A Study on Modification of Soil Reinforcement with Jute Fiber to Improve its CBR Value

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CERTIFICATE OF SUPERVISION

This is to certify that the work presented in this report entitled — "A Study on Modification of Soil Reinforcement with Jute Fiber to Improve its CBR Value"is carried out by Rakesh Pratim Nath, Roll No: PG/CE/23/15, a student of M.Tech 3rd semester, Department of Civil Engineering, Assam Engineering College, under my guidance and supervision and submitted in the partial fulfillment of the requirement for the award of the Degree of Master of Technology in Civil Engineering with specialization in Geotechnical Engineering under Assam Science and Technology University.

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Abstract

This reports describe the so far of the work of our project entitled **" A Study on Modification on Soil reinforcement with Jute fiber to improve it's CBR value "**. Here this report includes details of all experiments that has been performed on soil sample collected from Sipajhar area of Darrang district along with the mixing with jute fiber . The fiber was cutted to a length of 3cm and mixing with soil at various percentages. In this study the effect of jute fiber on the soil at 0.5%, 0.75%, 1% and 1.25% are studied. The analysis were done by studying the graph and result of the experimental result of California Bearing Ratio test and Proctor compaction test done in the soil sample.

The results reveal that the addition of jute fibers improves the load-bearing capacity of soil, with maximum CBR enhancement observed at 1.25% fiber content. The unsoaked CBR increased by 24.96%, while the soaked CBR demonstrated a remarkable improvement of 72.89%. These enhancements are attributed to the interlocking and tensile reinforcement provided by the jute fibers. However, reduction in MDD and an increase in OMC were observed as fiber content increased.

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

A basic part of the Earth's crust, soil is essential for the support of civil engineering constructions. It is the main component used to build roads, buildings, and other infrastructure. Natural soil's characteristics, however, differ greatly based on its structure, composition, and surrounding circumstances. Natural soil frequently lacks the stability and strength needed for particular engineering applications, which can result in issues like erosion, excessive settlement, and low load-bearing capability. The California Bearing Ratio (CBR) number, which shows the soil's resistance to deformation under load, is one of the most important factors used to evaluate the strength and appropriateness of soil for building. Improving the CBR value of soil has been a focal point in geotechnical engineering to enhance its performance and reliability.

Natural fiber-based soil reinforcement has drawn interest among other soil improvement methods because of its viability from an economic and environmental standpoint. A plentiful and biodegradable natural resource, jute fibre has shown promise as a soil reinforcing material. Because of their high tensile strength, longevity, and affordability, jute fibres are a great option for altering the characteristics of soil. By lowering dependency on artificial resources, adding jute fibres to soil improves its mechanical qualities and supports environmentally friendly building methods.

The study of soil reinforcement with jute fiber is particularly significant in regions where weak or subgrade soils are prevalent. Weak soils often pose challenges in constructing stable roads, embankments, and other structures, as they fail to provide adequate support. Soil reinforcement using jute fibers can mitigate these issues by improving the soil’s load-bearing capacity, reducing settlement, and enhancing its resistance to deformation. This, in turn, leads to more durable and cost-effective infrastructure development.

The California Bearing Ratio (CBR) test is widely employed to evaluate the strength and suitability of soil for pavement design. The CBR value is a crucial indicator of a soil's ability to withstand load and is directly related to its engineering properties. Low CBR values indicate poor strength and necessitate soil improvement measures. By incorporating jute fibers into the soil, it is possible to achieve a significant enhancement in CBR values, which translates into better performance under load conditions.

This research, titled "A Study on Modification of Soil Reinforcement with Jute Fiber to Improve its CBR Value," aims to investigate the potential of jute fiber as a soil reinforcement material. The study focuses on understanding the interaction between jute fibers and soil particles, optimizing fiber content for maximum strength improvement, and evaluating the resulting changes in soil's CBR values. Additionally, the research explores the environmental and economic benefits of using jute fiber as a sustainable alternative in geotechnical engineering.

In conclusion, the modification of soil properties using natural fibers such as jute is a promising approach to addressing the challenges associated with weak soils. This study seeks to contribute to the body of knowledge on soil reinforcement techniques, providing insights into the potential of jute fiber in enhancing soil strength and promoting sustainable construction practices. Through detailed experimentation and analysis, this research aims to demonstrate the efficacy of jute fiber reinforcement in improving the CBR value of soil, thereby paving the way for more robust and eco-friendly engineering solutions.

1.2 Types of Natural Fibre used in soil improvement

Natural fibers are used in soil improvement primarily for erosion control, soil stabilization, and enhancing soil organic matter. Below are the types of natural fibers commonly used in soil improvement:

1. Coir (Coconut Fiber)

- Derived from the outer husk of coconuts.
- Known for its high durability and water retention capacity.
- Used in erosion control mats, geotextiles, and mulching.

2. Jute Fiber

- Extracted from the jute plant stem.
- Biodegradable and eco-friendly.
- Commonly used in geotextiles for slope stabilization and erosion control.

3. Hemp Fiber

- Derived from the stalks of the hemp plant.

- Strong and durable, with good biodegradability.
- Used in soil blankets for erosion control and as mulch.

4. Sisal Fiber

- Extracted from the leaves of the Agave plant.
- Coarse and durable, suitable for making ropes and nets for soil stabilization.

5. Flax Fiber

- Derived from the flax plant.
- Biodegradable and improves soil organic matter when decomposed.
- Used in erosion control mats.

6. Wool Fiber

- Derived from sheep wool.
- High water retention capacity and nutrient enrichment properties.

7. Straw

- Byproduct of cereal crops like wheat, rice, or barley.
- Used for mulching to prevent soil erosion and retain moisture.

8. Cotton Fiber

- Extracted from the cotton plant.
- Biodegradable and used for improving soil organic matter.

9. Bamboo Fiber

- Derived from bamboo plants.
- Strong, biodegradable, and used in mats for slope stabilization.

1.2.1 Function of Natural Fibres

Natural fibers play a significant role in soil improvement due to their versatile properties. Here are the key functions they serve:

1. Erosion Control : Natural fiber mats or geotextiles slow down water flow, preventing soil from being washed away. It acts as a protective layer to stabilize loose soil and prevent wind or water erosion.

2. Soil Stabilization: Fibers provide mechanical reinforcement, improving the soil's load-bearing capacity. It used in areas prone to landslides or steep slopes to hold soil particles together.

3. Improved Water Retention: Natural fibers absorb and retain water, increasing the soil's moisture-holding capacity. This property is particularly beneficial in arid and semi-arid regions to support plant growth.

4. Organic Matter Enrichment : As fibers decompose, they release organic matter into the soil, improving soil fertility and structure. Enhances microbial activity, which is crucial for healthy soil ecosystems.

5. Mulching : Provides insulation to the soil, regulating temperature and reducing evaporation.

6. Improves Soil Structure : Fibers bind soil particles, reducing compaction and increasing porosity. Better porosity ensures improved aeration and root penetration.

7. Support for Vegetation Growth : Protects seeds and seedlings during germination and early growth stages. Fibers help in creating a stable environment for root development.

8. Eco-friendly and Biodegradable : Unlike synthetic materials, natural fibers break down naturally without harming the environment. This contributes to sustainable soil management practices.

Fig 1.1 : Coir fiber (Source = https://www.google.com/search?sca_esv=76438c6487a38795&sxsrf=ADLYWIIrX0HOWTpG8hCPy62175&q=coir+fiber&udm=2&fbs)

Fig 1.2 : Jute fiber

1. **Erosion Control**: Coir and jute mats prevent soil erosion on slopes and protect topsoil from runoff.
2. **Soil Stabilization**: Natural fibres like coir are mixed with soil to increase strength and stability, especially in road construction.
3. **Mulching**: Straw and jute are used as mulch to retain soil moisture, suppress weeds, and regulate temperature.
4. **Water Retention**: Fibers such as wool and coir improve soil's water-holding capacity, benefiting arid regions.
5. **Organic Matter Enrichment**: Decomposing fibers add nutrients and improve soil fertility.
6. **Seed Germination Support**: Jute and coir mats provide a conducive environment for seed germination and early plant growth.
7. **Riverbank Protection**: Natural fiber geotextiles stabilize riverbanks and reduce soil erosion caused by water flow.
8. **Reclamation of Degraded Lands**: Used in restoring lands affected by mining, deforestation, or construction.

1.3 Jute Natural fiber

Jute is a natural fiber extracted from the bark of the jute plant, primarily *Corchorus capsularis* and *Corchorus olitorius*. It is one of the most affordable and abundant natural fibers, widely used in various industries due to its eco-friendly properties. Known as the "Golden Fiber," jute is biodegradable, recyclable, and highly durable.

1.3.1 Characteristic of Jute Fiber

1. Strength: Strong and durable, making it suitable for industrial applications.
2. Biodegradability: Fully decomposes without harming the environment.
3. Moisture Retention: Absorbs and retains moisture, beneficial for agricultural purposes.
4. Texture: Coarse and rough, yet flexible for various uses.
5. Abundance: Readily available and cost-effective.

1.3.2 Advantages of Jute Natural Fiber

1. **Environmentally Friendly**:
   - Completely biodegradable and does not contribute to pollution.
   - Sustainable as it requires less water and chemical inputs during cultivation.

2. **Erosion Control**:
    - Jute mats and geotextiles are used for soil stabilization and erosion control, especially on slopes and riverbanks.
3. **Cost-Effective**:
    - Economical compared to synthetic alternatives.
    - Readily available in large quantities.
4. **Moisture Retention**:
    - Retains soil moisture when used as mulch, aiding in plant growth and reducing water loss.
5. **Organic Matter Addition**:
    - Decomposing jute improves soil fertility by adding organic matter and nutrients.
6. **Versatility**:
    - Used in agriculture (mulching, geotextiles), packaging (bags, ropes), and home decor.
7. **Durability**:
    - High tensile strength makes it suitable for long-term applications like geotextiles in construction projects.
8. **Lightweight and Flexible**:
    - Easy to transport and handle for various uses.
9. **Recyclable**:
    - Can be reused or repurposed, reducing waste.
10. **Support for Rural Economy**:

    - Jute cultivation and processing provide livelihood to millions of farmers and workers in developing countries

1.3.3 Application of Jute Fiber

- Geotextiles for soil stabilization.
- Mulching in agriculture.
- Sacks and ropes for packaging.
- Carpets, mats, and other home decor items.

Jute's sustainable and practical properties make it a preferred choice in eco-friendly and soil improvement applications

1.4 Comparison Between Natural Fiber and Synthetic Fiber

Table 1.1 : Comparison between Natural and Synthetic fiber

Aspects	Natural Fiber	Synthetic Fiber
Cost	Generally more economical and accessible in regions with natural fiber production.	Often more expensive due to manufacturing processes.
Water Absorption	Absorbs and retains water, beneficial for soil moisture retention.	Low water absorption, making them more suitable in wet or saturated conditions.
Soil Interaction	Enhances soil fertility as it decomposes, adding organic matter.	No contribution to soil fertility or organic matter.
Strength	Provides moderate reinforcement; strength decreases as it biodegrades.	Provides consistent and high tensile strength over long periods.
Application Areas	Ideal for short-term erosion control and vegetation establishment.	Suitable for long-term soil stabilization and structural reinforcement.
Decomposition	Biodegrades naturally, requiring periodic replacement in long-term projects.	Does not decompose, ensuring stability for decades.
Climate Suitability	Works well in low-impact and environmentally sensitive areas.	Performs well in extreme weather and harsh soil conditions.

