

SUSTAINABLE STABILISATION OF SOIL USING JUTE FIBRE IN DELHI REGION

A DISSERTATION

**SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE
OF**

**MASTER OF TECHNOLOGY
IN
GEOTECHNICAL ENGINEERING**

Submitted by:

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CANDIDATE'S DECLARATION

I, **ANKITA YADAV**, Roll No: **2K24/GTE/03** student of M. Tech (Geotechnical Engineering) , hereby declare that the project Dissertation titled “SUSTAINABLE STABILIZATION OF SOIL USING JUTE FIBRE IN DELHI REGION” which is submitted by me to the **Department of Civil Engineering, Delhi Technological University, Delhi** in the partial fulfilment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work was not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

ANKITA YADAV

Place: Delhi

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CERTIFICATE

I hereby certify that the Project Dissertation titled “SUSTAINABLE STABILIZATION OF SOIL USING JUTE FIBRE IN DELHI REGION” which is submitted by **ANKITA YADAV, Roll No: 2K24/GTE/03** Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the Degree of Master of Technology, is the record of the project work carried out by the student under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

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ABSTRACT

This study investigated randomly distributed natural fibers as a reinforcement for Poorly Graded Sandy Soil . Sands are found widely and are , particularly , vulnerable to variations in moisture and low strength in engineering-related issues . Weak soil frequently requires stabilisation when the intended use requires strength and durability . These soils are porous , and exist widely in parts of Northern and southern India . In building roads , subgrade strength should be increased when encountering weak subgrades , as the strength of the subgrade soil has a major impact on the thickness and lifespan of the pavement . Increasing strength and stability of the subgrade soil can help reduce pavement thickness through reduced construction costs , with traditional building materials being preserved for the generation to follow .

Jute Fibre for the improvement of soil is an advantageous option and low-cost for environmental conservation , it can be readily derived and improves engineering properties of soil . Soil subgrade enhancement is a perennial subject of concern for soil engineering . To strengthen the soil subgrades , I employed jute fibre , which is advantageous , as it is relatively cheap , readily available at a local level , biodegradable , and eco-friendly . I used

jute fiber mixed with soil at different lengths 40mm and 45mm and at different percentages 0.5% , 1% , 1.5% , and 2.0% , and the diameter of jute fibre is 2mm.

Compaction tests across different fibre contents established the specific characteristics of the compaction curves, as the fibre content was enhanced , so the OMC of the soil was increasing but the maximum dry density decreased . Maximum dry density reduced as the length of fiber was increased and OMC was observed to increase significantly . The engineering properties of the soil (poorly graded sand (SP)) , reinforced with jute fibre, were analysed in this study. The lab tests , Proctor and CBR were carried out using 40mm and 45mm long jute fibre that had different percentages (0.5%, 1.0%, 1.5%, 2.0%), to determine the optimal value of jute fibre.

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CONTENTS

CANDIDATE’S DECLARATION.....	II
CERTIFICATE.....	III
ABSTRACT.....	IV
ACKNOWLEDGEMENT.....	VI
CONTENTS.....	VII
LIST OF TABLES.....	X
LIST OF FIGURES.....	XI
LIST OF ABBREVIATIONS.....	XIII
CHAPTER 1.....	14
INTRODUCTION.....	14
1.1 GENERAL.....	14
1.2 TYPES OF NATURAL FIBERS.....	14
1.3 JUTE FIBER.....	15
1.4 FIBER REINFORCED SOIL.....	16
1.5 MOTIVATION OF STUDY.....	17
1.6 OBJECTIVES.....	17
CHAPTER 2.....	19
LITERATURE REVIEW.....	19
2.2 GAPS IN LITERATURE.....	22
CHAPTER 3.....	24
MATERIAL AND METHODOLOGY.....	24

3.1 METHODOLOGY	24
CHAPTER 4.....	25
EXPERIMENTAL PROGRAMME	25
4.1 GENERAL	25
4.2 MATERIAL PROPERTIES	25
4.2.1 SOIL SAMPLE	25
4.2.2 Grain Size Analysis:	26
4.2.3 Atterberg Limits.....	29
4.2.4 Moisture Content Test.....	31
4.2.5 Specific gravity	31
4.2.6 Standard Proctor Test.....	33
4.2.7 DIRECT SHEAR TEST	35
4.2.8 CALIFORNIA BEARING TEST	37
4.3 Jute Fibers	39
CHAPTER 5.....	40
SAMPLE PREPARATION.....	40
5.1 GENERAL	40
5.2 COMPACTION TEST.....	41
5.3 CALIFORNIA BEARING RATIO TEST	42
CHAPTER 6	43
EXPERIMENTAL OBSERVATIONS, RESULTS AND DISCUSSIONS.....	43
6.1 GENERAL	43
6.2 EFFECT OF JUTE FIBRE ON COMPACTION CURVES	43
6.2.1 FOR FIBRE LENGTH	43
6.2.1 FOR FIBRE LENGTH (45mm).....	45
6.3 EFFECT OF JUTE FIBRE ON CALIFORNIA BEARING RATIO TEST	48
CHAPTER 7.....	51

SUMMARY AND CONCLUSIONS	51
7.1 SUMMARY	51
7.2 CONCLUSIONS.....	52
REFERENCES	54

LIST OF TABLES

<i>Table 1. Properties of Natural Fibres.....</i>	<i>15</i>
<i>Table 2 Sieve analysis of soil</i>	<i>28</i>
<i>Table 3: Specific Gravity.....</i>	<i>32</i>
<i>Table 4 : Proctor Test.....</i>	<i>34</i>
<i>Table 5 : Direct Shear Test.....</i>	<i>35</i>
<i>Table 6 : California Bearing Test.....</i>	<i>37</i>
<i>Table 7 : Summary of index properties test.....</i>	<i>38</i>
<i>Table 8 : Summary of fibre properties</i>	<i>39</i>
<i>Table 9 : Soil Sample with 0.5% of Jute Fiber</i>	<i>43</i>
<i>Table 10 : Soil Sample with 1.0% of Jute Fiber</i>	<i>44</i>
<i>Table 11: Soil Sample with 1.5% of Jute Fiber</i>	<i>44</i>
<i>Table 12: Soil Sample with 0.5% of Jute Fiber</i>	<i>45</i>
<i>Table 13: Soil Sample with 1.0% of Jute Fiber</i>	<i>45</i>
<i>Table 14: Soil Sample with 1.5% of Jute Fiber</i>	<i>45</i>
<i>Table 15 : Laboratory Results of Standard Proctor Test.....</i>	<i>47</i>
<i>Table 16 : Effect of jute percentage on CBR value</i>	<i>50</i>

LIST OF FIGURES

<i>Figure 1 : Jute fibers.....</i>	<i>16</i>
<i>Figure 2 :Flowchart of Methodology.....</i>	<i>24</i>
<i>Figure 3: Soil collected site location</i>	<i>25</i>
<i>Figure 4: Soil Sample</i>	<i>26</i>
<i>Figure 5: Sieve Analysis</i>	<i>27</i>
<i>Figure 6 : Grading characteristics of study soil</i>	<i>28</i>
<i>Figure 7: Liquid Limit Apparatus.....</i>	<i>29</i>
<i>Figure 8 : Flow Curve.....</i>	<i>30</i>
<i>Figure 9: Plastic Limit.....</i>	<i>30</i>
<i>Figure 10 :Pycnometer</i>	<i>32</i>
<i>Figure 11: Compaction curve of unreinforced soil</i>	<i>34</i>
<i>Figure 12: Displacement vs Shear Stress.....</i>	<i>36</i>
<i>Figure 13: Normal Stress vs Shear Stress.....</i>	<i>36</i>
<i>Figure 14 : Penetration vs Load.....</i>	<i>38</i>
<i>Figure 15: 45mm Jute fibre.....</i>	<i>40</i>
<i>Figure 16 :Jute Fibre mixed in Soil Sample.....</i>	<i>41</i>
<i>Figure 17 : CBR.....</i>	<i>42</i>
<i>Figure 18: Compaction Curves for 40mm Jute Fibre Length</i>	<i>44</i>
<i>Figure 19 : Compaction Curves for 45mm Jute Fibre Length</i>	<i>46</i>
<i>Figure 20 :Effect of Fibre Content on MDD.....</i>	<i>46</i>
<i>Figure 21:Effect of Fibre Content on OMC</i>	<i>47</i>
<i>Figure 22 : Load Penetration Curve for 40mm fibre length.....</i>	<i>48</i>

<i>Figure 23: Load Penetration Curve for 45mm fibre length.....</i>	<i>49</i>
<i>Figure 24 : Effect of fibre content on CBR value.....</i>	<i>49</i>

LIST OF ABBREVIATIONS

- C_u = Coefficient of uniformity
- C_c = Coefficient of curvature
- D_{10} = Effective particle size (m)
- D_{30} = Diameter through which 30 % of the total soil particles is passing
- D_{60} = Diameter through which 60 % of the total soil particles is passing
- OMC = Optimum moisture content
- G = Specific gravity of soil
- MDD = Maximum dry density
- C = Cohesion
- Φ = Angle of internal friction
- τ = Shear strength
- σ = Normal stress
- γ_b = Bulk Density
- γ_d = Dry Density
- I_p = Plasticity Index
- W_p = Plastic limit
- W_L = Liquid Limit

CHAPTER 1

INTRODUCTION

1.1 GENERAL

In recent time, utilization of natural resources, increased filling of dumps, day by day increasing environmental pollution and exhaustible nature of non-renewable resources will have consequences to use naturally renewable resources. Hence a great interest has evolved for use of environmentally sound materials. Because of this reason, many experimental investigations have been carried out around the world resulting in many prospective applications for using natural fibers for soil reinforcement in the recent past. Term eco-composite emphasizes the role and significance of natural fibers in modern industry. It specifies from what part of the plant the fibers were extracted from and age of the plant along with its extraction method that influence the properties of natural fibers when used in soil reinforcement.

