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A Project Report
on
# "STABILIZATION OF BLACK COTTON SOIL USING RICE HUSK ASH AND CRUMB RUBBER"

Submitted in the partial fulfillment of the requirement for the VIII Semester Project Work -15CVP85 for the award of degree of

**Bachelor of Engineering**
in
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Submitted by


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**2018-2019**

**(Affiliated to Visvesvaraya Technological University, Belagavi)**

## *CERTIFICATE*

This is to certify that the Project entitled **"STABILIZATION OF BLACK COTTON SOIL USING RICE HUSK ASH AND CRUMB RUBBER"** is a bonafide work carried out by **PRIYANKA P (1GV15CV017), KRISHNE GOWDA S (1GV15CV010), MURALI B (1GV15CV012)** and **SUCHANDRA PRADHAN (1GV15CV025)** in partial fulfillment of the requirements for the award of BACHELOR OF ENGINEERING IN CIVIL ENGINEERING of the Visvesvaraya Technological University, Belagavi during the year 2018-2019. The report has been approved as it satisfies the academic requirements with respect to Project work prescribed by the V.T.U of the above mentioned degree.

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# ABSTRACT

Black Cotton Soil (BCS) is a major soil deposit in India. There is a presence of significant amount of montmorollonite in BCS which is the reason behind the alternate swell shrink property which occurs due to the changes in moisture content. The above property has proven to be troublesome for carrying out civil engineering activities. To encounter this problem stabilization is in practice. The utilization of waste materials such as Rice Husk Ash (RHA), Crumb Rubber (CR) as a soil stabilizer is a part of the innovative research gaining importance nowadays. As the disposal of scrap tyres and agricultural wastes has a potential negative impact on the environment causing pollution and finally affects the ecosystem, thus it is mandatory to make use of these wastes in an environmentally friendly way.

The main objective of the project is to study the geotechnical properties which include the Atterberg limits (LL, PL, PI, FI), Unconfined Compression Strength, Compaction parameters and CBR percent characteristics of Black Cotton Soil by using RHA, CR and its combination in various proportions like 5%, 10%, 15%, 20%, 25%, 30% for all the stabilizing materials used in our project for stabilization of BCS and to suggest the optimum proportion of stabilizer.

**KEYWORDS:** Black Cotton Soil (BCS), Rice Husk Ash (RHA), Crumb Rubber (CR), Liquid Limit (LL), Plastic Limit(PL), Plasticity Index(PI), Flow Index (FI), Optimum Moisture Content(OMC), Maximum Dry Density(MDD), Unconfined Compression Strength(UCS), California Bearing Ratio(CBR)

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## Chapter 1

# INTRODUCTION

A developing country like India in which has a large geographical area and population, demands vast infrastructure i.e. network of roads and buildings. Everywhere land is being utilized for various structures from ordinary house to sky scrapers, bridges to airports and from rural roads to expressways. Almost all the civil engineering structures are located on various soil strata.

Soil is defined as sediments or other accumulation of mineral particles produced by the physical or chemical disintegration of rocks plus air, water, organic matter and other substances that may be included, processes that includes disintegration of rock due to stresses arising from expansion or contraction with temperature changes that occur when water, oxygen and carbon dioxide gradually combine with minerals within the rock formations thus it is breaking down into sand, silt and clay.

In India different criteria have been applied to classify soils, the outstanding being geology, relief fertility, chemical composition and physical structure, etc. The major soil groups are: Alluvial Soil, Black Soils, Red Soils, Laterite and Lateritic Soils, Forest and Mountain Soils, Arid and Desert Soils, Saline and Alkaline Soils, Peaty and Marshy Soils. Black Soils also called regur and black cotton soils because cotton is the most important crop grown on these soils. Black Cotton Soils are spread over 5.46 lakh sqkm(16.6 per cent of the total geographical area of the country).