1.5 Objective of the research

Here are the some objective for my research work.

1. Assess the impact of varying jute fiber content and lengths on the California Bearing Ratio (CBR) values of soil, under both soaked and unsoaked conditions, to determine its suitability for improving load-bearing capacity.
2. Identify the optimal percentage of jute fiber addition (by weight) and its corresponding fiber length that yields the highest improvement in soil compaction properties, including Maximum Dry Density (MDD) and Optimum Moisture Content (OMC).
3. By using jute fiber to promote sustainable and eco friendly soil stabilization method.

CHAPTER 2

REVIEW OF LITERATURE

2.1 GENERAL

Many researches and studies have been done in different investigator and research worker to study the modification of soil reinforcement by adding Natural fibers to improve its CBR value. A brief review of previous work has been presented in this chapter.

2.2 Review of Literature

Sing et al. (2013) : They presents an experimental study on the influence of jute fiber on the California Bearing Ratio (CBR) value of soil from Itanagar, Arunachal Pradesh, India. The study investigated the effects of varying jute fiber content, length, and diameter on the CBR value of the soil. The results show that the CBR value of the soil increases significantly with the addition of jute fiber. The maximum increase in CBR value was 3 times (200%) over the plain soil, observed at a fiber content of 1% with a fiber length of 90 mm and diameter of 2 mm. The increase in CBR value can substantially reduce the thickness of the pavement subgrade, making jute fiber a cost-effective and eco-friendly reinforcement material for soil improvement.

Hossain et al. (2015) : This paper presents an experimental study on the use of jute fiber to improve the subgrade characteristics of soil. The researchers investigated the effect of jute fiber content, length, and diameter on the density, optimum moisture content, and California Bearing Ratio (CBR) of the soil. The results show that the inclusion of jute fiber decreases the maximum dry density and increases the optimum moisture content of the soil. However, the CBR value of the soil increases with the increase in jute fiber content, length, and diameter. The researchers conclude that using jute fiber, a cheap and locally available natural material, can be an effective way to improve the engineering properties of poor subgrade soils and reduce the cost of pavement construction.

Agarwal et al. (2010) : They discusses the application of jute fiber to improve the subgrade characteristics of soil. They conducted a series of Proctor Compaction tests and California Bearing Ratio (CBR) tests on soil mixed with jute fibers of different diameters (2-8 mm) and lengths (0.5-2.0 cm). The results show that the inclusion of jute fiber reduces the maximum dry density (MDD) and increases the optimum moisture content (OMC) of the soil. However, the

CBR value of the soil improved significantly with the addition of jute fiber, with the optimal improvement observed at 0.8% jute fiber content and 10 mm fiber length.

Yadav et al. (2016): The paper presents a study on the use of jute fiber reinforcement to improve the properties of expansive black cotton soil. The key findings are that the inclusion of jute fiber layers in the soil significantly improves its California Bearing Ratio (CBR) value, from 2.67% for the natural soil to 11.85% with 4 layers of jute reinforcement. The maximum dry density (MDD) also increased from 1.698 g/cc to 1.74 g/cc with 2 layers of jute, though it decreased slightly to 1.72 g/cc with 4 layers. The optimum moisture content (OMC) decreased from 19.54% to 15.98% with the jute reinforcement. Overall, the study demonstrates the effectiveness of using locally available and inexpensive jute fibers to stabilize and improve the engineering properties of expansive soils.

Kumar et al. (2013): They investigates the stabilization of clay soil using coconut coir fibers to improve its geotechnical properties for construction applications. Laboratory experiments were conducted on clay soil with varying percentages of coir fiber (0.25%, 0.50%, 0.75%, and 1.0%) to assess improvements in strength and stability. Tests included the California Bearing Ratio (CBR), Unconfined Compressive Strength (UCS), direct shear, and standard Proctor compaction. The results showed significant improvement in soil properties with coir fiber addition. The optimal performance was observed at 0.5% coir fiber content, where the unsoaked CBR value increased by 33% and the UCS value showed maximum enhancement. The study also found that coir fiber reduced soil plasticity, increased hydraulic conductivity, and enhanced compaction characteristics. The maximum dry density (MDD) increased, and the optimum moisture content (OMC) decreased at 0.5% fiber content, indicating better soil workability.

Hezazi et al. (2012) : They review papers investigates the concept of using discrete, randomly distributed fibers, both natural (e.g., coir, sisal, jute, bamboo) and synthetic (e.g., polypropylene, polyethylene, nylon, steel), to reinforce soils. Fibers are typically mixed into soil at dosages of 0.2–4% by weight, enhancing the soil's strength and stiffness. Laboratory tests, including direct shear, unconfined compression, and triaxial compression tests, show that fiber reinforcement increases peak shear strength, reduces post-peak strength loss, and shifts stress-strain behavior from strain softening to strain hardening.From the papers they found that strength improvements depend on fiber characteristics (e.g., aspect ratio, modulus of elasticity), soil properties (e.g., particle size, gradation), and test conditions (e.g., confining stress). Fiber reinforcement reduces maximum dry density due to compaction resistance but minimizes strength losses during saturation. Combining fibers with chemical binders like lime or cement reduces brittleness while maintaining ductility, improving overall soil behaviour. They also identified applications of fiber-reinforced soils are in pavement layers, retaining walls, earthquake engineering, slope protection, railway embankments, and foundation engineering. Despite its advantages, challenges include fiber-soil adhesion, clumping during mixing, and a lack of scientific standards.

Sharma et al. (2017): In this paper they focus on the improvement of engineering properties of soil by using jute fiber treating with the sand. Jute fiber is treated with the sand to enhance the engineering properties in case of pavement and earthen slopes. The aim of the present investigation is to determine the jute geo textile as soil reinforcement or soil stabilizer. This analysis discusses the potential of fine sand stabilization with jute is cut into approximately 20mm lengths as admixture. Their work has been taken up by addition of 20mm jute pieces as admixture. The varying percentage 0.5%, 1%, 1.5%, 2% of jute pieces of jute geotextile were mixed with fine sand of different densities and moisture content. Based on their observations and the results obtained, it can be concluded that the dry density increases with the increase of jute textile and maximum dry density was obtained at 1% addition of Jute textile. The unconfined compressive strength increases with the increases of jute textiles up to 1.5%, whereas the maximum unconfined compressive strength was reported at 1.5% is 3.82 Kg/cm2 Jute fibre textile content.

Familusi et al (2018) : Their main aim was to improve the load-bearing capacity and engineering properties of subgrade soil, which is crucial for supporting pavements and structures. The study specifically focused on the stabilization of two types of soil samples: lateritic and clay soils, using geotextile as a reinforcement material. The soil samples were classified according to the American Association of State and Highway Transportation Officials (AASHTO) standards, identifying them as A-7-6 and A-7-5, which are categorized as 'poor' subgrade materials.

The results demonstrated that the introduction of non-woven geotextiles significantly increased the strength of the soil samples. Specifically, the CBR values were higher when the geotextile was placed at a depth of H/4 from the base surface compared to when it was placed at the same depth from the top surface. The CBR values increased to 15.1% and 19.6% with geotextile reinforcement, indicating a marked improvement in soil strength.

Ashraf (2020): The researchers conducted experiments by reinforcing locally sourced clayey soil with varying percentages (0.2%, 0.4%, 0.6%, and 1%) and lengths (30mm, 60mm, and

90mm) of jute fibers. Laboratory tests, including the California Bearing Ratio (CBR) and Proctor tests, measured the impact of jute fibers on the soil's geotechnical properties.

Results showed that soil reinforced with 0.6% jute fibers exhibited the highest improvement in CBR value, with longer fibers (90mm) yielding better results. The maximum increase in soil strength was over 15% compared to unreinforced soil.

Hamid (2017) : They conducted experiment on locally sourced soil reinforced with varying lengths (30mm, 60mm, and 90mm) and percentages (0.25%, 0.5%, 0.75%, and 1%) of jute fibers. The California Bearing Ratio (CBR) test was used to assess the load-bearing capacity of both plain and reinforced soil. Thei results showed a substantial increase in CBR values with the inclusion of jute fibers. The optimal fiber content was found to be 0.75%, which provided the highest improvement. Soil reinforced with 90mm-long jute fibers exhibited a more than 200% increase in CBR compared to plain soil. The study also noted that longer fibers generally resulted in better reinforcement. The maximum improvement was achieved using fibers with a 2mm diameter, 90mm length, and 0.75% weight.

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 GENERAL

In the present study "A study on Modification of soil reinforcement with Jute fiber By improving it's CBR value" is carried out experimentally, utilizing the California bearing ratio (CBR) testing Arrangement.

3.2 METHODOLOGY

The experimental study is done to understand the behaviour of soil when they are subjected to different percentages of Jute fibre. To check the variation for both soaked and unsoaked CBR value jute fibre is added to the soil during compaction. In laboratory , soil index properties were determined in order to perform classification. For this purpose liquid limit , plastic limit, optimum moisture content and maximum dry density were determined According to Indian Standard specification along with the strength test. A flow chart of methodology is given below**.**

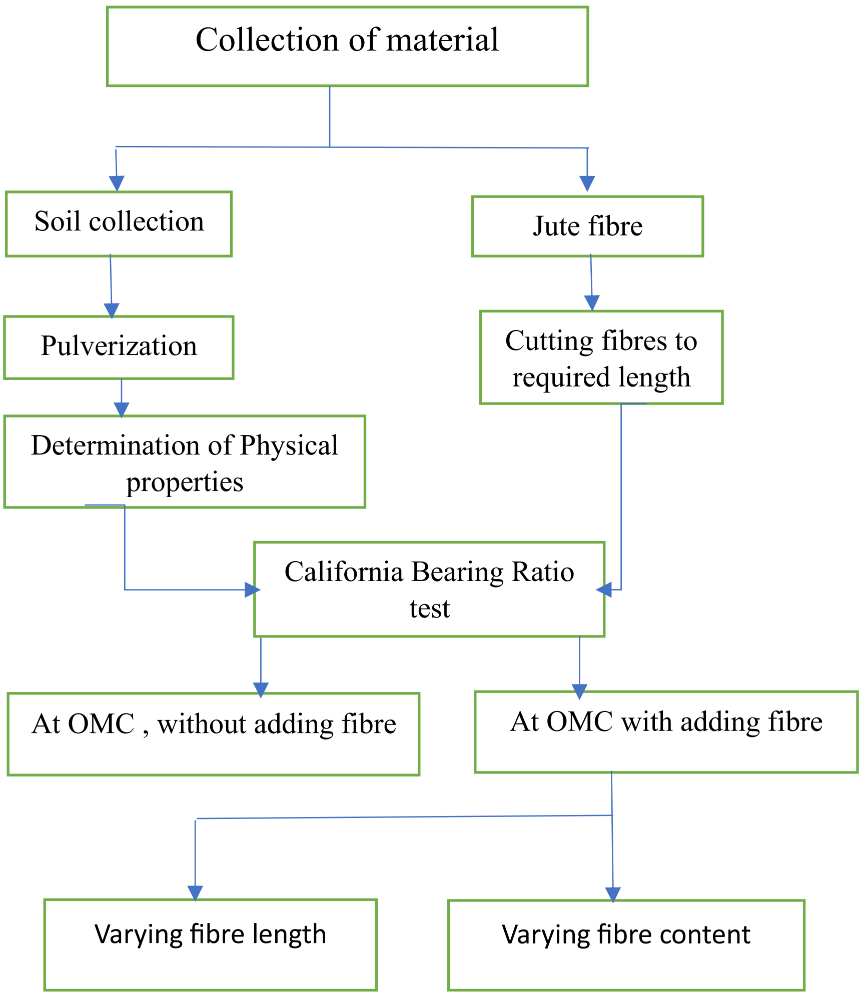

Fig3.1 Flow chart of Methodology

3.2.1 Collection and Preparation of soil sample

About 100kg of soil collected from Sipajhar, Darrang District. The coordinate of the are 26° 21' 58.9608" N , 91° 52' 76″ E. First an area is selected on the site and from that soil was collected at a depth of 1ft. All the excessive materials including stone, grass, leaves, vegetable roots and other organic materials are removed from the soil. Then the soil was taken to laboratory. The soil sample was air dried followed by pulverization and removal of any other excess materials before testing. According to IS code method soil is allowed to dry in the room temperature.

