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Study of the behaviour of cohesive soil under the effect of jute fibres as soil reinforcement

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Abstract - *Jute geotextile is made up of natural fibers 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 report presents a review of the deformation and strength characteristics of jute geotextile reinforced soils. The present study is aimed at determining the behaviour of clayey soil reinforced with jute fibers in a random manner. The results indicated that the unconfined compressive strength of clayey soil can be increased by the addition of jute fibers. A series of unconfined compression strength test are done to estimate the strength characteristics of compacted soil samples with jute fiber as a reinforcement as well as tests like specific gravity test, Proctor compaction test are performed to obtain some physical and engineering properties of the soil sample. Additional experiments are also performed with jute fiber mat in layers laid simultaneously within the soil sample. A detailed comparison is drawn for the results obtained in all the tests carried out. From the present study it is found that the UCS of the collected soil sample increases to an appreciably improving factor 1.95 for jute fiber mat coated with bitumen in layers within the soil sample.*

Key Words: **Geotextile, Jute, Biodegradable, Bearing capacity, Eco-friendly.**

1. INTRODUCTION

Now days due to increasing population, there is huge demand for competent land for infrastructural development and for living. This necessitates the use of land having soft (weak) soil also for development. But the presence of weak soil (eg. clay) supporting structural foundation results in low load bearing capacity and excessive settlement. Design, construction and maintenance structure in soft soil are one of the risky jobs in civil engineering.

The best option for this problem is to go for ground improvement/modification. This will facilitate increased bearing capacity of the ground and to decrease the settlement problems. Various ground-improvement techniques such as preloading, reinforcement, replacement, drainage control, grouting, chemical stabilization, Excavation and replacement with good quality of soil, preloading with vertical drains, stone columns etc. few examples . Several literatures carried out research to understand the role of reinforcement in improving the bearing capacity of foundation soils (Ahmed, 1993, Madhavi Latha et al., 2010).

In general, foundation of engineering structure is designed to transfer and distribute their loading to the underlying soil. This design is required to satisfy three main design criteria, namely the ultimate bearing capacity of foundation (i.e. strength), total settlement (i.e. serviceability) and economic feasibility of the foundation. For shallow foundation structures replacement or mixing technique could be advantageous. Various methods are available for this technique including the use of various novel geomaterials like fiber, coir, tyre shreds, plastic, etc. However, to implement any such method, the level of improvement shall be investigated to predict the bearing capacity and settlement behaviour of the structure. Research on the ultimate bearing capacity problems can be carried out using either analytical solutions or model studies. Earlier is being studied through theory of plasticity or other theoretical methods while the latter is achieved through conducting prototype, model and full scale tests either experimentally or numerically.

Jute, a natural fibre, has traditionally been in use as a sacking material in India as well as in abroad. The versatility of jute fabric has made it possible to meet the technical requirements in the field of Geotechnical Engineering. Fabrics made of jute were tried in Dundee, Scotland (Kings way Road construction) in 1920s and in Kolkata, India (Strand Road construction) in 1934 with success long before the concept of man-made geotextile emerged. Jute mesh was also used for erosion control and side slope protection in the highways at United States in early 1930s. The U.S.A. started using open wave Jute Geotextile principally for slope erosion control and till date it is popularly used for the same purpose. The Bureau of Indian Standards has also published guidelines on the above use (IS-14986-2001). Jute is produced mostly in Bangladesh, India and also in China, Thailand and Indonesia. Jute plant usually grows upto a height of about 3m with diameter varying between 20 to 30 mm. The jute fibers in the periphery of the plant are held together by sticky resin when harvested. The matured plants are cut, tied into bundles and kept submerged in water for about 20 days for wetting. Fibers are then extracted from stems, washed in clean water, dried in the sun and sent to mills. The fibers thus obtained are processed mechanically in the jute mills to make yarn of the required diameter and tensile strength. These yarns are then woven into fabric with desired physical, mechanical and hydraulic properties suitable for different geotechnical applications. The existing machinery of the jute mills can also produce non woven jute geotextiles.

