

# Strength behaviour of lateritic soils randomly reinforced with jute fibre

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**ABSTRACT:** This paper presents strength characteristics of a lateritic soil randomly reinforced with jute fibre. Jute fibre of different lengths was mixed with the soil. The fibre content was varied from 0 to 0.6% by weight of dry soil. Unconfined compression tests, triaxial compression tests and tensile strength tests were conducted on the soil-fibre mixes. Specimens for strength tests were prepared at the optimum moisture content and dry density of the mix. Results of strength tests indicated that the strength of reinforced soil increased with the % of fibre content and aspect ratio. However, in the case of unconfined compressive strength, there is an optimum fibre content for maximum strength. Jute fibre may be considered for reinforcement in lateritic soils when an open cut is to be made and stability is a problem. Reinforcing with jute fibre of pavements with heavy traffic and on lateritic soils improves tensile strength.

## 1 INTRODUCTION

Lateritic soils, which constitute an important group of residual soils of India, are essentially products of tropical or sub-tropical weathering and are predominantly coarse-grained and ferruginous in character. They form a good foundation material. They pose certain problems such as high permeability, and decrease of strength at a depth from the surface. Stability of cuts in vesicular laterites is a problem in the high shear stress level zones near the cuts. A simple flattening of the slope will not increase the stability.

Soils are commonly reinforced by continuous oriented inclusions, namely, strips, fabrics and grids (Vidal, 1969). Early civilizations mixed soil with straw or other fibre available for strengthening it. Several soil engineers used material like straw, jute, saw dust, horse-hair etc. as reinforcement to improve the engineering behaviour of soils.

Satyanarayana et al. (1977) studied the behaviour of a cement-treated expansive clay reinforced by fibres of glass and asbestos in compression and tension and found that addition of these fibres increased the tensile and unconfined compressive strengths. An increase of 25 to 55 percent in tensile strength and 5 to 30 percent in unconfined compressive strength is reported.

Tensile strength behaviour of lime-stabilized lateritic soil, plain and reinforced with coconut fibre were reported by Bhattacharya et al. (1984). Fibre-reinforced mixes were found to have developed increased flexural strengths over plain mixes. Freitag

(1986) observed that lean sand-clay mixes and different types of synthetic fibres showed higher compressive strengths than those unreinforced. The type of the fibre used did not seem to have significant effect on strength. Reinforcement of an expansive soil with 'Garware twine' has resulted in increased shear strength and tensile strength with increase in fibre content, where as the maximum dry density and flexural strength decreased with an increase in fibre content (Setty et al. 1990).

It has been reported that reinforcing a clayey soil-lime mix with coconut fibre has improved the compressive strength as well as tensile strength (Ramana Sastry et al. 1993). Rama Sarna et al. (1997) reported that coconut fibre can be directly mixed with soil for strengthening weak sub-grades. Considerable increase in CBR values has been reported. For the maximum compressive strength, there is an optimum content of fibre reinforcement.

Agarwal et al. (1997) studied the influence of fibre properties like weight, fraction and aspect ratio on the strength characteristics of a Kaolin soil mixed with random discrete fibres of polypropylene and jute. Their studies show that the unconfined compressive strength and undrained cohesion increase with fibre content for both the types of fibre. This increment is more with jute fibre as compared to polypropylene fibre.

In this paper the authors present results of laboratory tests (Suryanarayana, 1999) carried out to find the efficacy of jute fibre as a reinforcement in improving the strength of lateritic soils.

## 2 MATERIALS AND THEIR PROPERTIES

### 2.1 Soil

The lateritic soil used in this investigation has been obtained from a depth of about 1.0m below ground level, freed from organic matter, pulverised and sieved through the set of sieves specified in relevant Indian Standards for different tests and stored in air-tight containers.

### 2.2 Jute fibre

Air-dried jute fibre, generally used for packing purposes, has been obtained from local market. The fibre is cut into pieces of two different sizes. 20 mm and 30 mm and kept separately in air-tight containers for use in the investigation. Diameter of the jute fibre is 1 mm. Jute fibre is a bio-degradable material. In order to improve its resistance against degradation the fibre was dipped in hot molten asphalt so that a uniform thin film of asphalt is obtained on the fibres.