Fig 3.2 : Air drying of soil sample

3.2.2 Determination of Properties of Soil Sample

The following set of experiments are carried out:

1. Liquid limit test
2. Plastic limit test
3. Wet sieve analysis
4. Determination of specific gravity test
5. Unconfined compressive strength test
6. Proctor test
7. CBR test

3.2.2.1 Determination of plastic limit according to IS: 2720 (Part 5) 1985

This is determined by rolling out soil till its diameter reaches approximately 3mm and measuring water content for the soil which crumbles on reaching this diameter. This test is performed 3 times and the average of the three water contents is computed as the plastic Limit.

This is determined by using cone penetrometer taking at least four to five sets of values of penetration in the range 14 to 28 mm. The moisture content corresponding to cone penetration of 20 mm is taken as the liquid limit.

Fig 3.3 : Cone penetration test

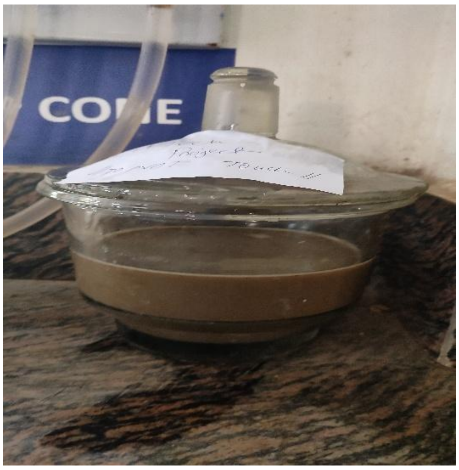

Fig 3.4: Sample placed for wet sieve analysis

3.2.2.3 Wet Sieve Analysis as per IS: 2720 (Part 5) 1985

The percentage of soil retained on the set sieves is calculated on the basis of total mass of sail sample taken and from these results the percentage passing through each of the sieves is calculated.

3.2.2.4 Determination of specific gravity with the help of 50 ml density bottle according to IS: 2720 (Part 3) 1980

The Specific gravity of solid particles is the ratio of mass of given volume of solids to the mass of an equal volume of water at 4°C. Specific gravity bottles determine liquid densities by measuring the difference between an empty and filled bottle and dividing by an equal volume of water to find the specific gravity of the substance. These bottles are also known as a density bottle or relative-density bottles.

3.2.2.5 The Unconfined Compressive Strength (UCS) test, as per IS 2720 Part 10

It is a standard procedure used to determine the compressive strength of cohesive soils. In this test, a cylindrical soil sample is subjected to an axial load without any lateral confinement, and the load at failure is recorded. The UCS is calculated by dividing the maximum load at failure by the cross-sectional area of the sample. This test is crucial for evaluating the strength characteristics of fine-grained soils, particularly in the design of foundations and slope stability analysis. The test is conducted in a controlled environment, ensuring that the sample remains undisturbed during testing.

3.2.2.6 Determination of Water Content-Dry Density Relation using Light Compaction as per IS:2720 (Part 7) 1980

Proctor compaction test is a laboratory method to determine the optimal moisture content and the maximum dry density of soil. The theory used in the experiment is that for any compactive effort, the dry density depends upon the moisture content of soil. The maximum dry density is achieved when the soil is compacted at relatively high moisture content and almost all the air is driven out, this moisture content is called optimum moisture content. After plotting the data from the experiment with water content as the abscissa and dry density as the ordinate, we can obtain the OMC and MDD.

3.2.2.7 Determination of California Bearing Ratio as per IS: 2720 (Part 16) 1980

According to IS: 2720 (Part 16) 1980, the strength of the subgrade is an important factor in the determination of the required thickness for a given flexible pavement. The California Bearing Ratio (CBR) is a measure of the strength of the subgrade of a road or other paved area, and of the materials used in its construction.

The CBR test is performed in a cylindrical mould, 150mm diameter and 175 mm high, which can be fitted to a detachable perforated base plate, and a collar. The mould with the extension collar attached is clamped to the base plate. The spacer disc is inserted (with the central hole of the disc at the lower side) over the base plate and a disc of coarse filter paper placed on the top of the spacer disc. The soil-water mixture is compacted into the mould in accordance with the methods applicable to the 150 mm diameter mould specified in IS: 2720 (Part 7)-1980 i.e. the test specimen is compacted in 3 layers using a 2.6 kg rammer with a free fall of 31cm by giving 56 number of blows on each layer.

The extension collar is removed and the compacted soil is trimmed carefully by means of a straightedge, any hole that may then, develop on the surface of the compacted soil by the removal of coarse material, is patched with smaller size material. Then the mould is turned upside down and the base plate as well as the spacer disc is removed. A disc of course filter paper is placed on the perforated base plate, the mould and the compacted soil is inverted and clamped to the base plate.

Fig 3.5 : Base plate, collar, spacer disc, mould , 2.5kg surcharge load used in CBR test

Fig 3.6 : a) Normal and b)Digital CBR testing machines

Submerge the prepared sample in water for 96 hours if the soaked CBR is required. The mould containing the specimen, with the base plate in position but the top face exposed, was placed on the lower plate of the testing machine. Surcharge weights, sufficient to produce an intensity of loading equal to the weight of the base material and pavement was placed on the specimen. To prevent upheaval of soil into the hole of the surcharge weights, 2.5 kg annular weight is placed on the soil surface prior to seating the penetration plunger after which the remainder of the surcharge weight was placed. The plunger was seated under a load of 4 kg so that full contact is established between the surface of the specimen and the plunger. The load and deformation readings are set to zero prior to application of the load. At the penetration rate of 1.25 minimum, load is applied into the soil. The load penetration readings are taken corresponding to specified penetration of 0.5, 1.0,15,20,25, 40, 5.0, 7.5, 10.0 and 125 mm shown in the these Corresponding to the penetration value of 2.5 and 5 mom the percentage CBR values of the soil specimens are recorded as well. At the end, the plunger was raised und the mould was detached from the loading equipment.

The necessary specimen data are recorded and the load penetration curve are plotted for each soil specimen. This curve is usually convex upwards although the initial portion of the curve may be convex downwards due to surface irregularities.

Correction is applied by drawing a tangent to the point of greatest slope and then transposing the axis of the load so that zero penetration is taken as the point where the tangent cuts the axis of penetration, whenever necessary.

The CBR values are usually calculated for penetrations of 2.5- and 5-mm. Corresponding to the penetration value at which the CBR values is desired, corrected load value is taken from the load penetration curve and the CBR calculated as follows:

California Bearing Ratio = Pt/Ps x 100

Where, Pt corrected unit (or total) test load corresponding to the chosen penetration from the load penetration curve and

Ps = unit (or total) standard load for the same depth of penetration as for FT taken from the table 3.1

Table 3.1: Standard load used in CBR test

Penetration depth (mm)	Unit Standard load (kg/cm2)	Total Standard Load (kg)
2.5	70	1370
5.0	105	2055

Generally, the CBR value obtained at 2.5mm penetration is normally higher than that at 5mm penetration. Whenever the CBR for 5 mm exceeds that for 2.5 mm, the test is repeated. If identical results follow, the CBR corresponding to 5 mm penetration is reported as CBR value the specimen.

Fig 3.7 : CBR compaction

Fig 3.8 : CBR mould placing in water for soaked CBR

3.3 Material

3.3.1 Jute Fiber

This study focuses on the use of jute fibre, a natural material, to enhance the California Bearing Ratio (CBR) value of soil. Jute is a biodegradable organic fibre that offers high tensile strength, rigidity, and durability. It is locally available, eco-friendly, and cost-effective, making it an ideal choice for sustainable soil reinforcement applications.

Fig 3.9 : Jute fiber

Fig 3.10 : Jute fiber mix with soil

In the experiment, jute fibre was procured from the Kharupetia area and dried under natural conditions to ensure its usability. The fibre was then cut into three specific lengths—3 cm, 6 cm, and 9 cm—to analyze the effect of fibre length on soil performance. To evaluate its impact on the soil, the fibre was mixed in varying proportions by weight: 0.5%, 0.75%, 1%, and 1.25%. These proportions were chosen to determine the optimum amount of jute fibre for improving soil properties.

The mixing process was carried out by randomly distributing the jute fibres within the soil to achieve uniform reinforcement. This random distribution simulates real-world applications where natural fibres may not be aligned systematically.

The addition of jute fibre is expected to improve soil strength by enhancing its load-bearing capacity, preventing deformation, and increasing resistance to shear stress. Moreover, using locally sourced and biodegradable materials like jute contributes to eco-friendly construction practices while reducing the environmental footprint of engineering projects. The findings of this study will provide valuable insights into sustainable soil stabilization techniques.

CHAPTER 4

EXPERIMENTAL RESULTS & ANALYSIS

4.1 Experimental Observation of Normal Soil

4.1.1 Plastic Limit

The Plastic Limit test for the soil was performed in laboratory according to IS: 2720 (Part 5)-1985 and found to be 21.15%.