1.2 TYPES OF NATURAL FIBERS

It is essential to mention that for a long time , Natural fibers have been used in many developing countries due to their availability and low cost in cement composites . The properties and composition of certain natural fibers are shown in Table 1.

Table 1. Properties of Natural Fibres

Type of fiber	Cellulose (wt%)	Lignin (wt%)	Hemicellulose (wt%)	Density (g/cm³)	Tensile Strength (MPa)	Moisture absorption (%)
Flax	71-78	2.2	18.6-20.6	1.4-1.5	345-1500	7
Hemp	57-77	3.7-13	14-22.4	1.48	550-900	8-9
Jute	45-71.5	12-26	13.6-21	1.3-1.46	393-800	307
Kenaf	31-37	15-19	21.5-23	1.2	295-930	12
Sisal	47-78	7-11	10-24	1.33-1.5	400-700	56-230
Cotton	85-90	0.7-1.6	5.7	1.21	287-597	890-1165
Coir	36-43	41-45	0.15-0.25	1.2	175-220	130-180

1.3 JUTE FIBER

Jute is one of the important natural fiber in the world. It is considered as the second most manufactured natural fiber after cotton. Jute is cultivated in huge quantity in the countries like India, Bangladesh, China and Thailand. It is the fibers from the bark of the jute plant, a plant that grows up to 2.5m height, and the stem base measures about 25 mm in diameter. Jute fibers of different species vary in terms of different properties. It is eco-friendly fiber which is used for making porous fabric used in filtration, drainage and soil stabilization.

Jute is a bast fiber and two species known are White Jute (*Corchorus capsularis*) and Tossa Jute (*Corchorus olitorius*). The complete jute plant, from root to stem can be used. From packaging materials, furnishing materials, vegetable uses, cooking fuel etc.

Because of its coarse nature, it is chiefly used as a raw material in producing packaging materials. The Jute fiber is fairly lustrous when retted and washed properly. The

fiber may have a color ranging from creamy white to brown. Jute and jute product is biodegradable, photodegradable, thermal degradable, non toxic, hydrophilic, droppable and less extensible, with a good moisture and U.V. Absorbing capacity. Due to the presence of cellulose and lignin respectively it resembles cotton and wood simultaneously. With these features, large numbers of traditional as well as diversified jute products can be produced.



Figure 1 : Jute fibers

1.4 FIBER REINFORCED SOIL

The fibre-reinforced soil is described as a soil mass comprising discrete randomly distributed elements, or fibres, that provide a reinforcement of the soil composite's mechanical behavior. Fibres with relatively high tensile strengths are embedded within the soil matrix that makes the fiber reinforced soil behave as composite.

Shear stresses applied to the soil develop the tensile resistance of fibers, thus reinforcing the soil. To reproduce the behavior of plant roots and strengthen the soil mass by reinforcement of superficial soil strata in which the effective stresses are low, random discrete flexible fibers are incorporated. Encouraging results from subsequent laboratory studies and some in-situ pilot tests have demonstrated the potential of the fibers to reinforce the soil mass and to create artificial replicate for vegetation effect. To reproduce the behavior

of plant roots and strengthen the soil mass by reinforcement of superficial soil strata in which the effective stresses are low, random discrete flexible fibers are incorporated.

1.5 MOTIVATION OF STUDY

The lifespan of pavement is closely connected to the subgrade soil beneath . Subgrade failure may result in surface fracture formation . Therefore, a new reinforcing material will become necessary to stabilize the subgrade . Jute fibre is an ideal choice for soil reinforcement due to its natural , biodegradable and environmentally friendly nature- therefore avoiding dependence on synthetic stabilizers . It is inexpensive , easily available, and renewable , making it suitable for sustainable construction practices . Although naturally produced jute has excellent tensile strength and flexibility in soil which is beneficial in enhancing soil stability , interlocking , and deformation resistance. However , its natural biodegradation is a major limitation that restricts its utility in civil engineering in the long run . Thus , to overcome this drawback and to maximize the functionality of jute for extended geotechnical applications , specific diameter , length and concentration of jute are used . On the other hand , the development of natural fibre composites is moving toward the development of ecologically friendly matrix materials which deliver superior performance at a lower cost than conventional synthetic matrices . Finally , the use of jute fibre as a soil reinforcement has been shown to be very promising in recent researches.

1.6 OBJECTIVES

The objectives of this study involve,

- To evaluate the enhancement in strength characteristics of sand reinforced with 40mm and 45mm lengths of jute fibre at varying fibre concentrations .
- To investigate and compare the effect of jute fibre length on Optimum Moisture Content and Maximum Dry Density when soil is reinforced with fibre .
- To assess the compaction characteristics of sand reinforced with jute fibre .

- To methodically analyse examine the overall structural behaviour of the soil-fibre composite with varying fractions and lengths of jute fibres.
- To determine the optimal Fibre parameters (ideal fibre content) that contributes to maximum increase in strength of the reinforced soil .

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

Mr.D.Rambabu et al, (2024) have done an investigation study on improvement in CBR value of soil reinforced with jute fibre: it found that adding jute fiber to soil increases California Bearing Ratio (CBR) compared to unreinforced soil. As the quantity of jute fiber increases, CBR values continue to increase significantly, with significant improvements observed up to around 5% fiber content. Longer and thicker jute fibers also increase CBRs and thus the reinforced soil is stronger and stiffer than plain soil as the results indicate.

Shwetha Prasanna et. al (2020) in their investigation called “Use of Jute Fiber in Soil Stabilisation : the work concludes that mixing jute fibre particles (0.5–2%) in the soil enhances its engineering characteristics such as strength quality. According to laboratory study, reinforcement of the soil exhibits much improvement over the stability of the soil, since the CBR and shear properties are better for the improved soil than for the un-reinforced soil. The fact that jute fiber can convert otherwise weak soils beneficial for construction purposes such as road subgrades and site development. Jute fiber works as an eco-friendly soil stabilizer.

Naveed Anjum Dar and Dr. Gunjan Bhalla, (2020) in “ Stabilization of Soil using Jute Fibre and Stone Dust : The results demonstrated that the California Bearing Ratio (CBR) of the soil increases substantially with the addition of jute fiber and this effect is further

pronounced as the fiber length and content increased. CBR showed the greatest improvement > 200 % vs. plain soil at 1 % jute fiber with 90 mm length . Stone dust also increased CBR but not as much as jute fiber . Under weak soil , fiber-reinforced soil is efficient for ground improvement .

Amitesh Kumat et. al, (2020) in their study titled “Stabilization of Mountainous Subgrade Using Jute Fibre and Cement : in the experiment found that jute fiber and cement applied to reinforce clayey subgrade is more effective than just treating untreated soil in establishing a California Bearing Ratio (CBR) of the material . The maximum CBR values for jute fiber were achieved at about 0.4% fiber content , while the best CBR for cement was around 5–7% depending on conditions . However , when adding jute fiber together with cement , CBR was markedly boosted considerably , especially when subjected to soaked conditions . In general , blending jute fiber with cement can also provide improved strength and load-bearing capacity of weak clayey soils .

Majid Rehman Rather and Er Vijay Kumar , (2019) in their study titled “ Soil Stabilization using Jute fiber : have noted that the reduction of the dry density of the jute fiber-based mixture as the percentage of jute fiber increased in combination with the moisture content , thus the results indicate limitations to the use within the highest moisture . Jute fiber reinforcement is therefore only applicable for soils that are considerably lower in moisture . The results indicate that jute will need to be carefully employed according to the moisture level of the soil for stabilization to work well .

Jothy V K Hema (2019) in their study titled “ Improvement of Shear Strength of the Soil by using Jute Fabric : The study shows that jute fabric used for soil improves shear strength much greater than that of raw soil. The most significant increases in shear strength occurred at an optimum jute fabric content of roughly 6%. Above this value , however , the shear strength started to decrease . The data suggests that the effective rates of jute fabric use for soil reinforcement are only up to an optimal percentage .

