APPLICATION OF NATURAL GEOTEXTILE TO IMPROVE THE CBR VALUE OF SUBGRADE IN ROAD CONSTRUCTION

A dissertation
submitted in partial fulfilment of the requirements for the award of the degree of

MASTER OF TECHNOLOGY
In
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DECLARATION

I hereby declare that the work presented in this report entitled **"Application of Natural Geotextiles to Improve the CBR Value of Subgrade in Road Construction"** 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 submitted in the Department of Civil Engineering, Assam Engineering College, Jalukbari, Guwahati – 13 under Assam Science & Technology University, is an authentic record of my own work carried out under the supervision and guidance of Prof. Bhaskar Jyoti Das, Associate Professor, Department of Civil Engineering, Assam Engineering College, Jalukbari, Guwahati – 13, Assam.

The subject matter embodied by me in this dissertation has not been submitted by me for the award of any other degree.

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ABSTRACT

This report depicts so far of the work progress in our project titled **“Application of Natural Geotextiles to Improve the CBR Value of Subgrade in Road Construction”**.

This report includes details of all the experiments that has been performed so far on soil sample along with the mixing of coconut husk as a waste material and coir geotextile at various layers and depths on the normal soil. In this study, effect of coconut husk as a waste material at various percentages like 1%, 1.5%, 2% and 3% on the soil were studied. The analysis was done on the experimental results and graphs obtained by the tests performed on normal soil sample and the soil sample mixed with coconut husk. Again, California Bearing Ratio test was conducted by placing coconut coir geotextile on the soil at different layers like H/3, H/2, 2H/3 and in double layers, where H is the height of CBR mould during compaction. A set of California Bearing Ratio test were also performed by keeping the coir geotextile at various depths like 1cm, 2cm, 3cm and 4cm from the top of the CBR mould. From the experimental observations it was clear that lowering the position of coir mat will have reduced effect on increase in CBR values of soil. The best position is near the top surface.

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INTRODUCTION

1.1 GENERAL

A well-developed road network forms an integral part of the development of any nation. The lack of resources available and their ever-increasing cost of materials and energy have motivated highway engineers to explore new alternatives in building new roads and rehabilitating the existing ones. The wide range of soil types available as highway construction materials have made it obligatory on the part of the highway engineer to identify and classify different soils. A survey of locally available materials and soil types conducted in India revealed wide variety of soil types.

Soil is a critical element influencing the success of a construction project. For traffic structures like roadway pavements, the sub-grade, which performs as the foundation of the structure is very important and has to be strong enough to support the entire structure. For the design of pavement structure, the subgrade soil and its properties are important as it gives adequate support to the pavement. To increase the life of pavement the subgrade must be able to support loads transmitted from pavement structure without excessive deformation under adverse climatic and traffic conditions. For using the soil as a good quality pavement material, it is a well-known fact that all soils do not possess all the desirable qualities. The subgrade performance of such soils should be increased by several modification techniques, when such soils cannot be replaced. Among that providing reinforcement to improve subgrade soil nowadays is widely adopted. Nowadays many reinforcing techniques are used to reinforce the soil, among that coir geotextile is most widely used. Soil stabilisation is the process of altering the engineering properties of soil by different methods, mechanical or chemical in order to produce an improved soil material which has all the desired engineering properties. Stabilisation can be used to treat a wide range of sub-grade materials from expansive clays to granular materials. The usage of natural fibres on the composites is well-known, because of its inherited qualities such as renewable, biodegradability etc. Furtherthey are available in abundance, nontoxic and non-hazardous in nature, naturally recyclable, less expensive.

The creation of non-decaying waste materials combined with a growing consumer population has resulted in a waste disposal crisis. The reasonable way to minimize such waste disposal problem is to utilise the material for engineering applications. This can be done by using them in improving the strength of soil in the field of geotechnical engineering.

Use of geo textiles has also become very popular in recent years. According to an estimate, about 100 million square kilometres of geo textiles will be used every year as a soil saver, if proper marketing strategy is adopted by the appropriate authorities. Being produced from natural resources, geo textiles are eco-friendly. Since synthetic geo textiles are expensive in India, cheaper substitutes like Coir have become more popular. Functionally there is no difference between man-made Geo-textile and Coir Geo-Textile. As a separator it prevents intermixing of sub-grade and sub-base.

In the present study the effect of coconut coir as a natural geo-textile material is used on sub-grade soil for road construction and is carried out experimentally, utilising the California Bearing Ratio (CBR) testing arrangement.

1.2 Sub Grade Soil in Road Construction

Sub grade soil is an integral part of the road pavement structure as it provides the support to the pavement from beneath. The sub grade soil and its properties are important in the design of pavement structure. The main function of the sub grade is to give adequate support to the pavement and for this the sub grade should possess sufficient stability under adverse climatic and loading conditions. Therefore, it is very essential to evaluate the sub grade by conducting tests. A weak sub-grade has been and still is one of major concerns to pavement design engineers due to its potential contribution to permanent deformation in flexible pavements, particularly in low-volume thin pavements. In such situations, the natural condition of poor sub-grade soils needs to be improved by suitable modification techniques to meet project requirements. Improving the strength of the sub-grade soils using additives is one such alternative.

1.2.1 Properties of Subgrade Soil

i. Stability: Sub grade soils must have sufficient resistance to permanent deformation under traffic loads.

ii. Incompressibility: The finished surface of the sub grade should be well compacted so that it prevents compressive under heavy traffic load and provides good support to road pavement.

iii. Durability: Subgrade soil is the most important component of road pavement. If the sub grade is weak, it affects the durability of the road pavement, hence the bearing capacity of sub grade soil should be sufficient for long term durability.

iv. Drain ability: Drain ability is also an important property of the sub grade. The sub grade must have excellent drain capacity otherwise it affects the strength of the pavement. Good drainage is necessary so as to prevent excessive moisture retention and minimize potential frost action.

v. Ease of compaction: Sub grade soils must have good compacting properties. A well-compacted subgrade surface increases the strength and durability of road pavements. Due to ease of compaction ensures high density and strength. Sub grade soils must have resistance to weathering therefore retain the desired support. There should be a minimum change in the amount of stability under adverse weather conditions and imposing water.

1.2.2 Subgrade Performance Depends on these Basic Characteristics

- Load-bearing capacity.
- Moisture content.
- Stabilization with cement or asphaltic binder.
- Additional base layers.
- Strength and stiffness of sub grade soil.

1.2.3 Strength & Stiffness of Subgrade Soil

Subgrade materials are typically characterized by their resistance to deformation under load, which can be either a measure of their strength (the stress needed to break or rupture a material) or stiffness (the relationship between stress and strain in the elastic range or how well a material is able to return to its original shape and size after being stressed). In general, the more resistant to deformation a subgrade is, the more load it can support before reaching a critical deformation value. Three basic subgrade stiffness/strength characterizations are commonly used:

- California Bearing Ratio (CBR),
- Resistance Value (R-value) and
- Elastic (resilient) modulus

Although there are other factors involved when evaluating subgrade materials (such as swell in the case of certain clays), stiffness is the most common characterization.

1.3 Geosynthetics

Geosynthetics are synthetic products used to stabilize terrain. They are generally polymeric products used to solve civil engineering problems. This includes eight main product categories: geotextiles, geogrids, geonets, geomembranes, geosynthetic clay liners, geofoam, geocells and geo composites. Figure 1.1 shows different types of geosynthetics which are being used now a days.

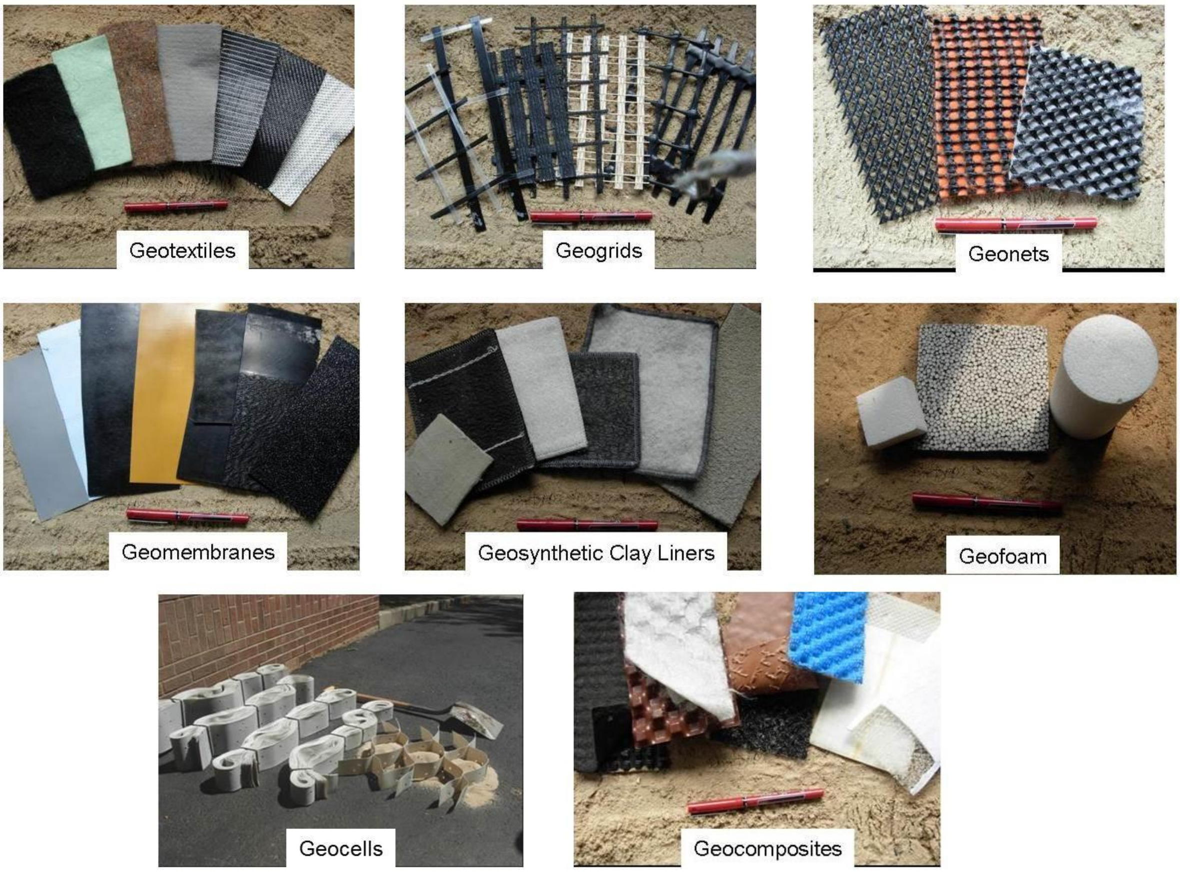

Figure 1.1: Types of Geosynthetics

Source: https://upload.wikimedia.org/wikipedia/commons/thumb/6/68/Geo2.jpg/1280px-Geo2.jpg

The polymeric nature of the products makes them suitable for use in the ground where high levels of durability are required. They can also be used in exposed applications. Geosynthetics are available in a wide range of forms and materials. These products have a wide range of applications and are currently used in many civil, geotechnical, transportation, geo environmental, hydraulic and private development applications including roads, airfields, railroads, embankments, retaining structures, reservoirs, canals, dams, erosion control, sediment control, landfill liners, landfill covers, mining, aquaculture and agriculture

Geotextiles form one of the two largest groups of geosynthetics. They are textiles consisting of fibres. These fibres are made into flexible, porous fabrics by standard weaving machinery or are matted together in a random nonwoven manner. Geotextiles are porous to liquid flow across their manufactured plane and also within their thickness, but to a widely varying degree. There are many specific application areas for geotextiles that have been developed; however, the fabric always performs at least one of four discrete functions: separation, reinforcement, filtration, and drainage.

Geogrids represent a rapidly growing segment within geosynthetics. Geogrids are polymers formed into a very open, grid like configuration, i.e., they have large apertures between individual ribs in the transverse and longitudinal directions. Geogrids are:

(a) either stretched in one, two or three directions for improved physical properties,

(b) made on weaving or knitting machinery by standard textile manufacturing methods, or

(c) by laser or ultrasonically bonding rods or straps together.

There are many specific application areas; however, geogrids function almost exclusively as reinforcement materials.

Geonets constitute another specialized segment within the geosynthetics area. They are formed by a continuous extrusion of parallel sets of polymeric ribs at acute angles to one another. When the ribs are opened, relatively large apertures are formed into a netlike configuration. Two types are most common, either biplanar or tri-planar. Their design function is completely within the drainage area where they are used to convey liquids or gases of all types.

Geomembranes represent the other largest group of geosynthetics. The materials are relatively thin, impervious sheets of polymeric material used primarily for linings and covers of liquids- or solid-storage facilities. This includes all types of landfills, surface impoundments, canals, and other containment facilities. Thus, the primary function is always containment as a liquid or vapor barrier or both. The range of applications, however, is great, and in addition to the environmental area, applications are rapidly growing in geotechnical, transportation, hydraulic, and private development engineering (such as aquaculture, agriculture, heap leach mining, etc.)

Geosynthetic clay liners, or GCLs, are an interesting juxtaposition of polymeric materials and natural soils. They are rolls of factory fabricated thin layers of bentonite clay sandwiched between two geotextiles or bonded to a geomembrane. Structural integrity of the subsequent composite is obtained by needle-punching, stitching or adhesive bonding. GCLs are used as a composite component beneath a geomembrane or by themselves in geo-environmental and containment applications as well as in transportation, geotechnical, hydraulic, and many private development applications.

Geofoam is a polymeric product created by processing polystyrene into a foam consisting of many closed cells filled with air and/or gases. The skeletal nature of the cell walls resembles bone-structures made of the unexpanded polymeric material. The resulting product is generally in the form of large, but extremely light, blocks which are stacked side-by-side and in layers providing lightweight fill in numerous applications.

Geocells (also known as Cellular Confinement Systems) are three-dimensional honeycombed cellular structures that form a confinement system when infilled with compacted soil. Infilled with soil, a new composite entity is created from the cell-soil interactions. The cellular confinement reduces the lateral movement of soil particles, thereby maintaining compaction and forms a stiffened mattress that distributes loads over a wider area. Traditionally used in slope protection and earth retention applications, geocells made from advanced polymers are being increasingly adopted for long-term road and rail load support.

A **geo composite** consists of a combination of geotextiles, geogrids, geonets and/or geomembranes in a factory fabricated unit. Also, any one of these four materials can be combined with another synthetic material or even with soil. The application areas are numerous and constantly growing. The major functions encompass the entire range of functions listed for geosynthetics like: separation, reinforcement, filtration, drainage, and containment.

1.4 Geotextile

Geotextile can be separated into two terms, ‘geo’ and ‘textile’. The word ‘geo’ comes from the Greek meaning ‘earth’, so geotextiles can be defined as the permeable textile materials that are used in combination with soil or any other civil engineering material. Geo textile is a branch of technical textiles. Geotextiles are synthetic and permeable materials used in civil construction projects to improve soil characteristics. Geotextiles make poor soils more suitable for construction, since they have the ability to separate, filter, reinforce, protect and drain soils. Geotextiles are typically used to improve soil characteristics before building embankments, roads, pipelines and earth-retaining structures. According to The Textile Institute geotextile is, “permeable textile material used for filtration, drainage, separation, reinforcement and stabilization purposes as an integral part of civil engineering structures of earth, rock or other constructional materials”.

1.4.1 Types of Geotextiles

Geotextiles are made from polymers such as polypropylene and polyester. They are divided into three categories, according to their manufacturing process:

- Woven fabric
- Nonwoven fabric
- Knitted fabric

Woven fabric geotextiles are the most common, and their manufacturing methods are similar to those of clothing textiles. This type of geotextile is made from two sets of parallel threads or yarns. These types of textiles perform the function of separation and increase the strength of the soil. As the yarn strength of their warp is much higher, they have more tensile strength. As a result, it is able to take much more load.

Nonwoven geotextiles are made from continuous yarn filaments or short staple fibres. They are bonded with thermal, chemical or mechanical techniques, or a combination of techniques. In case of nonwoven geotextiles, tensile strength is not very high, but their separation, drainage and filtration ability are better than others. Non-woven geo textiles are permeable geosynthetics, usually made by synthetic fibres.

Knitted geotextiles are created by interlocking a series of yarn loops together. These geosynthetics are made by combining the knitting technique with other methods like weaving. These types of textiles have good flexibility and are economically profitable. Although its use is less, but the demand for “Drainage and Soil Erosion Control” is increasing day by day.

1.4.2 Functions of Geotextiles

Geotextiles have several functions, which include filtration, drainage, reinforcement, cushioning, waterproofing and separation etc.

1.4.2.1 Geotextiles for Filtration

The filtration properties of geotextiles are used when there is a need for water to move in both directions. Geotextile plays an important role in filtration. Filtration is one of the most important functions of textiles used in civil engineering earthworks. Depending on the permeability of the material, geo-textiles increase the lateral flow of drain water, developing the kinetic energy of groundwater. Also helps to solve drainage problems around the house or on the street. These types of geotextiles can be woven or nonwoven, and they are used to prevent fine aggregates from moving between the soil layers.

1.4.2.2 Geotextiles for Separation

When a geotextile is installed between two different soils, it will prevent intermixing when water gets into the soil strata. To maintain the properties of two different types of soil, geo-textile plays an important role in this separation. This way, the required soil characteristics can be conserved. The main purpose of geo-textile is that when water enters the soil layer, the geo-textile will prevent water from mixing with the soil. By separating fine subgrade soil from the aggregates, which is the case of roads, the geotextile preserves the drainage properties and strength of the base material.

1.4.2.3 Geotextiles for Reinforcement

When geo-textiles are used to improve soil properties, its design is based on a number of basic factors, such as abrasion-capable, load-bearing, etc. As a result, it strengthens the soil by mixing with the soil. So, these types of textile materials are used to build embankments/roads on very poor graded soil. There are various types of reinforcement composites like knitted reinforcement, braided reinforcement, woven reinforcement etc.

1.4.2.4 Geotextiles for Sealing

A non-woven geo-textile fabric capable of restricting fluid flow from both sides. Impermeable geo-textiles are used to prevent contamination of pollutants above foul-smelling soils or groundwater.

1.4.2.5 Geotextile in Drainage System

A geotextile acts as a drain when it collects and transports the liquid or gas towards the outlet. Dense non-woven geo textiles provide an opportunity for water flow through three-dimension flat surface. The two main properties of geotextiles that involve infiltration are porosity and permeability. Depending on these properties, geotextiles can also promote the lateral flow of water, dissipating kinetic energy from the capillary rise of groundwater. Applications of this type of geotextile can be both vertical and horizontal, helping solve drainage problems along roads and structures.

1.4.3 Applications of Geotextile

Geotextiles are mostly used in road construction, especially to fill gaps between the roads to improve soil structure. Geotextile makes poor soil more beneficial for use and then easy to build in difficult places also. Geotextile are ideal materials used for Construction & infrastructure like roads, buildings, dams and many more. It improve & stability and decreases the process of wind & water erosion. It helps to prevent the erosion of soil but allows the water to drain off. A geotextile made from synthetic or natural fibres associated with soil thin pieces improves the soil characteristics. The scope of geotextiles in the civil engineering field is very vast, including the following applications:

- **Roads:** Geotextiles are widely used in road construction, reinforcing the soil by adding tensile strength. Geotextiles can be used as a rapid dewatering layer in the roadbed.

- **Railways:** Geotextiles are used to separate the individual soil layers, without impeding groundwater circulation where the ground is unstable. This also keeps the layer materials from shifting sideways under the constant shocks and vibrations from passing trains.

- **Agriculture:** Nonwoven fabrics are used for mud control, to improve paths and trails used by cattle or light traffic.

- **Drainage:** Geotextiles are used as filtering mechanisms for drainage in roads, highways, earth dams, reservoirs, retaining walls, drainage trenches, and many other applications.

- **Coastal work:** Geotextiles can help prevent erosion in river banks, canals and other bodies of water.

There are three key factors when designing geotextiles to improve soil characteristics:

- Friction or movement restraint between the geotextile and the soil
- Supporting any loads present
- Increasing shear strength

Geotextile fabrics can be impregnated with asphalt or other mixes, which makes them impermeable and capable of restricting the vertical flow of water. For this application, geotextiles must be nonwoven. Impermeable geotextiles can be used to prevent contamination of soil or groundwaters from pollutants above, also they may help in preventing the loss of potable water due to evaporation.

1.5 Coir Geotextile

Coir is a natural fibre extracted from fibrous husk of the coconut shell and is used to make a wide range of products such as ropes, mats, mattresses, fibre baskets, brushes, brooms, etc. India is the largest coir producer in the world accounting for major part of the total world production of coir fiber and coir products. Coir geotextiles (CGT) are permeable fabrics made from coir fiber extracted from coconut husk by mechanical processes. Coir geotextile is made of coir yarn or fibre which is biodegradable and environment friendly. It has good hygroscopic and hydrophilic properties. Biodegradability, hygroscopic and hydrophilic properties of geotextiles help in erosion control and to establish vegetation in varying slopes and environmental conditions. These properties make coir admirably suitable in areas where natural treatment of a soil surface for control of erosion is required. Coir Geo textiles is natural, strong, highly durable, resistant to rots, moulds and moisture, free from any microbial attack. Like other polymeric counterparts, coir geotextiles are developed for specific application in civil engineering like erosion control, ground improvement, filtration, drainage, river bank protection, road pavements, slope stability etc. The use of coir geotextiles in erosion control in embankment construction for roads and Railways, dam engineering, canals, etc. is well established. In order to prevent the soil from further degradation, natural geotextiles are used as soil cover to provide temporary protection for the soil which can effectively control erosion until the soil is stabilized by vegetation.

Coir geo-textiles are used for improvement of sub-grade soil strength in road pavements and stabilization of side slopes. Coir geo-textiles have been used in various places for improving the properties and strength of sub-grade soil layer by providing a physical separation of sub-base and sub-grade layers. The principal reason is enhancement of CBR and for that matter, bearing capacity of the sub-grade is separation along with the membrane effect. This biodegradable and environment friendly material is virtually irreplaceable by any of the modern synthetic substitutes.

Coir is a biodegradable product, abundant in India and can be used in an effective manner which reduces environmental pollution, give strength to the pavement, reduces the pavement thickness, and finally reduces the construction cost of the pavement. The coir fibre is relatively waterproof and is the only natural fibre resistant to damage by salt water. The addition of coconut-fibres significantly improved many of the engineering properties of the concrete. The ability to resist cracking and spalling were also enhanced. Adding of coconut coir fibre results in less thickness of pavement due to increase in CBR of mix and reduce the cost of construction and hence economy of the construction of highway will be achieved.

Composition of coir fibres and found that components of natural fibres are cellulose, hemicellulose, lignin, pectin, waxes and water-soluble substances. The cellulose, hemicellulose and lignin are the basic components of natural fibres. The coir geotextiles, mainly composed of plant fiber, conforms to the green concept which is conducive to reducing environmental pollution. For stabilization of slopes coir geotextiles can replace the traditional methods like stone pitching, bunding, terracing, etc. Especially in the application of erosion control, the water absorption and its retention are positive aspects of coir geotextiles. Due to the characteristics of longer durability, low cost, easy to use and availability, the coir geotextile is widely used in soil bioengineering and slope protection works.

The figure below (Figure 1.2) shows the use of coir geotextile for road construction purpose.

Figure 1.2: Use of Coir Geotextile for Road Construction

Source:https://www.google.com/url?sa=i&url=https%3A%2F%2Flink.springer.com%2Farticle%2F10.1007%2Fs40098-020-00412

1.5.1 Types of Coir Geotextiles

Coir geotextiles are Woven/Non-woven structures of natural coir fibres used in various geotechnical, Civil Engineering and soil conservation applications. Coir geotextiles are of different types, the two main geotextiles made from coir are:

- Woven coir geotextiles and
- Non-Woven coir geotextiles

1.5.1.1 Woven Coir Geotextile

- Coir mesh mattings of different mesh sizes are most common coir geotextile. Mesh mattings having different specifications are available with mesh opening sizes ranging from 4.2 mm to 20 mm. These matting of two-treadle weave in construction with the difference that the warp & weft are positioned at a distance to get mesh effect.
- Coir geotextile controls the soil erosion by acting as a ground cover which reduces the flow velocity of runoff water by forming check dams with the help of net

structured strands in firm contact with the soil which absorb the impact of water flow and resist washing down keeping the soil intact. The coir geotextile will also function as an in plane conveyor of water along the slope surface without disturbing the soil particles.

- Coir geotextile is capable of reducing the erosive effects of rain drops and controlling migration of soil particles of the exposed surface. The micro-climatic condition induced by the coir geotextile promotes the faster establishment of the vegetation. Choice of the right type of coir and plant species is critical for effective results.

Figure 1.3 shows different types of woven coir geotextiles of 400,700 and 900 gsm.

