		
	Curing period (days)		
	0	**7**	**30**
Soil alone	104	104	104
Soil + 0.5% RDJF	78	171	179
Soil + 1% RDJF	106	151	210
Soil + 1.5% RDJF	205	270	375
Soil + 2% RDJF	150	228	195
Soil + 2.5% RDJF	85	146	115

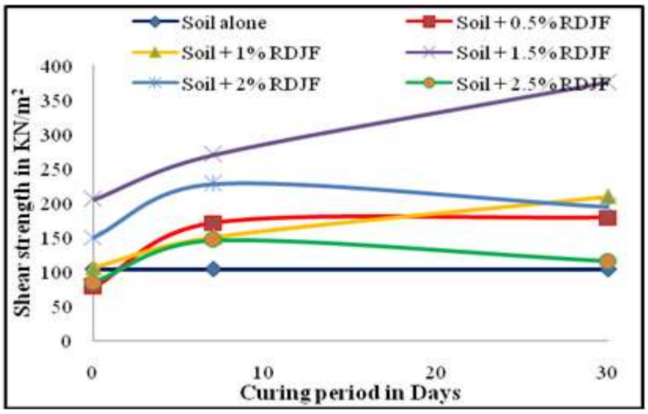


Chart -6: Variation of shear strength behavior of soil reinforced with RDJF

Unconfined Compressive strength tests were conducted on jute fiber reinforced soil samples prepared at obtained maximum dry density and optimum moisture content. Soil was reinforced with varying percentages of randomly distributed jute fiber by weight. Randomly distributed jute fibers were added from 0.5% to 2.5% with an increment of 0.5%. When Soil reinforced with 1.5% (by weight of soil) jute fiber, compressive strength increases and with further increasing of percentage of jute reduces compressive strength, this is due to addition of jute fiber leading to domination of fiber to fiber interaction rather than soil to fiber interaction.

Fig -4: Comparison of mould before and after testing

Jute fiber being one of the good water absorbent, it is important to determine the amount of water absorbed by jute, under coated and uncoated conditions. Test was conducted by immersing coated and uncoated jute fibers in water for 24 hours and then it was air dried for 1 hour.

Fig -5: Water absorption test

Fig -6: Jute fiber strands kept for air drying

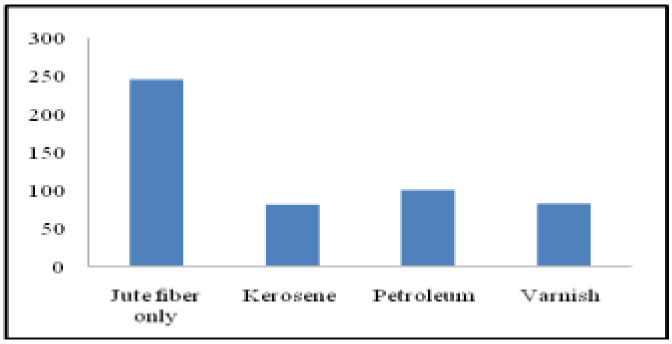


Chart -7: Variation of percentages of water absorption of jute fiber with and without emulsifier coating

Percentage of water absorbed by the uncoated jute fiber and the jute fiber coated with different emulsifiers is indicated in the Chart -7. It is found that jute absorbs more water; hence an attempt was made to reduce the water absorption of jute fiber by coating it with emulsifiers like kerosene, petroleum jelly and varnish. Upon coating emulsifier it is found that kerosene coated jute fiber absorbs less amount of water when compared to other emulsifiers.

UCS test was conducted for soil reinforced using RDJF with emulsifier coating and following were found.

