

Improvement of Load Carrying Capacity of Soil using Jute-Geotextile

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ABSTRACT: A comprehensive study is performed on soil and jute-geotextile to improve the load carrying capacity of subgrade soil. An extensive laboratory experiments are carried out to verify the improvement of load carrying capacity for clay soil. Permeability test, unconfined compressive strength (UCS) test and triaxial test are carried out to verify the behaviour of soil considering geotextile material. The sample behaviour is checked for six cases (Case 1: without considering geotextile material in the soil sample, Case 2: h/2 depth, Case 3: h/3 depth each, Case 4: h/4 depth each, Case 5: h/5 depth each and, Case 6: h/6 depth each, where, h is the height of the soil sample). The result shows that the load carrying capacity increases when the geotextile is taken into account as compared to soil without geotextile. It is to be noted that the load carrying capacity increases for case 2 to case 4 considering jute-geotextile in the soil sample. However, the load carrying capacity decreases for case 5 and case 6, though, more layers of jute-geotextile is considered in the soil sample. Finally, an optimum method is proposed to develop maximum load carrying capacity of soil incorporating jute-geotextile.

KEYWORDS: Jute-Geo-Textiles, Permeability, Unconfined Compression Test, Sub-Structural, and Axial Stress.

1. INTRODUCTION

Embankments or any other structure founded on soft clay or loose sand may undergo substantial settlement (Broms, 1999, and Borges and Cardoso, 2002). A foundation can be provided to the structure to improve the bearing capacity of loose soil. However, a shallow foundation may not be able to provide adequate capacity. Therefore, a deep foundation has to be provided to the structure, which may increase the cost of construction. Ground improvement may be the solution to provide adequate bearing capacity and reduce the construction cost (Panigrahi & Pradhan, 2019).

Geotextile has proved to be an economical and common choice for improving soil strength. Geo-textile can be separated into two terms, geo and textile, where geo means earth and textile means fabric (Annu & Verma, 2018). They stated that geotextile can be used in soil subgrade and retaining walls to increase water mobilization and decrease soil movement. The geotextile can be used to control soil erosion from roads, railways, and hydraulic structures (Pattnaik et al., 2016). Jute-geotextile is the most prime choice of geotextile material that has been used to improve the bearing capacity of soil below footing (Panigrahi & Pradhan, 2019). California Bearing Ratio (CBR) value increased due to reinforced soil with geo-jute and black carbon (Aaqii & Preetpal, 2023), and they have also observed an increase in the dry density of the reinforced sample.

Several research studies on jute-geotextile have been performed (Babu et al., 2008; Panigrahi & Pradhan, 2019; Thakur et al., 2021; Aaqii & Preetpal, 2023). However, studies on improving soil subgrade strength below the footing are limited. Previous studies mainly focused on the stability of embankment considering geo-synthetic material (Joshi & Arora, 2015; Raut et al., 2016; Zheng et al., 2021). Geo-synthetic is also used to verify the strength parameters and bearing ratio of fine soil (Carlos et al., 2016). Jute-geotextile is a biodegradable and environmentally friendly material, whereas geo-synthetic could be a risk to a sustainable environment (Ghosh et al., 2014). Therefore, geo-jute is considered for the present study to examine the soil strength improvement in clay. Previous studies focused on pavement design taking into account geo-jute on soil subgrade (Pavani et al., 2016). American Society of Testing Materials (ASTM) and Indian Standards (IS) codes are available for standardized procedures of geo-synthetic such as IS 13321-1 (1992),

ASTM D4873/D4873M-17(2021). RDSO/2007/GE: G-0008 (2007) is the guideline for the application of jute geotextile in railway and hill slopes. However, a standard guideline for geo-jute is essential to assess the performance and quality of any work.

