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Research Article

Strength and Stiffness of Soil Reinforced with Jute Geotextile Sheets

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Abstract

Reinforcing elements in the form of rods, sheets, strips, membranes such as Jute, Coir, and Bamboo to soil is prevalent for a long time and they are abundantly used in many countries like India, Philippines, etc. The main advantages of these materials are they are locally available, cheap and biodegradable. If these materials are used effectively, the rural economy can get uplift and also the cost of construction can be reduced. Further, the soil reinforcement causes significant improvement in tensile strength, shear strength, stiffness modulus and load carrying capacity of soil. Keeping this in view an experimental study was conducted with locally available (Itanagar, Arunachal Pradesh, India) soil reinforced with jute geotextile layers. The Jute Geotextile layers equal to plan dimensions (38 mm x 76 mm) of triaxial test samples were placed at equal vertical spacing within the soil in different combinations such as 1 layer, 2 layers, 3 layers and 4 layers. The shear strength parameters (c and ϕ) and stiffness modulus ($\sigma d/\epsilon$) of reinforced soil were determined in the laoratory using triaxial test set up. Further, these test results were compared with that of unreinforced soil. It was observed that inclusion of Jute Geotextile layer into the soil increases the shear strength parameters and stiffness modulus of soil and this increase is maximum corresponding to 4 layers of Jute Geotextile layers. Thus there is a significant increase in shear strength parameters and stiffness modulus of soil due to inclusion of Jute geotextile sheets as reinforcement.

Keywords: *Soil, Jute Geotextile Sheet, Shear strength parameters, Stiffness modulus, Triaxial compression test*.

1. Introduction

Reinforced soil is a composite material which is formed by the association of frictional soil and tension resisting elements in the form of sheet, strips, nets or mats of metals, synthetic fabrics or fibre reinforced plastics and arranged in the soil mass in such a way to reduced or suppress the tensile strain which might develop under gravity and boundary forces. It is well known that most granular soils are strong in compression and shear but weak in tension. The performance of such soils can be substantially improved by introducing reinforcing elements in the direction of tensile strains in the same way as in reinforced concrete. Reinforcing elements in the form of rods, sheets, strips, and membranes of Jute, Coir, and Bamboo in soil is prevalent for a long time and they are abundantly used in many countries like India, Philippines, etc. Saran, 2010 .The main advantages of these materials are that they are locally available and very cheap. They are biodegradable and hence do not create disposal problems in environment. Processing of these materials into a usable form is an employment generation activity in rural areas in these countries. If these materials are used effectively, the rural economy can get uplifted and also the cost of construction can be reduced, if the material use leads to beneficial effects in engineering construction. Considering the above facts, many researchers have studied the influence of reinforcement in the form of sheets, strip, mats, fiber, etc. on the strength parameters of soil. Gray and Ohashi, 1983 conducted a series of direct shear tests on dry sand reinforced with different synthetic, natural and metallic fibers to evaluate the effects of parameters such as fiber orientation, fiber content, fiber area ratios, and fiber stiffness on contribution to shear strength. Based on the test results they concluded that an increase in shear strength is directly proportional to the fiber area ratios and shear strength envelopes for fiber-reinforced sand clearly showed the existence of a threshold confining stress below which the fiber tries to slip or pull out. Andrews et.al, 1986 and Lawton et.al, 1993 used the polymeric mesh element and the discontinuous multioriented polypropylene elements to reinforce the soil and found that addition of reinforcing elements to soil contributes to the increase in strength and stiffness. Gray and Al Refeai 1986, Maher and Gray 1990, Ranjan et. al, 1994, 1996, Charan 1995, Consoli et al., 2002, Michalowski and Cermak, 2003], Gosavi et al., 2004, Yetimoglu and Inanir 2005, Rao et al., 2006, Chandra et al., 2008], Jadhao, and Nagarnaik, 2008, and Ayyappan et al., 2010 used the randomly distributed geogeosynthetic propylene fibers to reinforce the different soil types and concluded that there is significant improvement in strength and stiffness of soil due to inclusion of geosynthetic fiber. Sivakumar Babu and Vasudevan, 2008 and Singh et al, 2011 used the