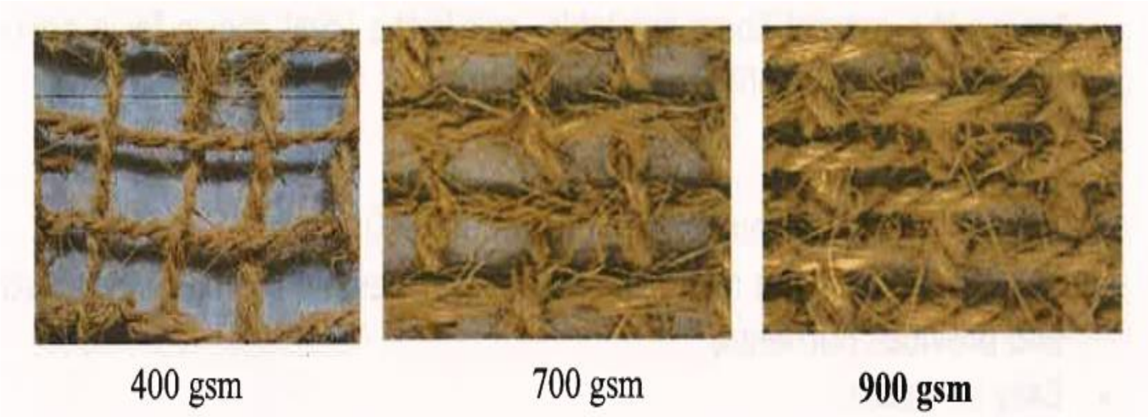

Figure 1.3: Different types of woven coir geotextile

Source: https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcRjxHn1EpS_kpIH48nJ-F8nFFcPhEEQF3S2RRR8N4XL2XD8jJAl55X97AoMeNv8TeB0o68&usqp=CAU

1.5.1.2 Nonwoven Coir Geotextiles

- The nonwoven coir geotextiles are composed of randomly packed coir fibers needle punched to the desired degree of packing. The felts have excellent moisture absorption and retention characteristics and form an ideal medium for plant growth.
- They have a minimum thickness of two mm. Nonwoven coir geotextiles are available in varying densities from 350 to 1000gsm. They are available in blanket form backed with nets made of jute/polypropylene/polyethylene.

Figure 1.4: Different types of non-woven geotextile

Source: https://geosyntheticsmagazine.com/wp-content/uploads/sites/26/2021/06/Woven-Vs-Nonwoven.jpg

1.5.2 Advantages of Coir Geotextiles

Among the natural fibres available, coir is the ideal choice for a geotextile material. Other advantages of coir geotextiles are:

- It is natural, easy to install, available in plenty, economical.
- It provides excellent micro climate for plant establishment and growth and provides nutrients,
- Good drapability over soil surface,
- Excellent air and water permeability,
- Coir geotextiles provide excellent check dam effect to reduce runoff velocity and minimize erosion potential,
- Eco friendly and non-polluting,
- Allow sunlight to pass through, and
- No chemicals are used during manufacturing.

1.5.3 Comparison between Coir Geotextile & Synthetic Geotextile

Table 1.1 below shows the various difference between natural coir geotextile and synthetic geo textile

Table 1.1: Difference between natural coir geotextile and synthetic geotextile

Coir Geotextile	Synthetic Geotextile
The high tensile strength of coir Synthetics originate from fibre protects steep surfaces hydrocarbons, which are obtained from heavy flows and debris movement. It can withstand considerable pedestrian movement and vehicular traffic without deterioration.	Synthetic geotextiles originate from hydrocarbons, which are obtained from non-renewable sources such as petroleum and natural gas. These are fast depleting and need to be used sparingly.
Totally bio degradable, 100% natural and provides nutrients. During the manufacturing process of coir yarn, no chemicals are used.	Recalcitrant, i.e., not bio- degradable, application of synthetics prevents the percolation of water into the underground water table
Water absorbent, thus acts as mulch on the surface and as a wick in the soil mantle.	Non hygroscopic, they alter the microclimate around the plants thus discouraging healthy vegetation.
Environmentally friendly and aesthetically pleasing and non-polluting.	Incineration or recycling also creates pollution due to release of harmful chemicals and gases
Provides excellent microclimate for plant establishment and healthy growth of vegetation.	Being a non-conductor of heat, increases the temperature of soil creating unfriendly atmosphere for the vegetation to grow
The thick and protruding fibres from the yarn render an extra protection against soil erosion and provide roughness to the surface floor and holds the soil particles in place.	Synthetics need 100% shielding from the ultra violet rays to prevent release of toxic gases into the environment leading to environmental pollution. The chemicals applied for shielding are toxic and pollute the environment.
The coir geo textiles give the grass plenty of room to grow and at the same time provides large number of "Check Dams" per square meter of soil media. Due to high resistance to salt water action, the coir geo textiles remain virtually unaffected when used against wave lap erosion.	Undergo slow attack of acid rain and UV light to produce poisonous chemicals

CHAPTER 2

REVIEW OF LITERATURE

2.1 GENERAL

Extensive research and studies have been done in different regions around the world by different investigators and research workers to study the application of geotextiles to improve the CBR value of subgrade of road construction. A brief review of the previous work has been presented in this chapter.

2.2 Review of Literature

Some of the selected literature collected from different sources are discussed below:

Giroud and Noirway (1982) after an extensive study developed design chart of unpaved pavement for using geosynthetic at the interface of base layer and subgrade soil.

Rowe & Soderman (1985) described conventional limit equilibrium techniques while incorporating the effect of soil-geotextile interaction in terms of an allowable compatible strain for the geotextile.

Ramaswamy and Aziz (1989) did experimental investigation on the behaviour of jute reinforced subgrade soil under dynamic load.

Mehndiratta et al (1993) and Patel, (1990) have reported that standard mould of diameter equal to 3 times the plunger diameter is found to be inadequate for determination of CBR value as the small size mould will provide additional confinement to geotextile. Therefore, the diameter of the mould is increased to 5 times the plunger diameter. Also, to determine the effect of lateral confinement on CBR value of reinforced soil, mould-plunger diameter ratio (D/d) is varied from 2 to 5 while the vertical pressure (surcharge), thickness of the specimen, method of compaction is kept the same as the standard test.

Rao and Balan (2000) in their research found the gaining importance of geotextiles like coir and jute because of their eco friendliness and low cost with reasonable durability. Coir is the husk of coconut, a common waste material and subsequently processed. Coir fiber is strong and degrades slowly compared to other natural fibers due to high lignin content. The advantages of coir geotextiles are the initial strength, stiffness and hydraulic properties of coir reinforcement are almost comparable to those of similar products made from polymer materials. They are of very low raw material price. By chemical treatment and polymer coating, the life of coir products can be improved. It can be laid on any surface owing to its flexibility and hence it is useful for geotechnical purpose. Coir fibers are environmentally friendly, biodegradable and aesthetically pleasing and easy to install and follows the contour the soil surface.

Mehndiratta et al (2005) conducted CBR and plate load test on unreinforced and geotextile reinforced subgrade. It was observed that the increase in elastic moduli of coir reinforced layer when coir is replaced by synthetic geosynthetic geotextiles are only 5 percent. They also investigated the durability of coir by accelerating its durability. It was observed that phenol treated coir extends the life of coir.

Dutta and Sarda (2007) carried out an experiment study to investigate the CBR behavior of waste plastic strips reinforced with stone dust/fly ash overlaying saturated clay.

Sivakumar et al. (2008) discusses the mechanism of improvement in strength, shrinkage, swelling and compressibility behavior of black cotton soil due to the inclusion of coir fibers through an experimental investigation using tri-axial swelling and compressibility tests.

Babu et al (2008) has developed a design methodology using IRC guidelines for the design of coir geotextiles reinforced road on the basis of laboratory experiment data and mathematical formulations.

Baruah, U.K. et al. (2010) conducted a number of CBR tests (both soaked and unsoaked conditions) using samples consisting of soil only and soil with layer of coir mat at different position from the top surface. Coir mat was provided at a depth of 1cm, 2cm, 3.0cm and 4.0cm from the top surface of soil in single layer at a time. They observed that the maximum CBR values are obtained for position of coir mat at 1cm. The CBR values then decrease for the coir mat position at 2cm and 3.0cm and at 4.0cm. For all types moulds CBR value for reinforcement at 4.0cm depth is nearly the same as for unreinforced soil. They found that the CBR value of the coir mat reinforced subgrade when soaked shows nearly twice the CBR value of the unreinforced (i.e., without the coir mat) under the condition. So, they concluded from the CBR test results that the CBR value of the soil has improved up to 63% for unsoaked condition and 190% for soaked condition when the position of coir mat is at 1cm from the top surface with the mould–plunger ratio of D/d=3. The CBR values decreases with the increase in mould size i.e., decrease in lateral confinement. The effect of lateral confinement is more for D/d =2 and CBR values observed are also higher than others. For D/d= 5 results are almost identical with the field CBR test results. Thus, they concluded that by increasing D/d ratio i.e., decreasing the lateral confinement, field conditions can be approached. At D/d =5 they got field condition. Again, the higher CBR values were obtained for position of coir mat at 1cm. From the design aspects they observed that the thickness of pavement may be reduced by approximately 75% if coir mat is placed above the subgrade.

Ramesh et al. (2010) compared compaction and strength behaviour of lime- coir fibre treated black cotton soil. Coir used in this study is processed fibre from the husk of coconuts. Black cotton soil reinforced with coir fibre shows only marginal increase in the strength of soil, inhibiting its use for ground improvement. They have found that strength properties of optimum combination of black cotton soil-lime specimens reinforced with coir fibres is appreciably better than untreated black cotton soil or black cotton soil alone with coir fibre. Lime treatment in black cotton soil improves strength but it imparts brittleness in soil specimen. Black cotton soil treated with 4% lime and reinforced with coir fibre shows ductility behavior before and after failure. An optimum fibre content of 1% (by weight) with aspect ratio of 20 for fibre was recommended for strengthening black cotton soil.

Arya et al. (2011) conducted the Standard Proctor Compaction Test, California Bearing Ratio Test and Plate Load Test of soil using raw waste plastic bottles. Thesoaked CBR value of soil mixed with plastic bottle is increased. From the plate load test, they have observed that the final settlement of soil stabilized with plastic bottle is much less than that of plain soil. Decrease in settlement points to the increase in the bearing capacity of soil.

Babu, K.K et al. (2011) reported the results of an exhaustive experimental study carried out to explore the behaviour of coir geotextile reinforced subgrade soils, in terms of California Bearing Ratio (CBR). Two subgrade soils, red soil (Soil-1) and Brown soil (Soil-2) and three varieties of coir geotextiles (H2M6, H2M8 and NW) were used in the study. CBR tests were conducted with coir geotextiles placed at depths of H/2, H/3 and H/4 from the top surface of soil where H is the depth of CBR test specimen. From the data generated, it was clear that the presence of coir geotextile influences the strength of the subgrade due to the interaction between soil and coir geotextile in soaked and unsoaked condition. Using multiple linear regression analysis, a mathematical model for estimating modified CBR was obtained, in terms of original CBR of the subgrade soil and properties of coir geotextile and depth of placement of coir geotextile.

Surendra. P. and Damgir R. M. (2011) used jute Geo - textiles as a tensile material for reinforcement of different kind of soils. Laboratory California bearing ratio (CBR) tests were performed to investigate the load – penetration behaviour of different 3 kinds of soils (Black Cotton Soil, Murum & both soil) with different kind of jute Geo – textiles (Woven jute Geo – textiles thickly netting & with thinly netting). Samples of soil tested for CBR without reinforcement & samples are also tested with jute Geo – textiles. Laid at various distance from top (i.e., 1/3, 2/3 & half distance) of compacted thickness of soil suitability for improvement of sub –grade in all aspect is calculated. Result shows that soil sample of 50% B. C. soil & 50 % murum with thick jute Geo – textiles laid at 1/3rd distance from top are most economical & increases the CBR to considerable extent. They concluded that the improvement of soil strength of CBR with jute – Geo textile material depends upon type of jute Geo textiles & it placing from top layer. The introduction of jute – Geo textile reinforcement in soil leads to decrease surface penetration & deformation. In the uniform deposit of murum type soil, introduction of a single layer of jute – Geo textile reinforcement from top 1/3rd distance of sub grade soil, increases significantly CBR values & soil – strength. The Figure 2.1 shows the trend of CBR using Jute.

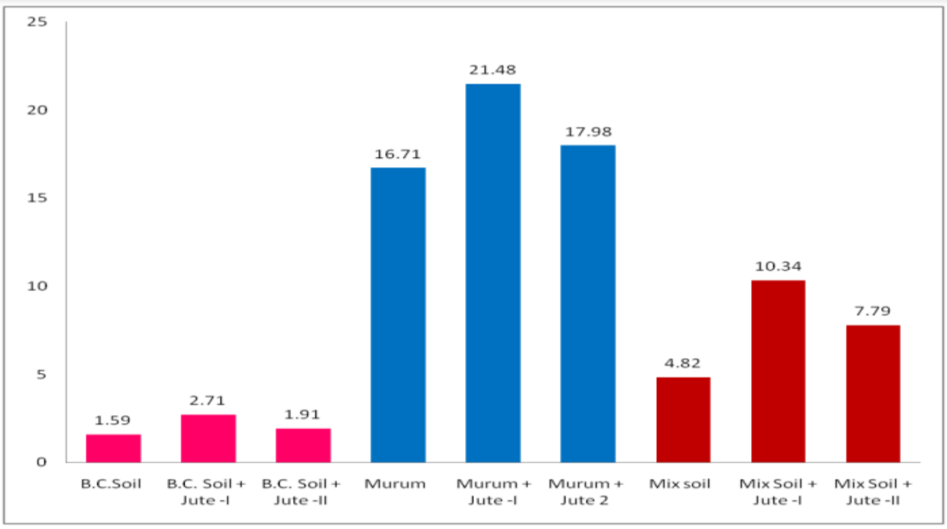

Figure 2.1: The Trend of CBR using Jute obtained by Surendra. P. Jadhav, R. M. Damgir

Mohana C. et al. (2011) summarized the use of geo-synthetics is ensured in a given geotechnical application. In their study the performance of woven and nonwoven coir geotextiles in unpaved and paved flexible pavement models are carried out experimentally, utilizing the California Bearing Ratio (CBR) testing arrangement. Compared with the unreinforced soil, all reinforced soil samples, show a slower increase in rate of penetration.

Rajkumar et al., (2012) discussed the performance of woven and nonwoven geotextile, interfaced between soft subgrade and unbound gravel in an unpaved flexible pavement system is carried out experimentally, utilizing the California Bearing Ratio (CBR) testing arrangement. And found that woven geotextiles give better performance compared to non-woven geotextile. They found that introduction of geotextile offers good resistance even to lower penetration. Further, the reinforcement ratio increases with an increase in penetration. Hence the use of geotextile is most advantage in an unpaved road with soft subgrade at higher penetration. The figure below shows schematic arrangement and photograph of the soil-aggregate in the CBR mould performed by Rajkumar et al.

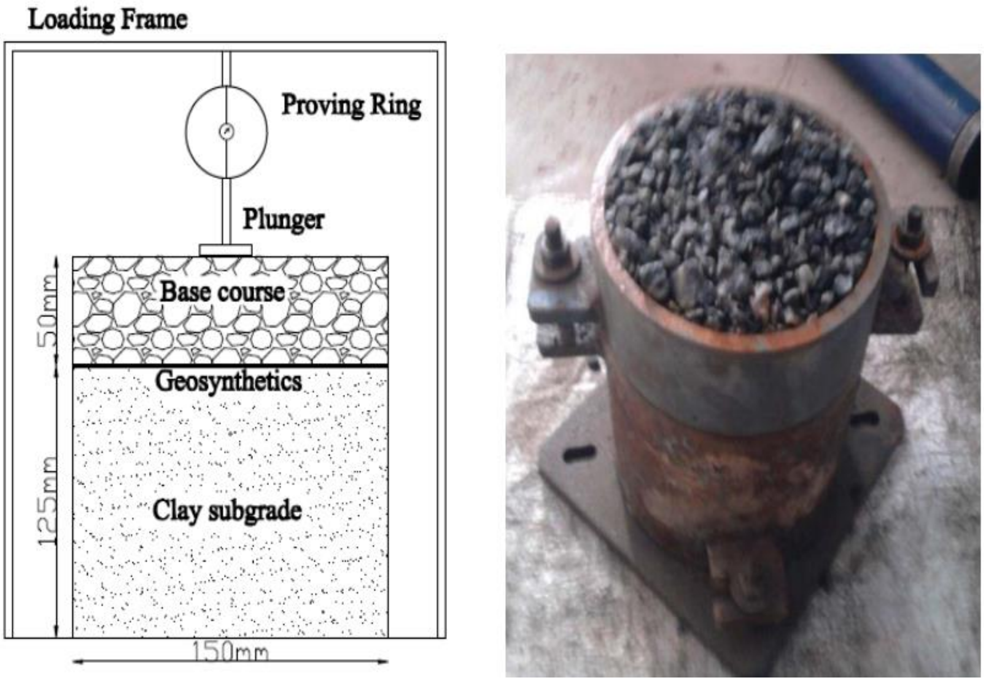

Figure 2.2: Schematic Arrangement and Photograph of the Soil-Aggregate in the CBR Mould by P. Senthil Kumar, R. Rajkumar

Sharma and Nathan (2012) explained the field experiments on weak sub-grades with and without coir geotextile. Also discussed two case study first, the construction of a village road namely, Kumbakkad and Chembakulam Road at Varkala Block in Trivandrum district Kerala and Second, Vellar Theru Road at Orthanadu Block in Thanjavur district Tamilnadu using coir geotextile as a reinforcement with sand cushion. Coir netting is spread directly over the roughly levelled poor sub-grade soil (agrarian soil). In the case of clayey sub-grades, it is recommended to spreading the fabric after placing a layer of sand of 10mm to 20mm thickness. The fabric is then surcharged with granular material preferably sand of 30mm to 50 mm thickness to act as a lower sub base. The fabric over the sub-grade may be spiked, if necessary, by use of J shaped wooden spikes driven at random as necessary to keep the netting in place during construction and rolling.

Mittal S.K. et al. (2013) introduced the scope of Coir textile as reinforcement to improve the performance of roads on black cotton soils. They expected that with the inclusion of coir geotextile layer below Granular Subbase (GSB) layer would be helpful in restricting the movement of upper pavement layers due to seasonal moisture variation in subgrade expansive, shrinkable soil. They studied the composition of coir fibres and found that components of natural fibres are cellulose, hemicellulose, lignin, pectin, waxes and water-soluble substances. The cellulose, hemicellulose and lignin are the basic components of natural fibres. The chemical composition of various natural fibres is given in the table below:

Table 2.1: Chemical composition of various natural fibre

Source: Verma and Sharma (2012)

S.N.	Material	Cellulose	Hemicellulose	Lignin	Pectin
1	Flax	81	14	3	3
2	Jute	72	13	13	<1
3	Hemp	74	18	4	1
4	Sisal	73	13	11	1
5	Cotton	92	6	-	-
6	Ramie	76	15	1	2
7	Wood	45	23	27	-
8	Coir	43	<1	**45**	4
9	Straw	40	28	17	8

They suggested the possible placement of coir geotextile in Rural Roads as shown Case- I to Case- III, in which Case-I represents the coir geotextile place over Subgrade between sand layer of 50 mm and layer of select soil is 300mm. In Case-II Subgrade made with total approved soil having CBR 3 to 4 %. CGT place directly placed over approved soil, then laying of coir geotextile and a sand layer of 25 mm over it. The Case-III shows, subgrade made with layer of approved soil of 350 mm, select soil of 200mm and design CBR will take 5%. They concluded that incorporation of CGT between sub-grade and sub-base layer is an emerging technology. It not only stops seepage of water but also brings reduction in thickness. The entrance of seepage water into the sub-grade is stopped by introducing the geotextile layer or membrane at the interface of Granular Sub-base layer (GSB) and sub-grade which retains the interruption of sub-grade soil into the spaces of granular sub-base layer, and this enables proper function of GSB as drainage layer. It is reducing intensity of stress on subgrade. Utilisation of non-conventional material, like CGT, in construction of roads can provide cost effective and eco-friendly solution for road by reducing the consumption of other conventional materials. The geosynthetic offers wide variety of products to solve may geotechnical problems being non-biodegradable and costly. Their use should be restricted the natural materials like coir geotextile can be an option to improve the poor sub-grade soil.

Bayat M. et al (2013) studied the effects of two types of additives for the soil (i.e., lime/cement) on the geotechnical and engineering properties of a soil. The results of the study indicate that optimum moisture content, maximum dry unit weight and plasticity index are affected by the addition of cement or lime. Also cement treatment result in increase of unconfined compressive strength (UCS) of the soils significantly. Whereas the test results indicate that there is an optimum of lime content so that the addition of a few percentages of lime results in increase of unconfined compressive strength. Generally, improvement in mechanical behaviours of the soil due to cement treatment was noticeably higher than lime treatment. Also, the results of tests show that the change of UCS of the specimens with the initial water content and curing time is significant, so that decreasing of initial water content or increasing of curing time results in increase of USC of the specimens. Also, the current study sought to characterize the relationship between secant modulus and UCS, curing time and cement or lime content.

Li et al. (2014) conducted direct tensile tests on soil reinforced with discrete fibre content. Parameters like fibre content, water content and dry density of soil were examined and concluded that tensile strength and tensile failure ductility of soil can be improved significantly with the fibre inclusion

Abhijith R.P (2015) deals with an experimental study on the utilization of natural coir fibres on unpaved roads. They used Lateritic soil collected from Manvela region of

Trivandrum district, Kerala. Liquid limit, plastic limit and shrinkage limit of soil sample were determined as per IS: 2720 (Part 5)-1985. Modified Proctor compaction were carried out to determine the optimum moisture content and maximum dry density of the sample as per IS: 2720 (Part 8)- 1983. Coir fibres of varying length from 0.5 to 3cm and varying percentage from 2 to 8 of total weight of soil were added with the soil and CBR test was conducted. The main objectives of their study were:

1. To find the improvement in CBR strength of subgrade soil using coir geotextiles.
2. To determine the optimum fibre percentage and fibre length using CBR test.
3. To locate the ideal position of coir geotextiles in subgrade soil.

From the test results, they concluded that the CBR strength using coir fibre was improved and optimum fibre length obtained was 1.5cm and optimum fibre content was 5% of total weight of soil. The optimum fibre percentage obtained was 5% of total weight of sample. The optimum fibre length obtained was 1.5cm. The ideal position for placing the coir geotextiles was at top position of the subgrade and the least value was obtained at bottom most position. The use of coir geotextiles increases the subgrade strength and thus improves pavement life.

Abdul et al., (2015) found that the use of coir geotextiles as subgrade reinforcement increased the subgrade strength and reduced the settlement. The coir geotextile significantly decreased the permanent vertical deformation over the loaded area of the pavement under repeated loading by restraining the lateral spreading of base material.

Mohanty (2015) explained the property of expansive soils with various proportions of this additive i.e., 10%, 20%, 30%, 40% & 50%, expansive soils are stabilized. In conclusion, addition of fly ash results in decrease in plasticity of the expansive soil, and increase in workability by changing its grain size and colloidal reaction. Tested under both soaked and un-soaked conditions, the CBR values of clay with fly ash mixes were observed. Analysis of the formerly found result exposes the potential of fly ash as an additive that could be used for improving the engineering properties of expansive soils.

Bindu et al., (2015) conducted plate load tests on soft clay bed using coir geocell mattresses with varying height. They concluded that the optimum height of geocell in chevron pattern with vertical strips at the joints is equal to width of the loading plate. Further increase in height had no significant effects in improving bearing capacity

Hussain et al. (2016) compacted the soil sample at its maximum dry density corresponding to its optimum moisture content in the Laboratory California Bearing Ratio (CBR) mould with and without natural Jute fibre. Natural Jute fibre sheets equal to the plan of CBR mould diameter were placed at various layers (second, fourth and fifth of soil's layers) to investigate its behaviour on CBR value. The experimental investigations were also involved natural Jute fibre coated with bitumen material to study the effect of bitumen material on the CBR value.

Chowdhury S. et al. (2016) focuses on issue of strengthening the clayey sand (SC) soil of Belapur at Navi Mumbai region, used as subgrade material through layered woven geotextile reinforcement. The reinforcement systems i.e., single layer placed at top (T), middle (M) and bottom (B), and double layers placed at top-middle (T-M), top-bottom (T-B), and middle-bottom (M-B) and three layers placed at top-middle-bottom of CBR sample. The CBR test was carried out for both un-soaked and soaked conditions to identify the most efficient geotextile reinforcement system for SC type of soil. The effectiveness of woven geotextile is governed by the no of layers used and the position of the layer. Test results shows that placing geotextile at top of the soil sample gives the most effective results. Test results shows that single layer of geotextile and double layer of geotextile also increases the bearing capacity of soil subgrade and ultimately, overall structural stability of the subgrade increases.