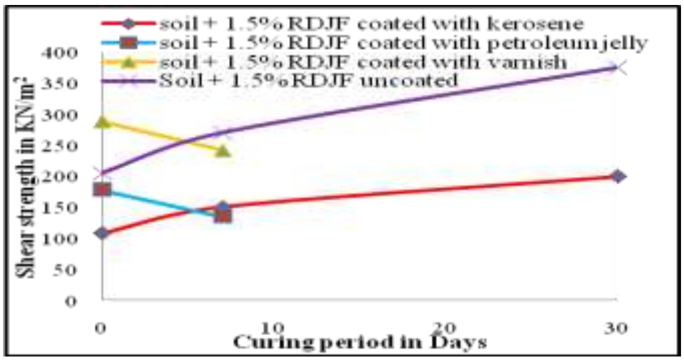


Chart -8: Variation of shear strength behavior of soil reinforced using RDJF with emulsifier coating

Note: * = 30 day test was conducted only for kerosene coated randomly distr ibuted jute fiber because after curing for 7 days the shear strength for petroleum jelly and varnish coated randomly distributed jute fiber were decreased.

Unconfined Compressive strength tests were conducted on coated jute fiber reinforced soil samples. Soil reinforced with 1.5% (by weight of soil) jute fiber coated with emulsifiers like kerosene, varnish and petroleum jelly. Result shows that soil reinforced with 1.5% (by weight of soil) kerosene coated randomly distributed jute fiber shows increased variation of shear strength from 0 day to 7 day where as other emulsifier coated randomly distributed jute fiber show decreasing variation in strength. Soil reinforced with 1.5% (by weight of soil) uncoated jute fiber has better shear strength than emulsifier coated randomly distributed jute fiber.

2.3 Stability analysis of slopes

Stability of the slope indicates the ratio of resisting movement to driving movement, which reflects the safety of the slope against sliding. The failure of a mass of soil located beneath a slope is called as a slide. It involves a downward and outward movement of the entire mass of soil that participates in the failure. The failure of slopes takes place mainly due to:

1. Action of gravitational forces
2. Seepage forces within the soil

They may also fail due to excavation, under cutting of its foot, or due to gradual disintegration of the structure of the soil. The determination of stability of slopes is necessary in a number of engineering activities such as

1. Design of earth dams and embankments.
2. Analysis of stability of natural slopes.
3. Analysis of the stability of excavated slopes.
4. Analysis of failure of foundations and retaining walls.

In practice there are various methods are available for assessing factor of safety of the slope. The common methods are

1. Culmann's method
2. Swedish circle method (slip circle)
3. Friction circle method
4. Bishop's method
5. Taylor's stability number method

We hereby have done an attempt to compare the stability of slope through factor of safety using Taylor stability number with Swedish slip circle approach.

2.3.1 Method of slices

Table -3: Variation of factor of safety of slopes by method of slices

Slope	Factor of safety		
	Soil alone	Soil +1.5 % RDJF	
		0 day	30 days
1.5:1	3.9	7.34	10.81
2.0:1	5.32	10.02	14.76
2.5:1	9.48	17.29	24.83
3.0:1	5.16	14.02	20.67

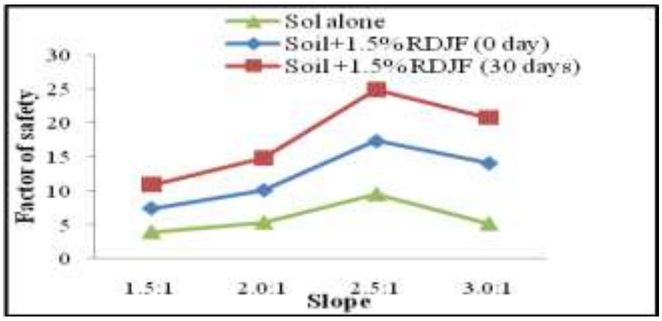


Chart -9: Variation of factor of safety of slopes by method of slices

This method was developed by Swedish engineer, who assumes the surface of sliding is an arc of a circle. In the above graph it is observed that with the increase in slope, there is gradual increase in factor of safety up to a certain slope value (2.5H: 1V) and further increase in slope causes reduction in factor of safety. We can also observe from graph that reinforced soil exhibit higher factor of safety when compared with soil alone, moreover 30 day cured soil reinforced with randomly distributed jute fiber sample has better factor of safety when compared with immediately tested reinforced soil sample.