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randomly distributed coir fibers as a reinforcing material to soil and found that there is a significant improvement in the shear strength parameters (c and ϕ) and California Bearing Ratio (CBR) value of soil due to inclusion of coir fiber. Further, Singh 2012 determined the laboratory CBR value of Itanagar (Arunachal Pradesh, India) soil with Jute geotextile sheets used in different combinations such as 1 layer, 2 layers, 3 layers and 4 layers and found that the CBR value of soil increases with the increase in layers of Jute Geotextile sheets. The increase in CBR value indicates the increase in load carrying capacity of pavement subgrade. Recently, the soil reinforcement techniques have been used to improve the performance of fly ash also to make it a suitable low cost construction material. Kaniraj and Gaytri, 2003, Chaudhary and Verma, 2005, Singh 2011, Singh and Kamsi, 2011 and Singh and Yachang 2012 used the randomly distributed synthetic fiber, synthetic geogrid sheets and Jute Geotextile sheets etc. as reinforcing materials to Dadri fly ash, Tisco fly ash and Itanagar fly ash and found that the shear strength parameters (c and ϕ) and CBR value of fly ash increases significantly.

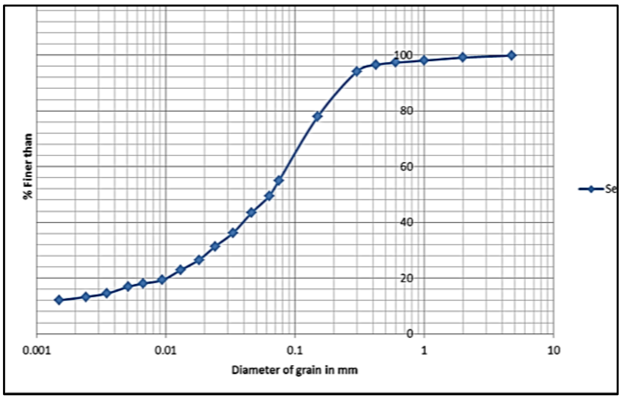

Fig.1: Grain size distribution curve of Soil

In the present investigation the influence of Jute-geotextile sheets on the shear strength parameters (c and ϕ) and the stiffness modulus value of soil have been reported. In this study a number of triaxial tests have been conducted on the samples of soil and soil reinforced with different layers of Jute-geo-textile sheets. The shear strength parameters and stiffness modulus values of reinforced soil have been determined under four different confining pressures (50 kPa , 100kPa, 150 kPa and 200 kPa) and compared with that of unreinforced soil specimen.

2. Material

In this study locally available (Itanagar) soil and Jute geotextile sheets obtained from local market have been used. The properties of these materials are given in the following sections.

2.1 Soil

The particle size distribution curve of soil is shown in Fig.1. The various physical and index properties of the soil were computed from the plot and are shown in Table 1

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2.2 Jute Geotextile Sheet

The Jute Geotextile sheet taken from the Jute bag, were collected from the local market. The average thickness of the sheet was 3mm. The view of the Jute Geotextile sheet are shown in Fig.2

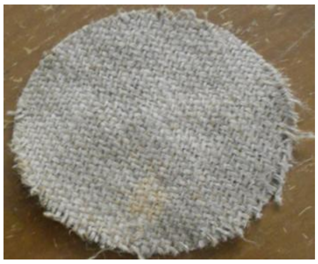

Fig.2: View of the Jute Geotextile Sheet

Table 1 Properties of Itanagar soil

S. No.	Property	Notation	Value
1	Specific Gravity	G	2.69
2	Liquid Limit	LL	20.30
3	Plastic Limit	PL	10.18
4	Plasticity Index	PI	10.12
5	Gravel Size	> 4.75 mm	0.2 %
6	Sand Size	0.075 mm -4.75 mm	46.98 %
7	Silt Size	0.002 mm – 0.075 mm	41.00 %
8	Clay Size	< 0.002 mm	12.00 %
9	Max^{m}. Dry Density	γ_d	18.00 %
10	Optimum Water Content	OMC	15 %

3. Tests and Results

In the present study test samples for triaxial compression tests were prepared using standard procedure and shear strength parameters and stiffness modulus of soil and reinforced soils were determined. The detail procedures of triaxial test and computation of test results are described in the following sections.