K. Ravi Kanth and K. Deepti (2019) in their study titled “An Experimental Study on Stabilisation of a Loose Soil by Using Jute Fiber : The study found that the addition of jute fiber up to 0.75% has increased critical engineering properties from loose soil such as maximum dry density and California Bearing Ratio (CBR), when compared to untreated soil. Improvements are shown to decline above 0.75% fiber. The optimum moisture content tended to decrease with higher jute levels, and the unconfined compressive strength in treated soils was greater than in the standard soil . The fact is that these results suggest that jute fiber , used in the proper proportions , significantly improves soil strength .

K. Arun Kumar et. al, (2019) in their study titled “Investigation of Soil Stabilization using Jute Fiber and Glass Powder : The addition of jute fibre and glass powder to clay soil had positive engineering effects compared with untreated soil . As seen , application of 2% jute fibre helped to promote unconfined compression stress for building applications. Additives also helped to stabilise and enhance dry density and optimum moisture content , indicating higher load-bearing performance . These findings imply that environmentally friendly soil stabilization can facilitate stronger and longer-lasting infrastructure.

Uzma Ashraf and Faiza Manzoor ,(2016) in their study titled “Application of Jute Fibers to Improve Sub Grade Characteristics of Silty – Clay Soil : as compared to untreated soil , supplementing soil with jute fibers enhances the California Bearing Ratio (CBR) and the unconfined compressive strength of natural soil , as reported in the study . The increase in soil strength was greater with longer jute fiber lengths and higher fiber contents. Maximum dry density tended to increase and optimum moisture content also changed with fiber addition . In general , jute fiber was an efficient sustainable reinforcement material for enhancing rudimentary geotechnical characteristics of soil .

K.Rajasekar et. al,(2014) in their study titled “ Experimental Testing of Natural Composite Material (Jute Fiber) : the study shows that jute fiber reinforced polymer composites have been fabricated using a layer-by-layer process . The properties of the composite were evaluated and compared with experimental and simulation results based on

mechanical testing and computer analysis . These results confirm that jute fiber can be used to improve composite material performance . In general, it demonstrates that jute fiber can be used for natural composites .

H. P. Singh and M. Bagra ,(2013) in their study titled “ Improvement in CBR value of soil reinforced by jute fiber : the study confirms that the addition of jute fiber into soil increases the California Bearing Ratio (CBR) , which indicates better soil strength . The improvement is larger with increasing length and dia of fibers . But when fiber levels are greater than 1% , uniform soil is challenging to maintain . A higher CBR enhancement , more than twice that of untreated soil , was observed at 1% fiber with longer and thicker fibers .

2.2 GAPS IN LITERATURE

Although jute fibre has shown increasing interest as a sustainable soil stabilization material , most previous studies have focused mostly on cohesive and fine- grained soils (clay, silt , and black cotton soil) . Very limited research has been conducted on stabilization of poorly graded sand (SP), whose low cohesion and poor interlocking characteristics may lead to different reinforcement behavior compared to cohesive soils . Hence , the applicability of existing findings to SP soil remains uncertain.

Moreover, there is a lack of available published experimental data on the CBR performance of jute fibre reinforced poorly graded sand . Thus far, studies reported on CBR values, penetration resistance, and load bearing behaviour of SP soil reinforced in presence or absence of jute fibre only partially cover the field . Most existing research emphasizes shear strength or UCS behavior rather than pavement-related performance through CBR testing. Another research gap is the insufficient clarity on optimum fibre content and effective fibre dimensions for poorly graded sand stabilization.

The results of previous studies have varied due to soil type , fibre length , aspect ratio , and testing procedure, which prevents obtaining standardized reinforcement parameters for SP soil. In addition , data on compaction properties such as MDD and OMC of jute fibre reinforced poorly graded sand is not readily accessible. SP soil content, because it contains low fines and poor water retaining capability, the compaction behaviour also needs to be studied further with fibre addition . In addition , available CBR testing of jute reinforced SP soil remains scarce in number, and comparative studies of natural fibre reinforcement in enhancing subgrade performance are limited. Thus , future experimental studies should aim to gain a better understanding of compaction and load bearing behavior of jute fibre reinforced poorly graded sand .

CHAPTER 3

MATERIAL AND METHODOLOGY

3.1 METHODOLOGY

The proposed methodology for this research are as follows:

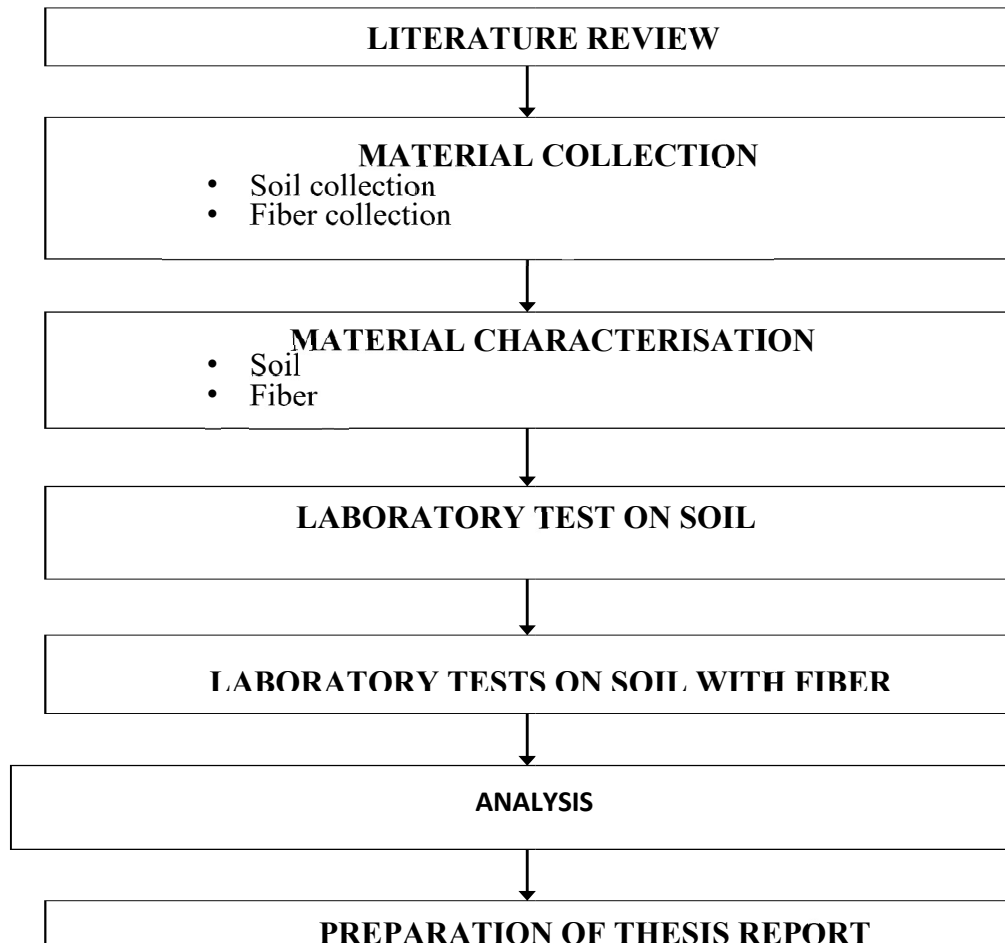


Figure 2 :Flowchart of Methodology

CHAPTER 4

EXPERIMENTAL PROGRAMME

4.1 GENERAL

The description of materials collected with their properties is presented in this chapter . The materials obtained for the current work are soil and jute fibers . Also compared are the different percentages and different fibre lengths of the jute fibre and their impacts on soil properties. To observe the jute fibres response under changing conditions under closely controlled environmental conditions , soil burial studies were carried out for the long-term durability of the fibres . The design of this experiment was to replicate extreme conditions as well as worst-case field scenarios .

4.2 MATERIAL PROPERTIES

4.2.1 SOIL SAMPLE

The samples of the sand was collected from Mcd primary school, Paschim Vihar, where it lies behind Sahibi River, at geographical coordinates 28.665N, 77.122E as shown in fig. 4.1.

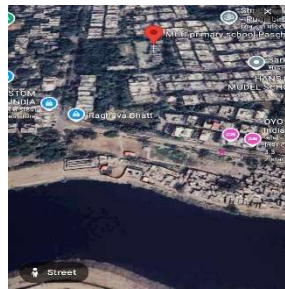


Figure 3: Soil collected site location

Some of the tests conducted are as follows:

- Classification Tests
- Grain Size Analysis
- Atterberg Limits: Liquid limit and plastic limit
- Physical properties
- Moisture Content Test
- Specific Gravity Test
- Compaction Test
- Standard Proctor Test
- Direct Shear Test



Figure 4: Soil Sample

4.2.2 Grain Size Analysis:

Grain size Distribution is a process used for determining the size distribution of particles in soil, sediments, or aggregates. This assists in determining the textural class of the material that may affect parameters such as permeability and strength.