4.1.2 Liquid Limit

Determination of Liquid limit test was performed by cone penetration method according to IS 2720 (Part 5) 1985. The graph plotted between water content and penetration is shown in figure 4.1

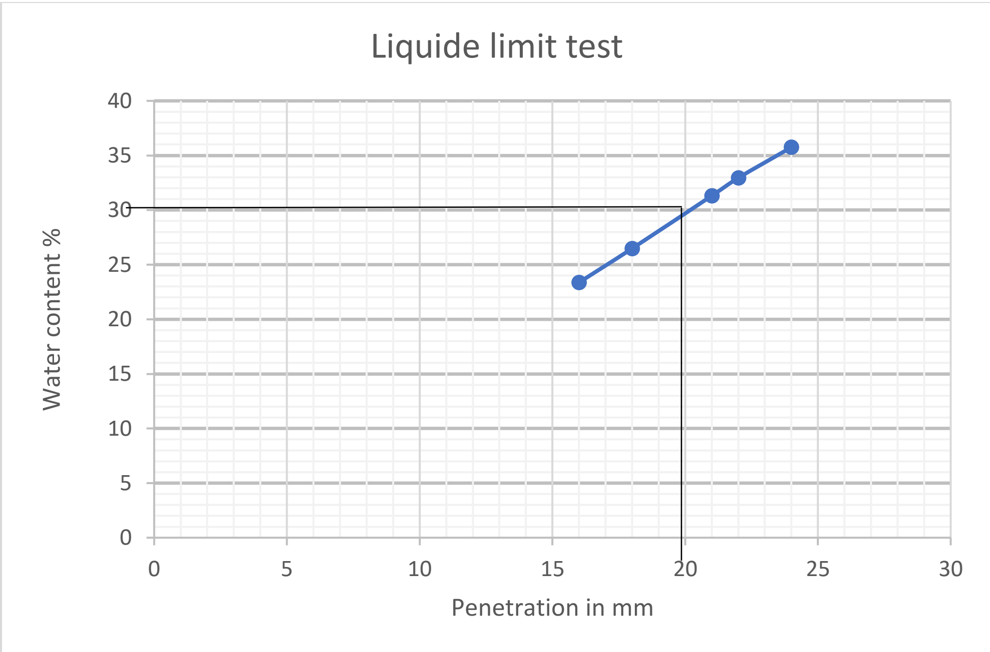

Fig 4.1 : Water content (%) vs Penetration (mm)

From the graph , Liquid limit of the soil is found to be 29.69%

Hence, Plasticity Index = LL-PL = 8.54%

From the result we can conclude that the type of soil is CL (Clay with Low plasticity).

4.1.3 Particle Size Distribution

The gradation of the soil sample was obtained by wet sieve and particle size distribution is shown in table 4.1 and graphical result is shown at figure 4.2.

Table 4.1: Particle size distribution of the soil sample

Sieve Size	Retained	% Retained	Cummulative % Retained	% Finer
4.75	0	0	0	100
2	0.08	0.04	0.402	99.60
1.18	0.091	0.0455	0.4475	99.55
0.6	0.132	0.066	0.5135	99.49
0.425	0.247	0.1235	0.637	99.36
0.3	0.32	0.16	0.797	99.20
0.15	2.03	1.015	1.812	98.19
0.075	11.55	5.775	7.587	92.413

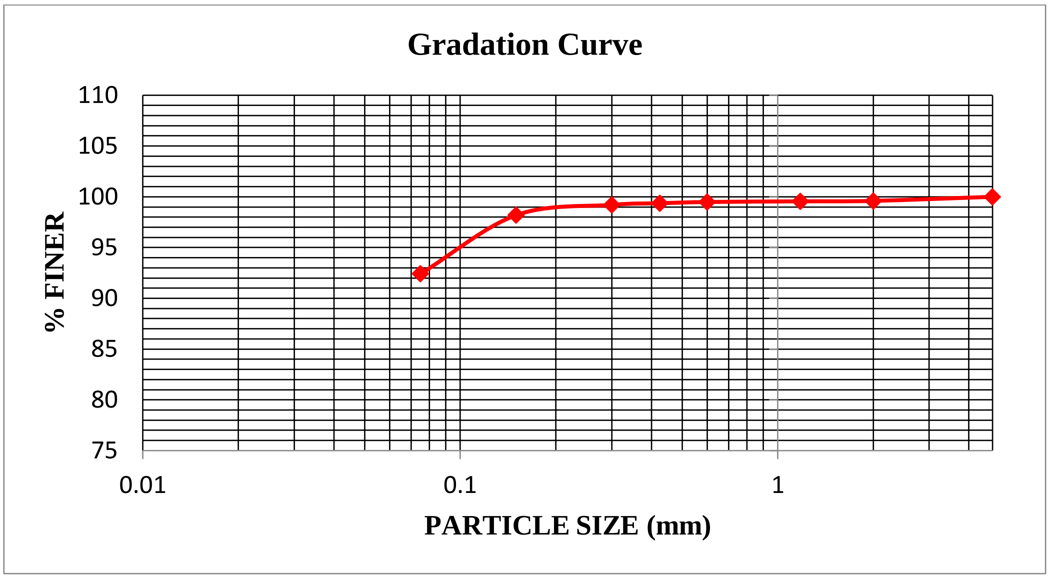

Fig 4.2 : Gradation Curve for Soil Sample

4.1.4 Specific Gravity

Determination of Specific Gravity was performed with the help of 50 ml density bottle according to IS:2720 (Part 3) 1980. Specific Gravity of the soil was found to be 2.40.

4.1.5 Unconfined Compressive Strength

The UCS test graph is shown in below and compressive strength is found to be 224.05

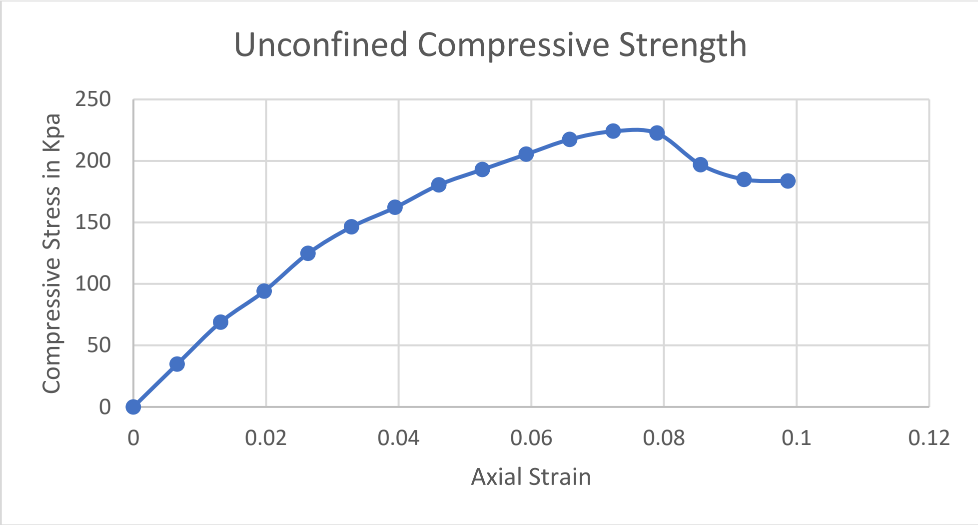

Fig 4.3: graph for UCS test

4.1.6 Proctor Compaction Test

The standard Proctor Compaction test was carried out in the laboratory and the determination of optimum moisture content corresponding to the maximum dry density was performed according to IS 2720 (Part 7) 1980. Figure 4.4 Shows Dry Density vs Water Content graph for normal soil without additives.

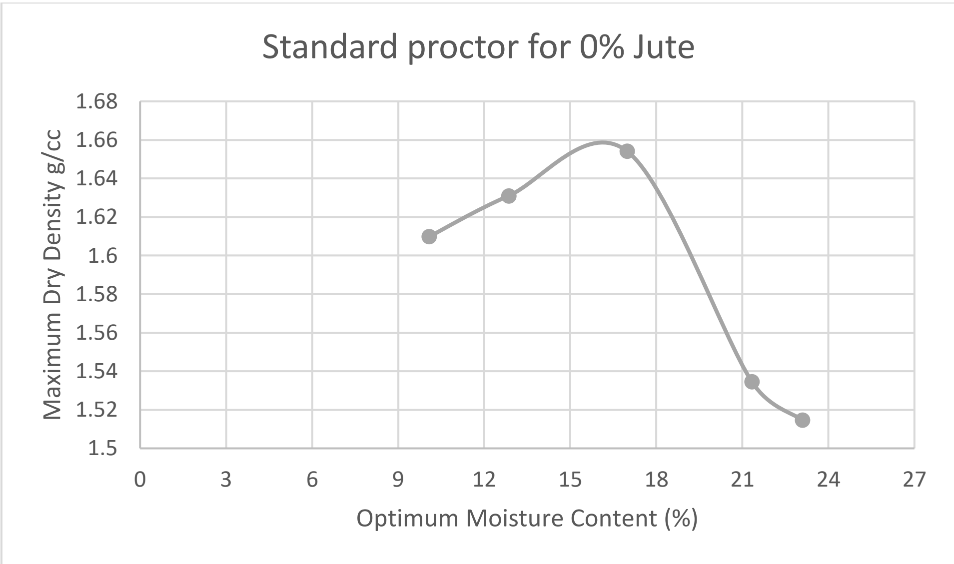

Fig 4.4 : Dry density vs water content

From the graph the optimum moisture content is 16.98 % and maximum dry density is found to be 1.65 g/cc.

4.1.7 California Bearing Ratio (Unsoaked Condition)

The california bearing ratio for the soil sample for unsoaked condition is determined as per IS 2720 (part 16) . Table 4.2 shows the result of this test.

Table 4.2: California Bearing ratio test result for soil sample (Unsoaked)

Penetration	Load (KN)	load (Kg)
0	0	0
0.5	0.285	29.1
1	0.554	56.6
1.5	0.963	98.3
2	1.184	120.8
2.5	1.717	175.2
3	1.948	198.7
4	2.188	223.2
5	2.543	259.4
7.5	3.151	321.5
10	3.7	377.4
12.5	3.943	402.2

The load vs Penetration plot for unsoaked condition is shown here

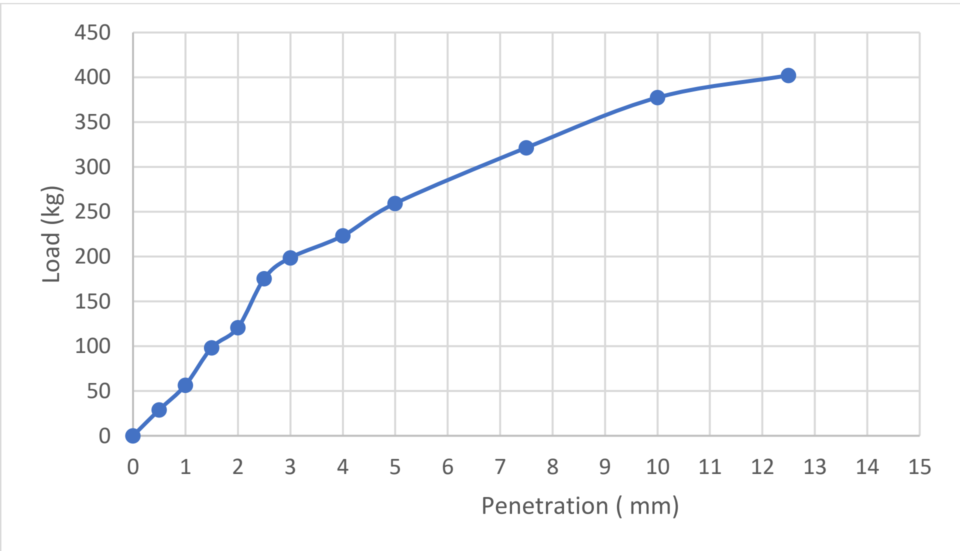

Fig 4.5 : Load vs penetration curve for unsoaked condition

From the test we have obtain that 2.5 mm CBR value = 12.78%

5 mm CBR value = 12.62%

4.1.8 California Bearing Ratio (Soaked Condition)

Table 4.3 shows the California Bearing test for the soil sample Soaked Condition.