3.1 Triaxial Test

Triaxial compression test specimens of soil and soil reinforced with Jute Geotextiles were prepared in a standard cylindrical mould of 38 mm diameter and 76 mm height. All the specimens were prepared at a dry density of 17.46 kN/m^3 i.e. 97 % of maximum dry density and corresponding water content of 14.55 % [18]. All the specimen were tested in a conventional triaxial apparatus under confining pressure of 50 kPa, 100 kPa, 150 kPa and 200 kPa in undrained condition (unconsolidated Undrained Test). Load on the soil samples were applied at a controlled strain rate of 1.5 % per minute until the specimen failed or up to strain of 20 %, whichever reached earlier. Based on the test results Deviator stress ~Strain curves of soil reinforced with various Jute Geotextile sheets (i.e. 0 layer, 1 layer, 2 layer, 3 layer and 4 layers) under different confining pressures (i.e. 50kPa, 100kPa, 150kPa and 200kPa) were drawn. One such curve is shown in Fig. 3 for the confining pressure of 50 kPa. It was observed during the test that failure stresses and failure strains increases with the increase in number of Jute Geotextile sheets. The values of deviator stress at failure corresponding to each combination of Jute geotextile sheet was computed from the plots of deviator stress ~ strains and the failure envelopes (for all the combinations of Jute Geotextile sheets i.e. 0 layer, 1 layer, 2 layers, 3 layers and 4 layers) were drawn using Mohr's circle diagram. One such Mohr's circle is shown in Fig. 4 for 1 layer of Jute Geotextile sheet. The values of cohesion (c) and angle of internal friction (ϕ) of reinforced soil were measured from the corresponding failure envelope and are shown in Table 2. Further, the ratio of deviator stress and corresponding strain for each combination of Jute Geotextile sheet under various confining pressures were evaluated to determine the stiffness modulus of reinforced soil. The value of stiffness modulus of soil reinforced with different combinations of Jute geotextile sheet are shown in Table 3.

3.2 Test Result

The test results obtained from triaxial compression tests performed on soil and Jute geotextile sheet reinforced soil specimens under confining pressure of 50 kPa are shown in Fig. 3 and Fig. 4. The values of shear strength parameters (c and ϕ) and stiffness modulus (σ_d/ϵ) of soil and soil reinforced with different combinations of Jute geotextile sheets are shown in Table 3 and Table 4.

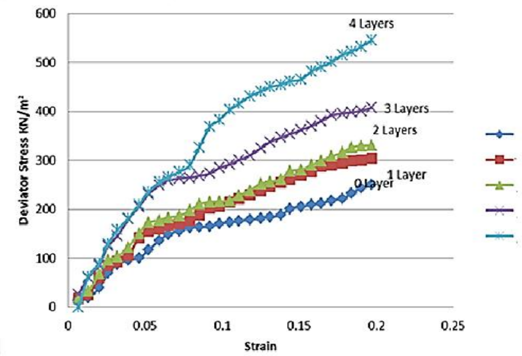

Fig. 3: Deviator Stress ~ Strain Curves of Reinforced Soil under Confining Pressure of 50 kPa

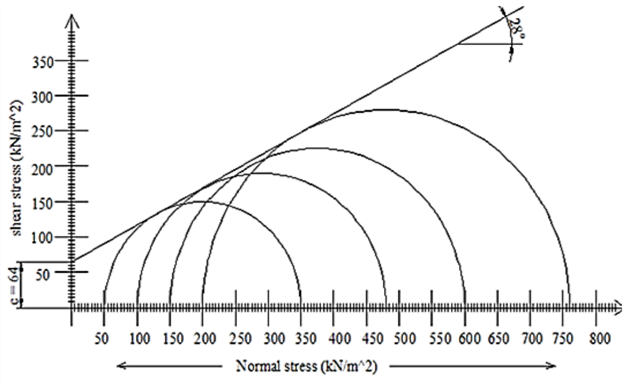

Fig. 4: Mohr's Failure Envelope for Soil Reinforced with 1 Layer of Jute Geotextile Sheet.

Table 2: Shear Strength Parameters of Reinforced Soil

No. of JGT Sheet	c (kN/m^2)	ϕ (Degree)	Percentage increase(c)	Percentage increase(ϕ)
0	55	26		
1	64	28	16	8
2	65	31	18	19
3	70	36	27	38
4	95	38	72	46

Table 3: Stiffness Modulus of Reinforced Soil

No. of JGT Sheet	Conf. Press (kN/m^2)	Stiffness Modulus (σ_d/ϵ)	Percentage increase in (σ_d/ϵ)	Average % increase in (σ_d/ϵ)
	50	1269		
0	100	1776		
	150	1903		
	200	2512		
	50	1548	22	
	100	1929	8.5	16
1	150	2286	20	
	200	2868	14	
	50	1675	32	
2	100	2284	28	
	150	2970	56	36
	200	3248	29	
	50	2067	63	
3	100	2793	57	71
	150	3452	81	
	200	4568	82	
	50	2769	118	
	100	3541	94	112
4	150	4492	136	
	200	5076	102	