Pavani A. et al. (2016) in their work studied on sub-grade soil to increase the CBR value by using jute with bitumen coated/polythene sheets. Index properties of the soil are determined. They found that the CBR value of soil increases from 2.52% to2.79% as the Jute Geotextile sheet is placed in the soil at 1/3rddepth of mould from top. As the number of JGT sheet increases, the CBR value increases further from 2.79% to 6.5% and load taken by soil for same penetration of plunger increases due to increase in resistance of soil. The Soaked CBR value of soil increases from 2.52% to 7.36% when three layers of jute coated with bitumen is used due to increase in tensile strength of jute when coated with bitumen. The Soaked CBR value increases from 6.17% when 1 sandwich layer of polythene and jute are placed to 6.96% when 3 layers are used.

Saikia B. D. and Synrem S. D. (2017) conducted various laboratory tests to determine feasibility of Brahmaputra River sand reinforced by Coconut coir mat in terms of CBR values. Coir mats were placed at 1cm, 2cm, 3.2cm and 4.2cm depths from top at different mould-plunger (D/d) ratio. Soils were compacted (statically) with the help of a hydraulic jack of capacity 5 t/cm2. They observed that CBR values of the soil have been improved up to 81.67% for unsoaked condition and 213.41% for soaked condition when the position of reinforcement was placed at 1cm from the top surface.

Tharun A. and Kumar P.M.S.S. (2017) described the performance of nonwoven geo-textile, interfaced between soft sub-grade and unbound gravel in an unpaved flexible pavement system, utilizing the California Bearing Ratio (CBR) testing arrangement. In order to evaluate the performance of the reinforcement the CBR load – penetration graphs were drawn. The relation of both soft sub-grade soil and soft sub-grade geo-textile soil separately. Soil properties and variations of load carrying capacity is found using CBR Tests. Optimum percentage of fibres and optimum size of geotextile is also found using CBR Test. They prepared the CBR test specimens by applying modified compaction efforts to unmixed and mixed clayey soil at their respective optimum moisture content (OMC) obtained in the compaction tests. Two types of tests were run, unsoaked and soaked. The soil is added with different ratios of coconut coir from 0% to 1%. The main parameters that are studied include C.B.R. The numbers of curves are placed. The improvement in load carrying capacity of the sub-grade soil was identified by using the CBR test. The coir fibre length varies from 0.5cm to 3cm and the optimum fibre length obtained was 1.5cm. The coir fibre percentage varies from 0% to 1% and at 1% fibre content maximum load carrying capacity can be seen. It was found that the compressive strength of soil increases when treated with coir (fibre) up to 1%. The increase may be due to the increase in shear parameters. It was difficult to prepare the identical samples (at constant dry density) of reinforced soil beyond 1 % of fibre content and hence in the present study the maximum coir fibre content was considered to be 1 % by dry weight of soil.

Sasi Anu J. and Sai Aparna J. (2017) used woven coir geotextile and coir geocells as soil reinforcement to improve the subgrade soil and NaOH to treat the geotextiles. The soil used is kaoline clay. The improvement in CBR value when coir geotextile placed at different depth in CBR mould is studied. The coir geocells with an aspect ratio of 0.75, 1 and 1.33 is used. They placed the geotextile at 1/3H, 1/2H and 2/3H (H, height of mould from top) in the mould and CBR values are determined. The maximum improvement in CBR value is 4.7%, obtained when the geotextile is placed at 1/3H. Because when it is placed at 1/3H it is within the pressure bulb. When the geotextile is placed at 1/2H as it is nearer to the pressure bulb the CBR value is increased and the value is 4.26%. There is not much increase in CBR value when it is placed at 2/3H because it is at a greater depth from pressure bulb. The CBR value of treated coir geotextile for soaked and unsoaked condition were also found out and the improvement in CBR value was noted. The increase in CBR value for treated reinforcement is 7.99% when it is placed at 1/2H. For soaked soil samples the CBR value is increased compared to unreinforced soil samples. The maximum value is obtained when the reinforcement is placed at 1/H and the maximum value is 3.99% for untreated soil samples and 4.79% for treated soil samples.

Ogundare D.A. et al. (2018) compared stabilization of two soil samples (lateritic and clay) using geotextile as reinforcement. They conducted Particle size analysis, Atterberg Limit test, moisture content, specific gravity, Compaction test and California Bearing Ratio test. CBR test were conducted with and without non-woven geotextiles with the non-woven geotextiles placed at depths H/4 from the top and base surfaces of the soil in single layer under unsoaked conditions to determine the strength of the soil samples. The result showed that the strength of the soil samples increased by introducing non-woven geotextile in the soil as the one placed at depth H/4 from the base surface showed higher CBR values (15.1% and 19.6%) than when placed at depth H/4 (14.1% and 18.2%) from the top surface. The experimental results give a clear indication that the presence of geotextiles increases the CBR value of the soil.

Shashikala et al. (2018) utilized coconut coir fibre for improving sub grade strength characteristics of clayey sand. In the paper, they conducted an experimental study to improve the strength of soil by reinforcing the soil by means of non-woven randomly distributed Coconut Coir Fibre (CCF). CCF was added to the soil in varying percentages of 0.3%, 0.6%, 0.9%, 1.2% and 1.5% and in varying lengths of 1cm, 2cm, 3cm, 4cm and 5cm, to determine the optimum percentage and optimum length of CCF at which maximum strength of soil was observed in Unconfined compression test and soaked CBR test. From the experimental results, it was observed that soil with 1.2 % CCF of length varying from 2cm to 3cm showed maximum increase in unconfined compressive strength of 43.2 % and 47.4 % respectively and soaked CBR value was found to increase by approximately four times that of unreinforced soil.

Ahamed S. et al. (2018) discussed the functions of nonwoven geotextiles and their effect on shear strength parameters (c&ϕ) of the soil. They prepared the soil for subgrade and mortar of stone dust and cement with ratio 3:1 for subbase. Four wooden moulds of length 30cm, width 10cm, height 30cm with an opening at top of the mould were used. For each type of soil two moulds were prepared, one is with geotextile and other is without geotextile. They conducted laboratory tests on two soil samples with and without using geotextiles and plotted the results. From the results it was clear that by the usage of non-woven geotextiles, the properties of the soil increases. Non-woven geotextiles worked effectively as the drainage and separation layers. They act as excellent filters in order to prevent piping.

Sani et al. (2020) performed compaction tests and Unconfined Compression tests to estimate the effect of rice husk ash admixed with treated sisal fibre on properties of lateritic soil as a road construction material. In this study, a number of California bearing ratio (CBR) tests were performed on expansive soil reinforced with randomly distributed jute fibres and. The effect of fibre length, fibre content and various percentages of fibres of different length mixed together were studied on CBR value of expansive soil.

Ramesh et al. (2019) performed California Bearing Ratio and Unconfined Compression tests on silty sand reinforced with basalt fibres and plastic PET bottles in the form of geocells to enhance the properties of silty soil as sub grade.

Terrasil Okeniyi, A.G. et al. (2020) examined the basic engineering and geotechnical properties of poor subgrade soil using woven Geotextile and nano chemical (Terrasil) to improve its strength. Experiments were carried out to investigate the application of Terrasil and inclusion of Geotextile on collected sample A (clay soil) and Sample B (sandy soil) under un-soaked conditions. Geotechnical test was conducted on the samples to determine natural moisture content, grain size analysis, Atterberg limit test, compaction and California bearing ratio test. CBR test were carried out by adding the Terrasil at varying proportion (2%, 4%, 6%,8%) and geotextile placement of 2/5 layer, 3/5layer and 4/5 layer of the compacted soil under the un-soaked conditions to determine the strength of the soil. The result shows that the addition of terrasil with geotextile increases the strength of soil and CBR value from 14% for clay and 26% at control for both clay and sandy soil samples respectively. At 4% terrasil dosage and 2/5 layer of geotextile placement distances from the base recorded the highest number of CBR values which are 22% and 36% of clay and sand respectively. The difference in the behaviour of the soil under un-soaked conditions improved on increasing the percentage at 4% dosage of Terrasil with 2/5layer horizontal placement of terrasil.

Kumar S. et al. (2020) used randomly distributed jute fibres to improve geotechnical properties of expansive soil collected from South Delhi (India). California Bearing Ratio (CBR) tests were carried out on the expansive soil blended with jute fibres. Jute fibres of length 10 mm and 30 mm were included in different percentages viz. 0.25, 0.50, 0.75, 1.00, 1.25 and 1.50 by the dry weight of the soil. The test results indicate that the inclusion of randomly distributed jute fibres significantly improves the CBR value of the soil. The Optimum value of fibre content is found to be 1.25%. An improvement of 226.92% in CBR value of the reinforced soil as compared to unreinforced soil has been observed at the optimum jute fibre content.

In their study, naturally occurring black cotton soil from South Delhi (India) having 96% particle fraction finer than 75 microns and 64.5% that of 2 microns was taken. Soil was classified as highly plastic clay and designated as CH according to the Bureau of Indian Standard (BIS) Classification. Based on activity of soil, they concluded that the soil is a normally active and contains illite clay minerals. The methodology they have adopted is shown in figure 2.3.

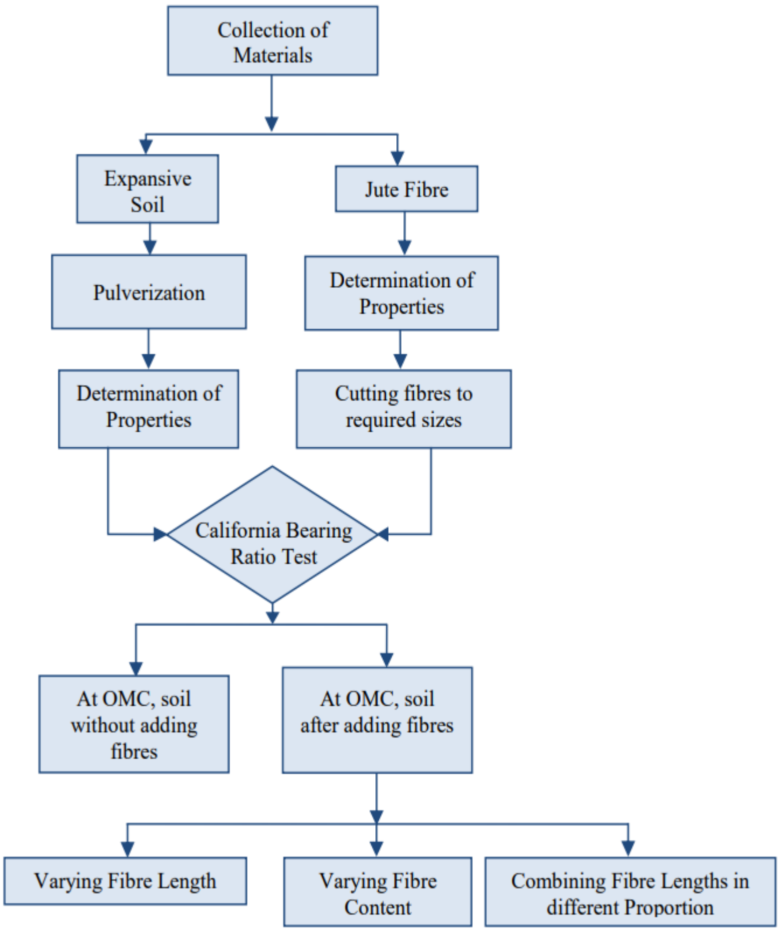

Figure 2.3: Flow Chart showing Methodology adopted by Kumar S. et al

A series of CBR tests were performed on unreinforced and randomly distributed fibre reinforced soil for this experimental study. The tests were conducted in unsoaked and soaked state in accordance with IS 2720 (Part 16). The mould used was a rigid metallic cylindrical in shape having inside diameter as 152 mm and height 178 mm. The matured soil specimen was filled in the mould in three layers having equal thickness. Each layer was compacted by giving 56 well distributed blows of a 26 N rammer dropped from a height of 310 mm. An electrically operated loading machine having a movable base which travels at a constant rate of 1.25 mm/minute to force a 50 mm diameter piston to penetration in to the soil specimen. The loads were carefully recorded as a function of penetration up to a total penetration of 12.5 mm on a pre-calibrated proving ring.

On the basis of laboratory investigations done by them, the California Bearing Ratio tests conducted on expansive soil reinforced with randomly distributed jute fibres, following conclusions were drawn:

- CBR value of expansive soil improved significantly with the inclusion of randomly distributed jute fibres.

- Jute fibre inclusion at 1.25% fibre content is found to give maximum CBR value for reinforced soil afterwards it decreases with increasing fibre content.

- CBR value of soil obtained in unsoaked condition is greater than in the soaked condition.

- CBR value of soil is higher at 4.93% when reinforced with fibres of aspect ratio 100 compared to 3.91% for fibres of aspect ratio 33.33 in soaked condition.

- Percentage increase in CBR value obtained for soil reinforced with 30 mm and 10 mm long fibres is 170.88 and 114.84 respectively compared to the unreinforced soil.

- At optimum fibre content, when reinforced with mix proportion p1 = 25 and p2 = 75 compared to unreinforced soil CBR value further increases to 5.95 in soaked condition and 226.92% increase in CBR value was obtained.

- The results of the study indicate that at 1.25% optimum fibre content soil reinforced with mix proportion p1 = 25 and p2 = 75 gives maximum improvement.

CHAPTER 3

METHODOLOGY & MATERIALS

3.1 GENERAL

In the present study the effect of geo-textile on sub-grade soil for road construction is carried out experimentally, utilising 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 layers of coir geotextile at different depths. To check the variation of both unsoaked and soaked CBR value coir geotextile is added to the soil during compaction. In the laboratory, the general soil index properties of the materials were determined in order to perform classifications. For this purpose, liquid limit, plastic limit, optimum moisture content and maximum dry unit weight of the specimens were determined according to Indian Standard specifications along with the strength tests. The test programme is divided into the following phases as depicted below:

1. Collection and preparation of soil sample.
2. Determination of physical properties of soil.
3. Determination of the CBR values using coconut husk as a waste material.
4. Determination of CBR value using coir geotextile in layers during compaction.
5. Determination of CBR value using coir geotextile at different depths to the soil.

3.2.1 Collection & Preparation of Soil Sample

About 100kg of soil was collected from kharghuli hill area at Malibagan. First an area was selected at site and from that soil was collected at a depth of 1ft to 1.5ft. All the excess material including stone, grass, leaves, vegetable roots and other organic materials are removed from the soil. Then the soil samples obtained from the field was taken to the laboratory and prepared by standard method before testing. The soil sample was air dried followed by pulverization and removable of any other excess material before testing. According to the IS Code method, the soil is allowed to dry in the room temperature.

3.2.2 Determination of Properties of Soil Sample

The following set of experiments are carried out:

1. Plastic Limit Test
2. Liquid Limit Test
3. Wet Sieve Analysis
4. Specific Gravity Test
5. Standard Proctor Test
6. California Bearing Ratio 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.

3.2.2.2 Determination of liquid limit by cone penetration method according to IS: 2720 (Part 5) 1985

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.

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 soil 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 4^0C. 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 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 densityas the ordinate, we can obtain the OMC and MDD.

3.2.2.6 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.

Figure 3.1: Base plate, collar, spacer disc, mould, 2.6 kg rammer, surcharge load 2.5 kg each used in California Bearing Ratio test

Figure 3.2: CBR testing machine (digital)

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 coarse filter paper is placed on the perforated base plate, the mould and the compacted soil is inverted and clamped to the base plate.

Figure 3.3: Test set up for California Bearing Ratio test

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 mm/min, load is applied into the soil. The load-penetration readings are taken corresponding to specified penetration of 0.5, 1.0, 1.5, 2.0, 2.5, 4.0, 5.0, 7.5, 10.0 and 12.5 mm as shown in the monitor. Corresponding to the penetration value of 2.5 and 5 mm the percentage CBR values of the soil specimens are recorded as well. At the end, the plunger was raised and 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 = P_T/P_S x 100

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

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

Table 3.1: Standard load used in CBR test

Penetration depth (mm)	Unit standard load (kg/cm^2)	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.

3.3 MATERIAL

3.3.1 Geotextile Material: Coconut Coir

In this study coconut coir is taken as the geotextile material to improve the CBR value of sub grade of road construction. Coconut coir is a biodegradable organic fibre material which is coarse, rigid and strong. The constituents of coconut coir have been found to be mostly cellulose and lignin. Coconut coir fibre is weather resistant and resistant to fungal and bacterial decomposition. The rate of decomposition of coconut coir is much less than any other natural fibre. These characteristics are attributed due to the high lignin content in the fibre.

First of all, the tests were carried out using coconut husk as a waste material to study its behaviour with soil as a mixture. About 20 kg of coconut husk is taken and air dried properly. The hard outer shell of the coconut husk is removed and then it was cut into uniform pieces of size of width 0.5cm and length 1cm with an aspect ratio of 0.5. The coconut coir was mixed with soil sample at a rate of 1%, 1.5%, 2% and 3% by weight of the soil sample for the particular test to be conducted.

Figure 3.4: Preparation of Coconut Husk **Figure 3.5:** Mixing of Coconut husk with Soil

Figure 3.4 and Figure 3.5 shows coconut husk cut into uniform pieces and mixing with soil thoroughly to perform different set of experiments.

A woven coir geotextile sheet of size 200cm×100cm was purchased and prepared for CBR test. The sheet was cut into circular pieces of diameter of 150 mm. The geotextile sheet was placed at various layers in the CBR mould and compaction was done. At first the prepared geotextile sheet was placed at layers of H/3, 2H/3, H/2 and in two layers where H is the height of CBR mould (excluding the surcharge height). The CBR tests for both soaked and unsoaked condition was carried out. Again, the geotextile sheets were placed at different depths of 1cm, 2cm, 3cm and 4cm from the top of the mould and unsoaked and soaked CBR were done accordingly.

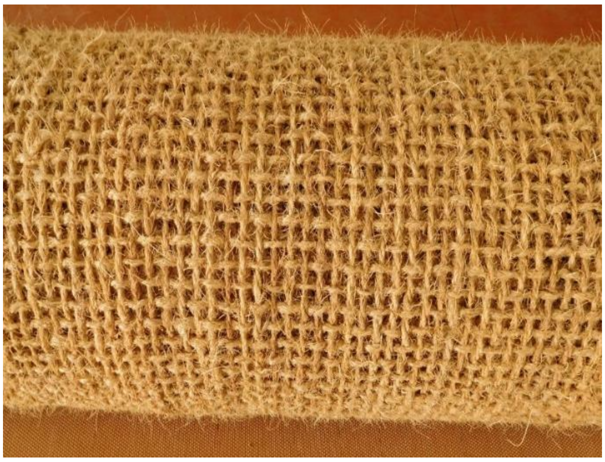

Figure 3.6: Coconut coir Geotextile sheet

Figure 3.7: Placement of geotextile sheet in CBR mould

3.3.2 Properties of the materials used

- Mass per unit area: 760.59 g/m^2
- Grade/Type/Class: 700 gsm (grams per sqm)
- Thickness at 2kPa: 9.21 mm
- Mesh size: 11.37mm×13.8mm
- Break load: 14.36 kN/m
- Peak load: 14.41 kN/m
- Tensile Strength: 30 kN/m

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 29.31%

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 & Penetration is shown in Figure 4.1.

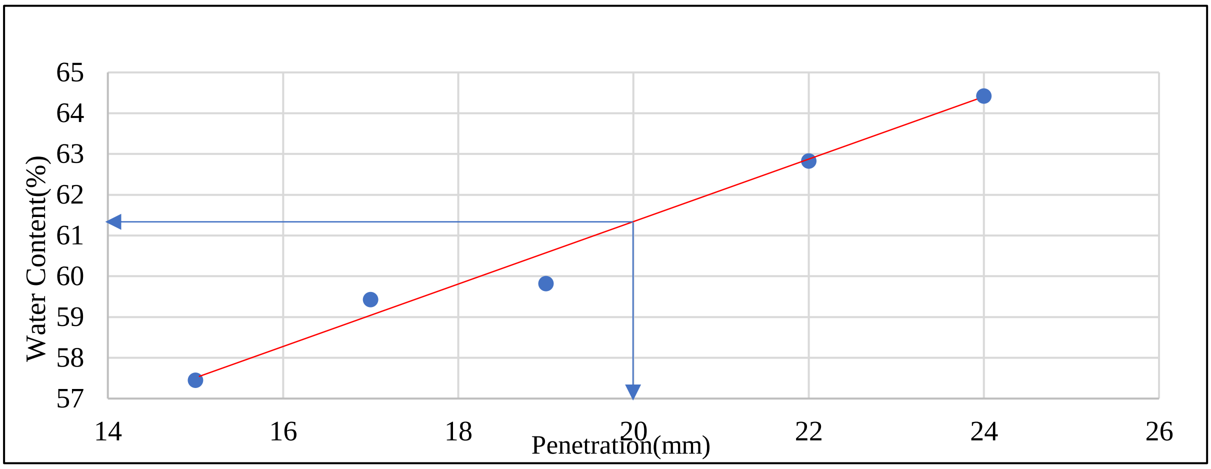

Figure 4.1: Water Content (%) vs Penetration(mm)

From the graph, the Liquid Limit of the soil is found to be 61.24%.

Hence, Plasticity Index= LL-PL=31.93%.

From the result, we can conclude that the type of soil is CH (Clay with High Plasticity).

4.1.3 Particle Size Distribution

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

Table 4.1: Particle size distribution of the soil sample

Sl No	Sieve Size (mm)	Retained	% Retained	Cumulative % Retained	% Finer
1	10	0	0	0	100
2	4.75	0	0	0	100
3	2	0.57	0.28	0.28	99.72
4	1.18	4.95	2.48	2.76	97.24
5	0.6	7.11	3.56	6.32	93.68
6	0.425	7.19	3.60	9.92	90.08
7	0.3	11.85	5.93	15.85	84.15
8	0.15	19.51	9.75	25.60	74.40
9	0.075	7.67	3.83	29.43	70.57
				% Finer	70.57

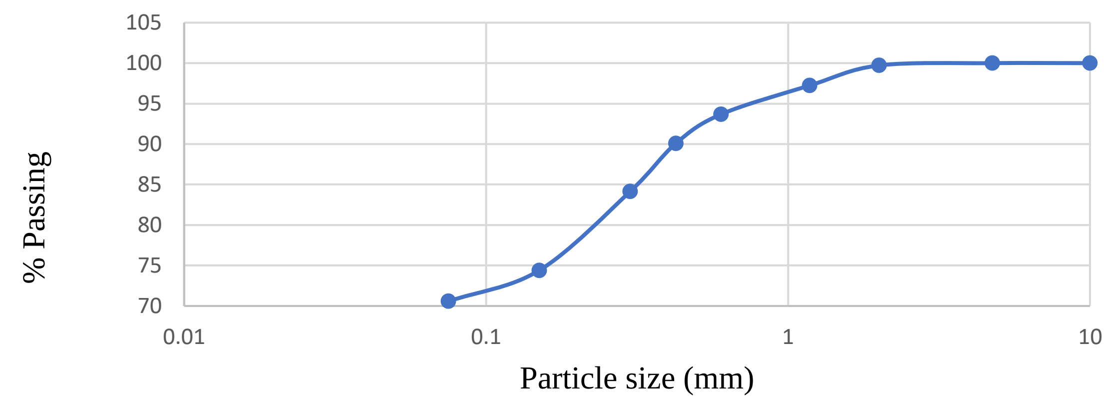

Figure 4.2: Gradation Curve for Soil Sample

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 is found to be 2.65.

4.1.5 Proctor Compaction test

The standard Proctor's 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 4.3 shows Dry Density vs Water Content graph for normal soil i.e., soil with 0% additives.