Grain size analysis focuses on soil being sand, silt, clay, or gravel. It can be used to interpret depositional environments, measure permeability and drainage properties, and establish the suitability of foundations and other structures.

Sieve Analysis is done to show the distribution of particles . Sieve Analysis means passing soil through a stack of sieves with progressively smaller mesh sizes , and after that, the retained material is weighed to get the percentage of each size fraction .



Figure 5: Sieve Analysis

Parameters calculated are as:

- D_{10} (Effective size): Particle size at 10% finer, indicates drainage capacity.
- D_{30} : Soil Particles of 30% finer.
- D_{60} : Soil Particles at 60% finer, used to calculate coefficient of Uniformity (C_u) and Coefficient of gradation(C_c).

Table 2 Sieve analysis of soil

Seive size(mm)	Weight Retained (g)	Cummulative Weight Retained(g)	Cumulative % Weight Retained	Passing percentage %
4.75	110.00	110.00	16.84	83.16
2.36	70.00	180.00	27.56	72.44
1.18	140.00	320.00	49.00	51.00
0.6	68.00	388.00	59.41	40.59
0.3	82.00	470.00	71.98	28.02
0.15	84.00	554.00	84.84	15.16
0.075	94.00	648.00	99.23	0.77
PAN	5.00	653.00		

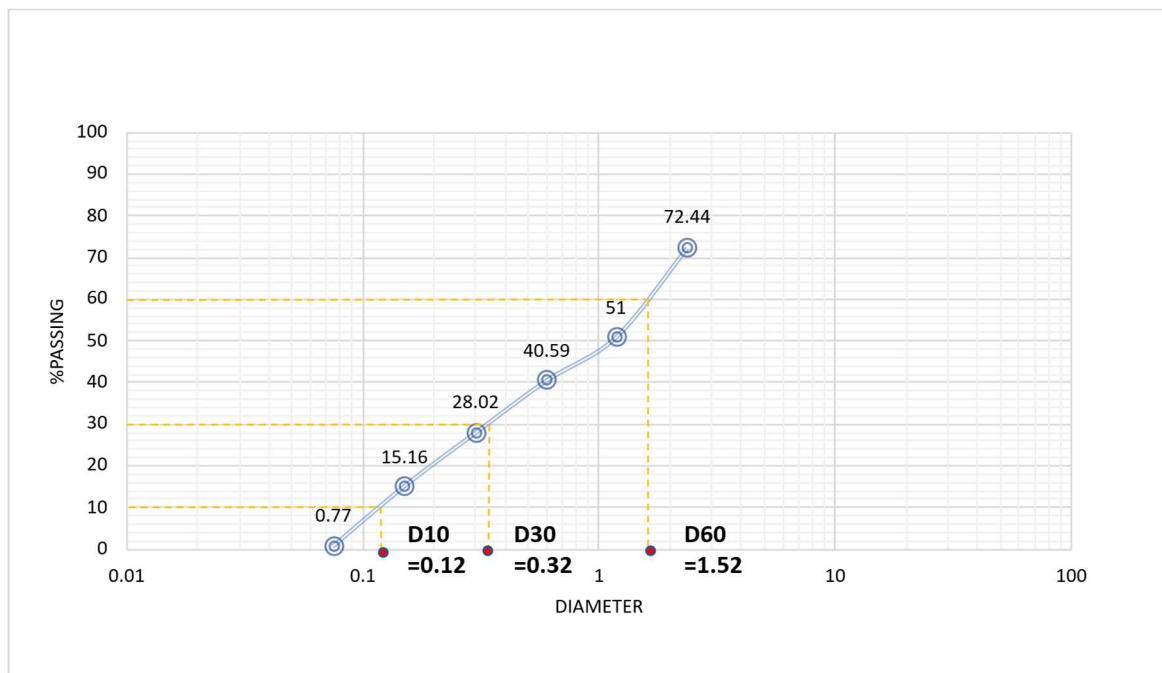


Figure 6 : Grading characteristics of study soil

From graph, we found

$D_{60} = 1.52\text{mm}$, $D_{30} = 0.32\text{mm}$, $D_{10} = 0.12\text{mm}$

- Uniformity coefficient $C_u = D_{60} / D_{10} = 12.7$
- Coefficient of curvature $C_c = (D_{30})^2 / (D_{60} \cdot D_{10}) = 0.56$

$C_u > 6$ and C_c does not lie between 1 and 3, so this soil is **SP** (poorly graded sand) .

4.2.3 Atterberg Limits

4.2.3.1 Liquid Limit (W_L)

With fine-grained soils , the liquid limit is a major property that reflects the water content at which the soil changes from plastic form to the liquid form . It represents the boundary where soil can flow under its own weight . As this property is important in clayey soils , its main purpose is to determine the consistency and behavior of clayey soils and helps to predict soil strength, compressibility, and settlement . Casagrande apparatus is used to obtain the liquid limit .



Figure 7: Liquid Limit Apparatus

By Interpolation,

For 25 number of blows,

Water content = 18.28 %

$\therefore$ Liquid Limit = 18.28 %

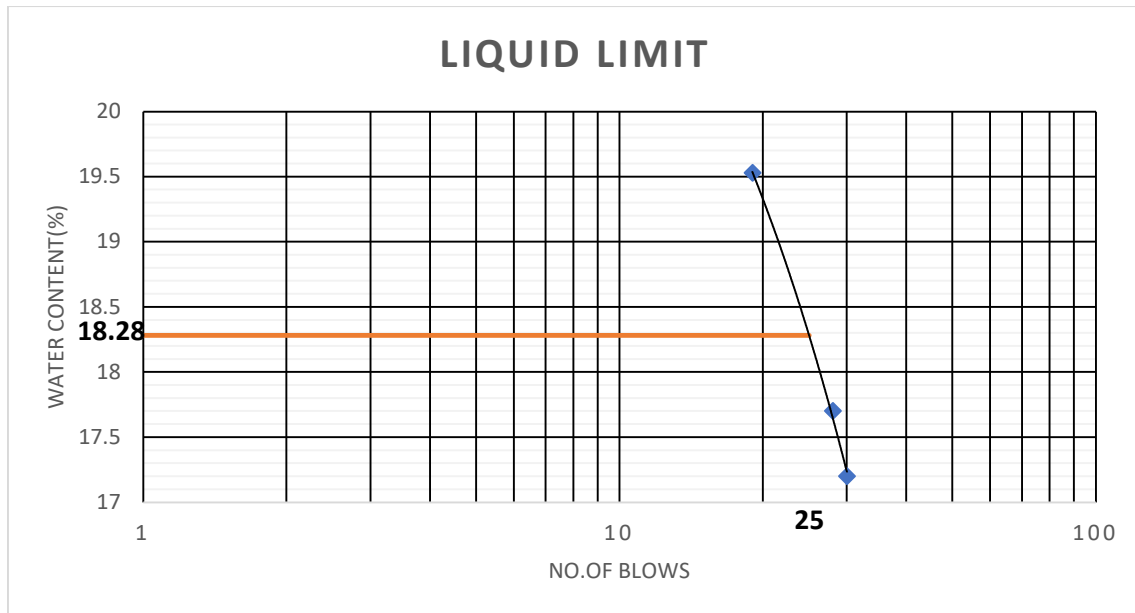


Figure 8 : Flow Curve

4.2.3.2 Plastic limit (W_p)

The plastic limit is a measure of the water content at which a soil changes from a plastic to a semisolid state, it is a measure of the water content of the soil at which it just starts to crumble if rolled into a thread about 3mm in diameter.



Figure 9: Plastic Limit

4.2.3.3 Plasticity Index (I_p):

The plasticity index (PI) is the range of moisture content over which a soil behaves like a plastic. It is calculated as:

$$PI = LL - PL$$

$$I = W_L - W_P$$

$$= (18.283 - 15.99)$$

$$I_p = 2.293$$

4.2.4 Moisture Content Test

Moisture content is quantity of water present in a soil or material, depicted as a percentage of dry weight. It is, therefore, one of the most significant factors of soil mechanics, agriculture and material science, for its significance in soil strength, compaction and behavior of soil. Oven dry method ($105^\circ\text{C} - 110^\circ\text{C}$), calcium carbide method, Torsion balance and electronic moisture meters are common methods of moisture content measurement. Moisture Content of this soil from moisture meter is found to be 8.77%.

4.2.5 Specific gravity

It is the ratio between the weight of soil solids and the weight of an equal volume of water. The soil is classified and properties such as void ratio, porosity etc are determined with the help of it. Specific gravity helps in calculating unit weight of soil in varying conditions and further finding out the particle size in wet analysis. The specific gravity of the soil sample is calculated using a pycnometer.