4. Interpretation of Test Result

It is observed from the results of Table 2 and Table 3 that there is a significant effect of Jute Geotextile sheet on shear strength parameters and stiffness modulus of soil. In case of plain soil the values of shear strength parameters (c and ϕ) from Table 2 are 55 kPa and 26 0 respectively. When 1 layer of Jute geotextile sheet is added to the soil, the c and ϕ values of soil increase to 64 kPa and 280 respectively. It is further observed that increasing the number of layers of Jute geotextile sheets in soil, these parameters of soil further increase and this increase is substantial (c = 95kPa and ϕ = 38 0) at 4 layers of Jute geotextile sheets. Hence the maximum increase in c and ϕ value of soil is 72 % and 46 % respectively for 4 layers of Jute geotextile sheets. Similar trends are observed from Table 3 for stiffness modulus of soil also. It is observed from Table 3 that the stiffness modulus of soil increases with the increase in Jute geotextile sheets and confining pressures. The average increase in stiffness modulus of soil due to 1 layer of Jute geotextile sheet is 16 %. When the number of layers of Jute geotextile sheet is increased to 2, 3, and 4, the average increase in stiffness modulus of soil is 36%, 71% and 112% respectively. It is to be mentioned here that the preparation of identical reinforced soil samples (i.e. at constant dry density and water content) beyond 4 layers of Jute geotextile sheets was not possible due to which test results on soil reinforced with 5 and more layers of Jute geotextile sheets are not shown in Table 2 and Table 3. The increase in shear strength parameters and stiffness modulus of soil after inclusion of Jute geotextile sheet in it is due to the fact that reinforcing elements interact with soil particles mechanically through surface friction and by interlocking. The function of the interlock or bond is to transfer the stress from the soil to the reinforcing elements by mobilising the tensile strength of reinforcing elements which results into decrease in tensile strain and improvement in load carrying capacity of reinforced soil. Further, improvement in stiffness modulus of soil due to inclusion of Jute geotextile sheet indicates the reduction in amount of immediate settlement of soil. Therefore, it can be concluded that addition of Jute geotextile sheet in soil improves its load carrying capacity and reduce the value of immediate settlement.

Conclusions

The shear strength parameters (c and ϕ) of soil increase due to inclusion of Jute geotextile sheet in soil. When the number of layers of Jute geotextile sheets are increase, these strength parameters of soil are further increases. The maximum increase in c and ϕ values of soil are 72 % and 46 % respectively for 4 layers of Jute geotextile sheets. The stiffness modulus ($\sigma d/\epsilon$) of soil increases with the inclusion of Jute geotextile sheet in soil. When the number of layers of Jute geotextile sheets are increase, the stiffness modulus of soil are further increases. The stiffness modulus of soil increases with the increase in confining pressures also. The average maximum increase in stiffness modulus of soil is 112 % for 4 layers of Jute geotextile sheets. The preparation of identical reinforced soil samples (i.e.at constant dry density and optimum water content) beyond 4 layers of Jute geotextile sheets was not possible in the laboratory and hence the numbers of layers of Jute geotextile sheets in the present investigations were restricted to 4 only.

Based on the present study it is concluded that the load carrying capacity of soil increases and amount of immediate settlement decreases when soil is reinforced with Jute geotextile sheets.

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References

Andrews, K. Z., McGown, A., Hytiris, N., Mercer, F. B and Swetland, D. B, (1986), The use of mesh elements to alter the stress strain behavior of granular Soils, Proc. of the third *International Conference on Geotextiles*; Vienna, 839-844

Ayyappan, S., Hemlatha, K. and Sundram, M., (2010), Investigation of engineering behaviour of soil, polypropylene fibers and fly ash mixtures for road construction, *International Journal of Environmental Science and Development, 1*(2), 171-175.

Chandra, S., Viladkar, M.N and Nagrale, P.P, (2008), Mechanistic approach for fiber-reinforced flexible pavements, *Journal of Transportation Engineering*; 134 (1), 15-23.

Charan, H.D, (1995), Probabilistic analysis of randomly distributed fiber-reinforced soil, Ph. D. Thesis; *Dept. of Civil Engg., IIT Roorkee*, Roorkee, India.

Choudhary, A.K. and Verma, B.P., (2005), Behaviour of reinforced fly ash subgrade, *Journal of Institution of Engineers* (I); 86, 19-21.