Fig-1: Jute fiber used as reinforcement

1.1 Objective of the study

The objective of the present investigation work is to study the application of jute geotextile reinforcement on silty clay soil and its effect on the bearing capacity of the soil. The scope of the study includes:

- To conduct a series of tests to find soil parameters.
- Examine the bearing capacity of soil sample with and without reinforcement.
- Experimental data, procedure and the results are discussed by considering jute fibers as reinforcement to improve the soil bearing capacity.

2. MATERIALS AND METHODOLOGY

In this work, the materials used for the test, the site from where the soil sample is collected, properties of the soil and the results of the tests that were carried out on the soil sample are discussed and presented.

2.1 Material

2.1.1 Soil

The locally available natural soil is used. To determine the type of soil, various tests are performed in the laboratory which is discussed in the next chapters. The Maximum dry density and optimum moisture content are also determined in the laboratory.

Fig-2: Soil sample

2.1.2 Jute

Jute fibers were collected from local site and were used as reinforcement in order to increase the bearing capacity of the soil. Jute fibers were used as it is easily available at a very low cost and efficiently increases the bearing capacity of the soil.

Fig-3: Jute fibres

2.1.3 Bitumen

Bitumen was used as protective coating to the jute fibers. As bitumen is a water repellent, it protects the jute from decaying due to water. It adds strength to the properties of the jute and makes it long lasting.

Fig-4: Jute layers coated with bitumen.

2.2 Collection of sample

The soil sample was collected from Kaziranga University (in front of New Building), Jorhat, Assam, India.

2.3 Experiments performed

2.3.1 Determination of Atterberg limits

This test is performed to determine the plastic and liquid limits of the soil sample.

2.3.1.1 Liquid limit test

This test is done to determine the liquid limit of soil as per IS: 2720 (Part 5) 1985.

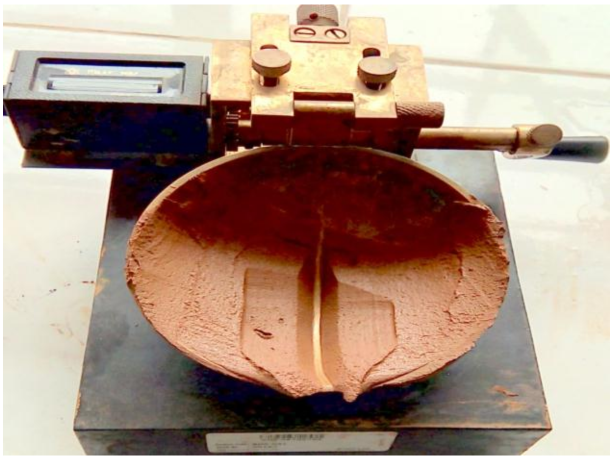

Fig-6: Cassagrande apparatus (Test for liquid limit).

Result: Average liquid limit of the sample is **31.05 %.**

2.3.1.2 Plastic limit test

Plastic limit may be defined in general terms, as the minimum moisture content at which the soil remain in a plastic state. It is determined by rolling out a thread of the fine portion of a soil on a flat, non porous surface.

Fig-7: Threads of soil in moisture container (test for plastic limit)

Result: Average plastic limit of the sample is **23.99 %**

2.3.1.3. Plasticity index:

Plasticity index = Liquid limit – Plastic limit

= 31.05% - 23.99%

= 7.06%

2.3.2 Specific gravity test

This test is done to determine the specific gravity of the soil sample by density bottle method as per IS: 2720 (Part 3) 1980.

Fig-8: Specific gravity test

Results:

Average specific gravity of the sample is **1.758**

2.3.3 Proctor compaction test

This test is done to determine the optimum moisture content and maximum dry unit weight of soil as per IS: 2720 (Part VII) 1980.