Figure 10 :Pycnometer

Calculations

The specific gravity (G) is calculated using the formula:

$$G_s = (W_2 - W_1) / [(W_4 - W_1) - (W_3 - W_2)]$$

Where:

W_1 = Weight of the empty pycnometer.

W_2 = Weight of the pycnometer with soil

W_3 = Weight of the pycnometer with soil and water

W_4 = Weight of the pycnometer with water only

Table 3: Specific Gravity

Weight (g)	Sample 1	Sample 2	Sample 3
W_1	690	690	690
W_2	990	990	992
W_3	1730	1726	1734
W_4	1572	1572	1572
G	2.1126	2.1126	2.3714

Average value of specific gravity is **2.19** at room temperature.

4.2.6 Standard Proctor Test

Compaction is the physical act of artificially shifting and packing the soil particles into a closer contact state using mechanical means to reduce the porosity (i.e., voids ratio) of soil and thus promote the soil mass dry density due to the removal of the air in voids through a process, first and foremost, dynamic, and rapid. The density of compacted soil mainly is influenced by its water content, compactive effort, soil type, and admixtures.

The laboratory compaction tests are conducted to determine the quantity of water where the weight of the soil grains per unit volume of the compacted soil is maximum; this is referred to as Optimum Moisture Content (OMC) and Maximum Dry Density (MDD).

Observations

- Diameter of mould = 10.2 cm
- Height of mould = 11.8 cm
- Volume of mould = 964.21 cm³
- Empty weight of mould (W₁) = 4184 g
- Weight of rammer = 2.6 kg
- Empty weight of mould (W₁) = 4184 g
- Dry Density $\gamma_d = \gamma_b / (1 + W)$

Table 4 : Proctor Test

S.No.	Weight of mould (Kg), W_1	Weight of compacted soil + mould (Kg), W_2	Volume of mould (cm^3)	Water added (%), W	Bulk density (g/cc), γ_b	Dry density (g/cc), γ_d	Dry density (kN/m^3), γ_d
1	4.184	5.382	964.21	6	1.596	1.505	14.758
2	4.184	5.530	964.21	8	1.744	1.614	15.827
3	4.184	5.594	964.21	10	1.826	1.660	16.279
4	4.184	5.560	964.21	12	1.864	1.664	16.318
5	4.184	5.450	964.21	14	1.834	1.609	15.778

The compaction curve for unreinforced sand showed optimum moisture content (OMC) and maximum dry density (MDD) as **11.18%** and **16.357 kN/m^3** respectively. The results of compaction curve for unreinforced sand as shown in Fig 4.8 .

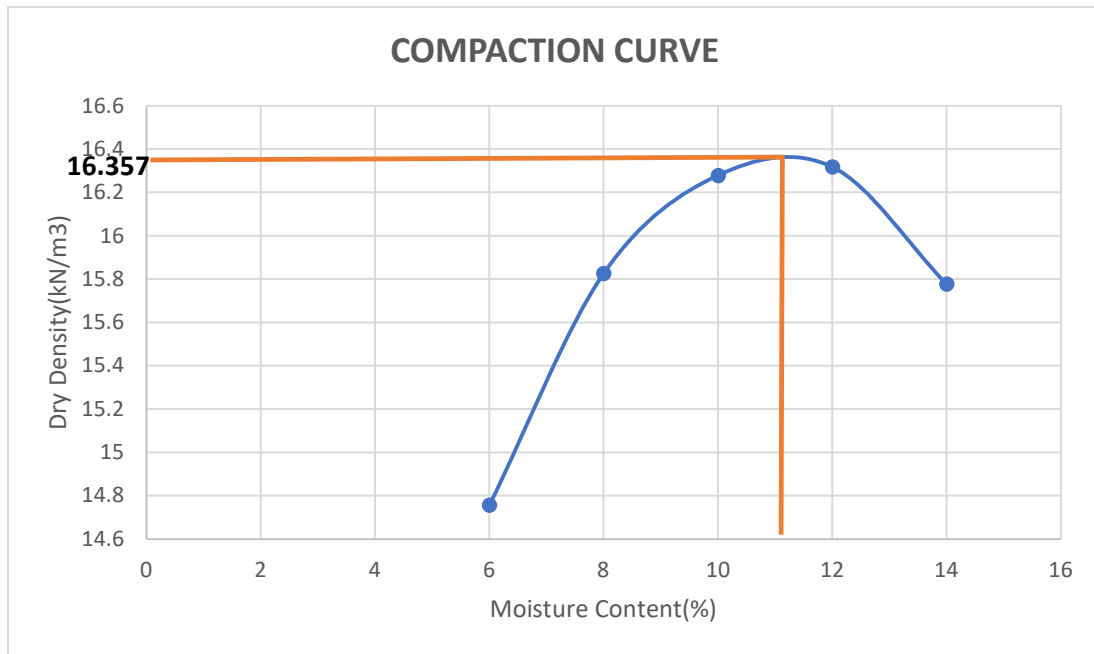


Figure 11: Compaction curve of unreinforced soil

4.2.7 DIRECT SHEAR TEST

The Direct Shear Test is utilized in Geotechnical Engineering for design such as stability of slopes, retaining walls or foundations. The resistance to shear is needed for determining factors such as the potential for failure in a slope, sufficient shear strength for the bearing capacity, measurement of the lateral earth pressure, etc. Hence Direct Shear Test is a lab test procedure to determine the shear strength parameters of the soil, cohesion c , and angle of internal friction.

Calculations

The shear strength (τ) of soil is calculated using Coulomb's Law:

$$\tau = c + \sigma \tan \phi$$

Where,

τ = Shear strength

c = Cohesion

σ = Normal stress

ϕ = Internal friction Angle

Table 5 : Direct Shear Test

S.No.	Normal Stress(kPa)	Max. Shear Stress(kPa)
1	50	37.4602
2	100	72.1002
3	150	106.7402