## 3 TESTS CARRIED OUT

The tests have been carried out for finding the index properties, compaction characteristics, unconfined compressive strength, tensile strength behaviour and shear parameters as determined from triaxial compression (quick) tests.

Tensile strength of soil-fibre mixes has been determined by conducting indirect tensile strength test (Cylinder split test or Brazilian Test).

Specimens used for the strength tests have been moulded at the maximum dry density and optimum moisture content of the particular reinforced soil-jute mix as obtained from the compaction tests.

### 3.1 Variables considered in the investigation

The following variables have been studied.

Fibre length (mm): 20 and 30

Fibre content (%): 0, 0.2, 0.4 and 0.6

Aspect ratio (length/diameter of fibre): 20 and 30

The length of fibres and fibre content (%) have been fixed taking into consideration factors like ease of mixing and compacting of the jute-reinforced soil mixes.

## 4 TEST RESULTS AND DISCUSSION

Tables 1 and 2 show the engineering properties of unreinforced soil and the compaction results of the reinforced soil respectively.

A perusal of the results presented in Table 2 shows that addition of fibre to the lateritic soil in general decreased the maximum dry density and in-

Table 1. Engineering properties of the soil.

Property	Value
Optimum moisture content (percent)	18
Maximum dry density $\text{kN/m}^3$	17.10
Unconfined compressive strength $\text{kN/m}^2$	103
Cohesion $\text{kN/m}^2$	30
Angle of internal friction (Degrees)	20

Table 2. Results of compaction tests.

Fibre content (%)	Maximum dry density $\text{kN/m}^3$		Optimum moisture content (%)	
	Aspect ratio		Aspect ratio	
	20	30	20	30
0.2	17.00	16.95	18.6	19.6
0.4	16.95	16.90	20.2	20.4
0.6	16.90	16.85	21.0	21.2

creased the optimum moisture content marginally. Fibre being very light material (specific gravity 0.5) compared to soil (specific gravity 2.62) even small quantities have a larger bulk. and addition of it to soil has replaced larger quantities of heavier material, resulting in marginal changes in compaction characteristics of the soil-fibre mixes. This is in accordance with the observation of earlier workers (Bhattacharya, et al. 1984, Ramana Sastry et al. 1993, Rama Sarma et al. 1997).

### 4.1 Unconfined compressive strength

Figure 1 presents the influence of fibre content and aspect ratio on the unconfined compressive strength (UCS) of the jute-soil mixes. For any aspect ratio the unconfined compressive strength increased with fibre content up to an optimum fibre content (0.4 percent in this study). With further increase in fibre content, the strength decreased. For any fibre content, mixes with 30 aspect ratio have resulted in higher strengths compared to mixes with aspect ratio of 20.

Aspect ratio of the fibre appears not to have significant effect on the optimum fibre content for strength. Jute fibre reinforcement has contributed to

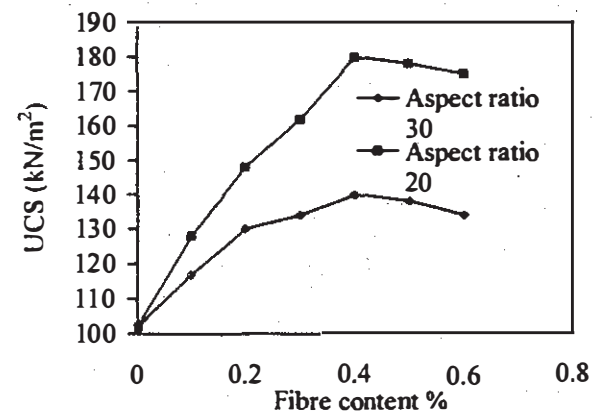


Figure 1. Effect of fibre content on UCS.

a significant increase of cohesion and reduction in the value of angle of internal friction and may be responsible for the increase in unconfined compressive strength with the increase in fibre content upto the optimum value. Beyond the optimum fibre content, the increase in compressive strength is less and the angle of internal friction remained practically constant with increase in fibre content. This may be responsible for the decrease in unconfined compressive strength. Studies carried out by earlier researchers (Satyanarayana et al. 1977, Ramana Sastry et al. 1993 and Bhattacharya et al. 1984) on stabilised soil mixes reinforced with various randomly oriented fibres also show that fibre-reinforcement improves the compressive strength of the reinforced soil and that there is an optimum fibre content for maximum compressive strength.