Fig-9: Rammering by 2.6 kg rammer

Fig-10: Proctor mould with compacted soil

Results:

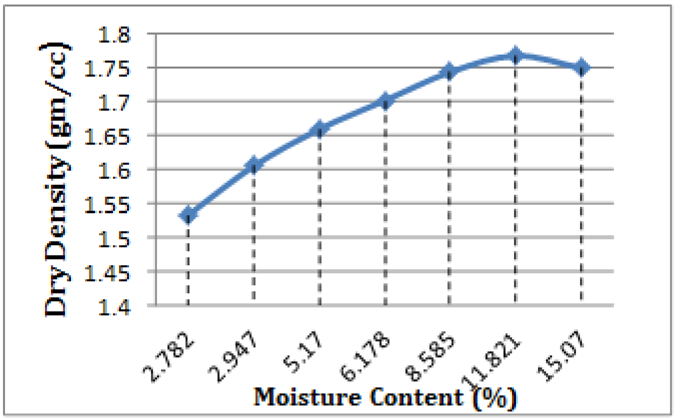

Chart -1: Graph between moisture content and dry density

Therefore,

Maximum Dry density of the soil sample is **1.767 gm/cc**

Optimum moisture content of the soil sample is **11.821%**

2.4 Determination of soil type from the experiments performed:

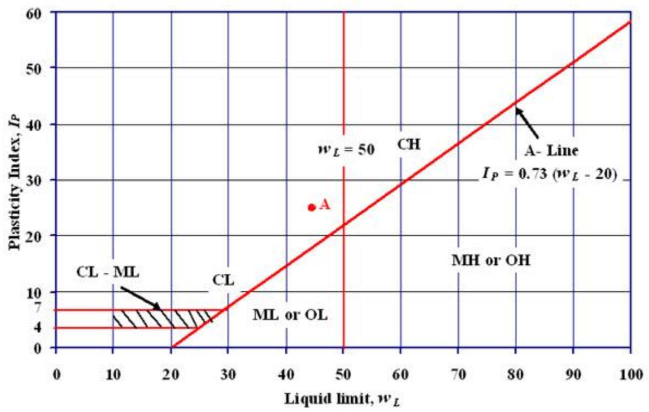

Fig-11: Plasticity chart as per Indian Standard Soil Classification system

From the experiments performed in the laboratory, the results obtained are summarized in the following table:

Table -1: Properties of the soil sample

Serial no	Soil property	Values
1	Liquid limit	31.05%
2	Plastic Limit	23.99%
3	Plasticity index	7.06%
4	Specific gravity	1.758
5	Maximum dry density	1.767 gm/cm^3
6	Optimum Moisture Content	11.821%

From the liquid limit and plasticity index, the soil type is classified as Clay with low plasticity (CI).

3. UNCONFINED COMPRESSION STRENGTH TEST

3.1. Introduction

It is always not possible to conduct the bearing capacity test in the field. Sometimes it is cheaper to take the undisturbed soil sample and test is strength in the laboratory. Unconfined Compression Strength (UCS) test is the measure of the resistance of the soil to external loading. The unconfined compression strength of a soil sample is the ratio of failure load and cross sectional area of the sample when it is not subjected to any confining pressure. It is the simplest and quickest laboratory method commonly used to measure the shear strength of a cohesive soil collected in natural state from the field. In this project, UCS test was performed for both unreinforced and reinforced soil samples and a comparison is made in terms of the bearing capacity.

3.2. UCS test without reinforcement:

Fig-12: UCS testing machine

3.2.1. Preparation of sample:

The UCS test was performed on the soil sample prepared with the optimum moisture content (OMC) and maximum dry density (MDD) as per the Proctor Compaction test carried out earlier. From the Proctor test,

Optimum moisture content (OMC), w = 11.821%

Maximum dry density (MDD), γ_d = 1.767 gm/cm^3

Volume of the specimen for UCS test (3.8cm dia and 7.6cm long) = 86.192 cm^3

Mass of soil required for preparation of the sample

= density × volume
= 1.767 g/cm^3 × 86.192 cm^3

= 152.301 g

Volume of water required to be added

= 11.821% of the soil mass

= 11.821/100 × 152.301g

= 18g = 18 ml

Fig-13: Soil specimen for Ucs test

Fig-14: Soil specimen under the plunger

Fig-15: Failed soil specimen

3.2.3. Observations:

Initial length of specimen, L_0 = 7.6cm

Initial dia of the specimen, D_0 = 3.8cm

Least count of proving ring = 0.002mm

Least count of dial gauge =0.01mm

Table -2: UCS test observation.