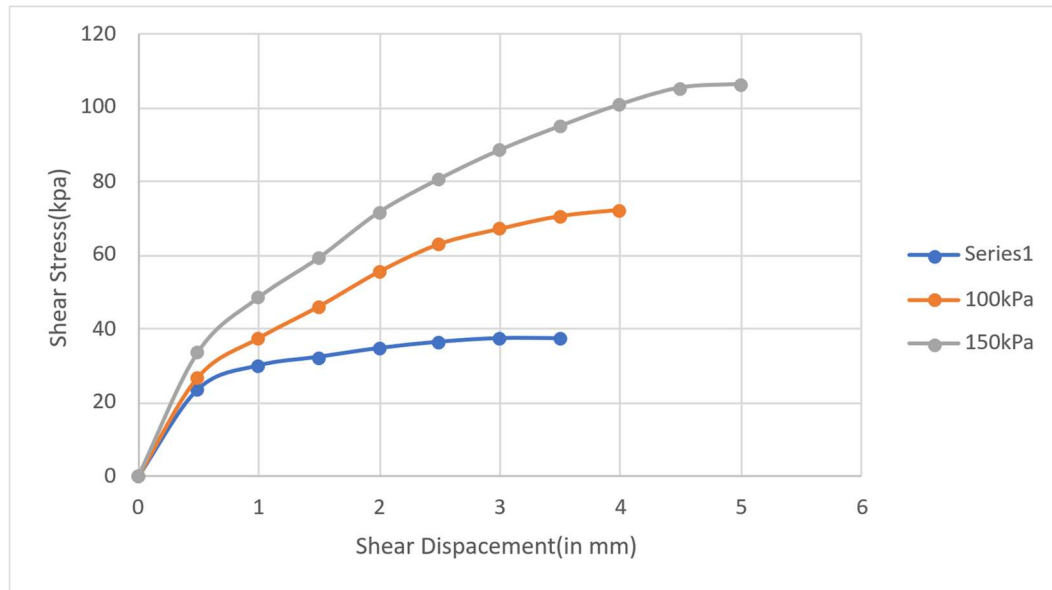


Figure 12: Displacement vs Shear Stress

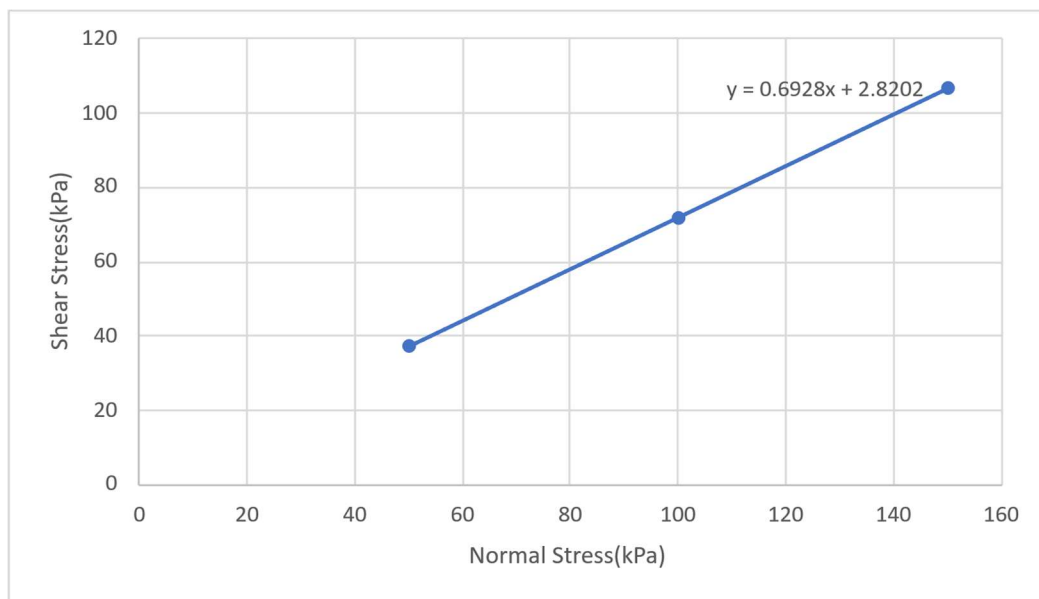


Figure 13: Normal Stress vs Shear Stress

From the above graph,

cohesion (c) = 2.8202 KN/m²

Angle of internal friction (ϕ) = 34.7°

4.2.8 CALIFORNIA BEARING TEST

The California Bearing Ratio test is a penetration assessment evaluates the mechanical strength of subgrade soils and basecourse materials in road construction . It measures the resistance of a soil sample to penetration by a standard plunger under strictly regulated conditions . The results are expressed as a percentage, denoting the soil's penetration resistance relative to a benchmark of standard highquality crushed stone .

Consequently, higher CBR values signify superior soil strength and enhanced load-bearing capacity . This empirical evaluation is extensively employed in flexible pavement design to determine the necessary thickness of individual structural layers . Furthermore, depending on specific project prerequisites , the procedure can be executed effectively in either controlled laboratory environments or in-situ field conditions .

Table 6 : California Bearing Test

Penetration (mm)	Load (Kg)
0	0
0.5	37.66
1	65.36
1.5	85.22
2	95.35
2.5	103.59
3	109.65
3.5	117.54
4	125.3
4.5	130.63
5	135.643228
5.5	145.29

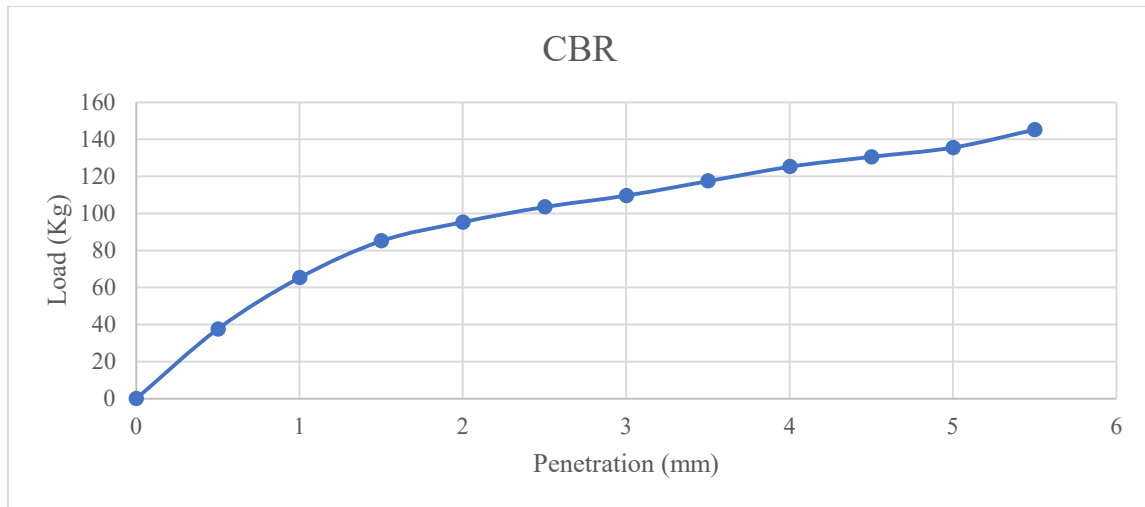


Figure 14 : Penetration vs Load

From the above table, we obtain CBR at 2.5mm = 7.56%

And CBR at 5mm = 6.6%

Therefore, value of CBR at 2.5mm that is 103.59Kg is taken for consideration.

Table 7 : Summary of index properties test

Laboratory test	Value
Specific gravity	2.109
Natural water content	8.44%
Grading	
Sand	99.23%
Silt and clay	0.765%
Consistency limits	
Liquid limit	18.283
Plastic limit	15.99%
Plasticity index	2.293%
IS Classification	SP
Compaction test	
Optimum moisture content	11.18%
Maximum dry density	16.357 kN/m ³

Shear strength	106.74 Kpa
CBR	7.56%

4.3 Jute Fibers

The processed jute fibres were obtained from a commercial firm. The jute fibres were de-stranded and cut into lengths of 40mm and 45mm . Diameter of the fibres was determined using vernier callipers upon averaging three sets of readings along the fibre length. The Summary of fibre properties of the jute fibres have been tabulated in below table.

Table 8 : Summary of fibre properties

Physical property	Value
Colour	Light brown
Diameter	2mm
Specific gravity	2.70
Fiber length Content Selected for the Study	40mm , 45mm
Fiber Content Selected for the Study	0.5%, 1.0% and 1.5% and 2.0 %

CHAPTER 5

SAMPLE PREPARATION

5.1 GENERAL

The air-dried sand samples were uniformly hand mixed with Fibres of 40mm and 45mm length with varying 0.5% , 1.0% and 1.5% by dry weight of soil .Table 6 presents the analytical results derived from multiple experiments designed to evaluate the structural characteristics of the sand matrix when reinforced with randomly and layered dispersed untreated jute fibre .To comprehensively assess these composites, the following primary laboratory evaluations were executed utilizing both fibre variants: (1 Standard Proctor compaction tests and (2) California Bearing Tests .



Figure 15: 45mm Jute fibre



Figure 16 :Jute Fibre mixed in Soil Sample

5.2 COMPACTION TEST

A Standard Proctor test was performed to assess compactive effort of soil samples and moisture content . This laboratory process finds the Optimum Moisture Content (OMC) for a material where a soil reaches Maximum Dry Density (MDD) . Compaction test is performed on both unreinforced sand and soil reinforced with untreated jute fibres in varied concentration levels in current study .Initially, air-dried sand at 3000 g was measured, and jute fibres at 40mm and 45mm lengths were prepared . The soil was then filled with jute fibres obtained evenly in the dry soil via 3 different percentages: 0.5% , 1.0% , and 1.5% by dry weight. The soil-fibre matrix was homogenistically mixed by manually blending it with an initial 6% moisture content . The compaction was subsequently repeated at 2% increments of moisture content .

This systematic assessment was performed for each concentration (0.5%, 1.0%, and 1.5%) of the jute fibres of various lengths to determine their respective OMC and MDD values

5.3 CALIFORNIA BEARING RATIO TEST

In this study, laboratory unsoaked California Bearing Ratio tests for 4 days was performed on lateritic soil treated with randomly dispersed jute fibers of lengths 40mm and 45mm . Each specimen was prepared with 5000g of dried soil and the jute fibers added at 0.5% concentration by the weight of the soil on the dry basis. In order to obtain the maximum dry density , the measured soil and fibres were consistently blended at the predetermined optimum moisture content . This uniform mixture was then compacted into five equal layers within a standard CBR mould according to IS 2720 (Part 16) – 1987 .



Figure 17 : CBR

Methodologically , this procedure was performed on the jute fibres for the remaining concentrations of 1.0% and 1.5% . Penetration load values were recorded at depths of 2.5 mm and 5.0 mm during the testing phase . According to common engineering practice , where the CBR percentage calculated at 5.0 mm penetration should be less than the value at 2.5 mm , the later was taken as the design value . If the penetration at 5.0 mm resulted in a higher CBR percentange the test was repeated to ensure the same .

CHAPTER 6

EXPERIMENTAL OBSERVATIONS, RESULTS AND DISCUSSIONS

6.1 GENERAL

This chapter discusses the results obtained from all the lab tests performed to assess water absorption capacity, strength improvement of sand reinforced with jute fibers .