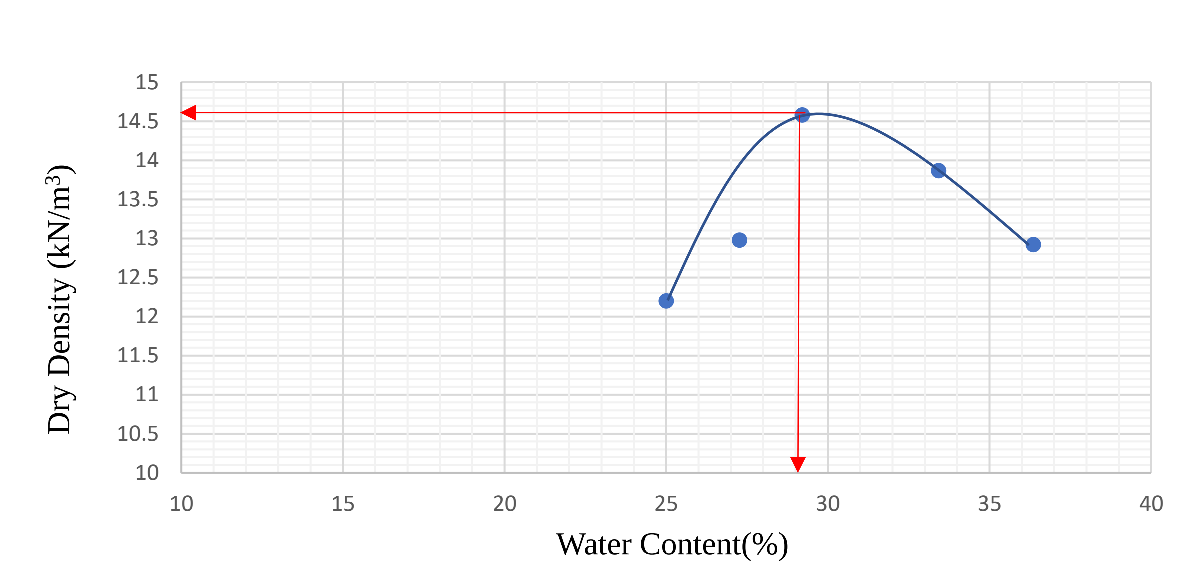

Figure 4.3: Dry Density vs Water Content

From the graph, the Optimum Moisture Content of the soil sample is 29 and the Maximum Dry Density is found to be 14.6 kN/m^3

4.1.6 California Bearing Ratio (Unsoaked Condition)

The California Bearing Ratio for the soil sample for unsoaked and soaked condition is determined as per IS: 2720 (Part 16) 1987. Table 4.2 shows the results of California Bearing Test for the normal soil sample in unsoaked condition.

Table 4.2: California Bearing Test results for the soil sample (Unsoaked)

Penetration (mm)	Load (kN)	Load (kg)
0	0	0
0.5	0.929	94.8
1	1.154	151.3
1.5	1.301	167.2
2	1.456	182.5
2.5	1.579	198.5
3	1.748	207.4
4	2.064	234.9
5	2.307	252.4
7.5	2.847	290.4
10	3.411	347.8
12.5	3.84	391.6

The load vs penetration graph for the normal soil sample in unsoaked condition is shown in Figure 4.4.

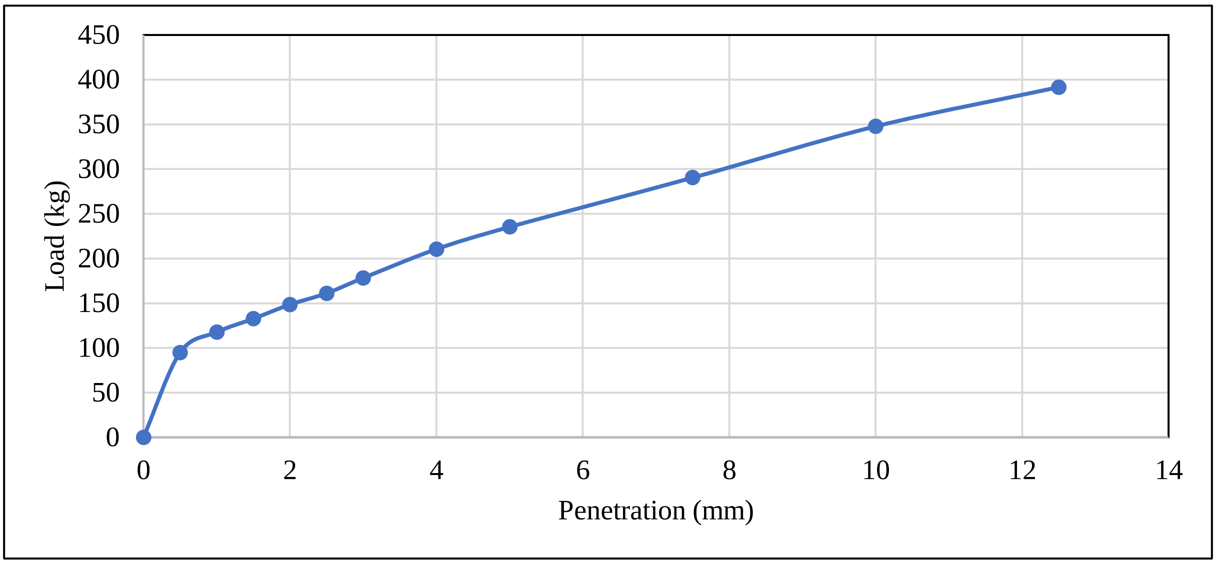

Figure 4.4: Load vs Penetration Graph (CBR test unsoaked condition)

From the test we have obtained that, 2.50 mm C.B.R Value % =11.76 and

5.00 mm C.B.R Value % = 11.45

4.1.7 California Bearing Ratio (Soaked Condition)

Table 4.3 shows the results of California Bearing Test for the soil sample in 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	0.1	10.2
1	0.155	15.8
1.5	0.209	21.3
2	0.266	27.1
2.5	0.317	32.3
3	0.367	37.4
4	0.481	49
5	0.593	60.5
7.5	0.818	83.4
10	1.001	102.1
12.5	1.124	114.6

The load vs penetration graph for the normal soil sample in soaked condition is shown in Figure 4.5

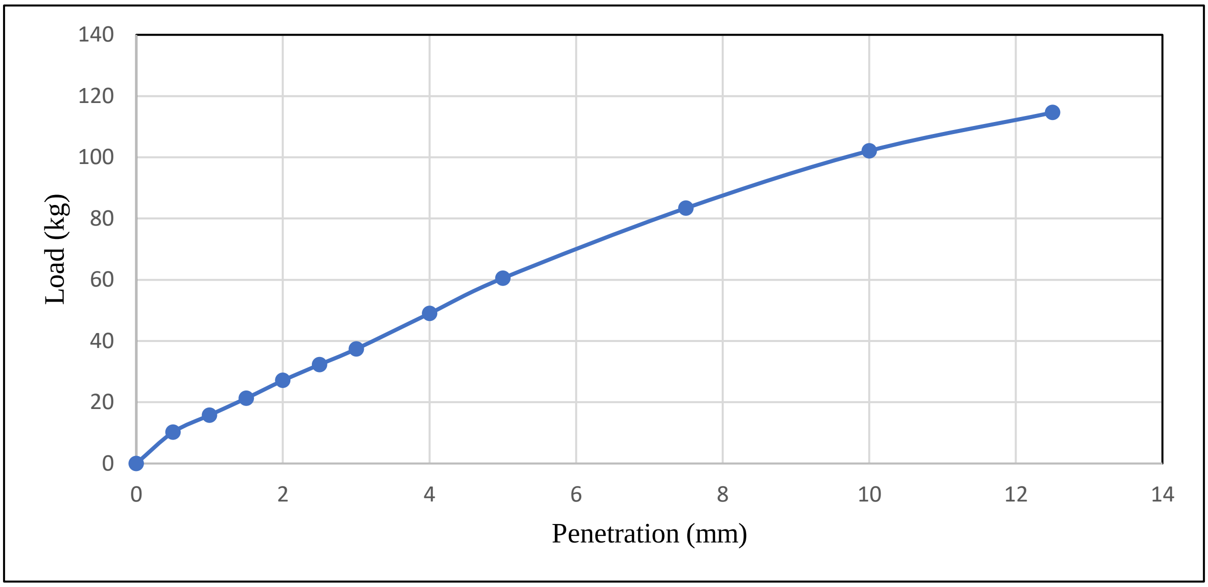

Figure 4.5: Load vs Penetration Graph (CBR test soaked condition)

From the test we have obtained that, 2.50 mm C.B.R Value % =2.36 and

5.00 mm C.B.R Value % = 2.94

The experimental results obtained for normal soil is summarized below:

- Plastic Limit: 29.31%
- Liquid Limit: 61.24%
- Plasticity Index: 31.93%
- Type of soil: CH (Clay with High Plasticity)
- Specific Gravity: 2.65
- Optimum Moisture Content: 29%
- Maximum Dry Density: 14.6 kN/m^3
- California Bearing Ratio (Unsoaked Condition): 11.76
- California Bearing Ratio (Soaked Condition): 2.94

4.2 Experimental Observation of Soil mixed with 1% Coconut Husk Fibre

4.2.1 Proctor compaction test for soil mixed with 1% Coconut Husk Fibre

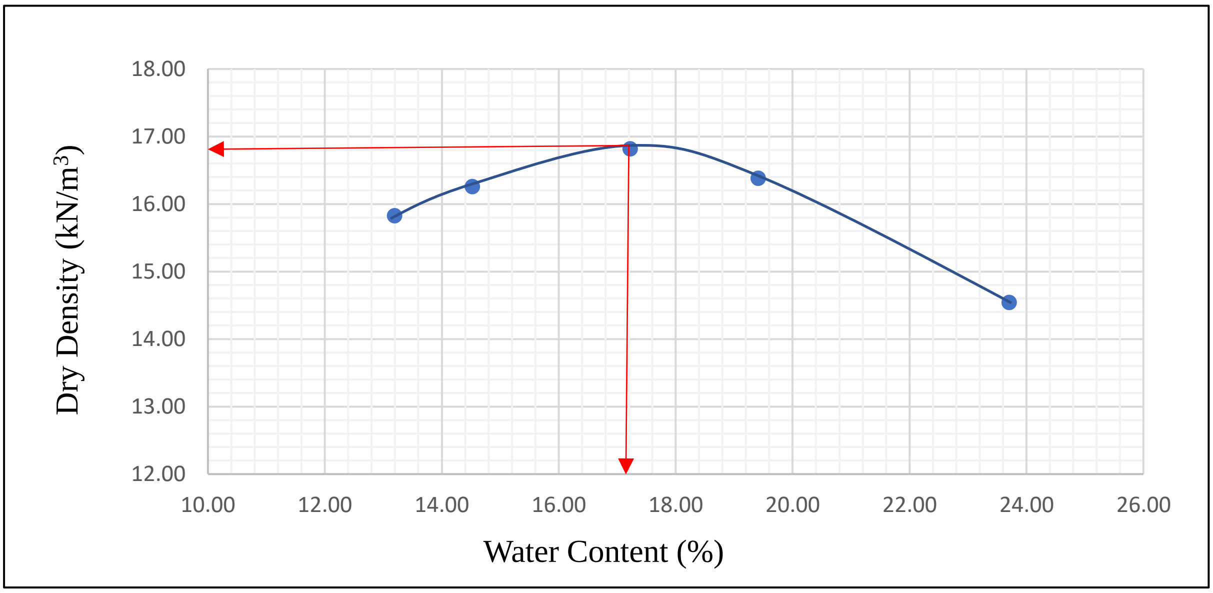

Figure 4.6: Dry Density vs Water Content (Soil mixed with 1% Coconut Husk Fibre)

From the graph, the Optimum Moisture Content of the soil mixed with 1% Coconut Husk Fibre e is 17.2 and the Maximum Dry Density is found to be 16.8 kN/m^3.

4.2.2 California Bearing Ratio test for soil mixed with 1% Coconut Husk Fibre (Unsoaked condition)

Table 4.4: California Bearing Test results for the soil mixed with 1% Coconut Husk Fibre (Unsoaked condition)

Penetration (mm)	Load (kN)	Load (kg)
0	0	0
0.5	0.612	62.4
1	1.025	104.5
1.5	1.316	134.1
2	1.545	157.5
2.5	1.744	177.8
3	1.956	199.4
4	2.307	235.2
5	2.612	266.3
7.5	3.264	332.9
10	3.838	391.4
12.5	4.347	443.3

The load vs penetration graph for the soil sample mixed with 1% coconut husk fibre in unsoaked condition is shown in Figure 4.7 below:

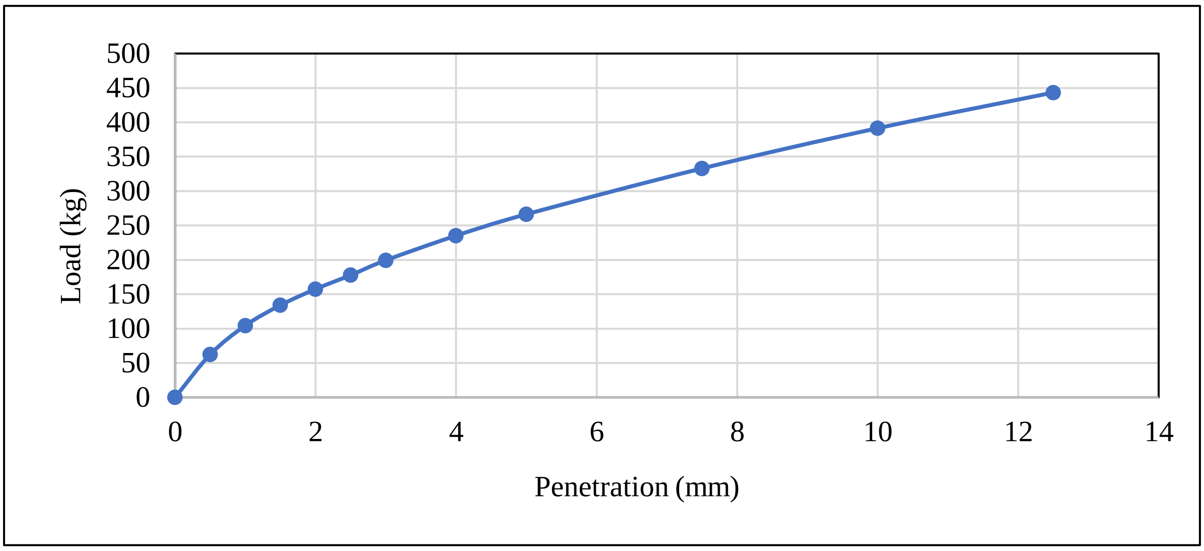

Figure 4.7: Load vs Penetration Graph (Soil mixed with 1% Coconut Husk Fibre in unsoaked condition)

From the test we have obtained that 2.50 mm C.B.R Value % =12.98 and

5.00 mm C.B.R Value % = 12.96

4.2.3 California Bearing Ratio test for soil mixed with 1% Coconut Husk Fibre (Soaked)

Table 4.5: California Bearing Test results for the soil mixed with 1% Coconut Husk Fibre (Soaked Condition)

Penetration (mm)	Load (kN)	Load (kg)
0	0	0
0.5	0.188	19.2
1	0.328	33.4
1.5	0.449	45.8
2	0.558	56.9
2.5	0.683	69.7
3	0.761	77.6
4	0.864	88.2
5	0.974	99.3
7.5	1.331	135.7
10	1.625	165.7
12.5	1.872	190.3

The load vs penetration graph for the soil sample mixed with 1% coconut husk fibre in soaked condition is shown in Figure 4.8 below:

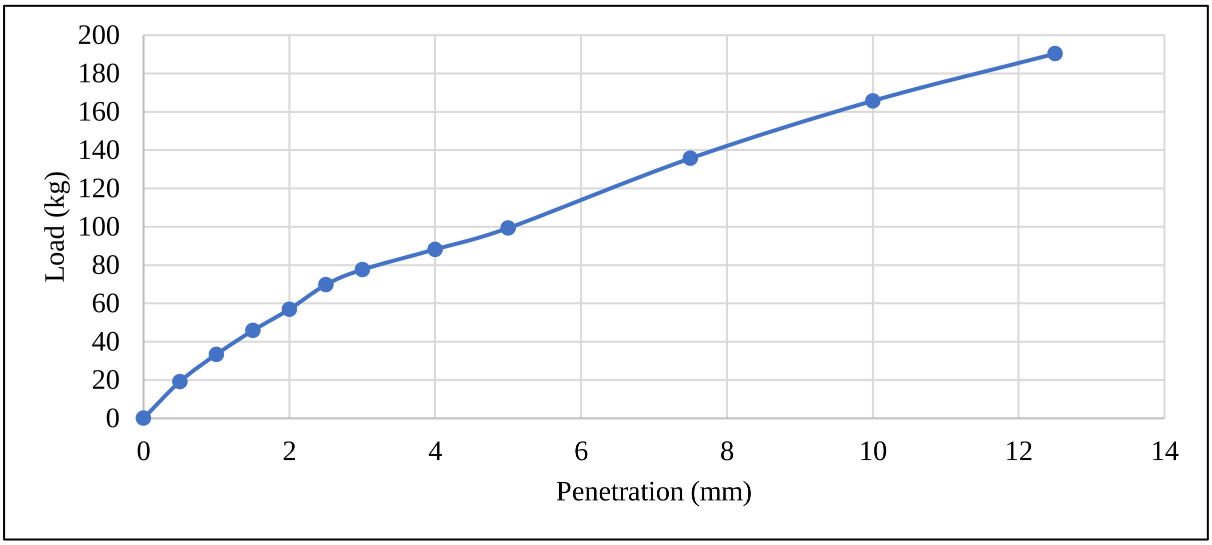

Figure 4.8: Load vs Penetration Graph (Soil mixed with 1% Coconut Husk Fibre in soaked condition)

From the test we have obtained that 2.50 mm C.B.R Value % =5.08 and

5.00 mm C.B.R Value % = 4.83

4.3 Experimental Observation of Soil mixed with 1.5% Coconut Husk Fibre

4.3.1 Proctor compaction test for soil mixed with 1.5% Coconut Husk Fibre

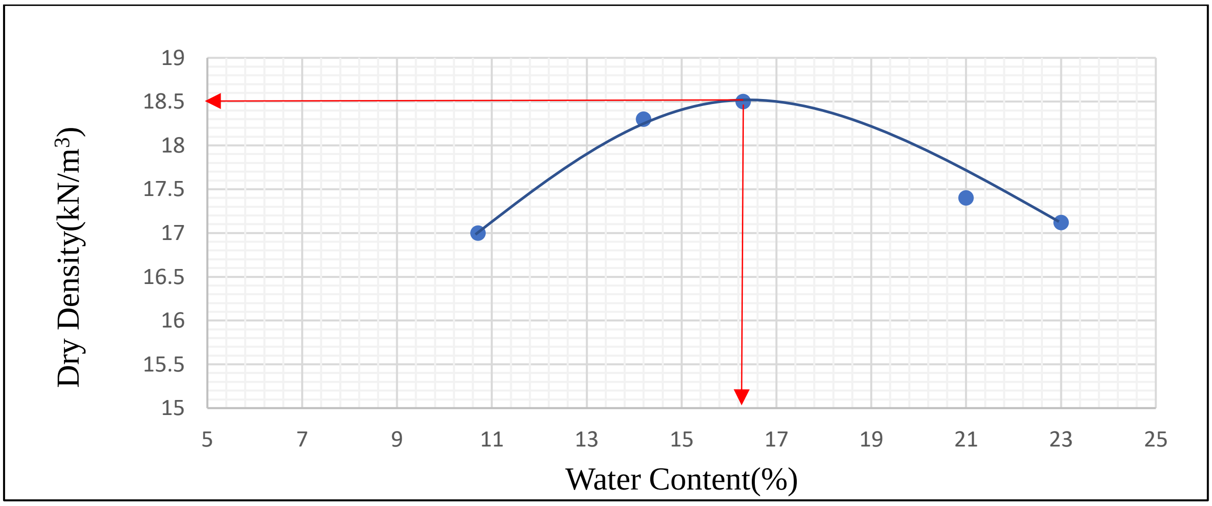

Figure 4.9: Dry Density vs Water Content (Soil mixed with 1.5% Coconut Husk Fibre)

From the graph, the Optimum Moisture Content of the soil mixed with 1.5% Coconut Husk Fibre is 16.2 and the Maximum Dry Density is found to be 18.5 kN/m^3.

4.3.2 California Bearing Ratio test for soil mixed with 1.5% Coconut Husk (Unsoaked)

Table 4.6: California Bearing Test results for the soil mixed with 1.5% Coconut Husk Fibre (Unsoaked condition)

Penetration (mm)	Load (kN)	Load (kg)
0	0	0
0.5	0.916	93.4
1	1.186	120.9
1.5	1.424	145.2
2	1.679	171.3
2.5	1.888	192.6
3	2.052	209.2
4	2.408	245.6
5	2.696	274.9
7.5	3.39	345.7
10	4.056	413.6
12.5	4.716	480.9

The load vs penetration graph for the soil sample mixed with 1.5% coconut husk fibre in unsoaked condition is shown in Figure 4.10 below:

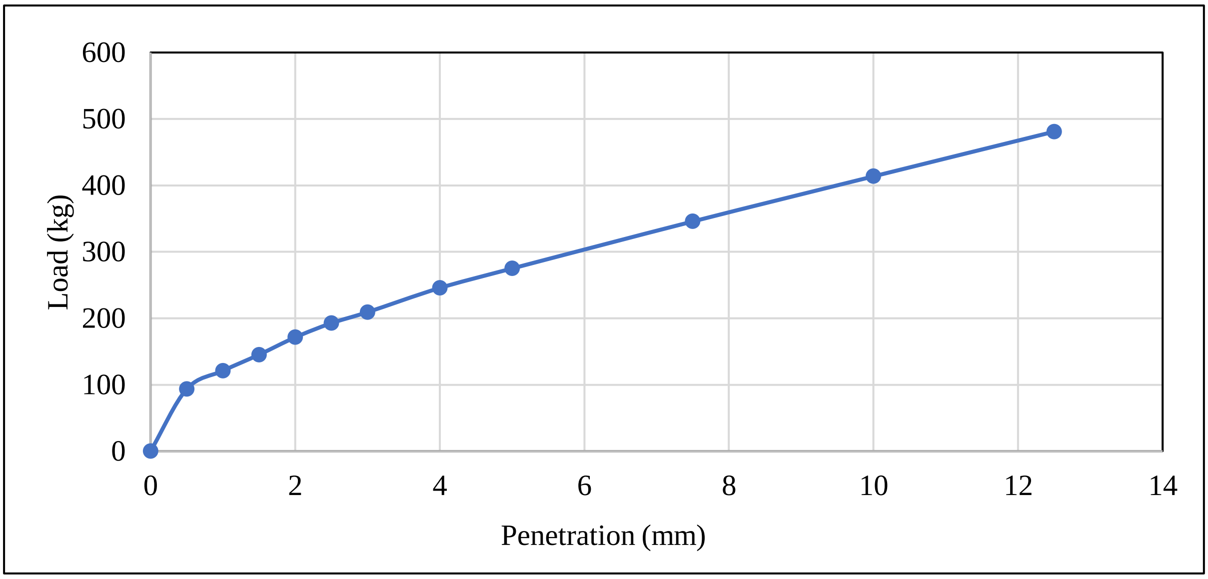

Figure 4.10: Load vs Penetration Graph (Soil mixed with 1.5% Coconut Husk Fibre unsoaked condition)

From the test we have obtained that, 2.50 mm C.B.R Value % =14.06 and

5.00 mm C.B.R Value % =13.38

4.3.3 California Bearing Ratio test for soil mixed with 1.5% Coconut Husk (Soaked condition)

Table 4.7: California Bearing Test results for the soil mixed with 1.5% Coconut Husk Fibre (Soaked condition)

Penetration (mm)	Load (kN)	Load (kg)
0	0	0
0.5	0.375	38.2
1	0.492	50.2
1.5	0.596	60.8
2	0.693	70.6
2.5	0.811	80.1
3	0.826	84.3
4	0.934	95.3
5	1.039	106.04
7.5	1.352	137.9
10	1.602	163.4
12.5	1.842	187.8

The load vs penetration graph for the soil sample mixed with 1.5% coconut husk fibre in soaked condition is shown in Figure 4.11 below:

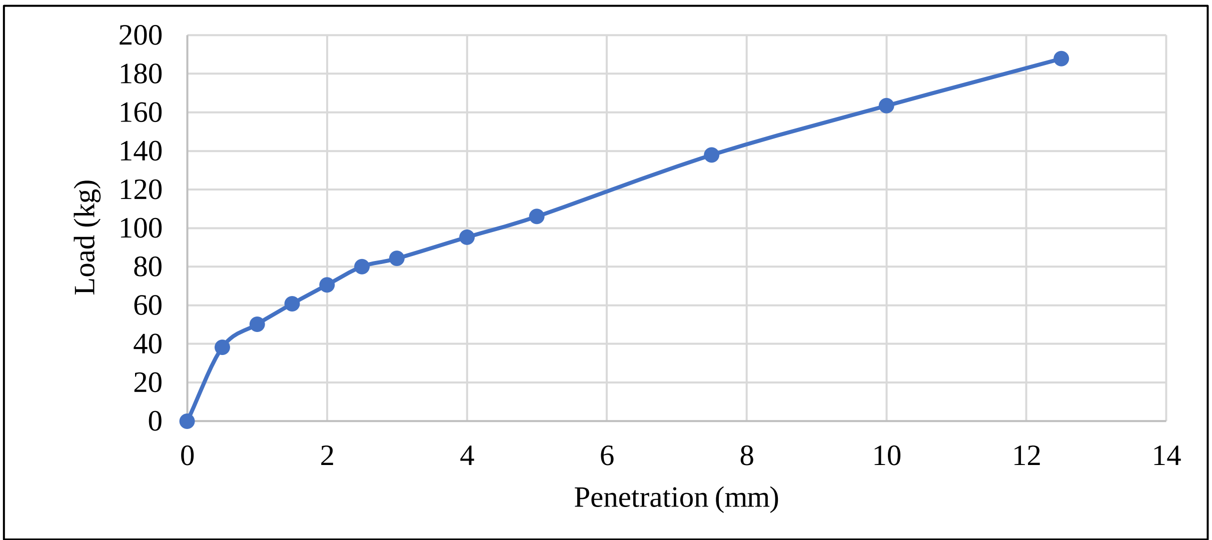

Figure 4.11: Load vs Penetration Graph (Soil mixed with 1.5% Coconut Husk Fibre in soaked condition)

From the test we have obtained that, 2.50 mm C.B.R Value % =5.85 and

5.00 mm C.B.R Value % =5.16

4.4 Experimental Observation of Soil mixed with 2% Coconut Husk Fibre

4.4.1 Proctor compaction test for soil mixed with 2% Coconut Husk Fibre

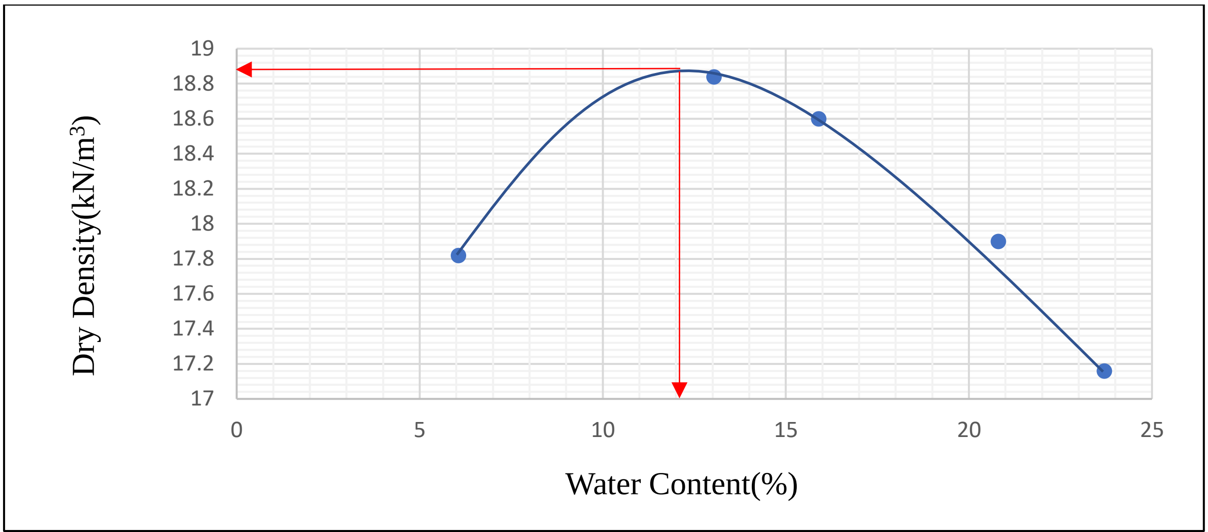

Figure 4.12: Dry Density vs Water Content (Soil mixed with 2% Coconut Husk Fibre)

From the graph, the Optimum Moisture Content of the soil mixed with 2% Coconut Husk Fibre is 12 and the Maximum Dry Density is found to be 18.84 kN/m^3 .

