Review Paper

DEFORMATION AND STRENGTH CHARACTERISTICS OF JUTE GEOTEXTILE REINFORCED SOILS

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Received January 15, 2014 Accepted May 10, 2014

ABSTRACT

A geotextile is a permeable geosynthetic made of textile materials and is suitable for separation, reinforcement, drainage and filtration functions and can be suitably used in overcoming geotechnical problems of soft soils encountered at construction sites. Jute geotextile is made up of natural fibres of jute. Though jute is biodegradable but due to its cost-effective and ecofriendly characteristics, it finds huge applications in geotechnical engineering. Jute geotextiles can be used to reinforce soils and improve its bearing capacity and stability. A number of studies have been conducted by different researchers to investigate the influence of jute geotextile on the geotechnical behaviour of soft soils. This paper presents a review of the deformation and strength characteristics of jute geotextile reinforced soils and fly ashes.

Key Words: Geosynthetic, Geotextile, Biodegradable, Reinforced soil, Deformation

INTRODUCTION

A geosynthetic is a planar product manufactured from a polymeric (synthetic or natural) material and used in contact with soil, rock, earth or other geotechnical-related material in civil engineering applications. Most geosynthetics are made from synthetic polymers such as polypropylene, polyester, polyethylene, polyamide, polyvinylchloride, etc. These materials are highly resistant to biological and chemical degradation. Natural fibres such as cotton, coir, jute, bamboo, etc. are used also as geotextiles and geogrids, especially for temporary applications.

Geosynthetics can perform five primary functions, filtration, drainage, separation, reinforcement (to resist stresses or contain deformations in geotechnical structures) and barrier. Geosynthetic applications are usually defined by their primary or principal function. In a number of applications, in addition to the primary function, geosynthetics usually perform one or more secondary functions (protection, cushion and surface erosion control). It is important to consider both the primary and secondary functions in the design computations and specifications. Geotextiles have proven to be among the most versatile and cost-effective ground modification materials and play an important role in geotechnical engineering works, especially roads and railways, foundations, embankments, and steep slopes and retaining walls.

Soil reinforcement is an effective and reliable technique for improving soil strength in a variety of applications. The primary purpose of reinforcing soil mass is to improve its stability, increase its bearing capacity and reduce settlements and lateral deformation. In the reinforcement function the purpose of the geosynthetic is to add tensile properties to the soil to produce a new material that has both compressive and tensile strength. Reinforcement is a result of the transference of tensile stresses from the soil to the reinforcement due to the friction developed between them. For geotextiles to be effective in reinforcement of the soil, sufficient deformation has to be allowed so as to enable the tensile strength of the fabric to come into play. This makes them particularly suitable in soft clay deposits which are by nature susceptible to large deformation. Jute is a coarse natural bast fibre crop, mostly grown in Bangladesh and India and is an annually renewable agri-resource. Cellulose, hemicellulose and lignin are the major constituents of

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jute fibres. Jute geotextile is manufactured from raw jute fibres in the jute mills and is biodegradable. In spite of the characteristics of biodegradability many researchers have worked with this material as it is cost-effective and environment-friendly. The engineering properties of jute fabrics are suitable for separation, reinforcement, drainage and filtration functions and can be suitably used in overcoming geotechnical problems of weak soil. From geotechnical engineering perspective, jute geotextiles have interesting properties. Jute geotextiles have high tensile strength and elastic modulus, low percentage elongation at break, excellent drapability and wettability, environment friendly, locally available in abundance and the cost is low. Investigations have shown that the strength properties of natural fibres are often superior to synthetics, and natural fibres would therefore be better suited for reinforcement function where a high modulus is desired.

AIMS AND OBJECTIVES

A limited number of experimental studies have been reported on the influence of inclusion of jute geotextile layers on the compaction, deformation and strength characteristics of soils and fly ashes. A review of the same is presented in this paper.

DISCUSSION

Influence on compaction characteristics

The dry unit weight of soil increases with the inclusion of jute geotextile layers. Ramaswamy and Aziz carried out standard proctor compaction tests on clayey soils without jute fabric as well as on samples with three layers of jute fabric embedded at mid-depth. Fig. 1 shows the effect of fabric layer on the soil compaction characteristics. For the same compaction effort, the soil is seen to be better compactible when the jute fabric is used.