Sl. no	Elapsed time (min)	Compression Dial Reading L.C=0.01	Strain $\in = \frac{A0}{L0}$ %	Corrected area A= $\frac{A0}{1-\epsilon}$ (cm^2)	Load "P" (kg)	Compressive stress= $\frac{P}{A}$ (kg/cm^2)
1	0	0	0	11.34	0	0
2	0.5	1.3	1.71	11.536	14.7	1.27
3	1	2.6	3.42	11.741	21	1.78
4	1.5	3.3	4.34	11.854	10.71	0.903

3.2.4. Results:

From the observations, the stress vs strain curve is plotted to find the unconfined compressive strength of the soil.

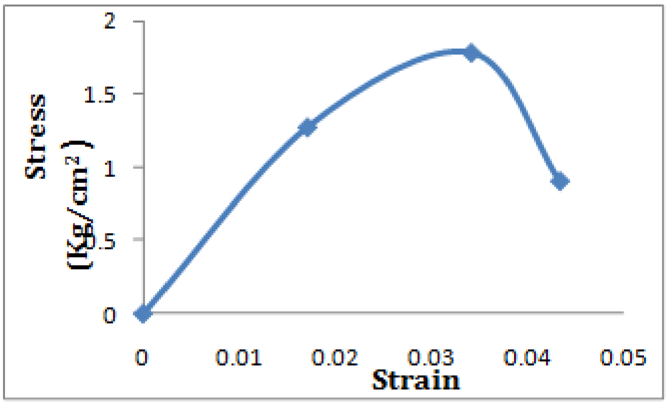

Chart -2: Stress – strain graph from UCS test without reinforcement

From the stress strain curve at failure, the unconfined compressive strength,

q_u = 1.78 kg/cm^2 = 1.78*98.1= 174.618 KN/m^2

Cohesion, c = q_u /2 = 174.618/2 kN/m^2

= 87.309 kN/m^2

Ultimate bearing capacity, q_u

= $cN_c + qN_q$

= $cN_c + \gamma D_f N_q$

= 87.309 × 5.14 + 20.51 × 0.5 × 1

= 459.023 kN/m^2

Net ultimate bearing capacity, q_{nu}

$$= q_u - \gamma D_f$$

$$= 459.023 - 20.51 \times 0.5$$

$$= 448.768 \text{ kN/m}^2$$

Safe bearing capacity, SBC = $(q_{nu} / FOS) + \gamma D_f$

$$= (448.768 / 3) + 20.51 \times 0.5$$

$$= 159.844 \text{ kN/m}^2$$

Thus the bearing capacity of the site from where the sample was collected is quite low. In the succeeding sections, the experiments carried out adding reinforcements are discussed. In this project we are dealing mainly with the UCS test.

3.3. UCS Test with reinforcement:

3.3.1. Introduction:

The reinforcement used in this project is jute geotextile. The UCS test was performed for reinforced soil in the following stages:

1) Adding jute fibers in varying percentages (by weight) of the soil mass and thorough mixing.
2) Adding jute in layers
3) Adding jute in layers coated with bitumen.

3.3.1.1. UCS test with jute fibers in definite percentage of the soil mass

In this stage, jute fibers are first cut into small lengths of 10mm and added to the soil mass in definite percentage and mixed thoroughly. The view of jute fibers used in this stage is shown in the figure .We have carried out tests for 2% jute by weight. The same procedure is followed for preparation of specimen and also the testing. The observations and results are discussed as follows.

Fig-16: Jute fibres cut in lengths of 10mm

Fig-17: Preparation of sample

Fig-13: Sample before failure for 2% jute

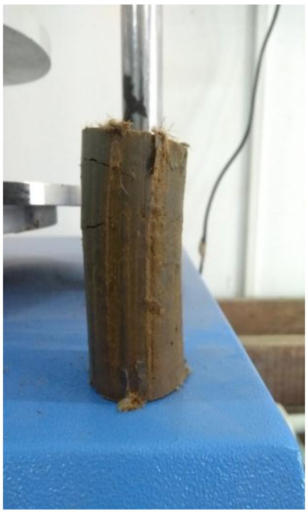

Fig-14: Sample at failure for 2% jute

Table -3: UCS test observation.