Table 4.3 : California Bearing test results for the soil sample (soaked)

Penetration (mm)	Load (KN)	Load (Kg)
0	0	0
0.5	0.069	7
1	0.108	11
1.5	0.17	17.3
2	0.225	23
2.5	0.287	29.3
3	0.35	35.7
4	0.485	49.5
5	0.618	63.1
7.5	0.913	93.1
10	1.164	118.7
12.5	1.408	143.6

The load vs penetration graph for soil in soaked condition is shown in fig 4.6

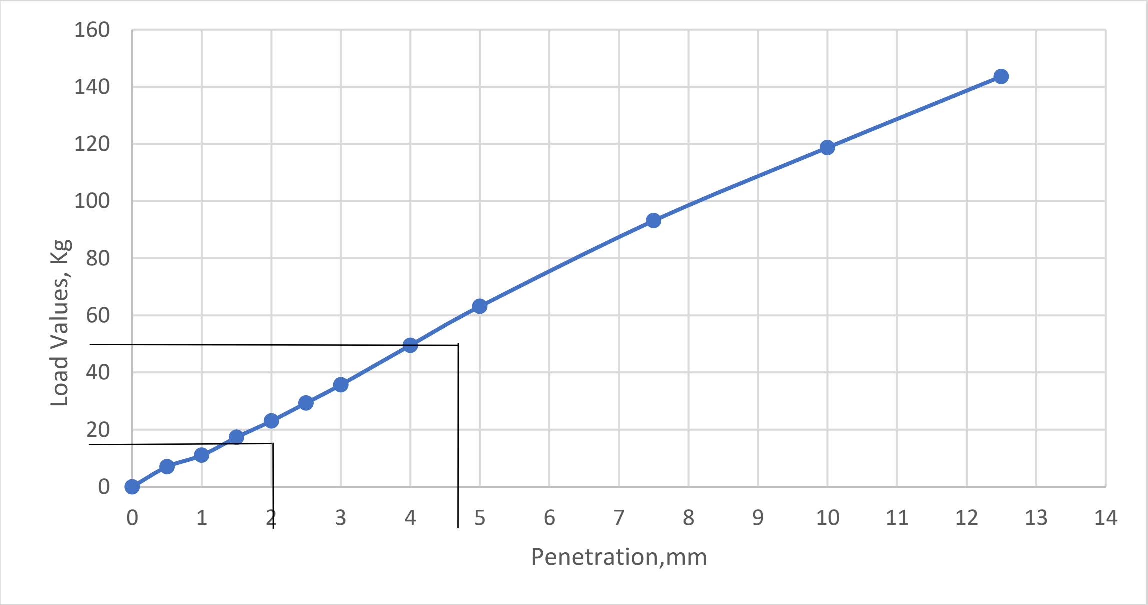

Fig 4.6 : Load vs Penetration Graph (soaked condition)

From the test we have obtained that 2.50 mm CBR value = 2.14%

3 mm CBR = 3.**07**%

4.2 Experimental observation soil mix with 0.5% Jute Fiber

4.2.1 Proctor compaction test for soil mix with 0.5% Jute Fiber

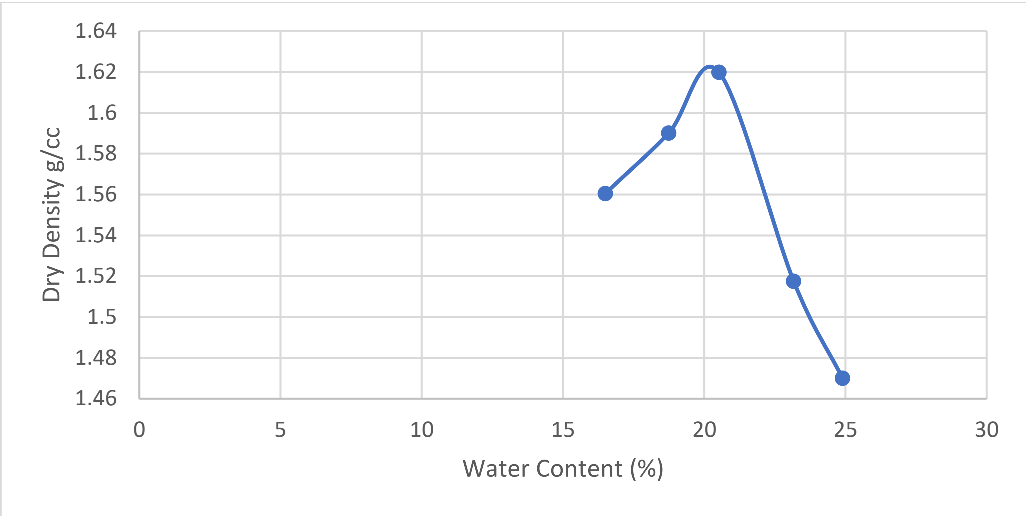

Fig 4.7 : Dry density and water content (Soil mix with 0.5% Jute)

From the graph the Optimum moisture Content is 20.52% and Maximum Dry density is found to be 1.62 g/cc after adding 0.5% Jute.

4.2.2 Unsoaked California Bearing Test for Soil mix with 0.5% Jute Fiber

Table 4.4 : CBR test result for soil mix with 0.5% Jute (unsoaked condition)

Penetration (mm)	Load (KN)	Load (Kg)
0	0	0
0.5	0.512745	54.52
1	0.776471	81.42
1.5	1.188235	123.42
2	1.408824	145.92
2.5	1.972549	203.42
3	2.168627	223.42
4	2.416667	248.72
5	2.797059	287.52
7.5	3.37549	346.52
10	3.927451	402.82
12.5	4.169608	427.52

Load vs penetration graph is shown below in fig 4.8

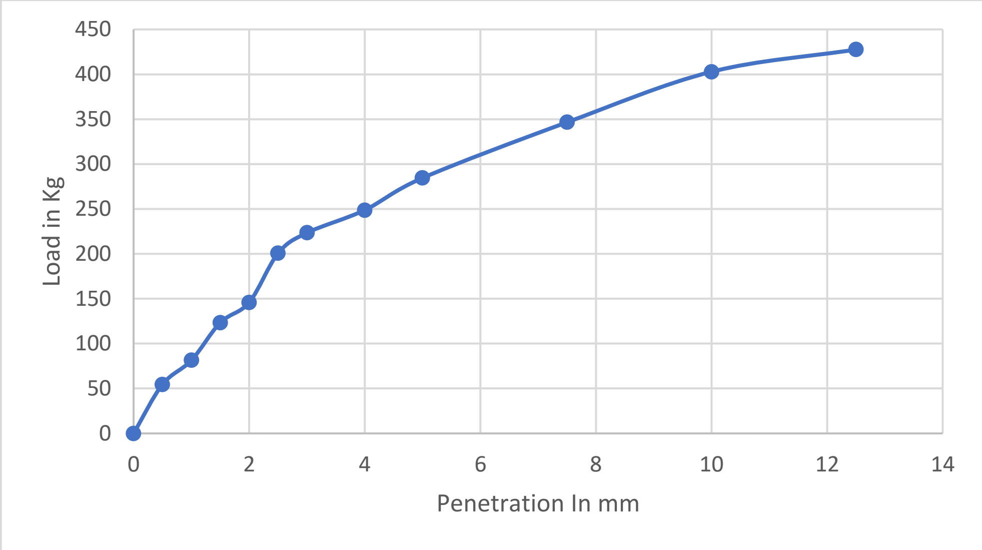

Fig 4.8 : Load vs Penetration Graph for soil mix with 0.5% Jute fiber (Unsoaked)

From the test we have obtained that 2.5 mm CBR value = 14.68%

5 mm CBR value = 13.88%

4.2.3 Soaked California Bearing Test for soil mix with 0.5% Jute Fiber

Table 4.5 CBR test result for Soil Mix with 0.5% Jute (Soaked)

Penetration (mm)	Load (KN)	Load (kg)
0	0	0
0.5	0.064	6.5
1	0.098	10
1.5	0.173	17.6
2	0.254	25.9
2.5	0.349	35.6
3	0.454	46.2
4	0.656	66.9
5	0.859	87.6
7.5	2.589	264
10	3.421	348.84
12.5	4.251	432.46

The Plot is shown below

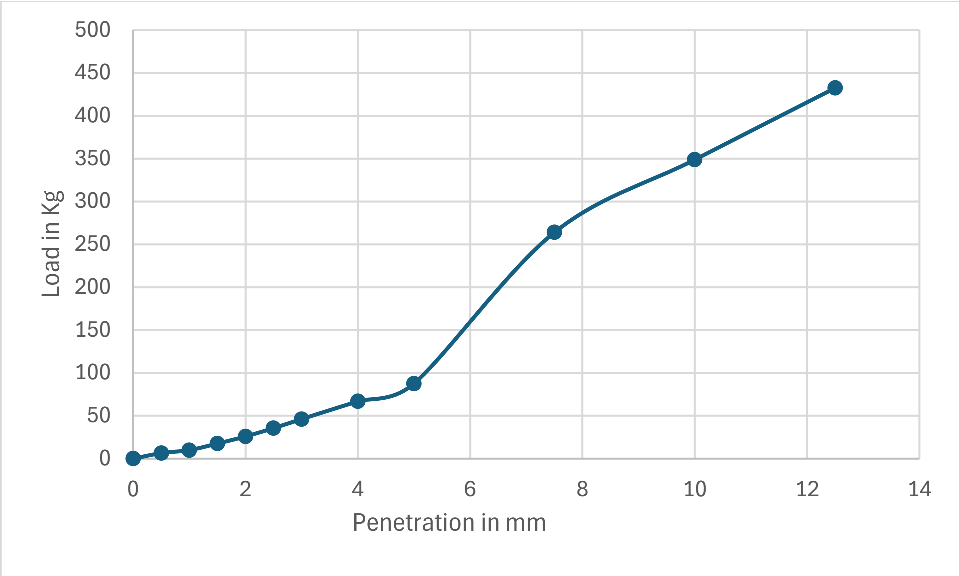

Fig 4.9 Load vs Penetration Plot for CBR 0.5% Jute contain soil (soaked)

From the test we have obtained that 2.5 mm CBR value = 2.6%

5 mm CBR value = 4.26%

4.3 Experimental observation soil mix with 0.75% Jute Fiber

4.3.1 Proctor compaction test for soil mix with 0.75% Jute Fiber

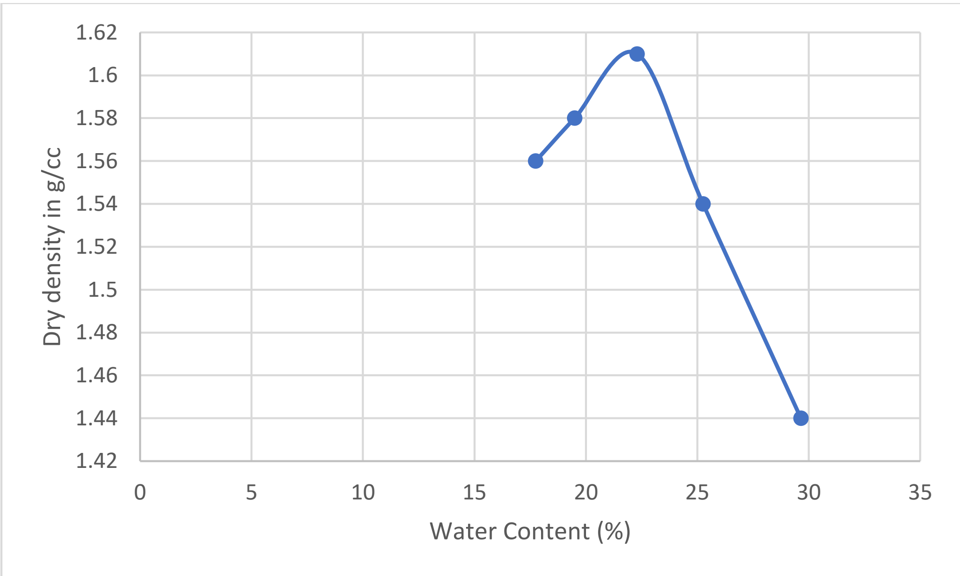

Fig 4.10: Dry density and water content (Soil mix with 0.75% Jute)

From the graph the Optimum moisture Content is 22.3% and Maximum Dry density is found to be 1.61 g/cc after adding 0.75% Jute.