4.4.2 California Bearing Ratio test for soil mixed with 2% Coconut Husk Fibre (Unsoaked)

Table 4.8: California Bearing Test results for the soil mixed with 2% Coconut Husk Fibre (unsoaked condition)

Penetration (mm)	Load (kN)	Load (kg)
0	0	0
0.5	1.003	102.3
1	1.415	144.3
1.5	1.654	168.7
2	1.861	189.8
2.5	2.038	207.9
3	2.259	230.4
4	2.657	270.9
5	3.016	307.6
7.5	3.637	370.9
10	4.242	432.6
12.5	4.797	489.2

The load vs penetration graph for the soil sample mixed with 2% coconut husk fibre in unsoaked condition is shown in Figure 4.13 below:

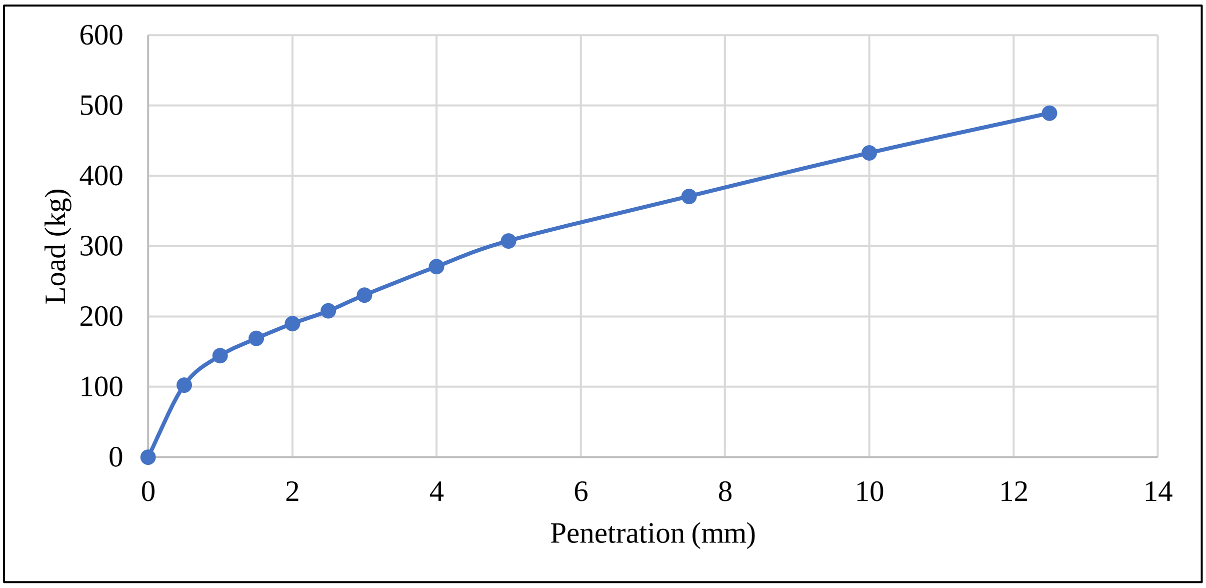

Figure 4.13: Load vs Penetration Graph (Soil mixed with 2% Coconut Husk Fibre in unsoaked condition)

From the test we have obtained that, 2.50 mm C.B.R Value % =15.18 and

5.00 mm C.B.R Value % =14.97.

4.4.3 California Bearing Ratio test for soil mixed with 2% Coconut Husk Fibre (Soaked)

Table 4.9: California Bearing Test results for the soil mixed with 2% Coconut Husk Fibre (soaked condition)

Penetration (mm)	Load (kN)	Load (kg)
0	0	0
0.5	0.389	39.7
1	0.585	59.7
1.5	0.732	74.7
2	0.844	86.1
2.5	0.942	96.1
3	1.028	104.8
4	1.173	119.6
5	1.299	132.5
7.5	1.562	159.3
10	1.764	179.9
12.5	1.959	199.7

The load vs penetration graph for the soil sample mixed with 2% coconut husk fibre in soaked condition is shown in Figure 4.14 below:

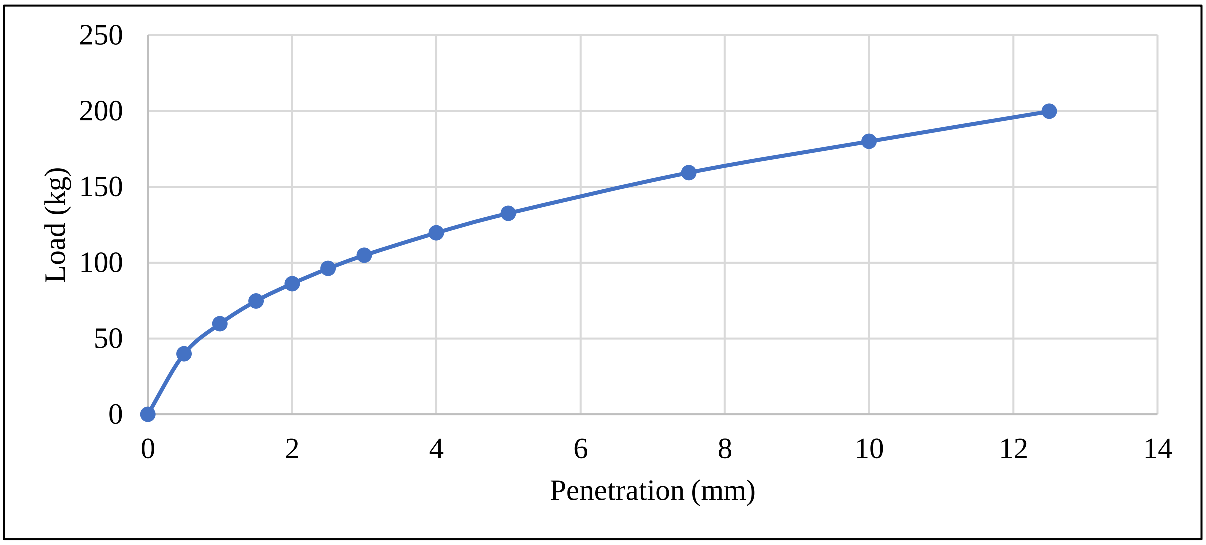

Figure 4.14: Load vs Penetration Graph (Soil mixed with 2% Coconut Husk Fibre in soaked condition)

From the test we have obtained that, 2.50 mm C.B.R Value % =7.01 and

5.00 mm C.B.R Value % =6.45

4.5 Experimental Observation of Soil mixed with 3% Coconut Husk Fibre

4.5.1 Proctor compaction test for soil mixed with 3% Coconut Husk Fibre

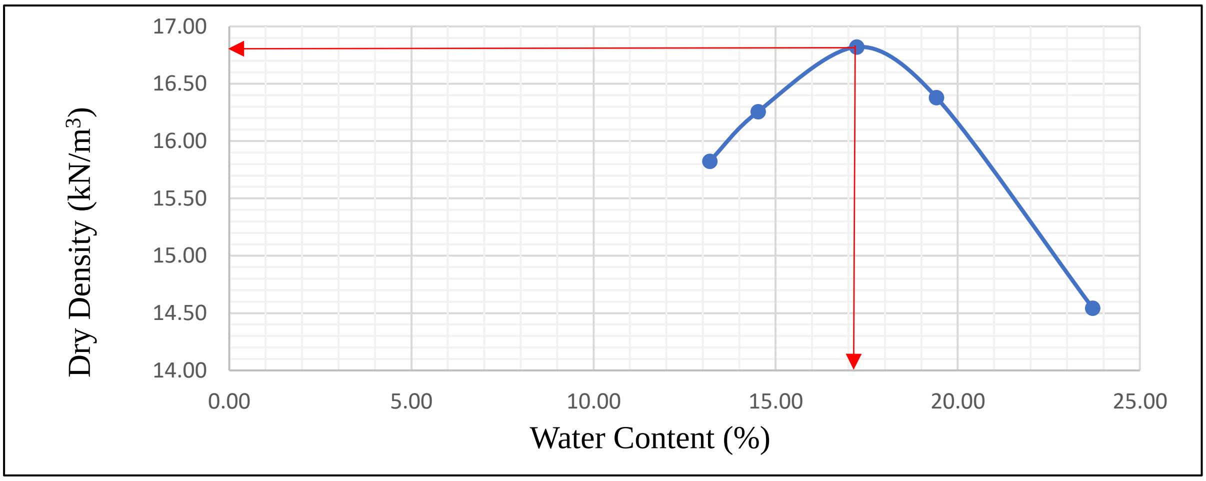

Figure 4.15: Dry Density vs Water Content (Soil mixed with 3% Coconut Husk Fibre)

From the graph, the Optimum Moisture Content of the soil mixed with 3% Coconut Husk Fibre is 17 and the Maximum Dry Density is found to be 16.8 kN/m^3.

4.5.2 California Bearing Ratio test for soil mixed with 3% Coconut Husk Fibre (Unsoaked)

Table 4.10: California Bearing Test results for the soil mixed with 3% Coconut Husk Fibre (unsoaked condition)

Penetration (mm)	Load (kN)	Load (kg)
0	0	0
0.5	0.851	86.8
1	1.076	109.7
1.5	1.306	133.2
2	1.515	154.5
2.5	1.787	182.2
3	1.983	202.2
4	2.388	243.5
5	2.743	279.7
7.5	3.360	342.6
10	3.910	398.7
12.5	4.419	450.6

The load vs penetration graph for the soil sample mixed with 3% coconut husk fibre in unsoaked condition is shown in Figure 4.16 below:

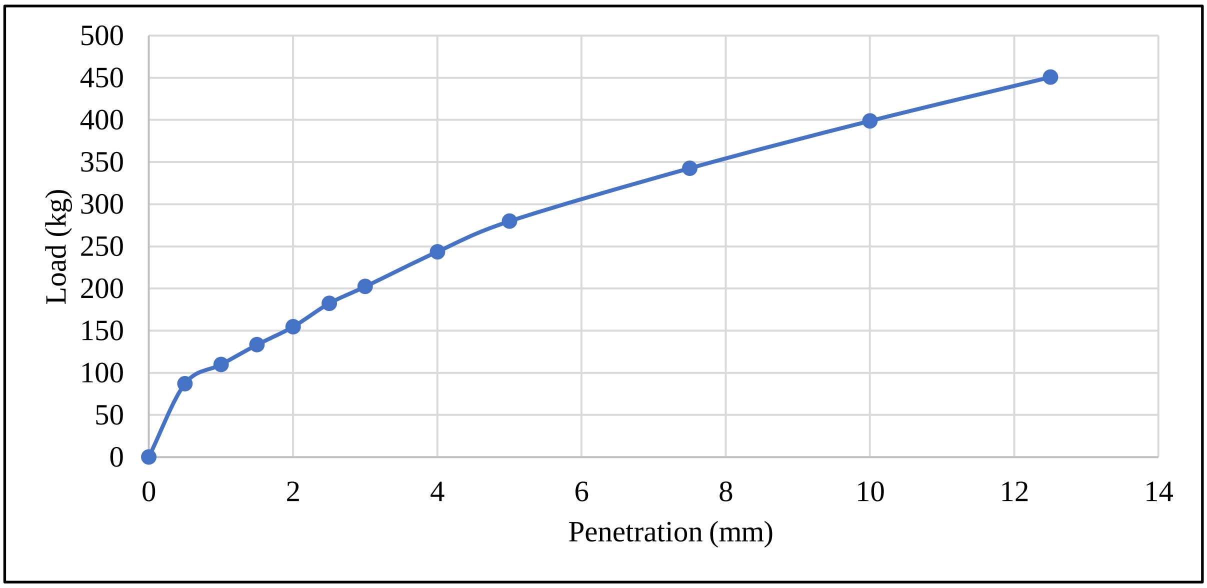

Figure 4.16: Load vs Penetration Graph (Soil mixed with 3% Coconut Husk Fibre in unsoaked condition)

From the test we have obtained that, 2.50 mm C.B.R Value % =12.3 and

5.00 mm C.B.R Value % =13.61

4.5.3 California Bearing Ratio test for soil mixed with 3% Coconut Husk Fibre (soaked)

Table 4.11: California Bearing Test results for the soil mixed with 3% Coconut Husk Fibre (soaked condition)

Penetration (mm)	Load (kN)	Load (kg)
0	0	0
0.5	0.191	19.5
1	0.323	32.9
1.5	0.432	44
2	0.527	53.7
2.5	0.612	62.4
3	0.689	70.3
4	0.846	86.3
5	0.993	101.3
7.5	1.298	132.4
10	1.584	161.5
12.5	1.865	190.2

The load vs penetration graph for the soil sample mixed with 3% coconut husk fibre in unsoaked condition is shown in Figure 4.17 below:

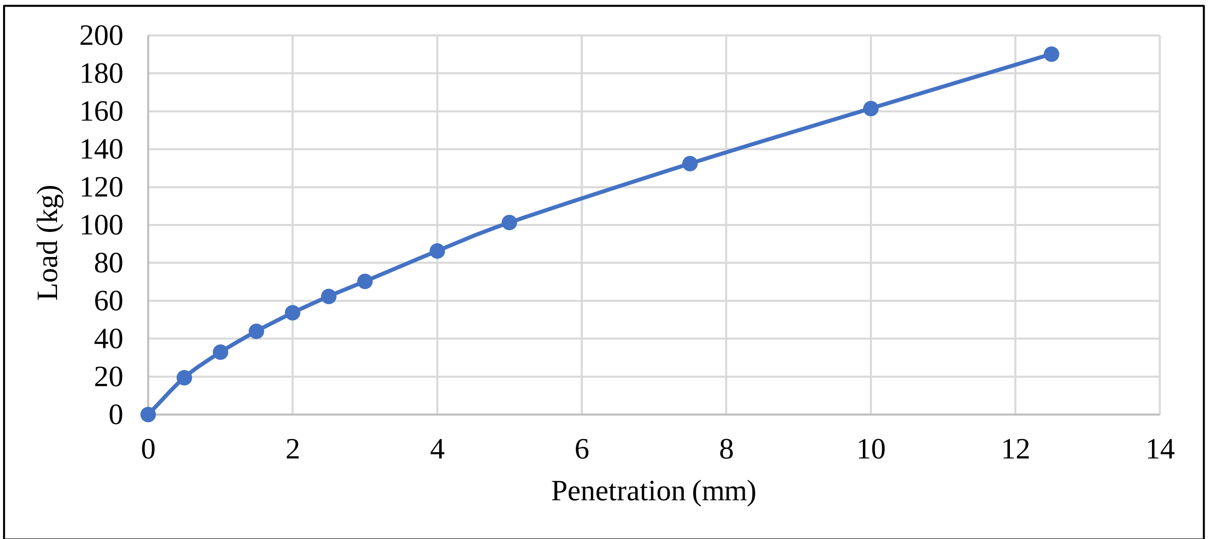

Figure 4.17: Load vs Penetration Graph (Soil mixed with 3% Coconut Husk Fibre in soaked condition)

From the test we have obtained that, 2.50 mm C.B.R Value % =4.56 and

5.00 mm C.B.R Value % =4.93

4.6 Experimental Observation of Soil when Coir Geotextile is added at different layers

4.6.1 California Bearing Ratio test for soil with coir geotextile placed at depth 1/3*H from the top surface (unsoaked)

Table 4.12: California Bearing Test results for the soil with coir geotextile placed at depth 1/3*H from the top surface (unsoaked condition)

Penetration (mm)	Load (kN)	Load (kg)
0	0	0
0.5	1.003	102.3
1	1.415	144.3
1.5	1.654	168.7
2	1.919	195.7
2.5	2.147	218.9
3	2.319	236.5
4	2.602	265.4
5	2.855	291.2
7.5	3.536	360.6
10	4.146	422.8
12.5	4.807	490.2

The load vs penetration graph for the soil with coir geotextile placed at depth 1/3*H from the top surface in unsoaked condition is shown in Figure 4.18 below:

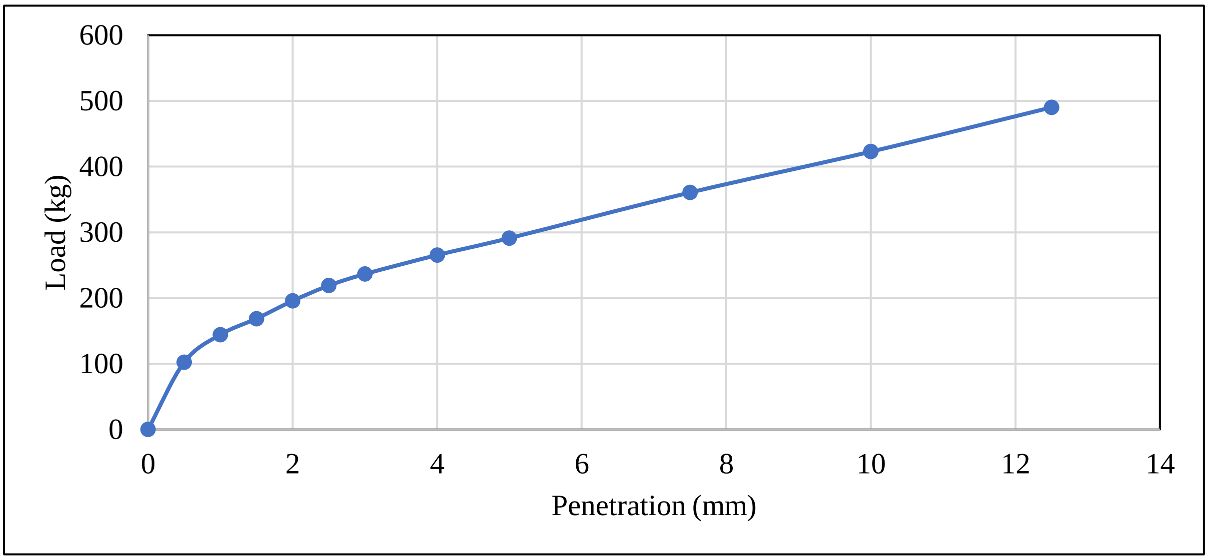

Figure 4.18: Load vs Penetration Graph (Soil with coir geotextile placed at depth 1/3*H from the top surface in unsoaked condition)

From the test we have obtained that, 2.50 mm C.B.R Value % =15.98 and

5.00 mm C.B.R Value % =14.17

4.6.2 California Bearing Ratio test for soil with coir geotextile placed at depth 1/3*H from the top surface (soaked condition)

Table 4.13: California Bearing Test results for the soil with coir geotextile placed at depth 1/3*H from the top surface (soaked condition)

Penetration (mm)	Load (kN)	Load (kg)
0	0	0
0.5	0.582	59.4
1	0.726	74
1.5	0.841	85.8
2	0.944	96.3
2.5	1.044	106.4
3	1.123	114.5
4	1.257	128.2
5	1.382	140.9
7.5	1.638	167
10	1.85	188.6
12.5	2.055	209.6

The load vs penetration graph for the soil with coir geotextile placed at depth 1/3*H from the top surface in soaked condition is shown in Figure 4.19 below:

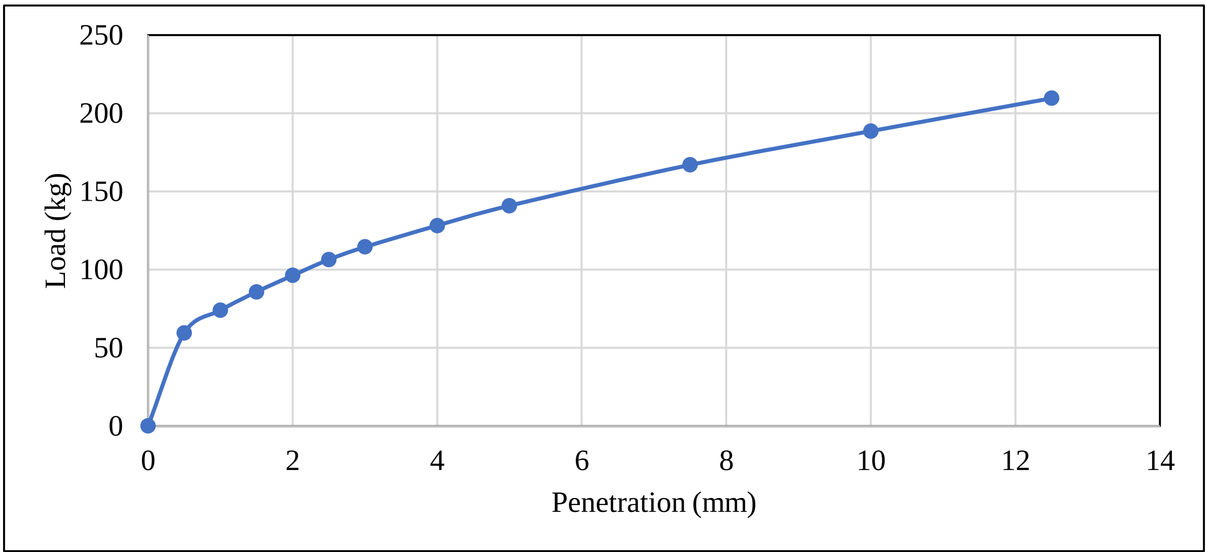

Figure 4.19: Load vs Penetration Graph (Soil with coir geotextile placed at depth 1/3*H from the top surface in soaked condition)

From the test we have obtained that, 2.50 mm C.B.R Value % =7.77 and

5.00 mm C.B.R Value % =6.86

4.6.3 California Bearing Ratio test for soil with coir geotextile placed at depth 1/2*H from the top surface (unsoaked)

Table 4.14: California Bearing Test results for the soil with coir geotextile placed at depth 1/2*H from the top surface (unsoaked condition)