A load test on a model footing placed the jute-geotextile in a single layer has been carried out in the paper by Panigrahi and Pradhan (2019), and the optimum position of geo-jute in the sandy soil sample has been found. Thakur et al. (2021) considered clayey soil and conducted CBR tests on soil with and without geo-synthetic material. Raut et al. (2016) conducted the CBR test on a soil sample using a single layer of geotextile at different depths, and the best result was observed when the geotextile was placed in the middle of the sample. They observed that the average value of liquid limit (LL) is 25%, plastic limit (PL) is 20.39%, and the average CBR value of soil without geo-textile is 22.88. The average CBR values of soil with geo-textile at depths of 3 cm, 6 cm, and 9 cm are 23.57, 24.19, and 23.47, respectively. Therefore, the average CBR value is higher when the depth of the geo-textile placed in the middle of the soil is 6 cm. According to Pavani et al. (2016), LL and PL are examined as 39.25% and 19.34%, respectively. UCS test is also carried out in this paper considering soil with and without jute-geotextile. UCS value is observed as 82.35 kN/m² when geo-jute is not taken into account. UCS test is also carried out where the jute-geotextile is placed at h/2 depth, h/3 depth, and h/4 depth. Results show that the UCS value increased to about 89.84 kN/m², 153.4 kN/m², and 300.0 kN/m² for placing geo-jute at h/2 depth, h/3 depth, and h/4 depth, respectively.

Previous research studies are limited to considering a single layer of geotextile material at different depths of soil samples. Otherwise, geotextile placed at different depths shows increased soil strength considering geotextile. However, placing geo-jute at different layers of soil does not always increase strength. Prasanna and Mendes (2020) reported that the cohesion value increased for mixing geo-jute pieces with soil up to 1%; after that, the cohesion value decreased.

In this paper, the improvement of load carrying capacity (P_u) of soil with and without incorporation of jute-geotextile is studied. Six cases are considered for this study: C1: without considering geotextile material in the soil sample, C2: h/2 depth, C3: h/3 depth each, C4: h/4 depth each, C5: h/5 depth each, and C6: h/6 depth each, as represented in Fig. 1 (C represents the Case). UCS and triaxial tests are performed

in the laboratory for these six cases, and the results of C2 to C6 are compared with C1. A permeability test is carried out to examine the seepage through soil with and without jute-geotextile. A consolidation test of soil is also implemented with and without considering jute-geotextile, and the results are compared to observe the elastic and plastic settlement of the system. Finally, an optimum method is recommended to get maximum load carrying capacity considering jute-geotextile placed in the soil sample. However, it is to be noted that natural biodegradable Jute Geotextile can be used for temporary soil stabilisation.

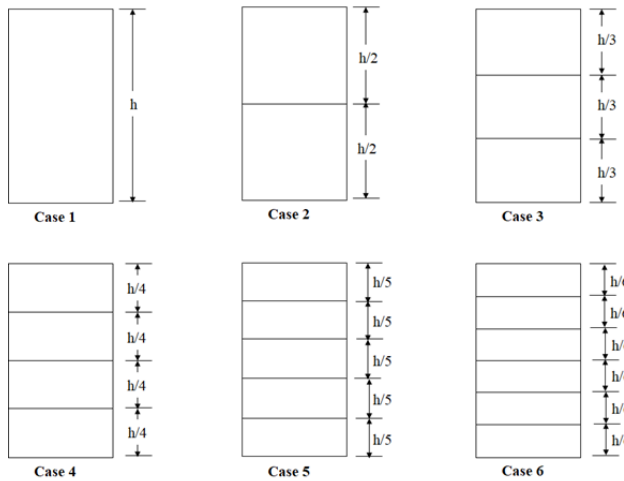


Figure 1 Soil sample without considering geo-jute (C1) and with incorporating geo-jute (C2 to C6), where jute-geotextile is placed at C2: $h/2$ depth, C3: $h/3$ depth each, C4: $h/4$ depth each, C5: $h/5$ depth each and, C6: $h/6$ depth each

2. METHODOLOGY AND PROPERTIES OF SOIL AND GEO-JUTE

The clay soil sample is collected from a river basin and subjected to various tests such as water content, specific gravity, liquid limit, plastic limit, and hydrometer analysis for soil to measure the properties of clay (Table 1). The particle size distribution of clay is depicted in Fig. 2. Woven geo-jute is considered for the present study and the properties of geo-jute, such as thickness, weight and tensile strength tests, are performed in the laboratory (Table 2). Permeability, UCS, triaxial and consolidation tests are carried out in the laboratory to compare the results with and without considering geo-jute

Table 1 Properties of soil measured in the laboratory

Sl. No.	Experiment	Results
1.	Water Content	32%
2.	Specific Gravity of clay	2.70
3.	Liquid Limit	80%
4.	Plastic Limit	47%