4.3.2 Unsoaked California Bearing Test for Soil mix with 0.75% Jute Fiber

Table 4.6 CBR test result for soil mix with 0.75% Jute Fiber

Penetration (mm)	Load (KN)	Load (Kg)
0	0	0
0.5	0.55	56.21
1	0.813	83
1.5	1.229	125.24
2	1.449	147.38
2.5	2.063	210.65
3	2.212	225.7
4	2.451	250.16
5	2.871	292.91
7.5	3.415	348.47
10	3.963	404.32
12.5	4.213	429.89

The Load Vs Penetration Graph of unsoaked CBR of soil mix with 0.75% Jute is Shown below

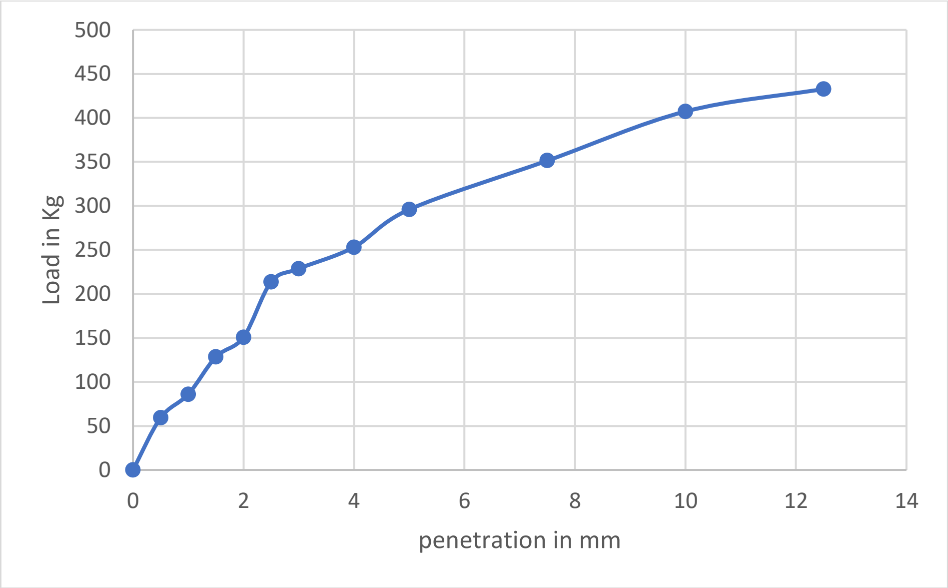

Fig 4.11 : Load vs Penetration graph for soil mix with 0.75% Jute fiber (unsoaked)

From the test we have obtained that 2.5 mm CBR value = 15.3%

5 mm CBR value = 14.25%

4.3.3 Soaked California Bearing Test for Soil mix with 0.75% Jute Fiber

Table 4.7 CBR test result for soil mix with 0.75% Jute Fiber (soaked)

Penetration (mm)	Load (KN)	Load (kg)
0	0	0
0.5	0.065	6.7
1	0.132	13.5
1.5	0.21	21.8
2	0.317	32.4
2.5	0.406	41.5
3	0.515	52.6
4	0.733	74.8
5	1	102
7.5	2.4	245
10	3.53	360.5
12.5	4.43	452.32

The Load Vs Penetration Graph is shown below

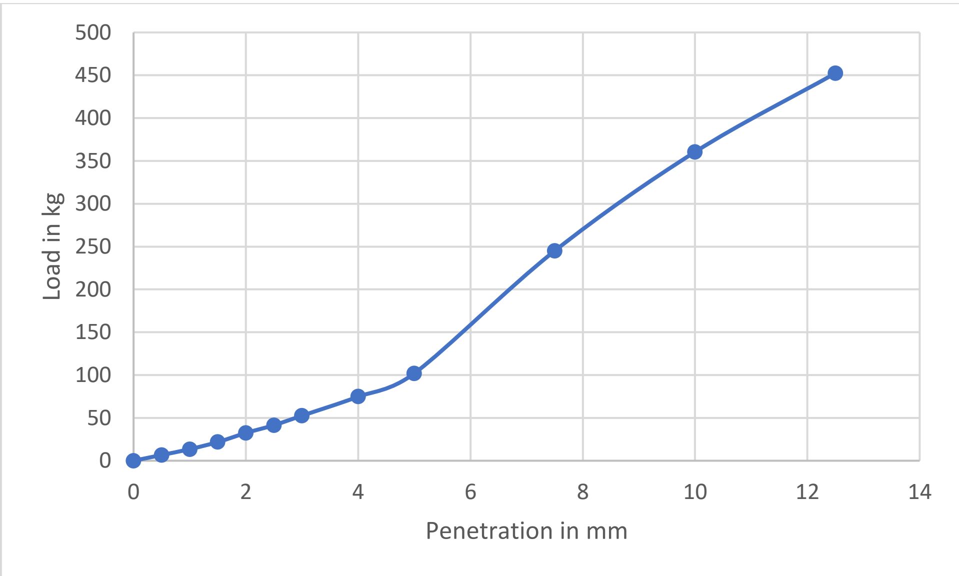

Fig 4.12 : Load vs Penetration Graph for soaked CBR test With 0.75% Jute fiber

From the test we have obtained that 2.5 mm CBR value = 3.02%

5 mm CBR value = 4.96%

4.4 Experimental observation soil mix with 1% Jute Fiber

4.4.1 Proctor compaction test for soil mix with 1% Jute Fiber

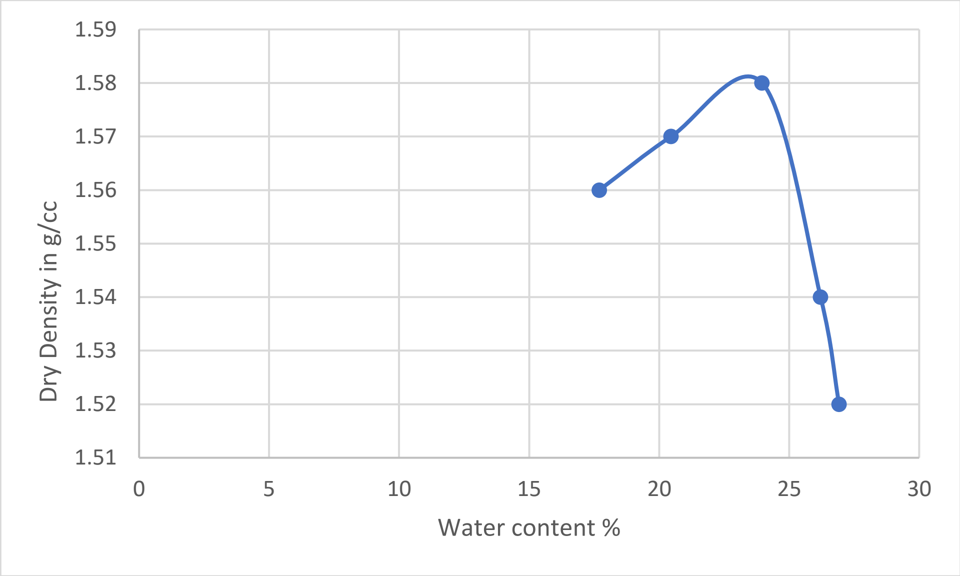

Fig 4.13 : Dry density vs Water content (Soil Mix with 1% Jute fiber)

From the graph the Optimum moisture Content is 23.96% and Maximum Dry density is found to be 1.58 g/cc after adding 1% Jute.

4.4.2 Unsoaked California Bearing Test for Soil mix with 1% Jute Fiber

Table 4.8 CBR test result for soil mix with 1% Jute Fiber (Unsoaked)

Penetration (mm)	Load (KN)	Load (Kg)
0	0	0
0.5	0.581	60.389
1	0.849	87.571
1.5	1.26	129.209
2	1.473	151.389
2.5	2.082	213.494
3	2.243	229.87
4	2.485	254.629
5	2.963	303.382
7.5	3.44	352.218
10	3.996	408.785
12.5	4.235	433.1

The Load vs Penetration Plot is shown here.

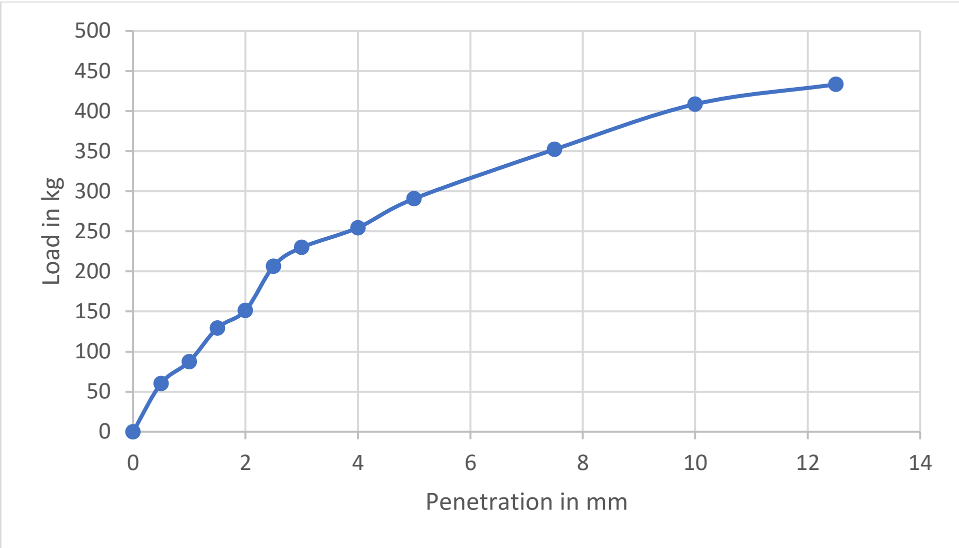

Fig 4.14 : Load vs Penetration Graph for Soil mix with 1% Jute (Unsoaked)