Penetration (mm)	Load (kN)	Load (kg)
0	0	0
0.5	0.925	94.3
1	1.298	132.4
1.5	1.533	156.3
2	1.776	181.2
2.5	1.979	201.9
3	2.149	219.2
4	2.506	255.6
5	2.757	281.1
7.5	3.401	346.8
10	4.073	415.3
12.5	4.741	483.4

The load vs penetration graph for the soil with coir geotextile placed at depth 1/2*H from the top surface in unsoaked condition is shown in Figure 4.20 below:

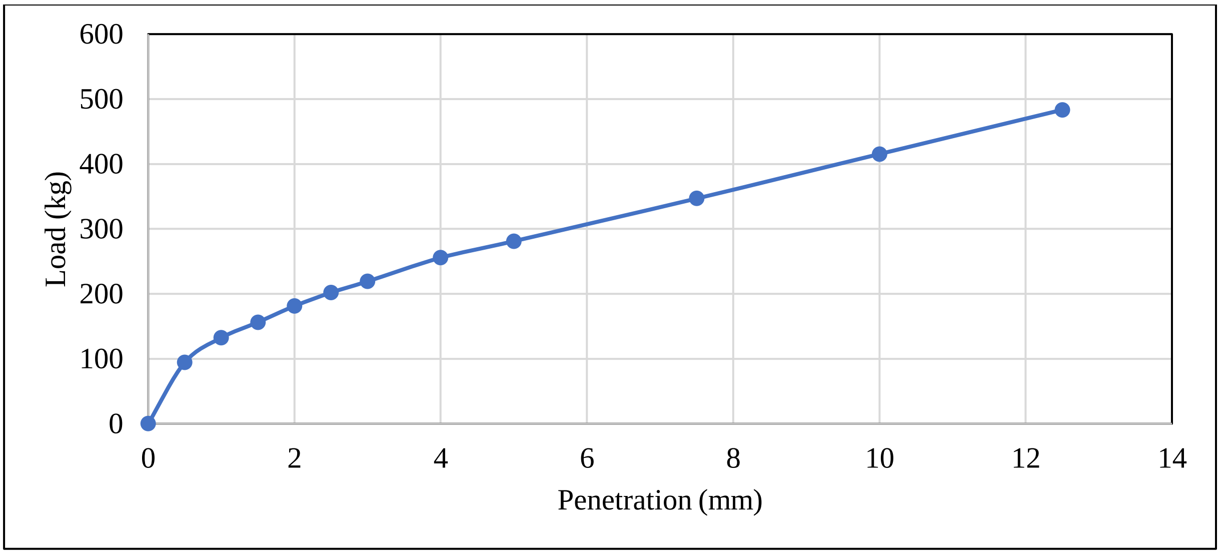

Figure 4.20: Load vs Penetration Graph (Soil with coir geotextile placed at depth 1/2*H from the top surface in unsoaked condition)

From the test we have obtained that, 2.50 mm C.B.R Value % =14.74 and

5.00 mm C.B.R Value % =13.68

4.6.4 California Bearing Ratio test for soil with coir geotextile placed at depth 1/2*H from the top surface (soaked)

Table 4.15: California Bearing Test results for the soil with coir geotextile placed at depth 1/2*H from the top surface (soaked condition)

Penetration (mm)	Load (kN)	Load (kg)
0	0	0
0.5	0.298	30.4
1	0.511	52.1
1.5	0.674	68.7
2	0.807	82.3
2.5	0.921	93.9
3	0.983	100.2
4	1.101	112.3
5	1.205	122.9
7.5	1.418	144.6
10	1.676	170.9
12.5	1.906	194.4

The load vs penetration graph for the soil with coir geotextile placed at depth 1/2*H from the top surface in soaked condition is shown in Figure 4.21 below:

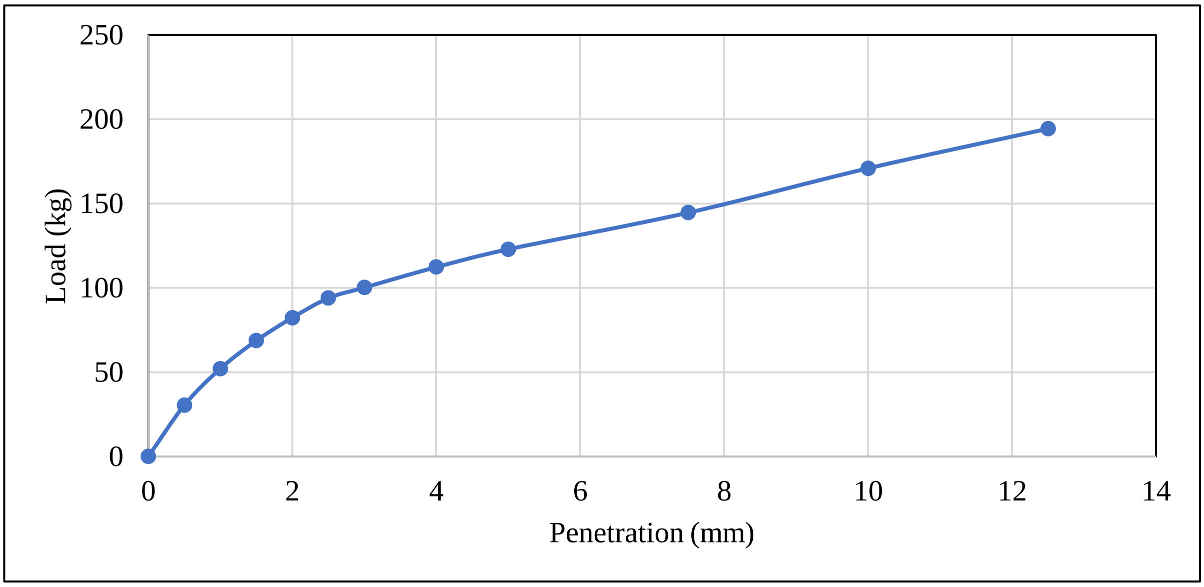

Figure 4.21: Load vs Penetration Graph (Soil with coir geotextile placed at depth 1/2*H from the top surface in soaked condition)

From the test we have obtained that, 2.50 mm C.B.R Value % =6.86 and

5.00 mm C.B.R Value % =5.98

4.6.5 California Bearing Ratio test for soil with coir geotextile placed at depth 2/3*H from the top surface (unsoaked)

Table 4.16: California Bearing Test results for the soil with coir geotextile placed at depth 2/3*H from the top surface (unsoaked condition)

Penetration (mm)	Load (kN)	Load (kg)
0	0	0
0.5	0.905	92.3
1	1.186	120.9
1.5	1.329	135.6
2	1.466	149.5
2.5	1.588	161.9
3	1.744	177.8
4	2.038	207.8
5	2.328	237.4
7.5	2.869	292.6
10	3.434	350.2
12.5	3.88	395.7

The load vs penetration graph for the soil with coir geotextile placed at depth 2/3*H from the top surface in unsoaked condition is shown in Figure 4.22 below:

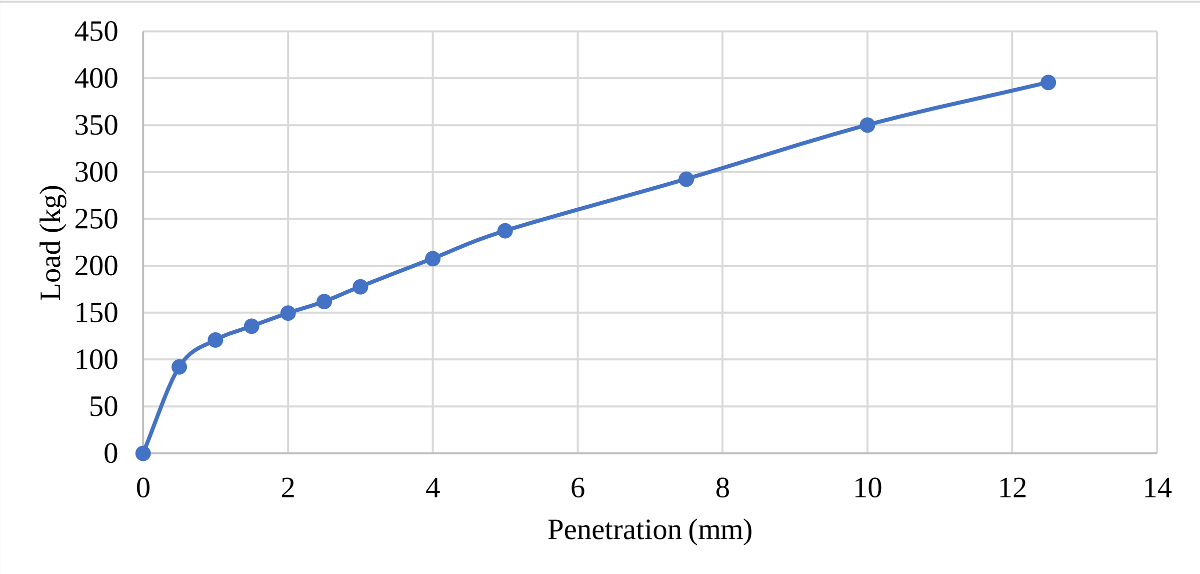

Figure 4.22: Load vs Penetration Graph (Soil with coir geotextile placed at depth 2/3*H from the top surface in unsoaked condition)

From the test we have obtained that, 2.50 mm C.B.R Value % =11.82 and

5.00 mm C.B.R Value % =10.26

4.6.6 California Bearing Ratio test for soil with coir geotextile placed at depth 2/3*H from the top surface (soaked)

Table 4.17: California Bearing Test results for the soil with coir geotextile placed at depth 2/3*H from the top surface (soaked condition)

Penetration (mm)	Load (kN)	Load (kg)
0	0	0
0.5	0.286	29.2
1	0.443	45.2
1.5	0.537	54.8
2	0.64	65.3
2.5	0.738	75.3
3	0.807	82.3
4	0.928	94.7
5	0.993	101.3
7.5	1.181	120.4
10	1.406	143.4
12.5	1.645	167.8

The load vs penetration graph for the soil with coir geotextile placed at depth 2/3*H from the top surface in soaked condition is shown in Figure 4.23 below:

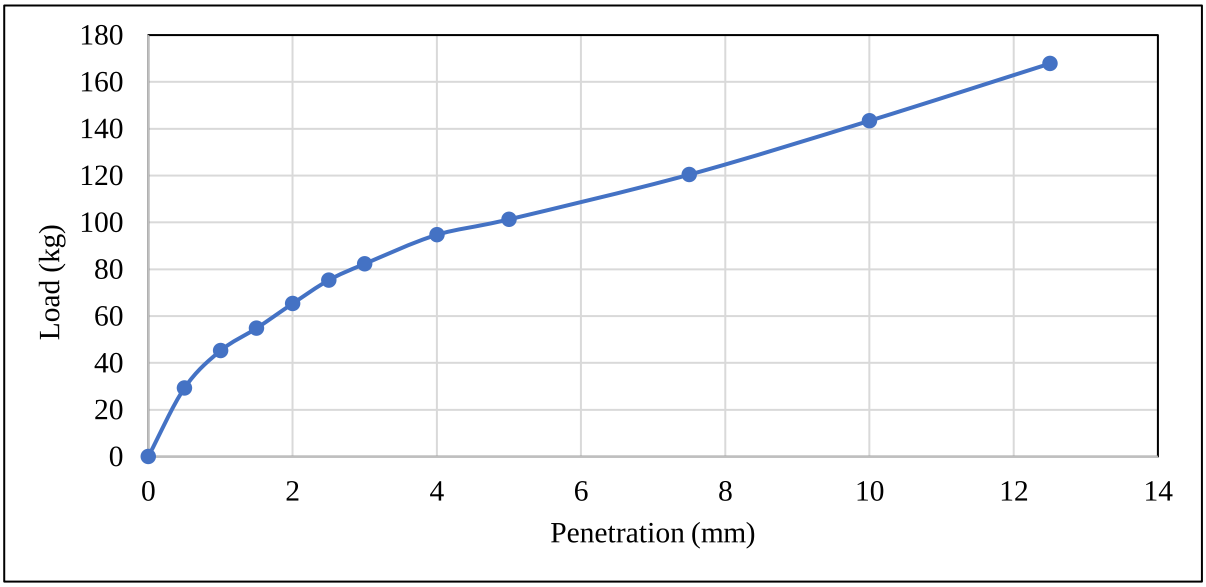

Figure 4.23: Load vs Penetration Graph (Soil with coir geotextile placed at depth 2/3*H from the top surface in soaked condition)

From the test we have obtained that, 2.50 mm C.B.R Value % =5.50 and

5.00 mm C.B.R Value % =4.93

4.6.7 California Bearing Ratio test for soil with coir geotextile placed at depth 1/3*H and 2/3*H from the top surface (unsoaked)

Table 4.18: California Bearing Test results for the soil with coir geotextile placed at depth 1/3*H and 2/3*H from the top surface (unsoaked condition)

Penetration (mm)	Load (kN)	Load (kg)
0	0	0
0.5	0.992	101.2
1	1.264	128.9
1.5	1.429	145.7
2	1.608	164
2.5	1.785	182.1
3	1.948	198.7
4	2.253	229.7
5	2.507	255.7
7.5	3.064	312.4
10	3.715	378.8
12.5	4.233	431.6

The load vs penetration graph for the soil with coir geotextile placed at depth 1/3*H and 2/3*H from the top surface in unsoaked condition is shown in Figure 4.24 below:

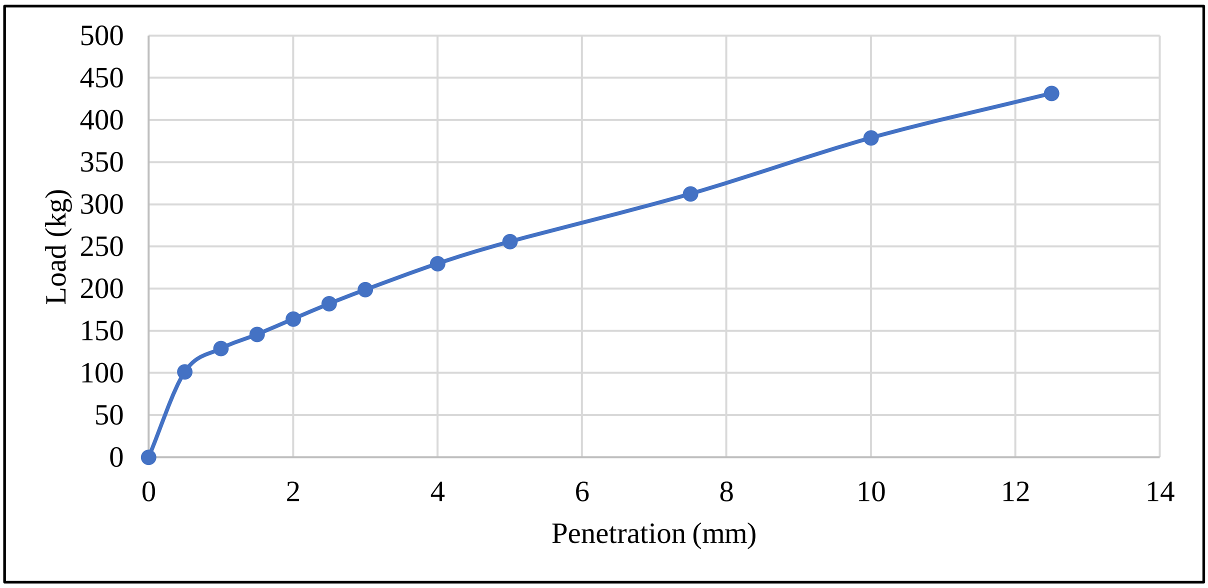

Figure 4.24: Load vs Penetration Graph (Soil with coir geotextile placed at depth 1/3*H and 2/3*H from the top surface in unsoaked condition)

From the test we have obtained that, 2.50 mm C.B.R Value % =13.29 and

5.00 mm C.B.R Value % =12.44

4.6.8 California Bearing Ratio test for soil with coir geotextile placed at depth 1/3*H and 2/3*H from the top surface (soaked)

Table 4.19: California Bearing Test results for the soil with coir geotextile placed at depth 1/3*H and 2/3*H from the top surface (soaked condition)

Penetration (mm)	Load (kN)	Load (kg)
0	0	0
0.5	0.375	38.2
1	0.492	50.2
1.5	0.596	60.8
2	0.693	70.6
2.5	0.792	80.8
3	0.881	89.8
4	1.039	105.9
5	1.18	120.3
7.5	1.467	149.6
10	1.702	173.5
12.5	1.886	192.3

The load vs penetration graph for the soil with coir geotextile placed at depth 1/3*H and 2/3*H from the top surface in soaked condition is shown in Figure 4.25 below:

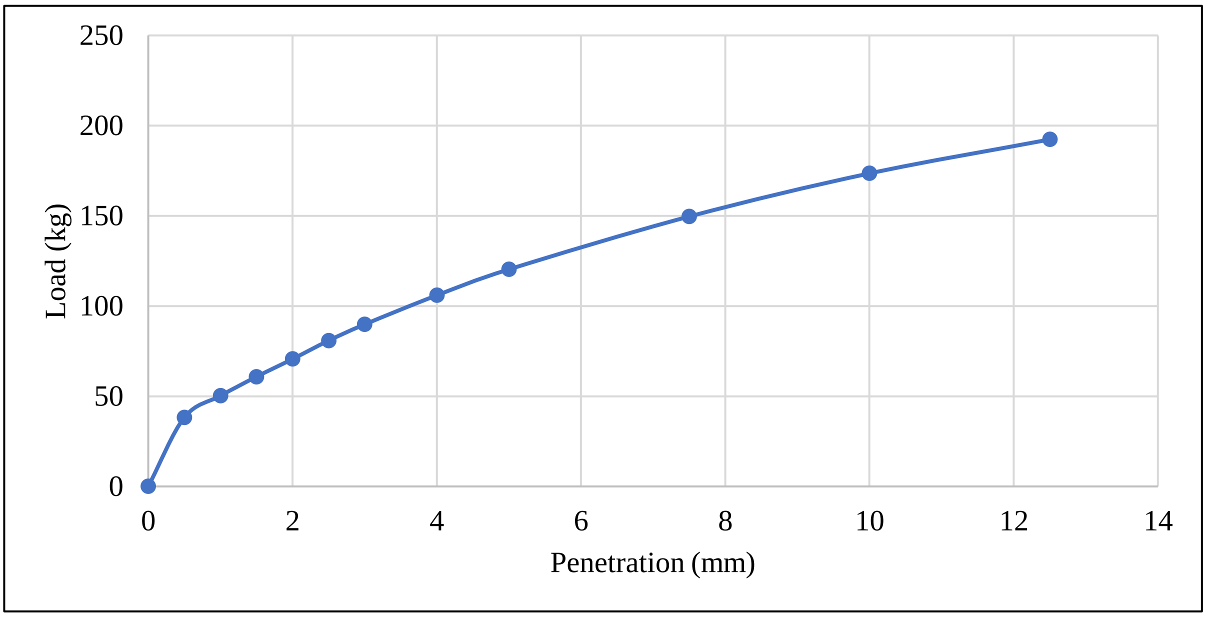

Figure 4.25: Load vs Penetration Graph (Soil with coir geotextile placed at depth 1/3*H and 2/3*H from the top surface in soaked condition)

From the test we have obtained that, 2.50 mm C.B.R Value % =5.90 and

5.00 mm C.B.R Value % =5.85

4.7 Experimental Observation of Soil when Coir Geotextile is added at different depths

4.7.1 California Bearing Ratio test for soil with coir geotextile placed at depth 1 cm from the top surface (unsoaked condition)

Table 4.20: California Bearing Test results for the soil with coir geotextile placed at depth 1 cm from the top surface (unsoaked condition)

Penetration (mm)	Load (kN)	Load (kg)
0	0	0
0.5	2.034	207.4
1	2.325	237.1
1.5	2.493	254.2
2	2.648	270
2.5	2.789	284.4
3	2.967	302.6
4	3.401	346.8
5	3.809	388.4
7.5	4.567	465.7
10	5.223	532.6
12.5	5.868	598.4

The load vs penetration graph for the soil with coir geotextile placed at depth 1 cm from the top surface in unsoaked condition is shown in Figure 4.26 below:

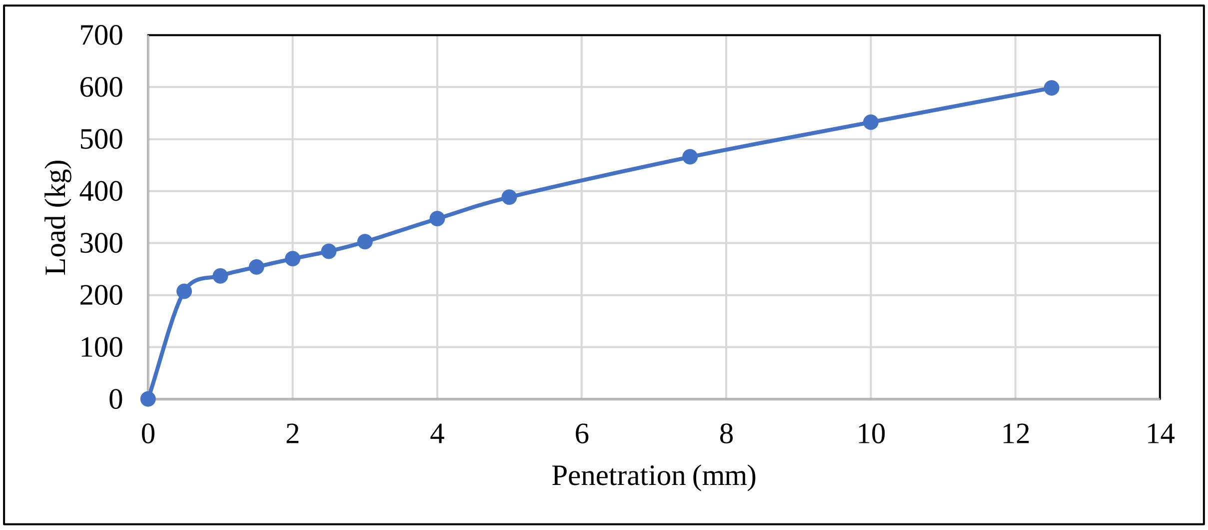

Figure 4.26: Load vs Penetration Graph (Soil with coir geotextile placed at depth 1cm from the top surface in unsoaked condition)

From the test we have obtained that, 2.50 mm C.B.R Value % =20.76 and

5.00 mm C.B.R Value % =18.90

4.7.2 California Bearing Ratio test for soil with coir geotextile placed at depth 1 cm from the top surface (soaked condition)

Table 4.21: California Bearing Test results for the soil with coir geotextile placed at depth 1 cm from the top surface (soaked condition)

Penetration (mm)	Load (kN)	Load (kg)
0	0	0
0.5	0.554	56.5
1	0.746	76.1
1.5	0.898	91.6
2	1.077	109.8
2.5	1.203	122.7
3	1.3	132.9
4	1.528	155.8
5	1.717	175.1
7.5	2.047	208.7
10	2.351	239.7
12.5	2.573	262.4

The load vs penetration graph for the soil with coir geotextile placed at depth 1 cm from the top surface in soaked condition is shown in Figure 4.27 below:

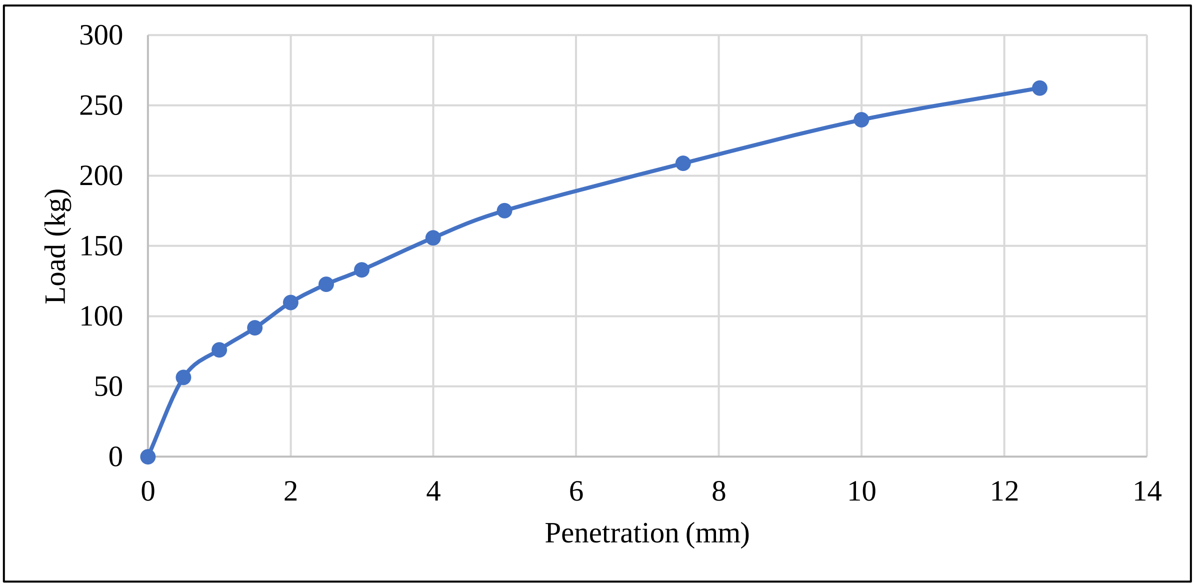

Figure 4.27: Load vs Penetration Graph (Soil with coir geotextile placed at depth 1cm from the top surface in soaked condition)