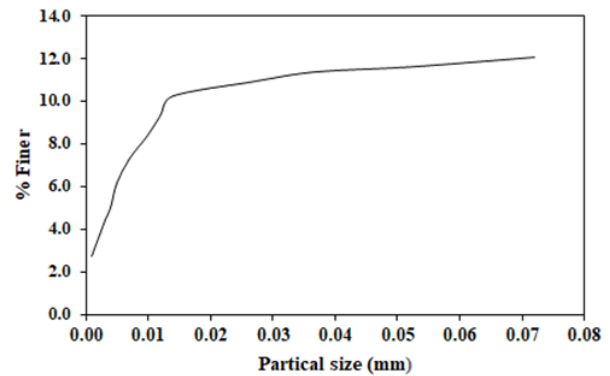


Figure 2 Particle size distribution of clay measured in the laboratory

Table 2 Properties of geo-jute measured in the laboratory

Classification	Properties
Type of geo-jute	Woven
Geo-textile	Textile
Weight	400 gm/m ²
Thickness (Initial)	0.018 m
Maximum tensile strength	2.16 kN/m

3. RESULTS AND DISCUSSION

Various tests are conducted in the laboratory to determine the load carrying capacity considering jute-geotextile placed in the soil sample at different depths (Fig. 1). The results are compared to verify the load carrying capacity of soil with and without considering jute-geotextile. An optimum method is suggested to use the geo-jute with soil at different depths to provide maximum load carrying capacity of soil. To obtain the maximum load carrying capacity, UCS and triaxial tests are performed in the laboratory. However, permeability and consolidation tests are carried out to examine seepage through the sample and the elastic-plastic property of the sample, respectively.

3.1 Unconfined compressive strength (UCS) test

UCS test is carried out on soil with and without considering geo-jute to compare the load carrying capacity. It is observed that the load carrying capacity (P_u) increased with increasing axial strain and decreased after failure (Fig. 3). Fig. 3 shows that P_u is less for C1 as compared to other cases where geo-jute is considered. The load carrying capacity is similar for C1 and C2 for higher values of axial strain, though primarily the load carrying capacity increases for C2 rather than C1. Thus, the maximum load carrying capacity ($P_{u,max}$) is the same for C1 and C2, whether the geo-jute is placed at a depth of $h/2$ for C2. The maximum load carrying capacity is increased for C3, C4, C5 and C6 (Fig.4).

Table 3 shows that the maximum load carrying capacity increases by 65% for C4 compared to C1, where the geo-jute is placed at a depth of $h/4$ in each soil sample. Although the geo-jute is placed in extra layers for C5 and C6 compared to C4 (Fig. 1), the maximum load carrying capacity decreased from C4. Therefore, C4 is the optimum method to place jute-geotextile. $P_{u,max}$ increased up to 8% for C3 compared to C1. The variation in $P_{u,max}$ is marginal for C4 to C5 (Table 3). Hence, geo-jute can be placed at different layers as per the requirements of the projects.

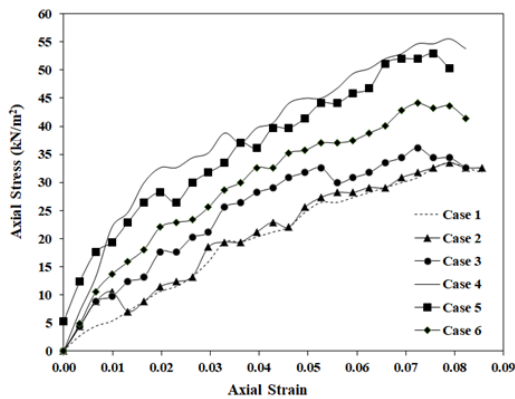


Figure 3 Load carrying capacity of soil with and without considering geo-jute in UCS test

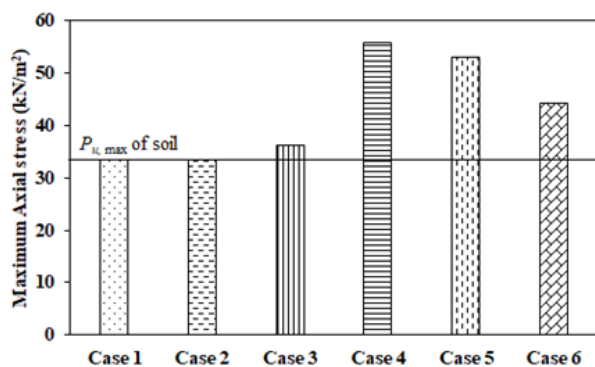


Figure 4 Maximum Load carrying capacity of soil with and without considering geo-jute in UCS test