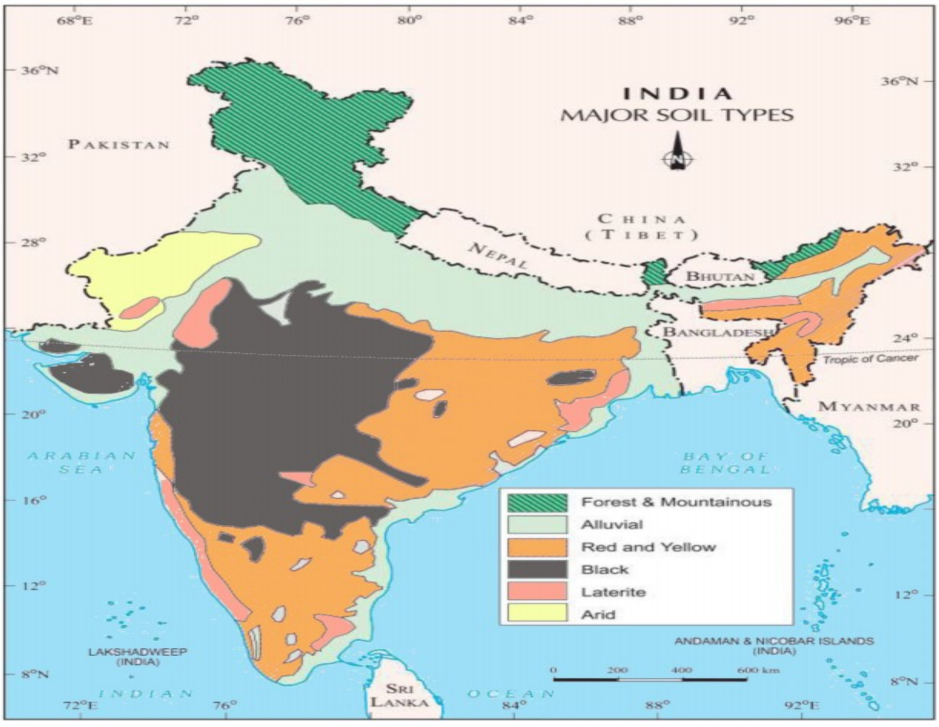


***Figure 1.1 Major soil types in India***

Soil is typically a non homogenous, porous, earthen material whose engineering behavior is influenced by changes on moisture content and density. Black Cotton Soil is clayey soil grayish to blackish in colour and contains montmorillonite clay mineral which has high expansive characteristics.

Rice Husk is a by-product of the rice milling. Due to the increasing rate of environmental pollution and the consideration of sustainability factor have made the idea of utilizing rice husk. The rice husk itself has a very rough surface which is abrasive in nature. These are hence resistant to natural degradation. This would result in improper disposal problems. So, a way to use these by-products is the best sustainable idea.

Crumb Rubber is the name given to any material derived by reducing scrap tires or other rubber into uniform granules with inherent reinforcing materials such as steel and fiber removed along with any other type of inert contaminants such as dust, glass or rock.

## 1.1 NECESSITY OF SOIL STABILIZATION

Civil engineering projects located in areas with soft or weak soils have traditionally incorporated improvement of soil properties by using various methods. Soil stabilization is being used for a variety of engineering work, were the main object is to increase the strength or stability of soil and reduce the construction cost by making best use of locally available material.

a) Cost effective solution for many roads and mine haul roads, having constant access is essential to the operation of business. Many soil stabilization techniques are permanent and do not need constant application to maintain the road conditions.
b) Treatment with efficient stabilizers allows production of long lasting and stable materials comparable to those graded aggregates in case of pavement construction.
c) Better soil gradation, reduction of plasticity index or swelling potential and increases durability and strength is improved.
d) The strength and stiffness of a soil layer can be improved by the use of binder materials and to permit a reduction of design thickness of the layers.

## 1.2 SOIL STABILIZATION

Soil stabilization a general term for any physical, chemical, biological or combined method of changing a natural soil to meet an engineering purpose. Stabilization can increase the shear strength of a soil and control the shrink-swell properties of soil, thus improving the load bearing capacity of soil.

### 1.2.1 Components Of Stabilization:

Soil stabilization involves the use of suitable stabilizing agents (binder materials) in weak soil to improve its geotechnical properties such as compressibility, strength, permeability and durability. The components of stabilization technology include soils and soil minerals and stabilizing agent or binders (cementitious materials).

a) **Soils -** Most of the stabilization has been undertaken in soft soils (silty, clayey peat or organic soils) in order to achieve desirable engineering properties.

b) **Stabilizing Agents -** These are the hydraulic (primary binders) or non- hydraulic binders(secondary binders) materials that when in contact with water or in the prescience of pozzolanic materials reacts with water to form cementitious composite materials.The most commonly used binders are: Cement, Lime, Fly ash, Blast furnace slag, Pozzolanas.

c) **Factors Affecting the Strength of Stabilized Soil -** Presence of organic matters, sulphates, sulphides, compaction, moisture content, temperature, Freeze-thaw and Dry-Wet effect and carbon dioxide in the stabilized soils may contribute to undesirable strength of stabilized minerals.