#### 4.2 Results of triaxial compression tests

Figures 2 and 3 show the variation of cohesion and angle of internal friction with % fibre content as obtained from triaxial compression tests. Irrespective of the aspect ratio, addition of jute fibre (0.2 percent) has resulted in a considerable increase in cohesion and large decrease in angle internal friction. With

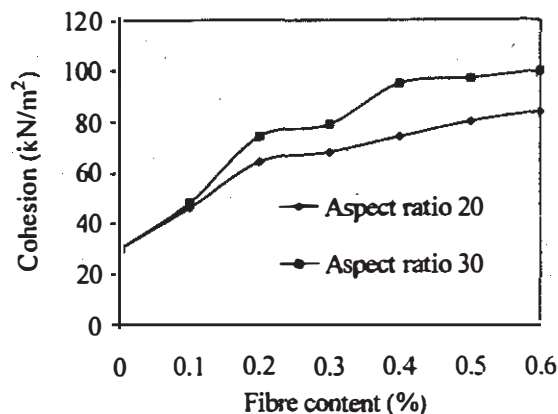


Figure 2. Effect on cohesion.

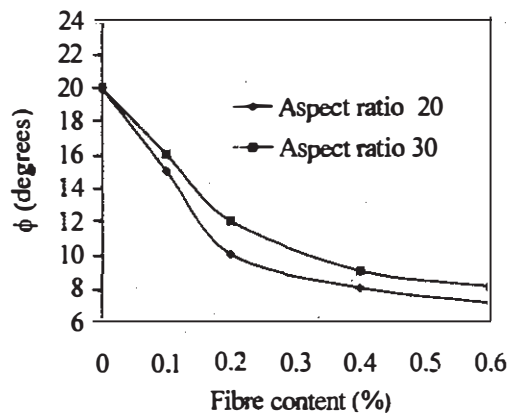


Figure 3. Effect of the fibre content on  $\phi$ .

further increase in fibre content, though there is fairly good increase in cohesion, a marginal decrease in the angle of internal friction is noticed. For any fibre content, reinforced mixes of aspect ratio of 30 have shown higher values of cohesion than those of aspect ratio of 20. However, with respect to angle of internal friction, reinforced mixes of aspect ratio 30 have shown slightly lower values of angle of internal friction than those of aspect ratio 20. Shear strength of the reinforced soil mixes increased with the jute fibre content as well as with the aspect ratio (Fig 4). These findings are in accordance with the observations of Agarwal et al. (1997). Open cuts in lateritic soils have posed stability problems to field engineers. In the light of improvement of shear strength of lateritic soil when reinforced with jute fibre; this technique may offer a solution to the problem.

#### 4.3 Results of tensile strength tests

The study of tensile strength of soils and stabilized materials has received very little attention of the engineers. Tensile stresses are set up in soils due to movement of traffic on pavements, shrinkage of soils due to seasonal variation in temperature and al-

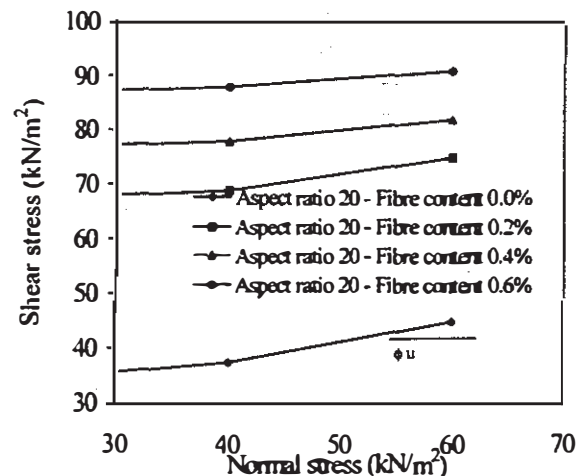


Figure 4. Effect on shear stress.