Sl no	Elapsed time (min)	Compression Dial Reading L.C= 0.01	Strain $\epsilon = \frac{\Delta L}{L0}$ %	Corrected area A = $\frac{A0}{1-\epsilon}$ (cm^2)	Load "P" (kg)	Compressive Stress = $\frac{P}{A}$ (kg/ cm^2)
1	0	0	0	11.34	0	0
2	0.5	1.25	1.64	11.529	2.1	0.182
3	1	2.65	3.48	11.748	11.5	0.983
4	1.5	3.5	4.68	11.896	19.95	1.677
5	2	4.8	6.31	12.103	28.35	2.342
6	2.5	5.7	7.5	12.259	33.6	2.740
7	3	7	9.21	12.490	25.2	2.017

The Stress vs strain curves for the UCS tests with 2%t of jute are shown below and the safe bearing capacities are calculated accordingly. Addition of 2% jute, the calculations are shown below in details:

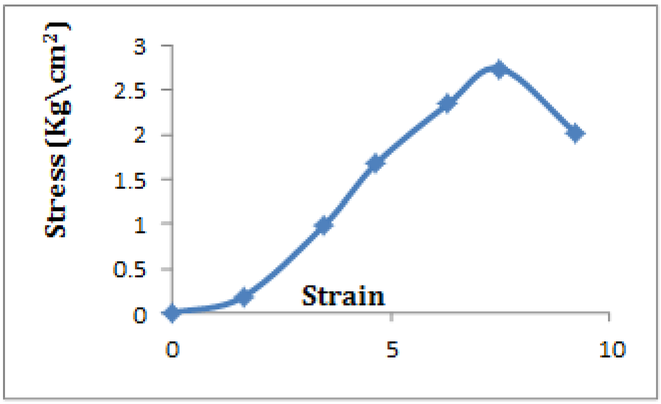

Chart -3: Stress – strain graph from UCS test using jute fibres

From the stress strain curve at failure, the unconfined compressive strength,

q_u = 2.740*98.1=268.794 kN/m^2

Cohesion, $c = q_u/2$ = 268.794/2 kN/m^2

= 134.397 kN/m^2

Ultimate bearing capacity, $q_u = cN_c + qN_q$

$= cN_c + \gamma D_f N_q$

$= 134.397 \times 5.14 + 20.51 \times 0.5 \times 1$

= 701.056 kN/m^2

Net ultimate bearing capacity, q_{nu}

$= q_u - \gamma D_f$

$= 701.056 - 20.51 \times 0.5$

= 690.801 kN/m^2

Safe bearing capacity, SBC = $(q_{nu} / FOS) + \gamma D_f$

$= (690.801 / 3) + 20.51 \times 0.5$

= **240.522 kN/m^2**

Thus it is observed that the UCS value for the reinforced soil sample is quite higher than that for the unreinforced soil sample. Also the safe bearing capacity of the soil sample has increased to an appreciably higher value than that obtained from UCS test carried out without reinforcement soil sample.

3.3.1.2. UCS test with jute fibers in layers:

In this stage, the jute is cut in square shape having side (20mm) equal to that of the soil specimen to be tested and thickness of 1.5 mm. The view of the layers used is shown in figure. The same procedure is followed for preparation of specimen and also the testing. The layers are palced in three layers simultaneously. The observations and results are discussed as follows.