### 1.2.2 Soil Stabilization Techniques:

The stabilization techniques involve two major types: Mechanical Stabilization and Stabilization by different types of admixers such as Lime, Cement, Flyash, Rice Husk Ash, Bituminous, Thermal, Electrical, Recycled rubber tyres (Crumb Rubber), Geotextiles and fabrics.

### I) Mechanical Stabilization

Mechanical Stabilization is the process of improving the properties of the soil by changing its gradation. This process includes soil compaction and densification by application of mechanical energy using various sorts of rollers, rammers, vibration techniques and sometime blasting. The stability of the soil in this method relies on the inherent properties of the soil material. Two or more types of natural soils are mixed to obtain a composite material which is superior to any of its components. Mechanical stabilization is accomplished by mixing or blending soils of two or more gradations to obtain material meeting the required specification.

### II) Stabilization by using different Types of Admixers

**a) Lime Stabilization**

Lime provides an economical way of soil stabilization. Slaked lime is very effective in treating heavy plastic clayey soils. Lime may be used alone or in combination with cement, bitumen or fly ash. Sandy soils can also be stabilized with these combinations. Lime has been mainly used for stabilizing the road bases and the subgrade. Lime changes the nature of the adsorbed layer and provides pozzolanic action. Plasticity index of highly plastic soils are reduced by the addition of lime with soil. There is an increase in the optimum water content and a decrease in the maximum compacted density and the strength and durability of soil increases.

**b) Cement Stabilization**

The soil stabilized with cement is known as soil cement. The cementing action is believed to be the result of chemical reactions of cement with siliceous soil during hydration reaction. The important factors affecting the soil-cement are nature of soil content, conditions of mixing, compaction, curing and admixtures used. The appropriate amounts of cement needed for different types of soils may be as follows: Gravels – 5 to 10%, Sands – 7 to 12%, Silts – 12 to 15%, and Clays – 12 – 20%.

**c) Chemical Stabilization**

Chemical stabilization of soil comprises of changing the physico-synthetic around and within clay particles where by the earth obliges less water to fulfill the static imbalance. Calcium chloride being hygroscopic and deliquescent is used as a water retentive additive in mechanically stabilized soil bases and surfacing.

Sodium chloride is the other chemical that can be used for this purpose with a stabilizing action similar to that of calcium chloride. Sodium silicate is yet another chemical used for this purpose in combination with other chemicals such as calcium chloride, polymers, chrome lignin, alkyl chlorosilanes, siliconates, amines and quaternary ammonium salts, sodium hexametaphosphate, phosphoric acid combined with a wetting agent.

**d) Fly ash Stabilization**

Fly ash stabilization is gaining more importance recent times since it has wide spread availability. This method is inexpensive and takes less time than any other methods. It has a long history of use as an engineering material and has been successfully employed in geotechnical applications.

Fly ash is a byproduct of coal fired electric power generation facilities; it has little cementations properties compared to lime and cement. Most of the fly ashes belong to secondary binders; these binders cannot produce the desired effect on their own. However, in the presence of a small amount of activator, it can react chemically to form cementations compound that contributes to improved strength of soft soil.

**e) Rice Husk Ash Stabilization**

Rice husk, rice straw and bagasse are rich in silica and make an excellent pozzolana. The Rice Husk Ash would appear to be an inert material with the silica in the crystalline form suggested by the structure of the particles, it is very unlikely that it would react with lime to form calcium silicates and that it would be as reactive as fly ash, which is more finely divided. So rice husk ash would give great results when it used as a stabilizing material. The ash would appear to be a very suitable light weight fill and should not present great.

**f) Bituminous Stabilization**

Bituminous soil stabilization refers to a process by which a controlled amount of bituminous material is thoroughly mixed with an existing soil or aggregate material to form a stable base or wearing surface. Bitumen increases the cohesion and load-bearing capacity of the soil and renders it resistant to the action of water. Bitumen stabilization accomplished by using asphalt cement, asphalt cutback or asphalt emulsions.