Table 3 Maximum load carrying capacity conducting UCS test presented in percentage

Load Carrying Capacity	C1	C2	C3	C4	C5	C6
Maximum axial stress (kN/m ²)	33.5	33.5	36.2	55.6	52.9	44.1
% increase	-	0 %	8 %	65 %	58 %	32 %

3.2 Triaxial test

A similar type of observation is made in the Unconsolidated Undrained (UU) triaxial test (the triaxial test is conducted as per IS 2720 (Part 11): 1993). Cell pressure is considered as 100 kN/m² for this study. Total vertical stress (σ_1) increases with increasing axial strain. However, the soil sample is confined in all directions. As a result, total vertical stress is higher for the triaxial test compared to the UCS test. The difference may be attributed to the differences in the stress path and boundary conditions between the two testing methods, together with unavoidable variations associated with specimen preparation and testing. Similar differences between UC and UU test results have been reported in previous studies (Bera et al., 2009; Ratananikom et al., 2015; Soldo et al., 2022; Dutta et al., 2025). Moreover, the confinement restricted lateral deformation and enabled the reinforcement to develop additional tensile resistance, resulting in a substantially higher peak deviator stress for reinforced soil. Fig. 5 shows that the total vertical stress is less for C1 and more for C4. However, the total vertical stress is higher in C3 than in C4. It is to be noted that the total vertical stress is almost similar for C1 where only soil sample is present and C2 where geo-jute is placed at the middle of the soil sample (Fig. 5). However, the variation in σ_1 is marginal for the cases except for C4 for higher values of strain in

triaxial test, whether the variation of axial stress is more for UCS test, due to confining pressure applied in triaxial test.

The maximum total vertical stress ($\sigma_{1, \max}$) is presented in Fig. 6 for different cases considered for this study. It is observed that the maximum load carrying capacity ($P_{u, \max}$) is increased for C2 to C6 considering geo-jute as compared to C1. However, load carrying capacity is higher for C4 than for the other cases, where geo-jute is placed at a depth of $h/4$ each. Maximum load carrying capacity is increased up to 52% for C4 (Table 4). However, the variation in $\sigma_{1, \max}$ is insignificant (about 1% – 10%) for C2, C3, C5 and C6 as compared to C1 (Table 4).

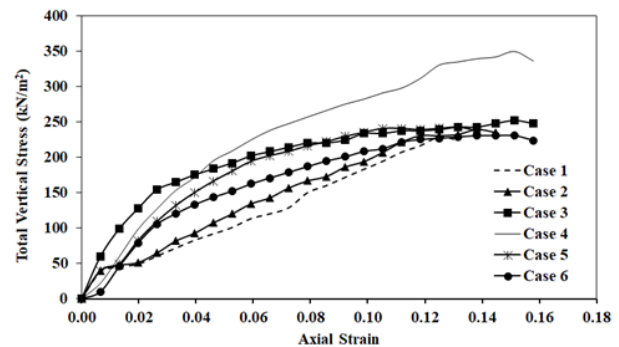


Figure 5 Load carrying capacity of soil with and without considering geo-jute in UU triaxial test

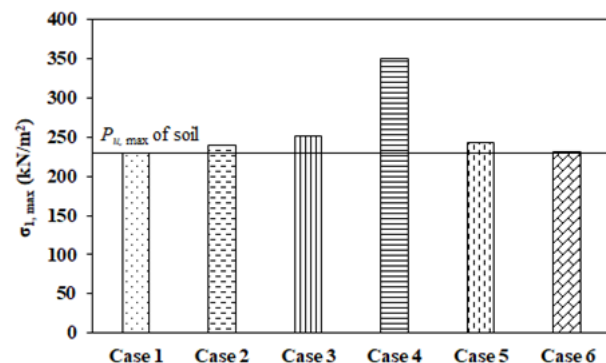


Figure 6 Maximum Load carrying capacity of soil with and without considering geo-jute in triaxial test

Table 4 Maximum load carrying capacity conducting triaxial test presented in percentage