![Fig. 1 : Effect of jute fabric on compaction characteristics of soil](image)

Influence on unconfined compressive strength

Ramaswamy and Aziz carried out unconfined compression tests on compacted samples, 100 mm diameter and 200 mm length, compacted at the standard proctor compactive effort using optimum moisture content 25%. Two layers of jute fabric were interposed within the samples at equal intervals while compacting for the jute fabric reinforced samples. Table 1 shows the influence of jute fabric on the Unconfined Compressive Strength (UCS) of samples compacted in the laboratory. The results show that the UCS of soil reinforced with jute geotextiles is better than the unreinforced soil. Bera et al. conducted a series of Unconfined Compressive Strength (UCS) tests on unreinforced fly ash as well as fly ash reinforced with jute geotextiles. Three fly ash samples (BBFA, KTPS1 and KTPS2) were procured from thermal power plants in West Bengal and the jute geotextile was obtained from the local market at Kolkata. The effects of number of layers of reinforcement on the unconfined compressive strength of reinforced fly ash were studied.
Table 1: Effect of jute fabric on UCS

<table>
<thead>
<tr>
<th>Moisture content (%)</th>
<th>25</th>
<th>30</th>
<th>35</th>
</tr>
</thead>
<tbody>
<tr>
<td>UCS (kN/m²)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i) Without fabric</td>
<td>110</td>
<td>45</td>
<td>36</td>
</tr>
<tr>
<td>ii) With fabric</td>
<td>330</td>
<td>115</td>
<td>65</td>
</tr>
<tr>
<td>Strain at failure (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i) Without fabric</td>
<td>8</td>
<td>10</td>
<td>22</td>
</tr>
<tr>
<td>ii) With fabric</td>
<td>26</td>
<td>30</td>
<td>42</td>
</tr>
</tbody>
</table>

The unreinforced and reinforced cylindrical fly ash specimens, 38 mm (dia.) x 76 mm (high) were prepared in the metallic split moulds with detachable collar, at optimum moisture content and maximum dry unit weight determined based on standard effort ASTM D 698.9 In reinforced specimens, reinforcements were placed in different layers, maintaining equal divisions along the height of the specimen, the number of divisions being equal to (N+1), for N number of layers of reinforcement. The UCS tests were carried out in accordance with ASTM D 2166.10 Fig. 2 shows the typical axial stress versus axial strain curves for unreinforced and reinforced fly ash. The peak compressive stress has been taken as the UCS of the sample. The curves of UCS versus number of layers of reinforcement for three types of fly ash are shown in Fig. 3. It is found that the UCS increases up to 5 layers of reinforcement as the number of layers of reinforcement increases, after which the increase in UCS is negligible or almost zero. It is observed that reinforcement up to four numbers of layers is effective and thereafter the increase in UCS is only marginal.

Influence on California bearing ratio

Ramaswamy and Aziz7 carried out CBR tests on samples in the saturated conditions, compacted at the standard proctor compactive effort using optimum moisture content 25%
Two layers of jute fabric were interposed within the samples at equal intervals while compacting for the jute fabric reinforced samples. Table 2 shows the influence of jute fabric on the California Bearing Ratio (CBR) values of samples compacted in the laboratory. The results show that the CBR values of soil reinforced with jute geotextiles are better than the unreinforced soil.

Table 2: Effect of jute fabric on CBR value

<table>
<thead>
<tr>
<th>Moisture content (%)</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBR (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i) Without fabric</td>
<td>5.0</td>
<td>4.7</td>
<td>3.5</td>
<td>2.6</td>
</tr>
<tr>
<td>ii) With fabric</td>
<td>8</td>
<td>6.8</td>
<td>5.2</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Singh\(^1\) conducted an experimental study on locally available soil reinforced with jute geotextile layers. In the study, a number of CBR tests (unsoaked and soaked) were conducted on soil alone and soil reinforced with different layers of Jute Geotextile (JGT). The soil and reinforced soil samples were prepared at maximum dry unit weight and optimum moisture content. The unsoaked and soaked CBR tests were conducted as per standard, IS 2720 (Part XVI).\(^12\) The observed soaked CBR values of the reinforced soil are shown in Table 3. The results show that there is a significant effect of jute geotextile layers on the CBR value of soil. The CBR value of reinforced soil increases with the increase in number of layers of jute geotextile and the increase is the maximum at four layers. When there is a further increase in jute geotextile layers from 4 to 5, the CBR value of the reinforced soil decreases. This indicates that the strength and stiffness of soil can be enhanced by inclusion of jute geotextile in layers. Singh and Yachang\(^13\) conducted a study to strengthen a fly ash by using jute geotextile sheet as reinforcement.
Table 3: Soaked CBR value of soil reinforced with Jute Geotextile (JGT)

<table>
<thead>
<tr>
<th>S/N</th>
<th>Number of JGT layers</th>
<th>CBR value</th>
<th>Increase in CBR value</th>
<th>Percentage increase in CBR value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>2.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>2.5</td>
<td>0.5</td>
<td>25</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>4.66</td>
<td>2.66</td>
<td>133</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>7.0</td>
<td>5</td>
<td>250</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>12.4</td>
<td>10.4</td>
<td>520</td>
</tr>
<tr>
<td>6</td>
<td>5</td>
<td>11.41</td>
<td>9.41</td>
<td>470</td>
</tr>
</tbody>
</table>