From the test we have obtained that, 2.50 mm C.B.R Value % =8.96 and

5.00 mm C.B.R Value % =8.52

4.7.3 California Bearing Ratio test for soil with coir geotextile placed at depth 2 cm from the top surface (unsoaked condition)

Table 4.22: California Bearing Test results for the soil with coir geotextile placed at depth 2 cm from the top surface (unsoaked condition)

Penetration (mm)	Load (kN)	Load (kg)
0	0	0
0.5	0.968	98.7
1	1.526	155.6
1.5	1.849	188.6
2	2.223	226.7
2.5	2.581	263.2
3	2.987	304.6
4	3.557	362.7
5	4.004	408.3
7.5	4.784	487.8
10	5.389	549.6
12.5	5.706	581.9

The load vs penetration graph for the soil with coir geotextile placed at depth 2 cm from the top surface in unsoaked condition is shown in Figure 4.28 below:

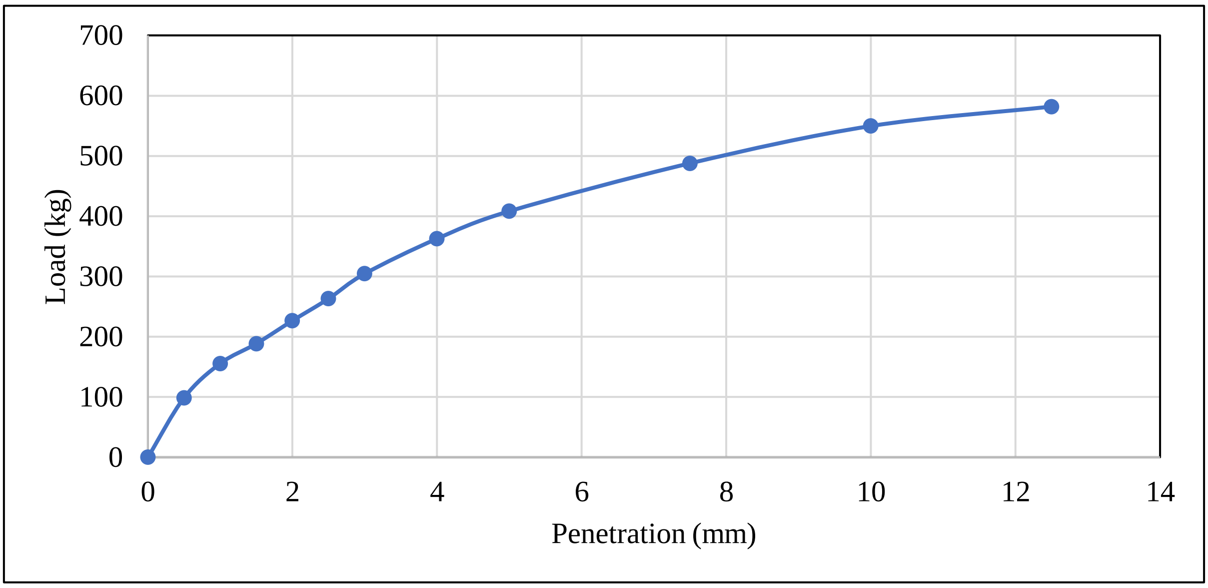

Figure 4.28: Load vs Penetration Graph (Soil with coir geotextile placed at depth 2cm from the top surface in unsoaked condition)

From the test we have obtained that, 2.50 mm C.B.R Value % =19.21 and

5.00 mm C.B.R Value % =19.87

4.7.4 California Bearing Ratio test for soil with coir geotextile placed at depth 2 cm from the top surface (soaked condition)

Table 4.23: California Bearing Test results for the soil with coir geotextile placed at depth 2 cm from the top surface (soaked condition)

Penetration (mm)	Load (kN)	Load (kg)
0	0	0
0.5	0.554	56.5
1	0.746	76.1
1.5	0.898	91.6
2	1.042	106.3
2.5	1.164	118.7
3	1.265	129
4	1.425	145.3
5	1.562	159.3
7.5	1.883	192
10	2.179	222.1
12.5	2.485	253.4

The load vs penetration graph for the soil with coir geotextile placed at depth 2 cm from the top surface in soaked condition is shown in Figure 4.29 below:

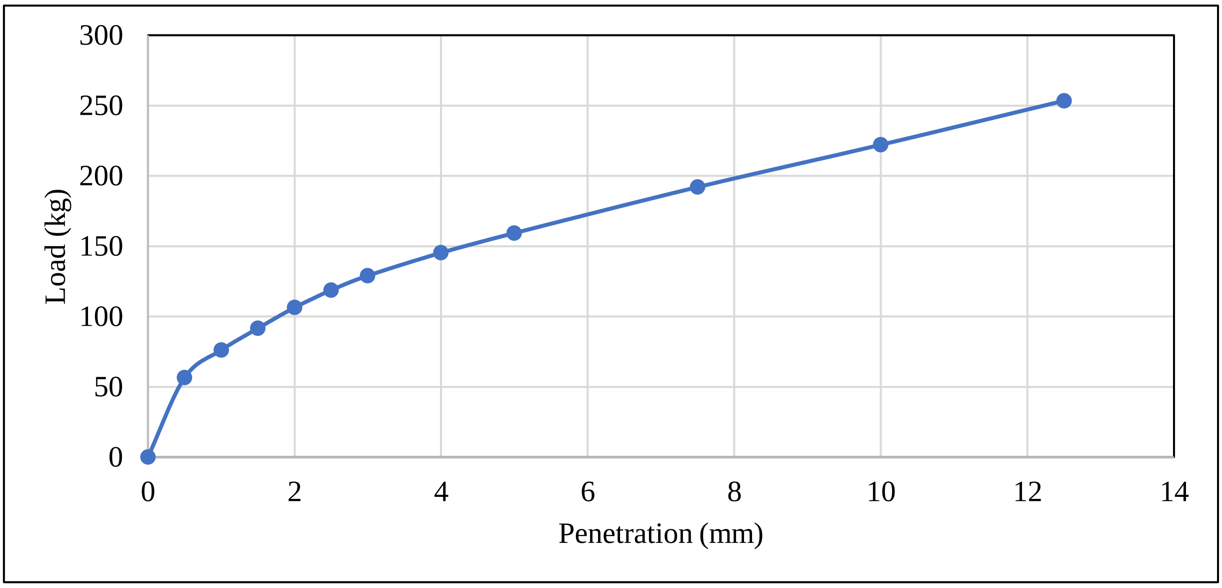

Figure 4.29: Load vs Penetration Graph (Soil with coir geotextile placed at depth 2cm from the top surface in soaked condition)

From the test we have obtained that, 2.50 mm C.B.R Value % =8.66 and

5.00 mm C.B.R Value % =7.75

4.7.5 California Bearing Ratio test for soil with coir geotextile placed at depth 3 cm from the top surface (unsoaked condition)

Table 4.24: California Bearing Test results for the soil with coir geotextile placed at depth 3 cm from the top surface (unsoaked condition)

Penetration (mm)	Load (kN)	Load (kg)
0	0	0
0.5	1.259	128.4
1	1.752	178.7
1.5	1.93	196.8
2	2.17	221.3
2.5	2.375	242.2
3	2.703	275.6
4	3.282	334.7
5	3.78	385.5
7.5	4.672	476.5
10	5.185	528.7
12.5	5.481	558.9

The load vs penetration graph for the soil with coir geotextile placed at depth 3 cm from the top surface in unsoaked condition is shown in Figure 4.30 below:

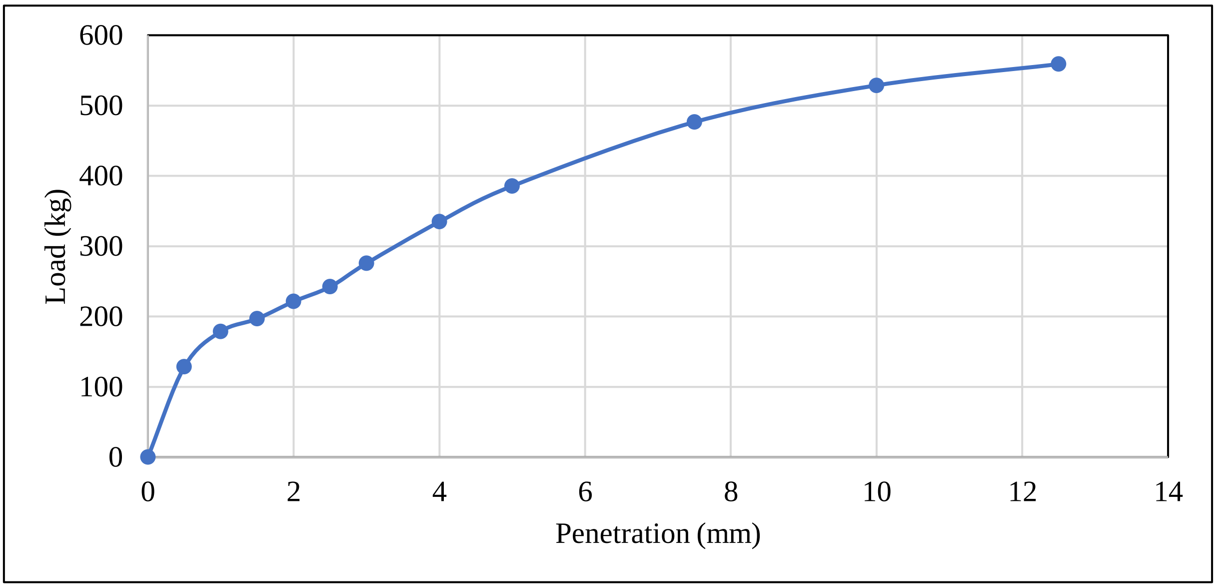

Figure 4.30: Load vs Penetration Graph (Soil with coir geotextile placed at depth 3cm from the top surface in unsoaked condition)

From the test we have obtained that, 2.50 mm C.B.R Value % =17.68 and

5.00 mm C.B.R Value % =18.76

4.7.6 California Bearing Ratio test for soil with coir geotextile placed at depth 3 cm from the top surface (soaked condition)

Table 4.25: California Bearing Test results for the soil with coir geotextile placed at depth 3 cm from the top surface (soaked condition)

Penetration (mm)	Load (kN)	Load (kg)
0	0	0
0.5	0.533	54.4
1	0.781	79.6
1.5	0.946	96.5
2	1.041	106.2
2.5	1.121	114.3
3	1.261	128.6
4	1.401	142.9
5	1.582	161.3
7.5	1.946	198.4
10	2.191	223.4
12.5	2.424	247.2

The load vs penetration graph for the soil with coir geotextile placed at depth 3 cm from the top surface in soaked condition is shown in Figure 4.31 below:

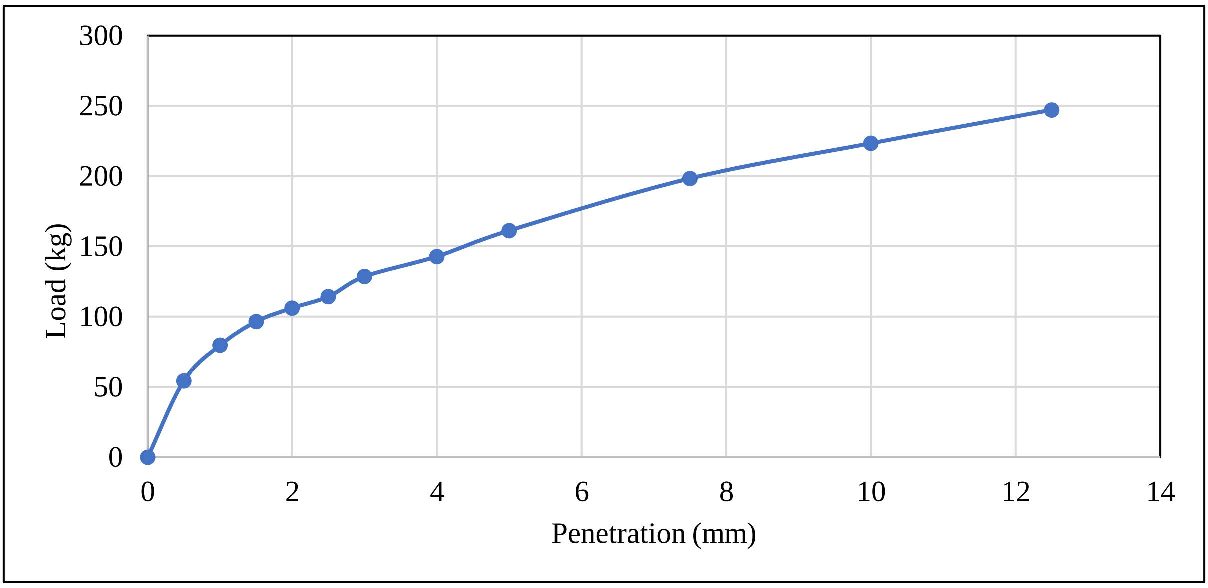

Figure 4.31: Load vs Penetration Graph (Soil with coir geotextile placed at depth 3cm from the top surface in soaked condition)

From the test we have obtained that, 2.50 mm C.B.R Value % =8.34 and

5.00 mm C.B.R Value % =7.85

4.7.7 California Bearing Ratio test for soil with coir geotextile placed at depth 4 cm from the top surface (unsoaked condition)

Table 4.26: California Bearing Test results for the soil with coir geotextile placed at depth 4 cm from the top surface (unsoaked condition)

Penetration (mm)	Load (kN)	Load (kg)
0	0	0
0.5	1.179	120.3
1	1.494	152.4
1.5	1.754	178.9
2	1.996	203.5
2.5	2.193	223.6
3	2.423	247.1
4	2.823	287.9
5	3.097	315.8
7.5	3.804	387.9
10	4.438	452.6
12.5	5.016	511.5

The load vs penetration graph for the soil with coir geotextile placed at depth 4cm from the top surface in unsoaked condition is shown in Figure 4.32 below:

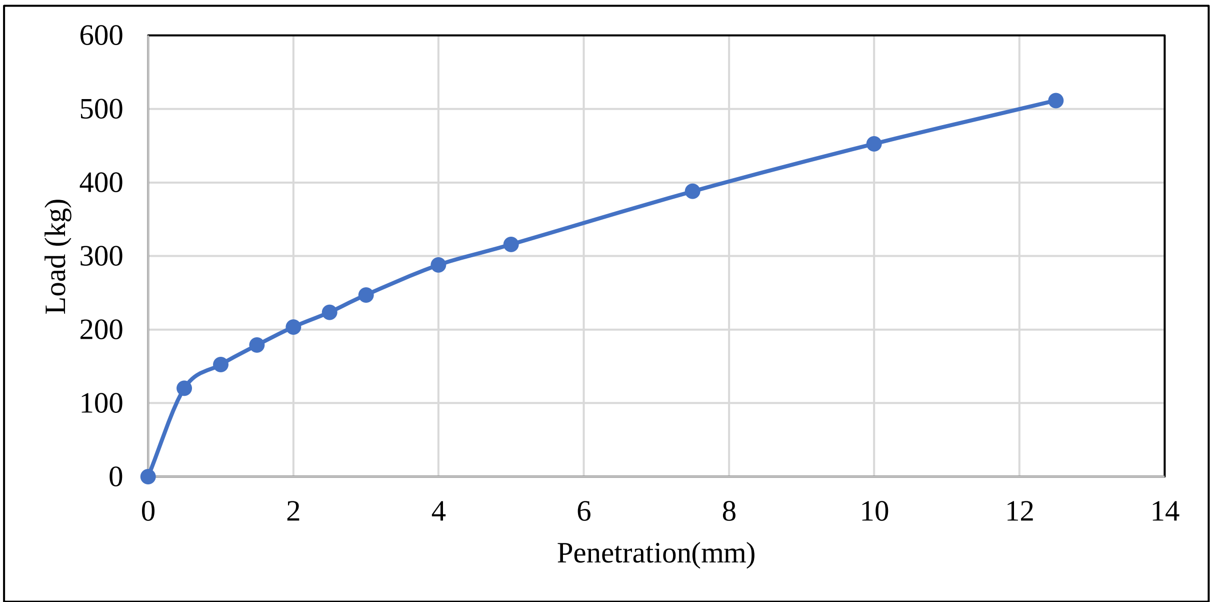

Figure 4.32: Load vs Penetration Graph (Soil with coir geotextile placed at depth 4cm from the top surface in unsoaked condition)

From the test we have obtained that, 2.50 mm C.B.R Value % =16.32 and

5.00 mm C.B.R Value % =15.37

4.7.8 California Bearing Ratio test for soil with coir geotextile placed at depth 4 cm from the top surface (soaked condition)

Table 4.27: California Bearing Test results for the soil with coir geotextile placed at depth 4cm from the top surface (soaked condition)

Penetration (mm)	Load (kN)	Load (kg)
0	0	0
0.5	0.576	58.7
1	0.739	75.4
1.5	0.859	87.6
2	0.968	98.7
2.5	1.072	109.3
3	1.16	118.3
4	1.301	132.7
5	1.459	148.8
7.5	1.786	182.1
10	2.082	212.3
12.5	2.387	243.4

The load vs penetration graph for the soil with coir geotextile placed at depth 4cm from the top surface in soaked condition is shown in Figure 4.33 below:

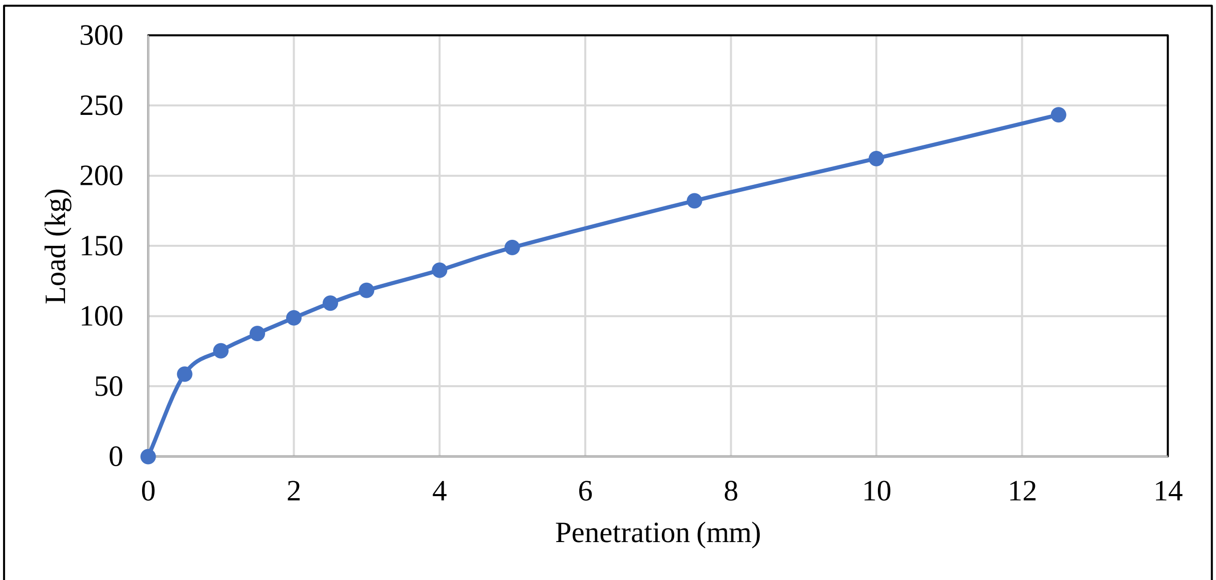

Figure 4.33: Load vs Penetration Graph (Soil with coir geotextile placed at depth 4cm from the top surface in soaked condition)

From the test we have obtained that, 2.50 mm C.B.R Value % =7.98 and

5.00 mm C.B.R Value % =7.24

4.8 Analysis of Experimental Observation in terms of Proctor Compaction Test (when the soil is mixed with Coconut Husk Fibre in various percentages)

The values of Maximum Dry Density and Optimum Moisture Content obtained from above experiments shows that it varies with the inclusion of coconut husk fibre with the soil. From the test results, the following observations can be seen:

- The maximum dry density for the soil sample has increased from when the soil is mixed with 1%,1.5% and 2% of coconut husk fibre respectively.
- The maximum dry density is decreased when 3% coconut husk fibre is mixed with the soil.
- Maximum dry density is highest when the soil is mixed with 2% coconut husk fibre.
- The optimum moisture content showed a decreasing value when the soil is mixed with 1%, 1.5% and 2% of coconut husk fibre respectively.
- The optimum moisture content increases when the soil is mixed with 3% coconut husk fibre.
- The optimum moisture content become lowest when the soil is mixed with 2% coconut husk fibre.

Figure 4.34 and 4.35 shows the variation of maximum dry density and optimum moisture content of soil mixed with different percentage of coconut husk fibre with respect to normal soil.

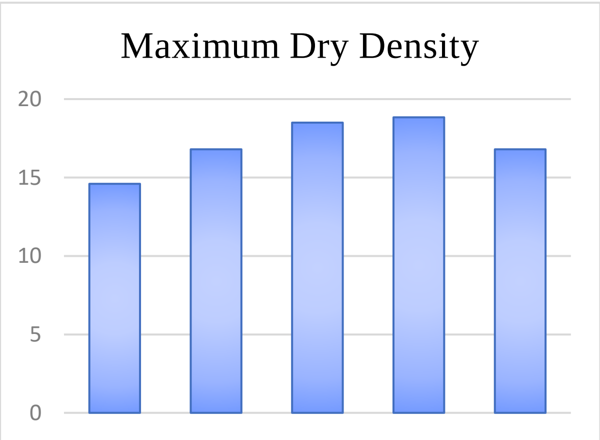

Figure 4.34: Variation of MDD with respect to normal soil

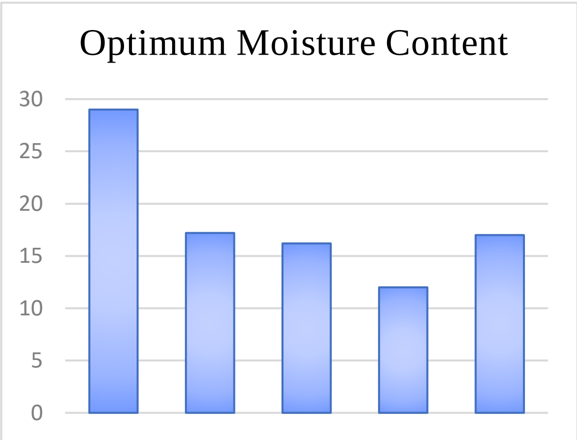

Figure 4.35: Variation of OMC with respect to normal soil

Table 4.28: Percentage change of Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) with respect to original soil with percentage of coconut husk fibre

Percentage of coconut husk	Optimum Moisture content (in %)	% change w.r.to original	Maximum Dry Density (in kN/m^3)	% change w.r.to original
Normal Soil	29	0	14.6	0
Soil+1% coconut husk	17.2	-40.69%	16.8	20%
Soil+1.5% coconut husk	16.2	-44.14%	18.5	32.14%
Soil+2% coconut husk	12	-58.62%	18.84	34.57%
Soil+3% coconut husk	17	-41.38%	16.8	20%

From the table it can be seen that the OMC has decreased up to 58.62% and MDD has increased up to 34.57% when 2% of coconut husk fibre was added to the soil.

4.9 Analysis of Experimental Observation in terms of California Bearing Ratio

4.9.1 Analysis of California Bearing Ratio values when the soil is mixed with coconut husk fibre in various percentages

In these results soil is added with different percentages of coconut husk. The main parameters that are studied include C.B.R. The numbers of curves are placed from the test results of C.B.R. tests are performed on the soil and soil mix with different percentage of coconut husk fibre. Coconut husk fibre increases the C.B.R values in this investigation. There is considerable improvement in compressive strength in case of all the soils on account of treatment with coconut husk fibre. It is noted that the compressive strength of soil increases when treated with coconut husk fibre up to 2%. The increase may be due to the increase in shear parameters. The CBR value again decreases when the soil is mixed with 3% coir fibre. Hence in this study the maximum coir fibre content was considered to be 3 % by dry weight of soil. The California Bearing Ratio value is highest when the soil is mixed with 2% coconut husk fibre. It indicates that the strength of soil increases with the increase in percentage of coconut husk fibre.

Figure 4.36 shows a comparison among the CBR values for untreated soil and the soil mixed with 1%, 1.5%, 2% and 3% coconut husk fibre as a waste material in unsoaked condition.