Fig-15: Jute fibres cut in square layers

Observations and results:

Fig-16: Preparation of sample with jute layers

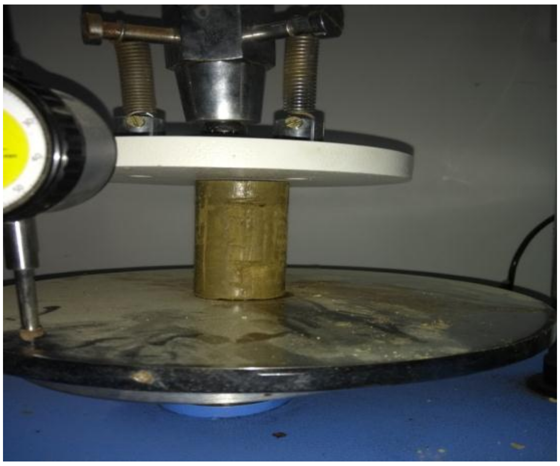

Fig-17: Sample under UCS

Fig-18: Sample before failure

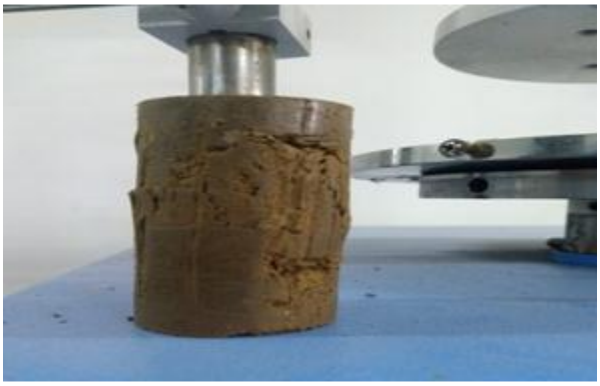

Fig-19: Sample after failure

Table -4: UCS test observation.

Sl no	Elapsed time (min)	Compression Dial Reading L.C= 0.01	Strain $\in = \frac{\Delta L}{L0}$ %	Corrected area A = $\frac{A0}{1-\in}$ (cm^2)	Load "P" (kg)	Compressive Stress = $\frac{P}{A}$ (kg/cm^2)
1	0	0	0	11.34	0	0
2	0.5	1.28	1.6	11.524	4.2	0.364
3	1	2.55	3.3	11.726	18.27	1.558
4	1.5	3.45	4.5	11.874	25.20	2.12
5	2	4.75	6.2	12.089	10.5	0.868

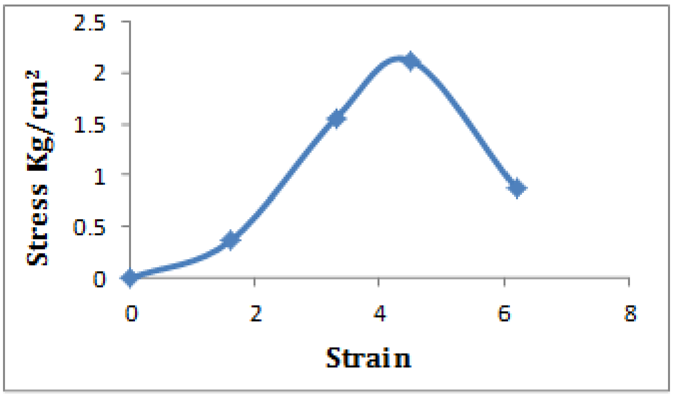

Chart -4: Stress – strain graph for jute layers placed simultaneously in the sample

From the stress strain curve at failure, the unconfined compressive strength,

$q_u = 2.12*98.1$

$= 207.972$ kN/m^2

Cohesion, $c = q_u /2$

$= 207.972/2$ kN/m^2

$= 103.986$ kN/m^2

Ultimate bearing capacity, $q_u = cN_c + qN_q$

$= cN_c + \gamma D_f N_q$

$= 103.986 \times 5.14 + 20.51 \times 0.5 \times 1$

$= 544.703$ kN/m^2

Net ultimate bearing capacity, $q_{nu} = q_u - \gamma D_f$

$=544.703 - 20.51 \times 0.5$

$= 534.488$ kN/m^2

Safe bearing capacity, SBC = $(q_{nu} / FOS) + \gamma D_f$

$= (534.488 / 3) + 20.51 \times 0.5$

= 188.417 kN/m²

3.3.1.3. UCS test with jute fibers (coated with bitumen) in layers:

In this stage, the jute layers similar to that previously used are coated with a thin layer of bitumen and then air dried. The view of the coated jute layers is used is shown in figure. The same procedure is followed as in the previous cases. The positions of the layers is also kept same for better comparison at the end. The observations and results of this stage are discussed as follows.