6.2 EFFECT OF JUTE FIBRE ON COMPACTION CURVES

6.2.1 FOR FIBRE LENGTH

Table 9 : Soil Sample with 0.5% of Jute Fiber

WATER CONTENT (%)	DRY DENSITY(kN/m ³)
12	13.864
13	14.662
14	15.026
15	14.988
16	14.434

Table 10 : Soil Sample with 1.0% of Jute Fiber

WATER CONTENT (%)	DRY DENSITY (kN/m³)
14	13.462
15	13.724
16	14.626
17	14.592
18	14.378

Table 11: Soil Sample with 1.5% of Jute Fiber

WATER CONTENT (%)	DRY DENSITY(kN/m³)
15	14.014
16	14.120
17	14.498
18	14.282
19	13.646

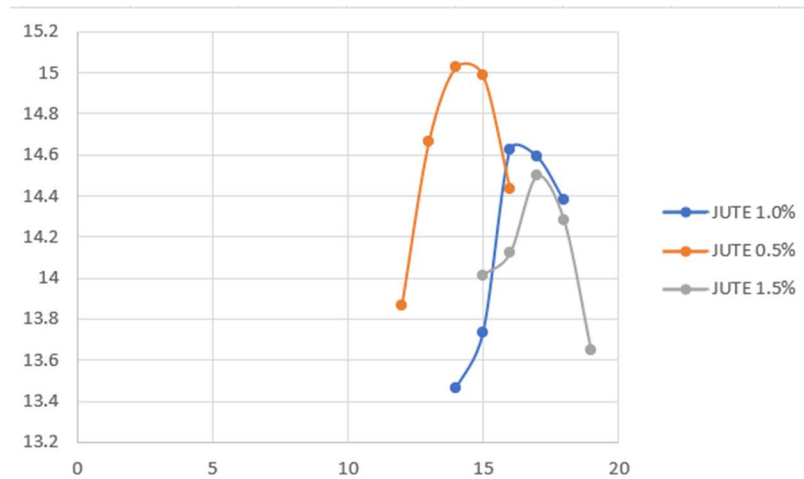


Figure 18: Compaction Curves for 40mm Jute Fibre Length

6.2.1 FOR FIBRE LENGTH (45mm)

Table 12: Soil Sample with 0.5% of Jute Fiber

WATER CONTENT (%)	DRY DENSITY(kN/m3)
13	13.766
14	14.426
15	14.434
16	14.428
17	14.232

Table 13: Soil Sample with 1.0% of Jute Fiber

WATER CONTENT (%)	DRY DENSITY(kN/m3)
16	12.542
17	12.824
18	12.826
19	12.802
20	12.710

Table 14: Soil Sample with 1.5% of Jute Fiber

WATER CONTENT (%)	DRY DENSITY(kN/m3)
15	13.924
16	14.062
17	14.136
18	13.528
19	13.194

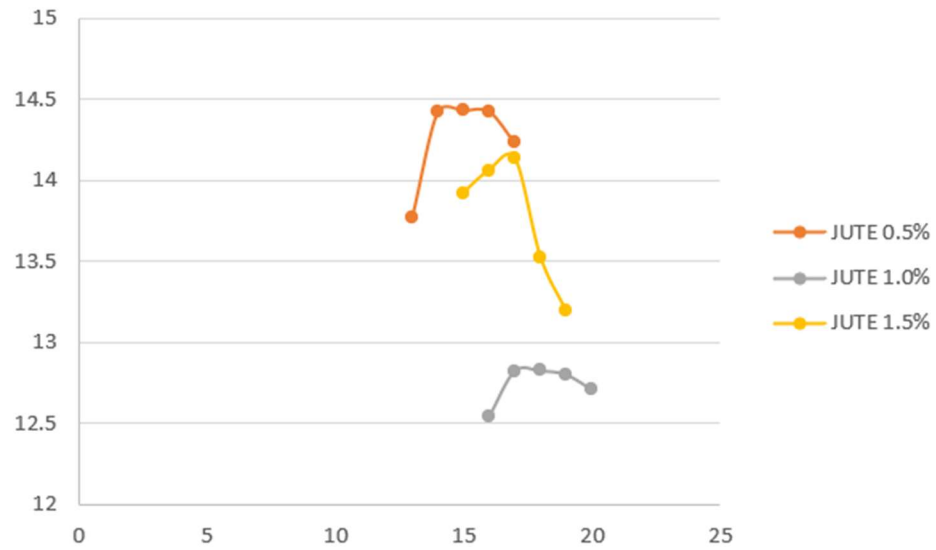


Figure 19 : Compaction Curves for 45mm Jute Fibre Length

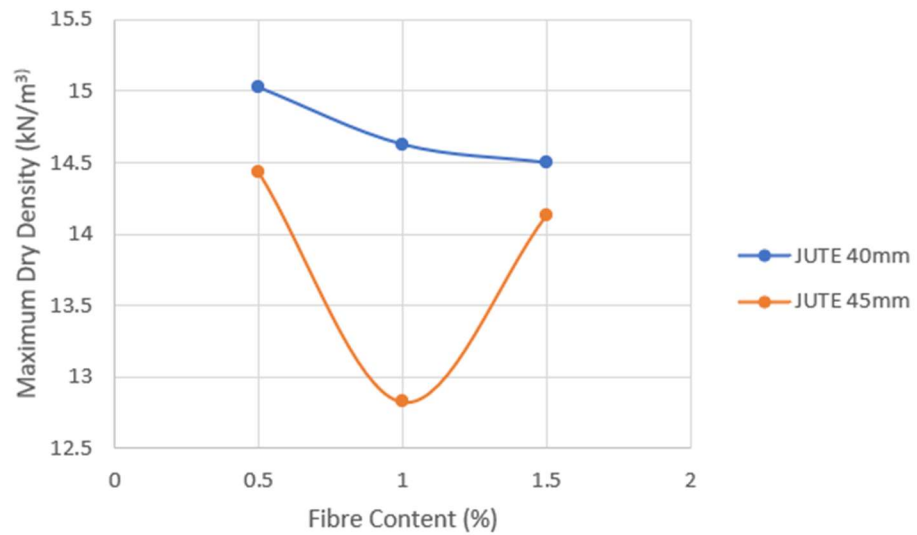


Figure 20 :Effect of Fibre Content on MDD

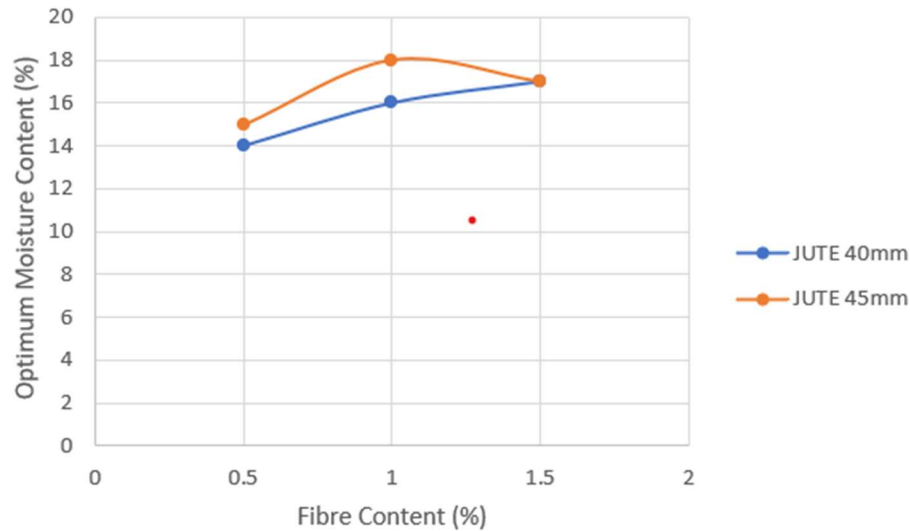


Figure 21:Effect of Fibre Content on OMC

The Compaction curves shows the effect of 40mm and 45mm jute fibre at various Fibre contents , as illustrated in Fig 17 and Fig 18 . Table 12 OMC and MDD at different contents . Based on Compaction Curves, OMC increases while MDD decreases when Fibre content increased for jute fibres from 0.5 % to 1.5% . Figure 20 illustrates an upward trend in OMC . Figure 18 presents a downward trend in MDD with respect to the fibre content . The OMC stabilizes or increases slightly after some fibre length .

Table 15 : Laboratory Results of Standard Proctor Test

Fibre content (%)	Jute Fibre length			
	40mm		45mm	
	MDD (kN/m ³)	OMC (%)	MDD (kN/m ³)	OMC (%)
0.5	15.026	14	14.434	15
1.0	14.626	16	12.826	18
1.5	14.498	17	14.136	17

Fig. 17 and Fig 18 showed that the compaction curves for both 40 mm and 45 mm jute fibres exhibit a reduction in MDD as Fibre concentration increases . This decrease in MDD is attributable to the fact that when Fibre content increases , lighter Fibre material replaces heavier soil material

With higher contents , the Fibre material creates a flocculated structure , which raises the void ratio and decreases the MDD . Fig. 19 depicts the linear decrease in MDD for jute fibre . Previous research has found a decrease in MDD and an increment in OMC due to fibre inclusion (Lawer, 2021) and (Lekha, 2015).