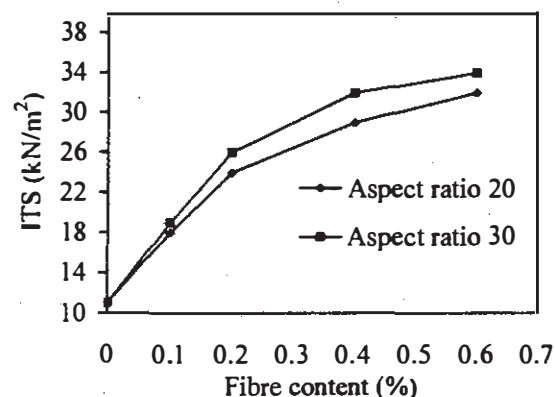


Figure 5. Effect on tensile strength.

ternate drying and wetting of soils. A knowledge of the tensile strength is needed in the study of earth dams, airport pavements etc. Reinforcement of a lateritic soil with jute fibre improves its tensile strength. For any fibre content, tensile strength increases with the aspect ratio. For any aspect ratio, randomly distributed fibrous material throughout the matrix of the soil contributes to the increase in tensile strength. Figure 5 shows the variation of indirect tensile strength (ITS) with fibre content. Studies carried by Bhattacharya et al. (1984), Ramana Sastry et al. (1993) and Datir et al. (1997) on lime-stabilized lateritic soils reinforced with fibres like coir, jute, and polypropylene fibres reported remarked increase in tensile strength (flexural and direct) over those stabilized with lime alone.

## 5 CONCLUSIONS

Studies carried out on a lateritic soil randomly reinforced with jute fibre show that this natural fibre, available in plenty as a by-product of jute industry, is quite an efficacious and an economic material for reinforcement. The size (length) of the jute fibre and the amount to be used for reinforcement has to be fixed based on ease with which a uniform mix can be made and compacted. It is observed that the unconfined compressive strength, shear strength and tensile strength of the reinforced mixes increase with the fibre content and aspect ratio. However, the unconfined compressive strength of the randomly reinforced mixes increased up to an optimum fibre content (0.4 percent in the present study). Further increase in fibre content resulted in a loss of strength. Increase in tensile strength of reinforced soil mixes may be taken as an advantage in the con-

struction of high density and heavy traffic pavements. Further, reinforcement of lateritic soil with jute may be used in zones of high shear stresses to improve the stability of open cuts in the regions of lateritic soils.

## REFERENCES

- Agarwal K.B. & Subash Chandra 1997. Improvement in strength and bearing capacity of clay due to fibre reinforcement. *Proceedings of the Indian Geotechnical Conference*.
- Bhattacharya P.G. & Pandey B.B. 1984. Effect of density on strength and modulus of plain and fibre reinforced lime - lateritic soil mixtures under static and repeated load. *Proceedings of Indian Geotechnical Conference*.
- Datir D.D., Pandya H.P., Mankad V.M. & Panehal D.A. 1997. Effect of Polypropylene Fibre on tensile strength of stabilized soil. *Proceedings of Indian Geotechnical Conference*.
- Freitag R. 1986. Soil randomly reinforced with fibres. *Journal of Geotechnical Engineering. ASCE. Vol. 112*.
- Rama Sarma, K & Rajesh.G. 1997. Improvement of CBR values using coconut fibre. *Proceedings of Indian Geotechnical Conference*.
- Ramana Sastry. M.V.B. & Satyakumari T. 1993. Strength characteristics of a plain and fibre reinforced lime treated expansive soil. *Indian Roads Congress Highway Research Bulletin No 49*.
- Satyanarayana B. & Srivastava K.M. 1977. Tensile and compressive strength of soil-cement-glass and soil-cement-asbestos fibre mixes. *1<sup>st</sup> National Symposium on expansive soils held at H.B.T.I. Kanpur*.
- Setty K.R. Narayana Swamy & Anantha Krishna Murthy. 1990. Behaviour of fibre reinforced black cotton soil. *Proceedings of Indian Geotechnical Conference*.
- Suryanarayana N. 1999. Strength characteristics of jute - fibre reinforced lateritic soil. *Thesis submitted for award of M. Tech Degree. J.N. Technological University. Andhra Pradesh. India*
- Vidal H. 1969. The principle of reinforced earth. *Highway Research Record No. 282. H. R. B. Washington*.