Load Carrying Capacity	C1	C2	C3	C4	C5	C6
Maximum Total Vertical stress (kN/m ²)	229	239	252	349	243	231
% increase	-	5 %	10 %	53 %	6 %	1 %

3.3 Permeability test

The strength of soil can be improved by mixing admixtures such as cement, lime, fibres which reduce the permeability (Annu & Verma, 2018; Lakshmi et al., 2018). The optimum method to place the geo-jute in the soil sample is C4, considering the UCS test and triaxial test. In this paper, a comparison study has been carried out between C1 and C4 considering the falling head permeability test (as per IS 2720 (Part 17): 1986). It is observed that the coefficient of permeability decreases in C4 rather than C1. Hence, the k value is found to be higher when the soil sample is considered, and the k value is lower when jute-geotextile is placed in the soil sample (Table 5).

The coefficient of permeability decreases up to 40% when jute-geotextile is considered in the soil sample (C4). A similar type of observation is made in Zumrawi and Abdalgadir (2019). They have considered one layer of nonwoven geotextile in the soil and compared it with the soil sample. Hence, the permeability is found to be decreased by about 60%.

Table 5 Change in coefficient of permeability with and without considering geo-jute

Cases	Type	Average coefficient of permeability, k (cm/sec)
C1	Soil without geo-jute	0.005
C4	Soil with geo-jute placed at h/4 depth each	0.003
-	Decrease k in percentage from C1 to C4	40 %

3.4 Consolidation test

The consolidation test was carried out as per IS 2720 (Part 15): 1986 to examine the settlement characteristics of soil with and without jute-geotextile. The remoulded soil specimens were prepared and carefully fitted into the oedometer ring. Porous stones and filter papers were placed on both sides of the specimen to enable drainage during testing. The specimen was saturated before the application of vertical pressure. Consolidation loading was then applied in successive increments in accordance with IS 2720 (Part 15): 1986, with each load increment being approximately double the previous one. Settlement readings were recorded at regular time intervals until the rate of deformation became negligible, indicating the completion of primary consolidation. The specimen was unloaded stepwise after completing the loading cycle, and the observed compression and rebound responses were used to evaluate the consolidation characteristics of the soil.

In this test, it is not feasible to place 3 layers of geotextile in the specimen. Therefore, the comparative study is performed considering one layer of geo-jute in the soil sample (C2) and comparing it with C1 (Table 6). It is observed that the soil sample is more elastic than the geo-jute placed in the soil sample. However, plastic settlement is higher for C2 than for C1. This is due to the woven geo-jute considered for the present study. However, settlement reduces when woven geo-synthetic is incorporated in the soil sample compared to the soil sample (Kim & Dinoy, 2021). Further study is required to conduct consolidation tests considering jute-geotextile with the soil sample.

Table 6 Settlement characteristics of soil with and without considering geo-jute in consolidation test

Cases	Elastic settlement (mm)	Plastic settlement (mm)
C1	0.238	1.24
C2	0.17	3.00

4. CONCLUSIONS

The load carrying capacity is increased in the present study by performing UCS tests, triaxial tests, permeability tests, and consolidation tests. The properties of soil and geo-jute are determined in the laboratory. Woven geo-jute is considered for this study to verify the load carrying capacity when placed in the soil sample and compared with the soil without considering jute-geotextile. The conclusions are drawn as follows:

1. Inclusion of jute-geotextile with soil significantly increases the load carrying capacity. Therefore, non-consideration of geo-jute leads to a reduction in the load carrying capacity of soil in the case of higher values of applied load.

2. Incorporation of jute-geotextile has an important effect on the load carrying capacity of soil. The effect of jute-geotextile placed in the soil sample is less in the case of one layer and two layers. However, the load carrying capacity increases substantially for three layers of geo-jute.
3. Consideration of four and five layers of jute-geotextile placed in the soil sample decreases the load carrying capacity compared to three layers.
4. Initially the load carrying capacity reduces for three layers of jute-geotextile, and then increases significantly with further increase in axial strain.
5. The permeability of the soil sample including jute-geotextile is found to be decreased compared to the soil sample, which is beneficial for the stability of any structure.
6. Settlement of the soil sample considering jute-geotextile is more than that of the soil sample. Therefore, further study is required to examine the settlement properties of soil incorporating jute-geotextile.

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