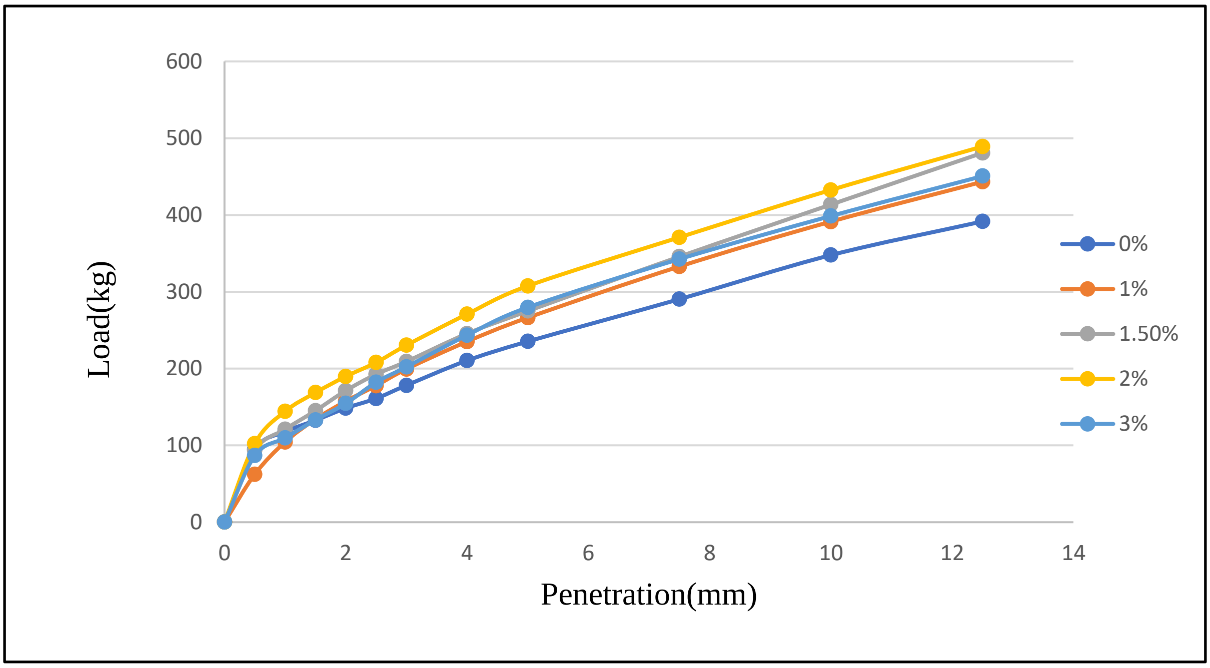

Figure 4.36: Comparison curve of California Bearing Ratio when soil is mixed with different percentages of coconut husk (unsoaked condition)

Figure 4.37 shows a comparison among the CBR values for untreated soil and the soil mixed with 1%, 1.5%, 2% and 3% coconut husk fibre as a waste material in soaked condition.

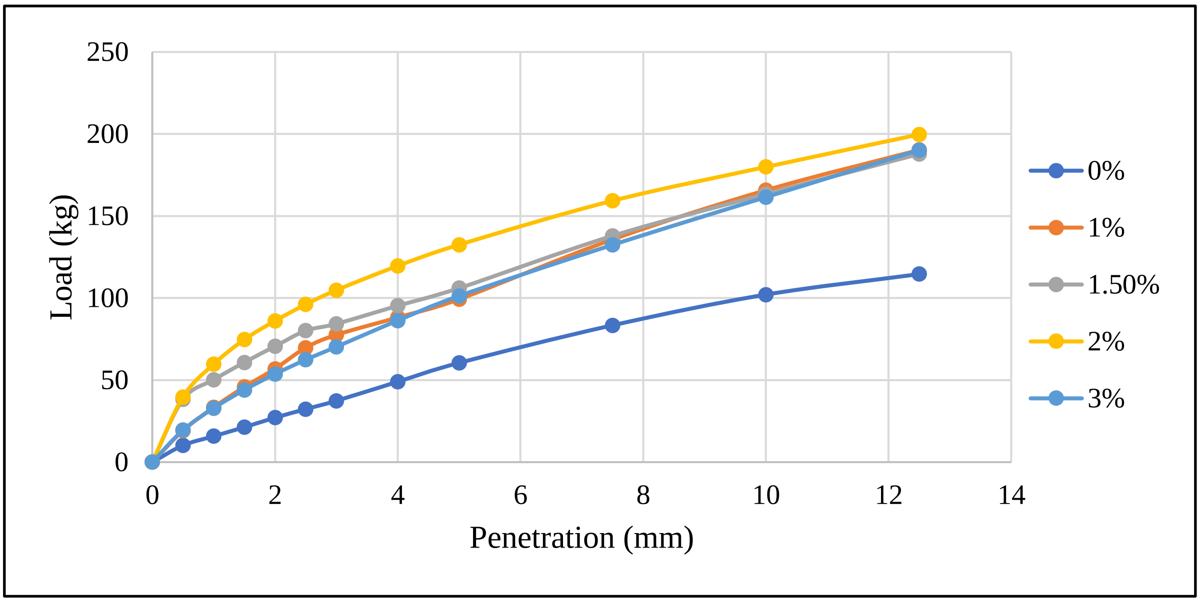

Figure 4.37: Comparison curve of California Bearing Ratio when soil is mixed with different percentages of coconut husk (soaked condition)

Table 4.29: Percentage change of California Bearing Ratio value with respect to original soil with percentage of coconut husk fibre

Percentage of coconut husk	Unsoaked		Soaked	
	CBR value	% change w.r.to original	CBR value	% change w.r.to original
Normal Soil	11.76	0	2.94	0
Soil+1% coconut husk	12.98	10.37%	5.50	87.07%
Soil+1.5% coconut husk	14.06	19.55%	6.05	105.78%
Soil+2% coconut husk	15.18	29.08%	7.01	138.43%
Soil+3% coconut husk	13.61	15.73%	4.93	67.68%

Table 4.29 shows that highest value of CBR when the soil is treated with coconut husk fibre up to 2% and it increases up to 29.08%(unsoaked) and 138.43% (soaked) with respect to the CBR value of untreated soil. But CBR value again decreases when the soil is mixed with 3% coir fibre for both soaked and unsoaked condition**.**

4.9.2 Analysis of California Bearing Ratio values when Coir Geotextile is placed on the soil at different layers

A number of CBR tests were conducted (both soaked and unsoaked conditions) using samples consisting of soil only and soil with layer of coir sheet at different layers from the top surface. The coir geotextile sheet was placed at H/3, H/2, 2H/3 and in double layers where H is the depth of CBR test specimen during compaction while performing CBR test. From the data generated, it is clear that the presence of coir geotextile influences the strength of the subgrade due to the interaction between soil and coir geotextile in soaked and unsoaked condition. The results of CBR test showed that there is an increase in CBR value of soil when coir geotextile is added to the soil in different layers for both unsoaked and soaked condition.

Figure 4.38 shows a comparison among the CBR values using samples consisting of soil only and coir geotextile is placed on the soil at different layers in unsoaked condition.

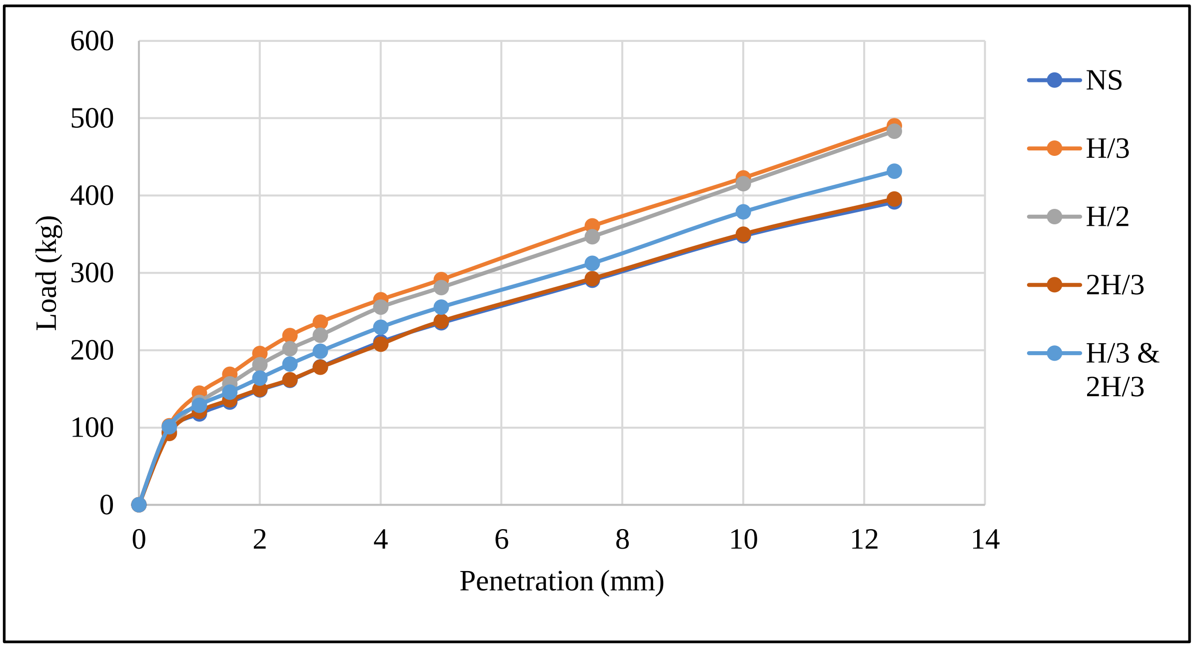

Figure 4.38: Comparison curve of California Bearing Ratio when coir geotextile is placed on the soil at different layers (unsoaked condition)

Figure 4.39 shows a comparison among the CBR values using samples consisting of soil only and coir geotextile is placed on the soil at different layers in soaked condition.

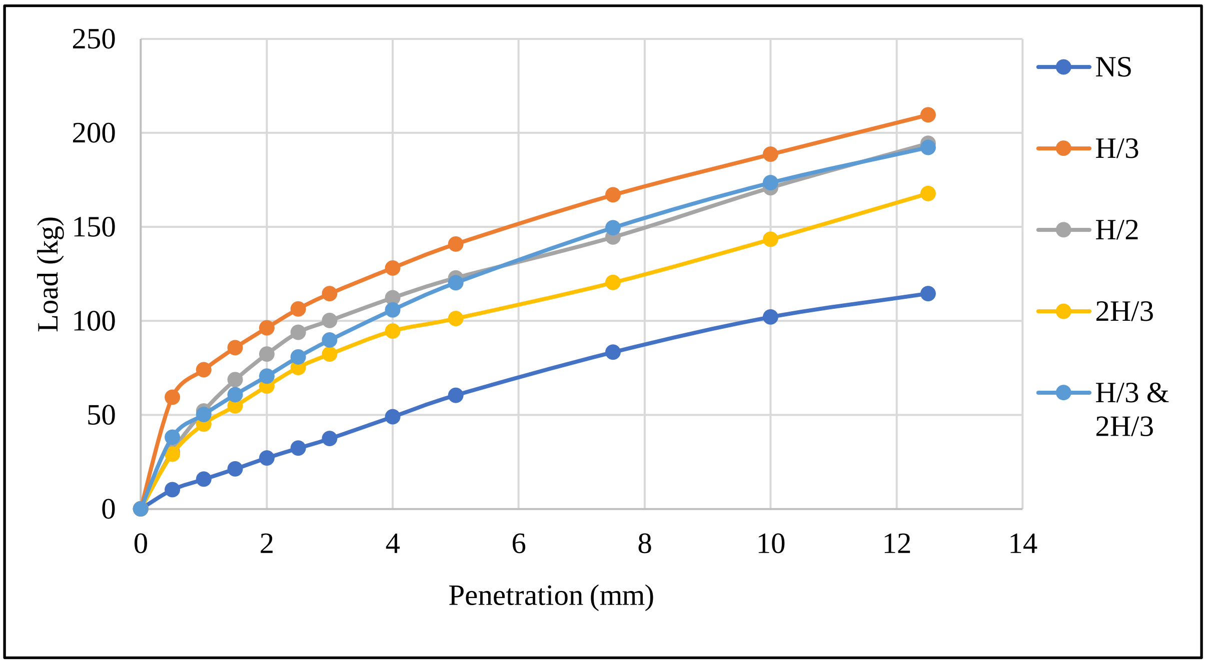

Figure 4.39: Comparison curve of California Bearing Ratio when coir geotextile is placed on the soil at different layers (soaked condition)

The above comparison curves shows that the CBR value is maximum when geotextile is placed at a depth of 1/3 H from the top surface. But CBR value decreases when geotextile is placed at a depth of 2/3 H, H/2 and in double layer from the top surface. The value is lowest when geotextile is placed at a depth of 2/3 H among all the layers.

Table 4.30: Percentage change of California Bearing Ratio value with respect to original soil with layers of coir geotextile sheet

Layers of coir geotextile	Unsoaked		Soaked	
	CBR value	% change w.r.to original	CBR value	% change w.r.to original
Normal Soil	11.76	0	2.94	0
Geotextile at layer 1/3 H	15.98	35.88%	7.77	164.28%
Geotextile at layer 1/2 H	14.74	25.34%	6.86	133.33%
Geotextile at layer 2/3 H	11.82	0.51%	5.50	87.07%
Geotextile at layer 1/3 H & 2/3 H	13.29	13.01%	5.90	100.68%

Table 4.30 shows that when geotextile is placed at a depth of 1/3 H from the top surface highest increase in percentage of CBR is up to 35.88% for unsoaked condition and 164.28% for soaked condition with respect to the CBR value of untreated soil. But CBR value decreases when the geotextile layer is placed at H/2, 2H/3 and in double layers for both soaked and unsoaked condition**.** The CBR value is lowest when geotextile is placed at depth 2/3 H from the top surface. The change in percentage of CBR at 2/3H is up to 0.51% for unsoaked condition and 87.07% for soaked condition with respect to the CBR value of untreated soil.

4.9.3 Analysis of California Bearing Ratio values when Coir Geotextile is placed on the soil at different depths

During the experimentation coir geotextile sheet is provided at a depth of 1cm, 2cm, 3cm and 4.0cm from the top surface of soil in single layer at a time. It is observed that the maximum CBR values are obtained for position of coir geotextile at 1cm for both unsoaked and soaked conditions. The CBR values then decrease for the coir geotextile position at 2cm and 3.0cm and at 4.0cm. The CBR value is lowest when the coir geotextile is placed at depth 4cm from the top surface. Thus, it is seen that lowering the position of coir mat will have reduced effect on increase in CBR values of soil. The best position is near the top surface.

Figure 4.40 shows a comparison among the CBR values using samples consisting of soil only and coir geotextile sheet placed on the soil at different depths in unsoaked condition.

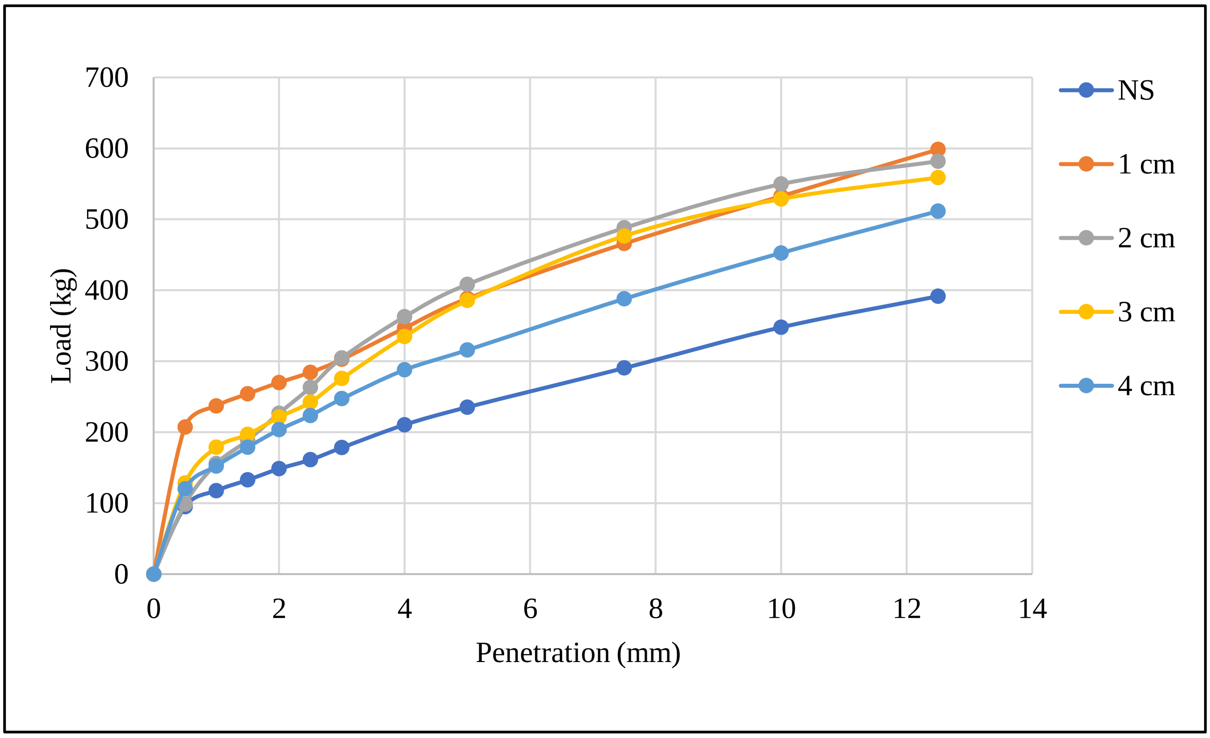

Figure 4.40: Comparison curve of California Bearing Ratio when coir geotextile sheet is coir geotextile sheet placed on the soil at different depths (unsoaked condition)

Figure 4.41 shows a comparison among the CBR values using samples consisting of soil only and coir geotextile sheet placed on the soil at different depths in soaked condition.

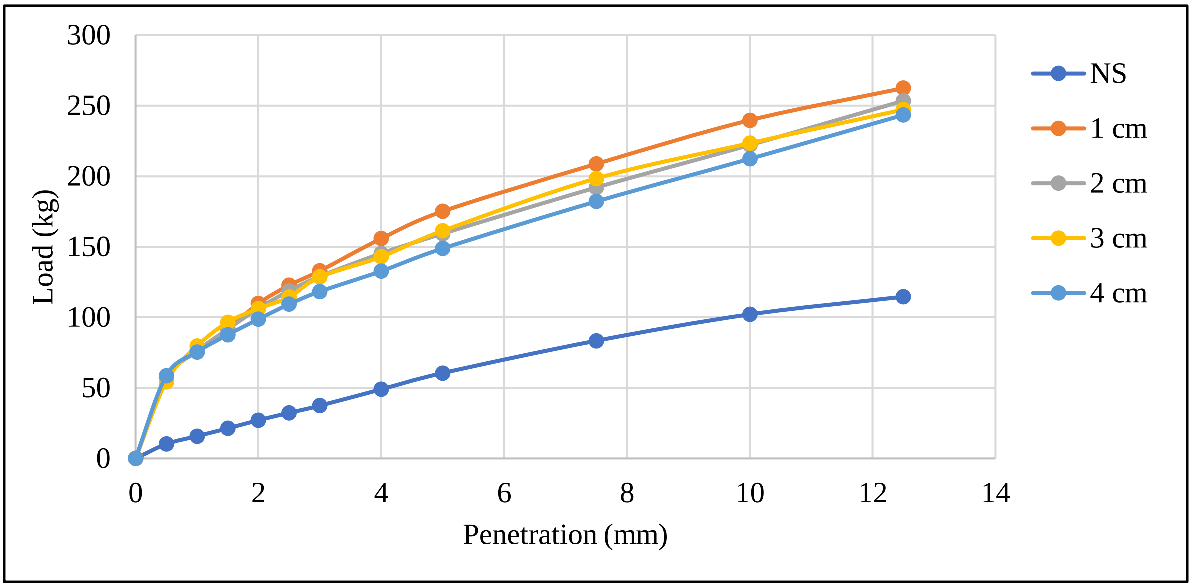

Figure 4.41: Comparison curve of California Bearing Ratio when coir geotextile sheet placed on the soil at different depths (soaked condition)

Table 4.31: Percentage change of California Bearing Ratio value with respect to original soil with coir geotextile sheet placed on the soil at different depths

Depths of coir geotextile	Unsoaked		Soaked	
	CBR value	% change w.r.to original	CBR value	% change w.r.to original
Normal Soil	11.76	0	2.94	0
Geotextile at depth 1cm	20.76	76.53%	8.96	204.76%
Geotextile at depth 2cm	19.87	68.96%	8.34	183.67%
Geotextile at depth 3cm	18.76	59.52%	7.98	171.43%
Geotextile at depth 4cm	16.32	38.77%	6.86	133.33%

From the CBR test results on Table 4.31, it is observed that CBR value of the soil has improved up to 76.53% for unsoaked condition and 204.76% for soaked condition when the position of coir mat is at 1cm from the top surface.

4.10 Factors Affecting the Study

Literature study reveals that the resistance of soil in terms of CBR value and shearing depend on:

i. Density and water content of soil.
ii. Type of soil.
iii. Method of compaction.
iv. Position of the geotextile from the top surface of the soil.
v. Sizes of the moulds
vi. Type of geotextile used, etc.

Out of the stated factors, only two factors are taken up for consideration in this study. The two factors are: -

i. Position of the layer of coconut coir mat from the top surface of the soil.
ii. Effect of Position of Coir geotextile in CBR Mould.

Thus, it is seen that lowering the position of coir geotextile will have reduced effect on increase in CBR values of soil. The best position is near the top surface. This result is justified with the following explanation. The reason for higher CBR values for the position of coir geotextile near the top surface may be justified in two ways. First the presence of coir geotextile at depth near the top surface has provided maximum confinement to granular subgrade soil used in CBR mould than other position of coir geotextile. So, the CBR value observed is found to be highest.

CHAPTER 5

CONCLUSION & SCOPE FOR FUTURE STUDY

5.1 General

On the basis of experimental observation and results, the following conclusions are drawn. A few suggestions for further study are also included in this chapter.

5.2 Conclusion based on Proctor Compaction test and California Bearing Ratio

1. Coconut husk fibre is a waste material which could be utilized in a sub base for paved and unpaved roads.
2. From the experimental results it is found that the load taken by the soil sample increases with the increase in percentage of fibre content thereby CBR values of soil-coir fibre mix increases with increasing percentage of fibre.
3. Maximum improvement in CBR value is observed when 2% of coir is mixed with the soil and it again decrease when 3% of coir is mixed with the soil. It is concluded that proportion of 2% coconut husk fibre in soil giving maximum unsoaked and soaked CBR value.
4. The use of coconut husk as a waste material increases the sub-grade strength and thus improves pavement life.
5. CBR value of soil increases when coir geotextile is added to the soil in different layers for both unsoaked and soaked condition.
6. Maximum improvement in CBR value is observed when geotextile is placed at a depth of 1/3 H from the top surface.
7. The reason for higher CBR values for the position of coir geotextile at a depth of 1/3 H from the top surface may be justified as presence of coir geotextile at 1/3 H depth has provided maximum confinement to granular subgrade soil used in CBR mould than other position of coir geotextile.
8. It is concluded that lowering the position of coir geotextile will reduce the effect on increase in CBR values of soil. The best position is near the top surface.
9. When coir geotextile sheet is provided at a depth of 1cm, 2cm, 3cm and 4.0cm from the top surface of soil in single layer at a time, it is observed that the maximum CBR values are obtained for position of coir geotextile at 1cm for both unsoaked and soaked conditions.

10. The fact that in the soaked condition the inclusion of coir geotextile has improved the CBR at a very high rate which is in general is a very good additive to high rainfall and high water table state and where roads have to perform very often in a soaked condition.
11. From the design aspects it is observed that the thickness of pavement may be reduced if coir mat is placed above the subgrade.
12. Processing of coir waste in usable form is an employment generation activity in coir fibre manufacturing units and the effective use of coir waste can uplift rural economy and leads to beneficial effects in engineering construction.

5.3 Scope for Future Study

This study on application of geotextile to improve the CBR value of subgrade for road construction can be further continued taking the following points under consideration.

1. The number of soil samples of different types should be increased to get a better scenario.
2. Study can be done on the uniformly distributed coir fibre in different layers.
3. The correlation between unsoaked and soaked value of CBR will be analysed.
4. The number of percentages of mixing can be increased to get a better scenario.
5. Study can be done on a greater number of uniformly distributed coir geotextile in different layers.
6. Different type of soil can be used to observe the behaviour of coconut husk as a waste material and coir geotextile in different layers while compacting.
7. Different type of natural as well as synthetic geotextile can be used.
8. Study can be done on the experimental results obtained by using synthetic geotextiles.

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