From the test we have obtained that 2.5 mm CBR value = 15.5%

5 mm CBR value = 14.71%

4.4.3 Soaked California Bearing Test for Soil mix with 1% Jute Fiber

Table 4.9 CBR test result for soil mix with 1% Jute Fiber (Soaked)

Penetration (mm)	Load (KN)	Load (kg)
0	0	0
0.5	0.07	7.2
1	0.138	14.1
1.5	0.23	23.5
2	0.39	40.25
2.5	0.46	47.9
3	0.571	58.265
4	0.795	81.121
5	1.08	110.65
7.5	2.434	248.2
10	3.62	370.998
12.5	4.52	461.5

The Load vs Penetration plot is shown below

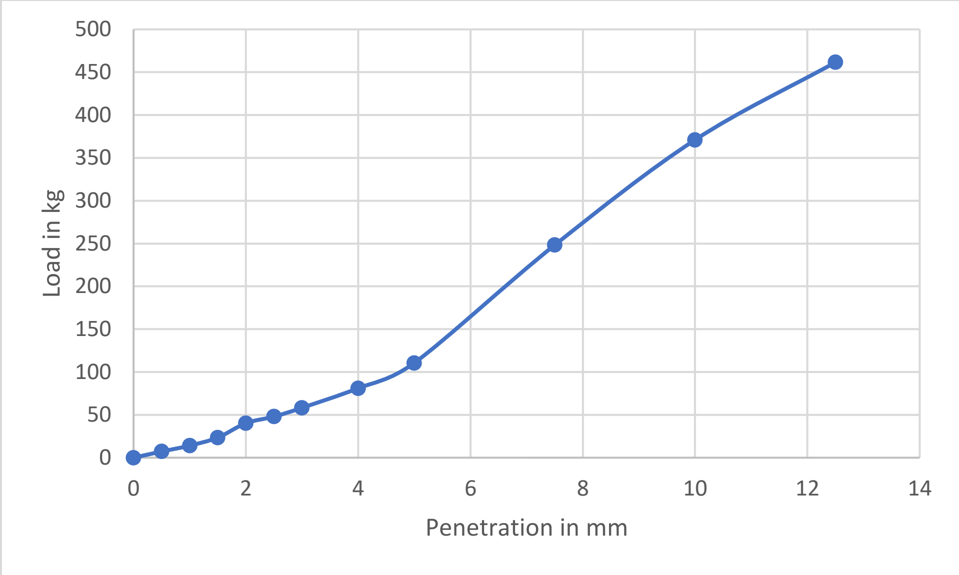

Fig 4.15: Load vs Penetration plot (1% Jute mix with soil Soaked CBR)

From the test we have obtained that 2.5 mm CBR value = 3.49%

5 mm CBR value = 5.38%

4.5 Experimental observation soil mix with 1.25% Jute Fiber

4.5.1 Proctor compaction test for soil mix with 1.25% Jute Fiber

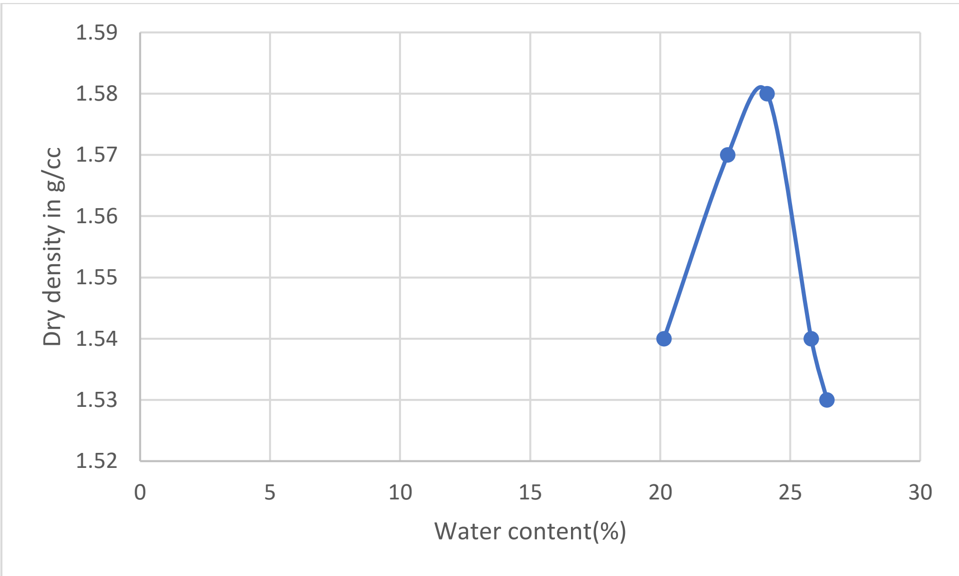

Fig 4.16 : Dry density vs Water content (Soil Mix with 1.25% Jute fiber)

From the graph the Optimum moisture Content is 24.12 % and Maximum Dry density is found to be 1.58 g/cc after adding 1.25% Jute.

4.5.2 Unsoaked California Bearing Test for Soil mix with 1.25% Jute Fiber

Table 4.10 CBR test result for soil mix with 1.25% Jute Fiber (Unsoaked)

Penetration (mm)	Load (KN)	Load (Kg)
0	0	0
0.5	0.6	62.04
1	0.8641	89.53
1.5	1.28	131.921
2	1.492	153.743
2.5	2.131	218.726
3	2.263	232.224
4	2.503	256.704
5	3.057	313.287
7.5	3.462	354.5
10	4.015	410.911
12.5	4.256	435.73

The Load vs penetration plot is shown below

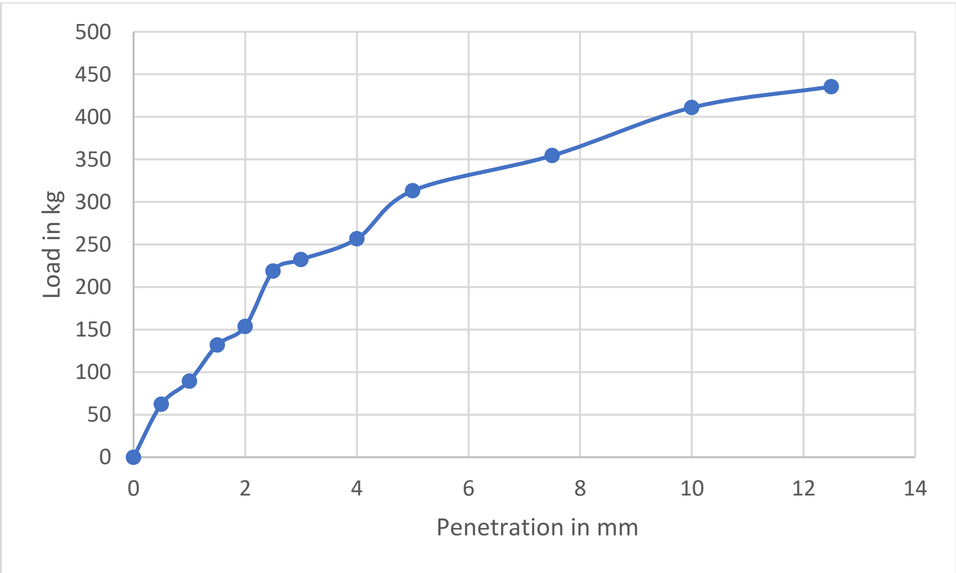

Fig 4.17: Load vs Penetration Plot for CBR (unsoaked) with 1.25% Jute.

From the test we have obtained that 2.5 mm CBR value = 15.97%

5 mm CBR value = 15.24%

4.5.3 Soaked California Bearing Test for Soil mix with 1.25% Jute Fiber

Table 4.11 CBR test result for soil mix with 1.25% Jute Fiber (Soaked)

Penetration (mm)	Load (KN)	Load (kg)
0	0	0
0.5	0.07	7.5
1	0.138	16.15
1.5	0.23	28.9
2	0.39	41.46
2.5	0.46	50.76
3	0.571	61.92
4	0.795	83.75
5	1.08	118.41
7.5	2.434	256.22
10	3.62	388.59
12.5	4.52	472.37

The Load vs Penetration Plot is shown below

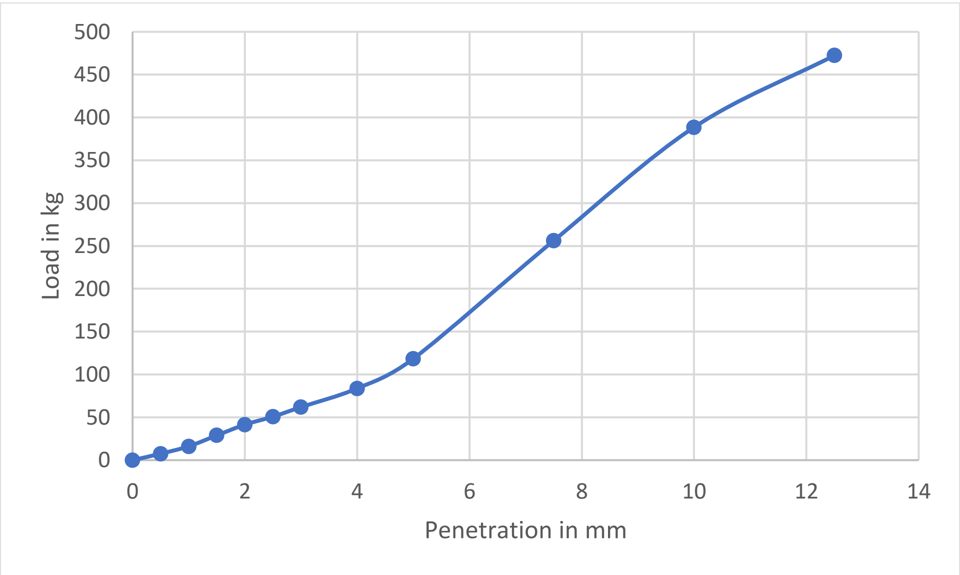

Fig 4.18 : Load vs Penetration plot for soil mix with 1.25% Jute (soaked)

From the test we have obtained that 2.5 mm CBR value = 3.7%

5 mm CBR value = 5.76%

4.6 Analysis of experimental Observation in terms of Proctor compaction test (When the soil is mix with Jute Fiber at different percentages)

The values of Maximum Dry Density and Optimum Moisture Content obtained from the above experiment shows variation when we added Jute fiber of 3cm length with the soil. From the test result the following observations can be seen.

- The Maximum Dry Density of the soil has decreased from the normal soil when Jute fiber is add 0.5%, 0.75%, 1% and 1.25% by weight to the soil.
- The Maximum Dry Density is found to be constant at 1% and 1.5% Jute fiber is mixed with soil.
- The Optimum Moisture Content shows an increasing trend when the soil mix with 0.5%, 0.75% and 1% Jute fiber.
- The Optimum Moisture Content also increase when the Soil is mix with 1.5% Jute Fibre.

Below Figure 4.18 and 4.19 shows the variation of Maximum dry density and Optimum moisture content of the soil when the soil mix with different percentages of Jute fiber.