The type of bitumen to be used depends on the type of soil to be stabilized, method of construction and weather conditions. In frost areas, the use of tar as binder must be avoided because of its high temperature maximum susceptibility. Asphalts and tars are bituminous materials which are used for stabilization of soil, generally for pavement construction. Bituminous materials when added to a soil, it imparts both cohesion and reduced water absorption.

**g) Thermal Stabilization**

Thermal change causes a marked improvement in the properties of the soil. Thermal stabilization is done either by heating the soil or by cooling it. Heating: As the soil is heated, its water content decreases. Electric repulsion between clay particles is decreased and the strength of the soil is increased. Freezing: cooling causes a small loss of strength of clayey soils due to an increase in inter-particles repulsion. However, if the temperature is reduced to the freezing point, the pore water freezes and the soil is stabilized.

**h) Electrical Stabilization**

Electrical stabilization of clayey soils is done by a process known as electro-osmosis. As a direct current (DC) is passed through a clayey soil, pore water migrates to the negative electrode (cathode). It occurs because of attraction of positive ions (cations) that are present in water towards cathode.

The strength of the soil is considerably increased due to removal of water. Electro-osmosis is an expensive method, and is mainly used for drainage of cohesive soils. Incidentally, the properties of the soil are also improved.

**i) Stabilization by Geo-textiles and Fabrics**

Geotextiles are porous fabrics made of synthetic materials such as polyethylene, polyester, nylons and polyvinyl chloride. Woven, non-woven and grid form varieties of geotextiles are available. Geotextiles have a high strength. When properly embedded in soil, it contributes to its stability. It is used in the construction of unpaved roads over soft soils. Reinforcing the soil for stabilization by metallic strips into it and providing an anchor or tie back to restrain a facing skin element. Past research has shown that the strength and load-bearing capacity of subgrades and base course materials can be improved through the inclusion of non-biodegradable.

## 1.3 TERMINOLOGIES:

**Density of soil**- density of soil is the mass of soil per unit volume.

**Bulk Density**- It is the total mass of the soil per unit of its total volume expressed in $g/cm^3$ or $kg/m^3$.

**Dry Density**- It's the mass of solids per unit of total volume of the soil mass

**Density of solids**-The density of soil solids is the mass of soil solids per unit of volume of solids.

**Unit weight of soil mass**- The unit weight of a soil mass is its unit weight per unit volume

**Water Content**- The water content is defined as the ratio of weight of water to the weight of solids in the given mass of soil.

**Specific Gravity**- It is the ratio of the weight of a given volume of soil solids at a given temperature to the weight of an equal volume of distilled water at that temperature, both weights being taken in air.

**Voids ratio**- Voids ratio of a given soil sample is the ratio of the volume of soil solids in the given soil mass.

**Porosity**-The porosity of a given sample is the ratio of the volume of voids to the total volume of the given soil mass.

**Air-voids ratio** – The ratio of volume of air to the total volume of mass of soil.

**Bearing Capacity** – The ability of the underlying soil to support the foundation loads without shear failure.

**Bearing Pressure** – Empirically derived factors used in bearing capacity equation that usually correlates with the angle of internal friction of the soil.

**Bulk Density** – Soil density –The total mass of water and soil particles contained in a unit volume of soil.

# Chapter 2

# LITERATURE REVIEW

From literature review we accumulate the information and details regarding the progress of our project. The journal publications directs particular views of the soil stabilization with their stabilizing material and below are some of available literature reviews related to the project works are reported.

## 2.1 RICE HUSK ASH & CRUMB RUBBER: AN OVERVIEW

**Vishal Ghutke, Pranita Bhandari, Vikash Agarwal "Stabilization of soil by using Rice Husk Ash" (2018) [1]**

A large part of central India and a portion of south India are covered with black cotton soils. These soils are residual deposit formed from basalt and trap rocks. These soils are quite suitable for growing cotton. Black cotton soils are clay of high plasticity. The soils have high shrinkage and swelling characteristics and shearing strength and bearing capacity of the soils is extremely low. To overcome these circumstances soil should be treated and stabilized. The chemical analysis on rice husk was found to contain mainly silica, potassium, iron, calcium, magnesium, aluminum when RHA mixed with black cotton soil by mass in proportion of 4%, 8%, 12% and 16 %.

The black cotton soil was obtained from country side field Nagpur, the rice husk ash obtained by burning of rice husk from the milling industry Nagpur. The specific gravity of soil decreases with increase in a RHA. Liquid limit and plastic in soil first increases upto4% and then decreases with increases in proportion of RHA. MDD decreases with increase in proportion of RHA. CBR value increases up to 12% RHA and then decreases hence; at mixing 12% RHA strength is maximum.