Consoli, N.C., Montardo, J.P., Prietto, P.D.M and Pasa, G.S., (2002), Engineering behavior of sand reinforced with plastic waste, *Journal of Geotechnical and Geoenvironmental Engg.*, ASCE; 128 (6), 462-472.

Gosavi, M., Patil, K.M., Mittal, S and Saran, S.,(2004), Improvement of properties of black cotton soil subgrade through synthetic reinforcement, *Journal of Institution of Engineers* (India); 84, 257-262.

Gray, D. H and Al Refeai, T, 1986. Behavior of fabric versus fiber reinforced sand, ASCE *Journal of Geotechnical Engineering*; 112, 804-820

Gray, D.H. and Ohashi, H, 1983. Mechanics of Fiber Reinforcing in Sand, ASCE Journal of Geotechnical Engineering,109 (3), 335-353Jadhao, D.P. and Nagarnaik, P.B., (2008), Performance Evaluation of Fiber Reinforced Soil- Fly Ash Mixtures, Proc. Of the 12th *International Conference of International Association for Computer Methods and Advances in Geomechanics* (IACMAG), held from October 1-6, at Goa, India, 1(2), 171-175.

Kaniraj, S.R.and Gayathri, V., (2003), Geotechnical behaviour of fly ash mixed with randomly oriented fiber inclusion, *Journal of Geotextiles and Geomembranes*, 21 (3), 123-149

Lawton, E. C., Khire, M. V and Fox, N. S., (1993), Reinforcement of soils by multioriented geosynthetic inclusion, ASCE *J. of Geotech*. Eng. Div.; 119(2), 257-275.

Maher, M. H and Gray, D. H., (1990), Static response of sands reinforced with randomly distributed fibres, ASCE J. *of Geotech*. Eng. Div.; 116(11), 1661-1677.

Michalowski, R.L and Cermak, J., (2003), Triaxial compression of sand reinforced with fibers, *Journal of geotechnical and Geoenvironmental Engg*. ASCE; 129 (2), 125-136.

Ranjan, G., Vasan, R. M and Charan, H. D., (1994), Behavior of plastic fibre-reinforced sand, *Journal of Geotextile Geomembranes;* 13(8), 555-565.

Ranjan, G., Vasan, R. M and Charan, H. D., (1996), Probabilistic Analysis of Randomly Distributed Fiber-Reinforced Soil, *J. of Geotechnical Eng.* ASCE; 122 (6), 419-26.

Rao, A.S., Rao, K.V.N., Sabitha, G.and Suresh, K., (2006), Load deformation behaviour of fiber reinforced gravel beds Overlying soft clay, *Proc. of a National conference on corrective engineering practices in troublesome soils held at Kakinada* July,8-9, 2006, 187-190

Saran, S., (2010), Reinforced Soil and its Engineering Applications, I. K. International Pvt. Ltd, New Delhi, 2nd Edition

Singh, H.P., Sharma, A. and Chanda, N., (2011), Study of strength characteristics of coir fiber reinforced soil, Proc. of *International conference on Advances in Materials and Techniques for Infrastructure Development (AMTID 2011) held at NIT Calicut*, India, June 28-30,. Paper No. G002.

Singh, H.P., (2012.), Improvement in CBR value of soil reinforced with Jute geotextile sheets, *International Journal of Earth Sciences and Engineering*, 05 (02), 1438 -1442.

Singh, H.P., (2011), Strength Characteristics of Fly ash Reinforced with Geosynthetic Fiber, *International Journal of Earth Science and Engineering;* 04 (06), 969-971.

Singh, H.P. and Kamsi, Yabom, (2011), Use of fly ash reinforced with geogrid sheets as a pavement subgrade, *International Conferences on Advances in Materials and Techniques for Infrastructure Development* (AMTID 2011) held from September 28-30 at NIT Calicut, Kerala, India.

Singh, H.P., and Yachang, Omo., (2012), Use of fly ash reinforced with Jute geotextile as a pavement subgrade, *International Journal of Earth Science and Engineering*, 5 (4), 562-567.

Sivakumar Babu, G. L. and Vasudevan, A. K., (2008), Strength and stiffness response of coir fiber- reinforced tropical soil. *ASCE Journal of Materials in Civil Engineering*; 20(9), 571-577.

Yetimoglu, T. and Inanir, O.E., (2005), A Study on bearing capacity of randomly distributed fiber-reiforced sand fills overlying soft clay, *Journal of Geotextiles and Geomembranes*, 23(1), 174-183.