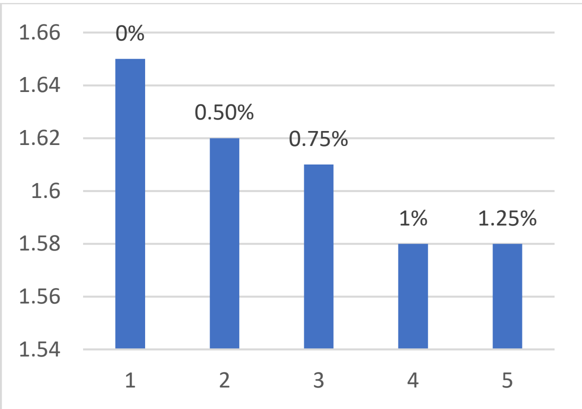

Fig 4.19 : Variation of MDD w.r.t. normal soil

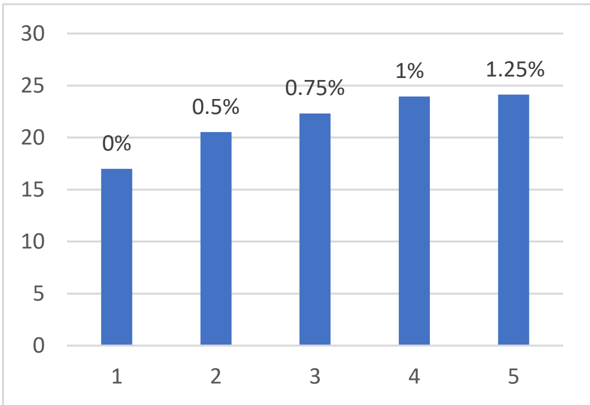

Fig 4.20 : Variation of OMC w.r.t. normal soil

Table 4.12 Percentage Change in Optimum Moisture Content and Maximum Dry Density w.r.t. original soil with percentage of Jute fiber addition.

Normal Soil	OMC (%)	% change w.r.to original	MDD (g/cc)	%change w.r.to orginal
0% Jute	16.98	0%	1.65	0%
0.5% Jute	20.52	20.84%	1.62	-1.81%
0.75% Jute	22.3	31.33%	1.61	-2.42%
1% Jute	23.96	41.1%	1.58	-4.24%

1.25% Jute	24.12	42.04%	1.58	-4.24%

From the above thable we can see OMC is increase upto 42.04% when 1.25% jute is mixed with soil. Again from the table we got see that MDD is decreased upto 4.24% when 1% and 1.25% jute fiber is mix with soil.

4.7 Analysis of Experimental Observation in terms of California Bearing Ratio

4.7.1 Analysis of California Bearing Ratio values when the soil is mix with Jute fiber in various percentages

In these tests the soil is mix with Jute fiber at various percentages and studied the C.B.R. test. The nos. of curves are placed from the test results of CBR , test are performed on the soil and mix with different percentage of Jute fiber. The fiber length was 3cm. Jute fiber has increased the C.B.R. Values in the investigation. There is considerable improvement in compressive strength in case of all the soil on account to treatment with Jute fiber. It is noted that of 2.5 mm penetration C.B.R. percentage value of the Unsoaked C.B.R. test is increases more than that of 5mm penetration C.B.R. percentage value. But in case of Soaked C.B.R 5mm penetration Value increases more. It is may be because of increase in shear parameter of the soil.

Fig 4.20 shows the comparision among CBR values (unsoaked) for untreated soil and soil mix with 0.5%, 0.75%, 1% and 1.25% Jute fiber.

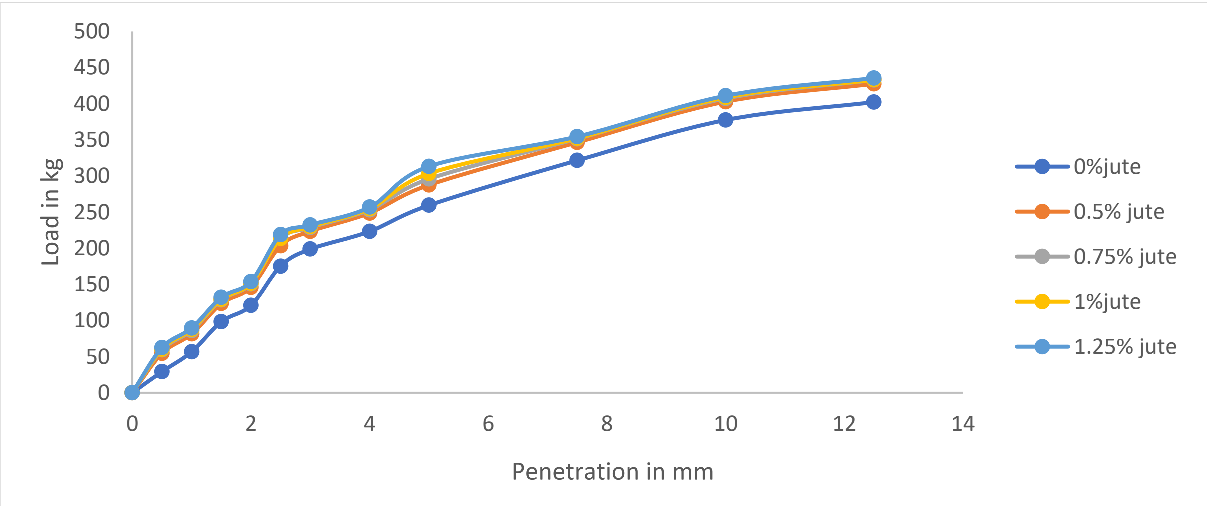

Fig 4.21: Comparison curve of california bearing ratio when soil is treated with different percentages of jute fiber (Unsoaked condition)

Fig 4.21 shows the comparision among CBR values (soaked) for untreated soil and soil mix with 0.5%, 0.75%, 1% and 1.25% Jute fiber.

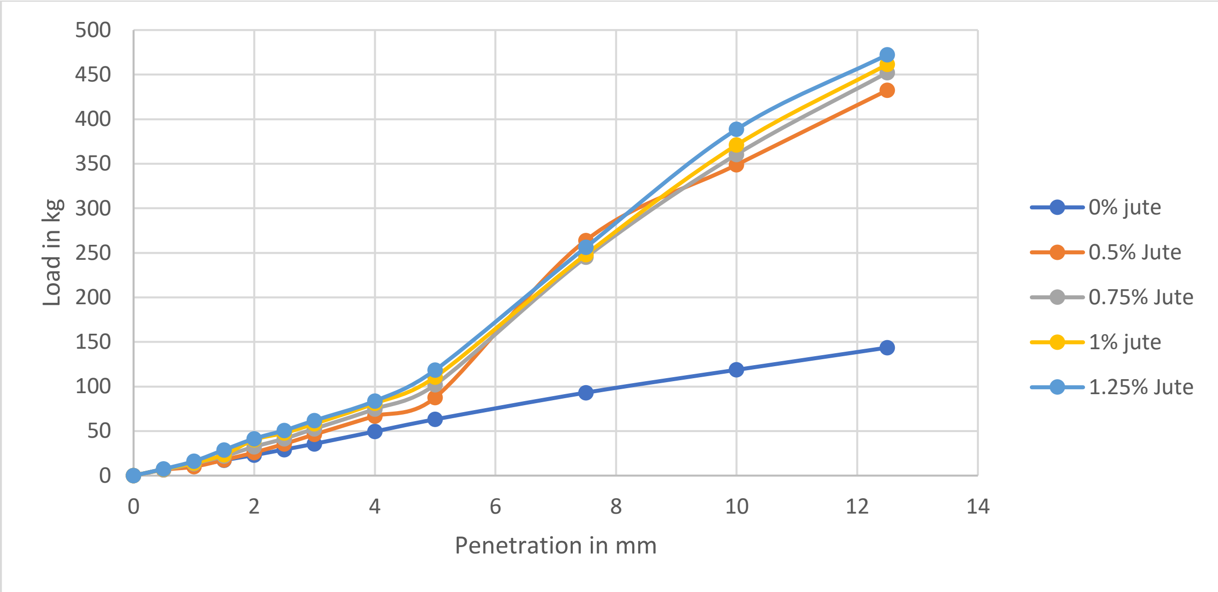

Fig 4.22: Comparison curve of california bearing ratio when soil is treated with different percentages of jute fiber (soaked condition)

Table 4.13: Percentage change of 2.5 mm C.B.R. value w.r.t. the original soil with percentages of Jute fiber

Normal soil	Unsoaked		Soaked	
	CBR value	% change w.r.t original	CBR value	% change w.r.t original
0% Jute	12.78	0 %	2.14	0 %
0.5% Jute	14.68	14.86 %	2.6	21.49 %
0.75% Jute	15.36	20.18 %	3.02	41.12 %
1% Jute	15.5	21.28 %	3.49	63.08 %
1.25% Jute	15.97	24.96 %	3.7	72.89 %

Table 4.13 shows that Unsoaked C.B.R. values increases upto 24.96 % but Soaked C.B.R values increases upto 72.89% when mix with 1.5% jute fiber.

CHAPTER 5

CONCLUSION & SCOPE FOR FUTURE STUDY

5.1 General

On the basis of the experimental observation and results the following conclusions are drawn. Since the difference is found to be less hence we cannot conclude it and need to study further in future. A few suggestion for further study are also included in this chapter.

5.2 Conclusion based on Proctor Compaction test and California Bearing Ratio test

Jute fiber is a natural fiber which could be utilized to improve the soil reinforcement. The research conducted on the modification of soil properties with jute fiber to enhance its California Bearing Ratio (CBR) value reveals promising results in terms of both engineering performance and environmental sustainability. The following conclusions can be drawn from the test results and findings.

- The addition of jute fiber (3cm length) enhances the soil's load-bearing capacity with increase in the percentage of addition of fiber. Thereby CBR value is increase with increase in the percentage of jute fiber is mixed with soil.
- It is seen that the unsoaked CBR value of the soil increased by up to 24.96% with 1.25% jute fiber content, while the soaked CBR value showed a remarkable increase of up to 72.89% when it mix with 1.25% jute fiber.
- This improvement is attributed to the increased shear strength and interlocking effect provided by the jute fibers.
- The jute fiber content 1.25% (by weight) was obsereved to provide maximum increase in the CBR values.
- It is seen that the Maximum Dry Density of the soil is slightly decreased with the increase in percentage fiber content to the soil.
- The Optimum Moisture Content (OMC) of the soil showed a progressive increase, reaching 42.04% higher than the original soil with 1.25% jute fiber mix with the soil.

The use of jute fibers, a biodegradable and locally available material, contributes to eco-friendly construction practices and reduces reliance on synthetic materials. It is a cost-effective method for soil modification, particularly in areas with weak subgrade soils.

5.3 Scope for Future Study

This Study on modification of soil reinforcement with Jute fiber to improve its CBR value, can be take further. Some are discuss below:

1. The length of jute fiber adding to the soil will varies like 6 cm, 9 cm etc. to get a better scenario.
2. Study can be done on uniformly distributed jute fiber in different layers like H/4, H/3 etc.
3. The percentage of mixing the fiber can be increased in the soil.
4. Different type of soil sample can be used to observe the behaviour of jute fiber with that type of soil.
5. Finding correlation between unsoaked CBR and soaked CBR can be analyzed.

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