**Jai Prakash, KusumKumari, Vijay Kumar-"Stabilization of Soil using Rice Husk Ash" (2017) [2]**

Chemical stabilization of soil using cement, lime, etc. is costly in order to introduce new material which can reduce the cost of chemical stabilization review is made on Rice Husk Ash (RHA). Rice Husk is a waste material from paddy crops. After burning it gives rich amount of silica which may be used as a chemical stabilizer for Soil stabilization.

If soil contains medium or coarse sandy particles then mixing of RHA will occupy the void created by coarser particles, further leads to increase in shearing and bearing capacity due to increase in chemical bonding other than gravitation force.

If major particle of soil contain clay minerals like montmorillonite then RHA which is having high silica content, replace exchangeable ion further leads to decrease in cat ion exchange capacity (CEC). CEC decrease due to decrease in –ve ion as Si replaces other metallic ion such as Na, Mg, etc. Exchangeable ion present in the soil water leads to swelling of soil if it contains clay minerals like montmorillonite as they form weak bond between clay particles. As clay surface is negatively charged Si make stronger bond than other metallic ion present in clay minerals.

Rice Husk is mixed in various proportions like 5%, 10%, 15% and 20% various tests were also conducted in this mixes in order to find optimum proportions. From the engineering analysis the following conclusions were drawn: The addition of RHA alone to the test soil resulted in decrease in the value of Liquid Limit, MDD and increase in OMC.

**V.S.Ghutke, Dr.S.A.Dhale, P.S.Bhandari-"Stabilization of Black cotton soil by using Rice Husk Ash, Fly ash and Coconut coir Fibre" (2017) [3]**

The Black cotton soil behavior is attributed to the presence of a mineral montmorillonite. The wide spread up black cotton soil has posed challenges and problems to the construction activities. Soil improvement using waste materials like slag, rice husk ash, silica fumes, etc. in geotechnical engineering has been in practice from environmental point of view.

The black cotton soil used was brought from Nagpur. RHA collected from Ellora rice mill and fly ash collected was from Koradi thermal power station Nagpur. The coconut coir fiber is an important commercial product obtained from husk of coconut and is elastic enough to twist without breaking and it holds a curl as though permanently waved. Here the black cotton soil is treated with various proportions such as 6%,12%,15,24%,30% of RHA,8%, 16%, 24%, 32% of fly ash and 3%, 6%, 9% and 12% of coconut coir fiber (CCF) at atterberg limit, specific gravity, OMC and MDD is evaluated. By addition of RHA, Fly Ash and coconut fiber Liquid limit and Plastic limit is decreased .OMC decreases with addition of fly ash and coir fiber where as it will increase on addition of RHA.MDD value increases by addition of Fly ash and Coir fiber and it will decrease on addition of RHA.

**Jitendra Singh Yadav – "Influence of Crumb Rubber on the geotechnical properties of clayey soil" (2017) [5]**

The paper aims at assessing the impact of the waste tyre inclusion on the geotechnical properties of clayey soil. Discarded rubber in the form of crumb rubber of size ranging between 0.8 and 2mm varying from 0 to 10%was used in investigation. Several tests namely, Compaction, unconfined compressive strength, split tensile strength, California bearing ratio, consolidation and swelling pressure , along with microstructure studies have been carried out on different combinations of clayey soil and crumb rubber.

The locally available soil sample obtained from Kanota, Jaipur was used in this investigation. The soil being classified was CI (clay of medium plasticity). The physical attributes namely specific gravity, Atterberg's limits, maximum dry unit weight, optimum moisture content and free swelling pressure of soil was investigated. The soil sample used in the investigations has consisted of high Illite content with quartz.

Incorporation of crumb rubber beyond 10% is not practical because of the poor bonding between clay and rubber particles and accumulations of rubber particles at the higher content. Maximum dry unit weight and optimum moisture content of clayey soil decrease as the content of crumb rubber in the mixture increases. Unconfined compressive strength and spilt tensile strength of the clay have not significantly affected by the inclusion of the rubber up to 5%.Incorporation of higher amounts of crumb rubber reduces the strength vigorously.