Fig-20: Jute layers coated with bitumen

Observations and results:

Fig-21: Preparation of sample

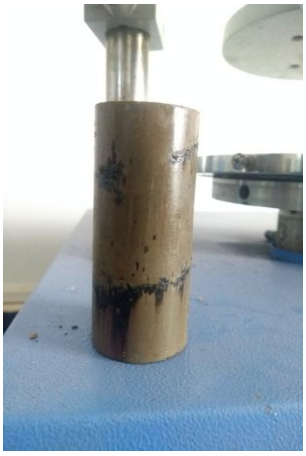

Fig-22: Sample before failure

Fig-23: Sample under UCS

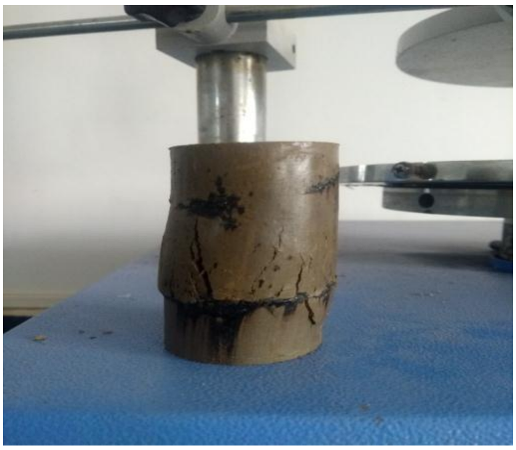

Fig-24: Sample after failure

Table -5: UCS test observation.

Sl no	Elapsed time (min)	Compression Dial Reading L.C= 0.01	Strain $\epsilon = \frac{A0}{L0}$ %	Corrected area A = $\frac{A0}{1-\epsilon}$ (cm^2)	Load "P" (kg)	Compressive Stress = $\frac{P}{A}$ (kg/ cm^2)
1	0	0	0	11.34	0	0
2	0.5	2.35	3.09	11.701	9.03	0.772
3	1	3.6	4.73	11.903	22.47	1.887
4	1.5	4.5	5.92	12.053	30.45	2.526
5	2	5.9	7.76	12.294	38.85	3.160
6	2.5	6.65	8.75	12.427	43.05	3.464
7	3	6.9	9.07	12.471	9.03	0.724
8	3.5	7.5	9.86	12.580	6.09	0.484

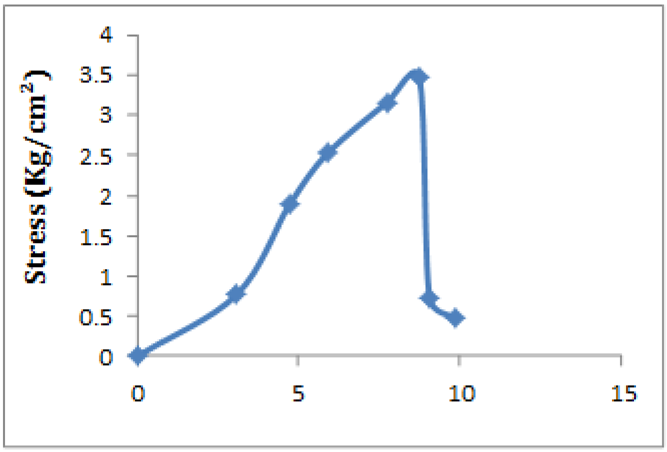

Chart -5: Stress – strain graph for jute layers coated with bitumen placed simultaneously in the sample