The reinforcing elements were placed within the specimen in layers at equal vertical spacing and the number of layers varied from 1 to 5. The unreinforced and reinforced fly ash samples were prepared at maximum dry unit weight and optimum moisture content. The 4 days soaked CBR tests were conducted as per standard procedure, IS 2720 (Part XVI). The variation of CBR value of fly ash with number of jute geotextile layers is shown in Fig. 4. It is observed that the CBR value increases with increase in the number of geotextile layers. The increase in CBR value is marginal in case of lesser number of layers, whereas there is a significant increase in CBR value, when number of layers is increased to 4. The study indicates that the optimum number of jute geotextile layers is 4 for which there is maximum improvement in CBR value of fly ash.

Fig. 4: Variation of CBR value of fly ash with number of jute geotextile layers

**Influence on bearing capacity**

Ramaswamy and Aziz conducted static load tests in tanks of 1 m diameter and 1.2 m height filled up with compacted clay and overlaid by jute geotextile. The long term (six weeks) static loading tests were conducted under simulated wheel loads of about 1000 N on bearing plate of 200 mm diameter generating a surface contact pressure of 31.8 kN/m² for evaluating the performance of jute geotextile in stabilizing weak subgrade soil. Fig. 5 shows the load-settlement behaviour of the subgrade soil with 200 mm thick aggregate layer. The schematic profiles of subgrade/sub-base interface with and without jute geotextile during the static loading test
are shown in Fig. 6. The rut-time relationships for sustained seven weeks loading test under different experimental conditions are shown in Fig. 7. The results of static load tests reveal that the performance of jute geotextile is satisfactory in stabilizing weak subgrade soil. Ghosh et al.\textsuperscript{14} carried out a study to enhance the bearing capacity of square footing on pond ash by jute geotextile reinforcement. Tests on model footing were conducted by placing the footing on pond ash reinforced with jute geotextile layer. The experiments were conducted in a tank of size 0.6 x 0.6 m\textsuperscript{2}, 0.4 m deep with an 80 mm model square footing of 8 mm thick mild steel plate.

![Graph showing load settlement behaviour of the subgrade soil](image)

**Fig. 5:** Load settlement behaviour of the subgrade soil

![Diagram showing subgrade/sub-base interface profile with and without jute geotextile](image)

**Fig. 6:** Subgrade/sub-base interface profile with and without jute geotextile
Fig. 7: Rut-time relationships for sustained seven weeks loading test

The test bed was prepared by compacting moist pond ash layer by layer at Proctor’s OMC (37%). To maintain the equal vertical spacing of 25 mm between two consecutive reinforcement layers within the pond ash bed, thickness of the each compacted layer was kept as 25 mm. The plots of bearing capacity ($q_{rs}$) at different settlement ratios ($s/B$) versus number of layers ($N$) of reinforcement for values of $u/B = 0$ and $u/B = 0.3125$ are shown in Figs. 8 and Fig. 9, where $u$ is the depth of first layer of reinforcement beneath the footing.

Fig. 8: Bearing capacity versus number of layers curves for $u/B = 0$
From the graphs, it is noted that with increase in number of layers, $q_r$ increases but for up to a certain value of $N$ and after that the value becomes almost constant or the increase in $q_r$ is insignificant. The optimum number of reinforcement layers ($N_{opt}$) is the number of reinforcement layers at which the bearing capacity at any settlement attains its maximum value and in Fig. 10, it is found that with increase in $u/B$ ratio, $N_{opt}$ decreases rapidly up to the value of $u/B = 1.25$ and thereafter the rate of decrease is negligible. The study suggests that the optimum number of reinforcement layer in pond ash depends on the values of $u/B$ ratio.
CONCLUSION

Due to the inherent characteristics of the jute geotextile, it finds a significant application in geotechnical engineering as soil fabric for initial reinforcement of soil in layers as well as stabilization and protection of weak soil. The review of the literature shows that the stress-strain characteristics of the jute geotextile reinforced soil are better than the soil alone. Jute geotextile is biodegradable and is preferred for ecological reasons in geotechnical applications over synthetic geotextiles. Inclusion of jute geotextiles in layers into the soil increases the strength (unconfined compressive strength, CBR value, bearing capacity, etc.) significantly. The increasing in strength depends on the number of jute geotextile reinforcement layers incorporated and increases with increase in number of reinforcement layers. In general, the improvement in strength is very significant when the soil is reinforced with 4 layers of jute geotextile at equal vertical spacing between two consecutive layers of reinforcement.

REFERENCES

12. IS 2720 (Part XVI), Stand.methods of test for laboratory determination of CBR, Bureau of Indian Standards, New Delhi, India, (1965).