6.3 EFFECT OF JUTE FIBRE ON CALIFORNIA BEARING RATIO TEST

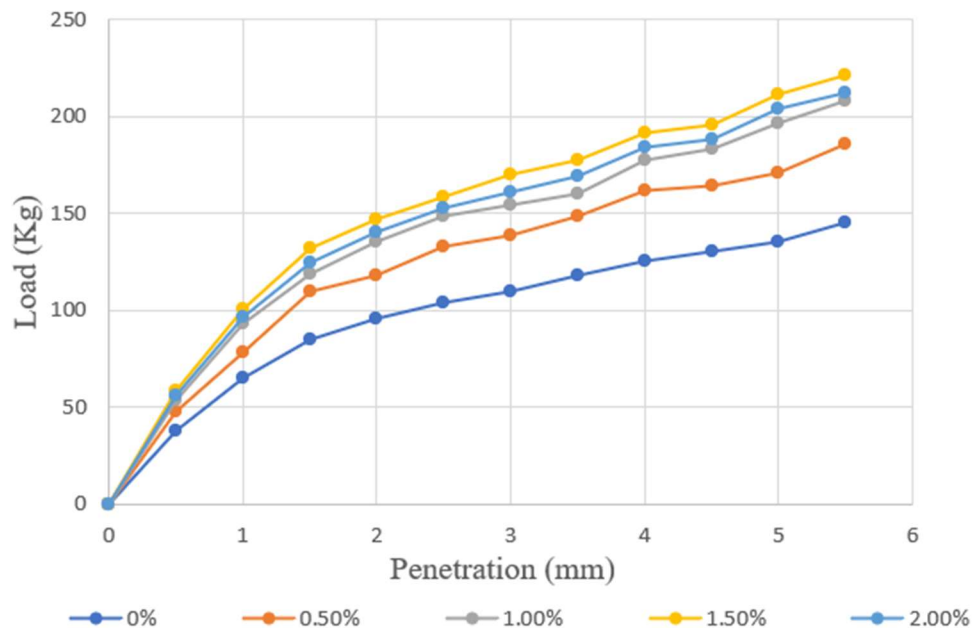


Figure 22 : Load Penetration Curve for 40mm fibre length

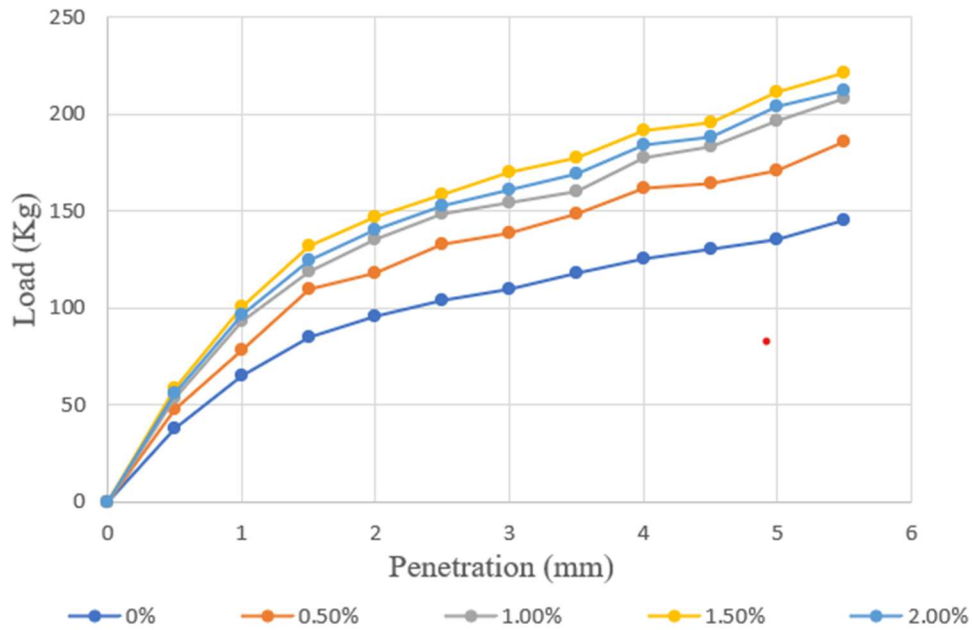


Figure 23: Load Penetration Curve for 45mm fibre length

Fig. 22 and 23 are typical load - penetration curves for unsoaked CBR containing jute fibres of 40 mm and 45 mm diameter, respectively. Fig. 24 depicts that CBR strength rises with fibre content up to optimum content and then decreases because of the formation of flocs by fibres in soil mass in jute fibres. The increased CBR strength in jute fibres is a direct result of the mechanical interlocking between jute fibres and the soil interface. The jute resists particle movement and distributes load more effectively during penetration. This increases shear strength and bearing resistance of soil.

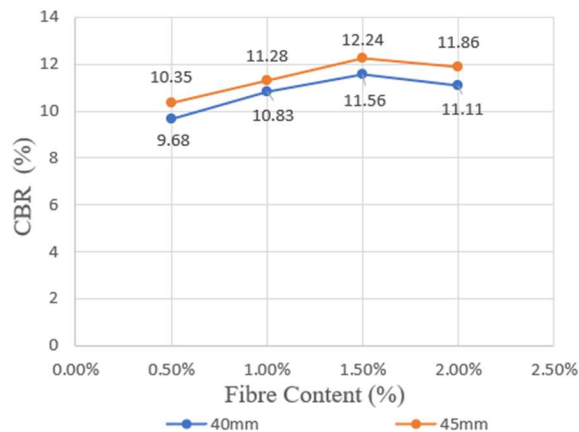


Figure 24 : Effect of fibre content on CBR value

Table 16 : Effect of jute percentage on CBR value

JUTE PERCENTAGE (%)	CBR VALUE	
	40mm	45mm
0.5	9.68	10.35
1.0	10.83	11.28
1.5	11.56	12.24
2.0	11.11	11.86

Fig 24 shows the optimum CBR value was found at a fibre content of 1.5 % for the 40mm and 45mm fibre length . After the optimum jute content , CBR decreases because excess fibers create more voids and reduce proper compaction of soil . Too much jute also causes fiber clustering and weak contact between soil particles . This lowers dry density and weakens load transfer in the soil mass . As a result , penetration resistance decreases , reducing the CBR value .

CHAPTER 7

SUMMARY AND CONCLUSIONS

7.1 SUMMARY

The present investigation focused on applying randomly distributed jute fibres as reinforcement for poorly graded sandy soil (SP) to enhance its engineering properties and load-bearing capacity . Since poorly graded sands are found to be weak and are subject to moisture distribution and variation , soil integrity is significantly affected and thus soil stabilization is required for pavement and subgrade purposes . Jute fibre was chosen as the reinforcement material due to its relatively low cost , locality , biodegradability and eco-friendliness .

For all laboratory test, the standard Proctor compaction and CBR test were performed using jute fibres of 40 mm and 45 mm length with 0.5%, 1.0%, 1.5% and 2.0% fibre contents. It can be noticed that the OMC increased with increase in fibre content and fibre length while MDD decreased because the soil particles are substituted with lightweight fiber.

With the use of jute fibre , the CBR values also improved significantly , confirming improvements in soil strength and stability . The optimum performance was observed at

1.5% fibre content , with 45 mm fibre showing better improvement than 40 mm fibre . The report confirmed that jute fibre reinforcement of poorly graded sandy soil enhances the strength , stability , and deformation resistance through better interlocking and tensile reinforcement . Therefore, jute fibre can be considered an environmentally sustainable and economical substitute for soil stabilization and subgrade improvement works.

7.2 CONCLUSIONS

The following results were concluded based on the experimental studies:

Compaction of fibre : fibres enabled OMC to rise for both the two fibre lengths . Studies showed that addition of Fibre causes an increase in OMC .

- Density trends : MDD for 40mm and 45mm specimens tended to decline steadily with increasing fiber content as the soil solids were replaced with lighter (fiber) content .
- Once you increase jute percentage and increase the water content the dry density decreases which suggests we cannot utilize these jute fibres where the moisture content of soils is significant.
- OMC rises as the thickness of jute fibre increases ; the value of OMC can then either stabilize or slightly increase after a certain fibre length.
- Thicker jute fibre is associated with an immediate reduction in the maximum dry density.
- Optimal Reinforcement Ratio (CBR) : peak values of CBR for 40mm and 45mm jute fibre reinforcement soil were obtained at an optimal jute fiber concentration of 1.5% .
- The CBR of 45mm fibre was greater than the CBR of 40mm fibres . Hence , CBR value improves with increasing fibre length . Untreated fibres at 1.5% fiber resulted in a 1.20 fold increase in CBR for 40mm fibre length compared to a 1.26-fold increase in CBR with 45mm fibre length .

In conclusion, addition of the jute fiber , promotes strengthening and soil load-bearing capacity by increasing the CBR value and increasing soil stability . It also increases its resistance to deformational stresses by improved interlockage and tensile strengthening in soil bulk. Jute being a natural material is biodegradable and economical . In this respect, it is very convenient for soil stabilization. As a result, this produces a better composite material resulting greatly to a better structural stability as well as stronger load - bearing capability of sandy subgrades .

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