From the stress strain curve at failure, the unconfined compressive strength,

q_u = 3.464 kg/cm² = 3.464*98.1=339.818 KN/m²

Cohesion, c = q_u /2 = 339.818/2 kN/m²

= 169.909 kN/m²

Ultimate bearing capacity, q_u

$= cN_c + qN_q$

$= cN_c + \gamma D_f N_q$

= 169.909 × 5.14 + 20.51 × 0.5 × 1

= 883.587 kN/m²

Net ultimate bearing capacity, $q_{nu} = q_u - \gamma D_f$

= 883.587 – 20.51 × 0.5

$= 873.332\ kN/m^2$

Safe bearing capacity, SBC = $(q_{nu} / FOS) + \gamma D_f$

$= (873.332 / 3) + 20.51 \times 0.5$

$= 301.36\ kN/m^2$

4. Final results and discussions.

4.1 Final comparison between the results of UCS tests of all the cases of unreinforced and reinforced soil samples:

Fig-24: Failed samples (from left) of unreinforced soil, with 2% jute fibres thoroughly mixed, with three layers of jute placed simultaneously, with three layers of jute coated with bitumen placed simultaneously

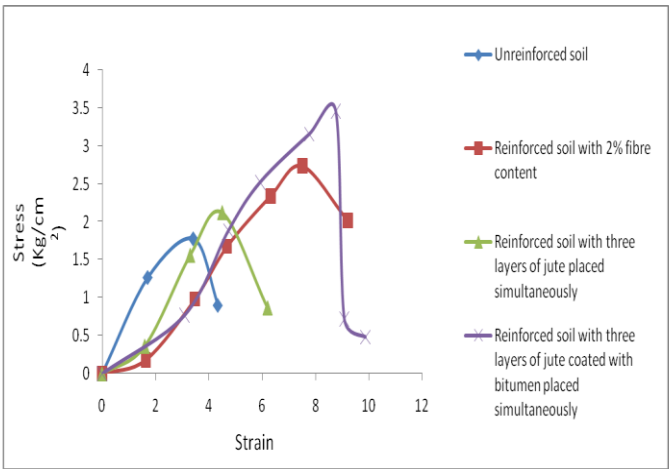

Chart -6: Curves showing comparisons of the maximum UCS values for all the cases of unreinforced and reinforced soil sample

The table below summarizes the optimum UCS and SBC of the soil sample under all the cases:

Table -6: Effect of jute in unreinforced and reinforced soil samples.

Serial no	Reinforcement condition	Maximum UCS (kN/m^2)	Safe Bearing Capacity (kN/m^2)
1	Unreinforced soil	174.618	159.844
2	Thorough mixing of jute fibers	268.794	240.522
3	Jute in layers without bitumen coating	207.972	188.417
4	Jute in layers with bitumen coating	339.818	301.36

The following points can be finally drawn from the above table:

1) Among all the cases of reinforcement conditions, the highest value of UCS and SBC for soil sample is obtained when jute is added in layers coated with bitumen, the UCS and SBC of the soil sample are found to be higher than those obtained for addition of jute layers without bitumen coating.

2) When jute is added in layers without bitumen coating, the results obtained are not found to be satisfactory and the corresponding SBC is found to be lower than the mixing case.

3) For thorough mixing case, when jute fibers are added in 2% by weight the UCS and SBC of the soil sample are found to be higher than those obtained for addition of jute layers without bitumen coating, though they are lower than the jute added in layers coated with bitumen.

5. 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, 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.

An experimental study was carried out to investigate the properties, unconfined compressive strength and safe bearing capacity of soil sample under the effect of random inclusion of jute fibers. The study brings forth the following conclusions:

1) The UCS of the collected soil sample increases to an appreciably high value 268.794 kN/m^2 for jute fiber content of 2% from an initial value of only 174.618 kN/m^2 for the unreinforced soil sample.

2) The corresponding SBC of the soil sample has also much increased to 240.522 kN/m^2 from 159.844 kN/m^2

In case of layers of jute geotextile,

1) For jute reinforcement in layers with bitumen coating, the UCS of the collected soil sample increases to an appreciably high value 339.818 kN/m^2 when all the three layers are placed simultaneously within the sample from an initial value of only 207.972 kN/m^2 for jute reinforcement in layers without bitumen coating.

2) The corresponding SBC of the soil sample has also much increased to 301.36 kN/m^2 from 188.417 kN/m^2

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