2.3.2 Taylor's stability number method

Table -4 Variation of factor of safety of slopes by Taylor's stability number method

Slope	Factor of safety		
	Soil alone	Soil +1.5 % RDJF	
		0 day	30 days
1.5:1	2.71	5.58	8.22
2.0:1	3.03	6.22	9.17
2.5:1	3.28	6.74	9.93
3.0:1	3.58	7.35	10.84

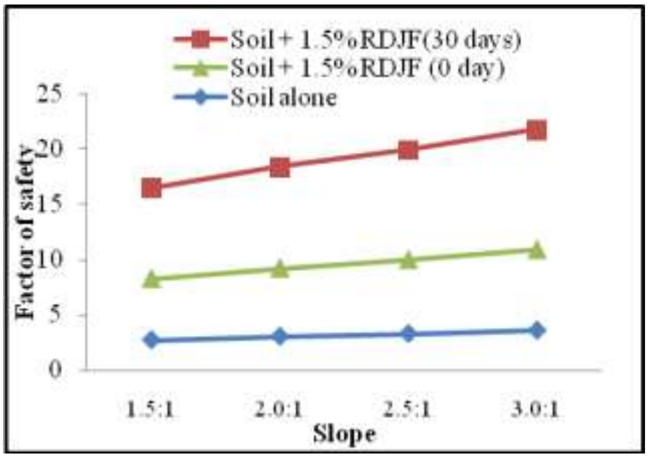


Chart -10: Variation of factor of safety of slopes by Taylor's stability number method

On improvement to the method of slices, Taylor determined the value of dimensionless quantity for finite slope using friction circle method along with an analytical procedure and proposed Taylor's stability number for analysis of stability of slopes. From the above graph, we can observe that the factor of safety is directly proportional to the slope. Increase in slope gradually increases the factor of safety. Reinforced soil exhibit higher value of factor of safety when compared to soil alone, moreover 30 day cured reinforced soil sample has better factor of safety when compared to 0 day reinforced soil.

3. CONCLUSIONS

1. Soil reinforced with randomly distributed jute fiber reduces the maximum density of the soil fiber matrix; they may be due to replacement of higher density soil by lower density jute fiber.

2. Soil reinforced with varying percentage of randomly distributed jute fiber initially reduced the moisture content and increased thereafter. Maximum reduction in optimum moisture content was at 1.5% (by weight of soil) of randomly distributed jute fiber (by weight of soil)

3. Soil reinforced with 1.5% (by weight of soil) randomly distributed jute fiber (by weight of soil) increases the unconfined compressive strength by 97% on compared with soil alone at 30 days curing. The improvement in the strength is due to passive inclusion of the fiber in the soil with offer resistance against the sliding of the soil during shear.

4. Uncoated randomly distributed jute fibers exhibit greater shear strength when compared with that of coated ones. The shear strength of varnish and petroleum jelly coated randomly distributed jute fiber decreased after curing for 7 days, but it increased for kerosene. However the compressive strength of uncoated randomly distributed jute

fibers (1.5% (by weight of soil) by weight of soil) was 87.5% more than that of kerosene coated fibers.

5. Stability analysis of slope using Taylor's stability found that soil reinforced with optimum randomly distributed jute fiber shows 2 folds increased in the factor of safety on compared with soil alone for all slopes in general.

6. Stability analysis of slope using method of slices found that soil reinforced with optimum jute fiber shows 2.7 folds to 4 folds increase in the factor of safety on compared with soil alone for 1.5:1 slope to 3:1 slope respectively, however at 2.5:1 slope shows higher factor of safety for soil reinforced with 1.5% (by weight of soil) randomly distributed jute fiber on compared with soil alone as well as soil reinforced with same percentage of jute fiber for other slopes.

7. On comparing Taylor's stability number and method of slices, the slope of 2.5H:1V has shown acceptable factor of safety by both the methods, in case if we increase the slope for example 3H:1V, the factor of safety has been increased in case of Taylor's stability number method but decreased for method of slices. On observing all these variations, we suggest 2.5H: 1V as an optimum slope and method of slices is considered as preferable one.

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