**L.Kokila, G.Bhavitra, V.Haripriya – "Experimental Investigation on Soil Stabilization using Rubber Crumbs on Expansive Soils" (2017) [6]**

In this study the stabilization is carried out by using increasing percentage of rubber crumbs along with lime under suitable test. The main objective is to increase the CBR value. Expansive soil (Black cotton soil) is investigated in this project is dried and crushed to get the soil sample for conducting soil tests. The index properties and engineering properties of the soil were found from the soil tests in accordance with the procedure mentioned in IS 2270.The stabilization of black cotton soil is done by constant 3% of lime and an increasing percentages of rubber crumb powder 5%, 10%, 15%.

The observations concluded were that the; Increase in CBR value with increasing percentage of rubber crumbs at 3% of lime as constant therefore reduced pavement thickness and increased stability. Optimum moisture content and maximum dry density increases with increase in percentage of rubber crumb powder. The soil stabilized with rubber crumbs along with lime is more suitable for shallow foundation. It's a cost effective method of stabilization and a best solution for environmental problem. It's a new resource for the construction industry.

**B. Sri Vasavi, Dr. D.S.V. Prasad – "Stabilization of Expansive Soil Using Crumb Rubber Powder and Cement" (2016) [8]**

This paper presents the stabilization of expansive soil using crumb rubber powder (CRP) and cement at varying percentages (2%, 5%, 7% and 9% and also 2%, 4% and 6% respectively). The soil properties, compaction, California bearing ratio and direct shear test were used to gauge the behavior and performance of stabilized soil.

Black cotton soil is the soil which exhibits swelling in rainy season and shrinkage in summer season. This kind of abnormal behavior is due to the presence of montmorillonite mineral. The investigations carried out on the black cotton soils obtained from Narakodur village, Andhra Pradesh. CRP used in the study is of 1.18mm down size. Cement used for the experimental investigation was 43 grade OPC used in percentages of 2%, 4%, 6%.From the standard proctor compaction test, it was observed that the maximum dry density reduced with the increase in percentage of crumb rubber due to its light weight property. The cohesion decreases with increase in CRP up to 7%and then increases with further increase in 9% of CRP, angle of internal friction decreases with increase in CRP up to 7% and then increases with further increases in 9% of CRP.

**Yadav J.S, S.K.Tiwari - "Effect of inclusion of Crumb Rubber on the unconfined compressive strength and wet-dry durability of cement stabilized clayey soil" (2016) [9]**

Crumb rubber and cement were added to clayey soil at ranges of 2.5%-10% and 3%-6% respectively. The results of the investigation revealed that the incorporation of crumb rubber influenced the unconfined compressive strength, axial strain at failure, energy absorption capacity and wet-durability of the cement-stabilized clay. The study reveals that as the content of crumb rubber in the cement-stabilized clayey soil increases the unconfined compressive strength deceases but prosperously changes the behavior of cement stabilized clay from brittle to ductile. The weight loss of the cement-stabilized clay mixed with crumb rubber increases as the content of crumb rubber increases. With the prolongation of the curing period, the weight loss of cement-stabilized clay mixed with crumb rubber decreases. Further, the weight loss of 90 days cured specimens of clayey soil incorporated with 6% cement and crumb rubber up to 5% meets the recommendation of the material to be used in construction of road pavements as a base, sub-base and shoulder.

Soil sample was taken from Jaipur city. Some of the properties such as Atterberg limits, Specific gravity, Maximum dry density, and Optimum moisture content were being determined. Crumb rubber obtained from the S&J Granulate solution having the particle size between 0.8-2 mm was used in this investigation.OPC-43 grade cement was used for the determination. Both maximum dry density and optimum moisture content of the clay decreases with the addition of crumb rubber, whereas inclusion of cement in the rubberized clay leads to decreases in the density and increased the optimum moisture content of the mixtures.

**Rathan Raj R, Bhanupriya S, Dharani R – "Stabilization of soil using Rice Husk Ash" (2016) [10]**

In this present investigation the type of solid waste namely rice husk ash for stabilization is selected to study the effects of same on the index on engineering characteristics of problematic soil. The rice husk ash is mixed with soil in various proportions like 5%, 10%, 20%, 30%, 40%, 50% and 80%. The natural soil sample 1(clay soil) was collected from site in Kodambakam area at 1.5 m depth from ground level by making open trench. Soil sample 2(alluvial soil) was collected from the site near by Chennai at 1.50m depth from the ground level by making open trench. The soil is air dried at room temperature and sieve through 425 micron sieve before the laboratory test.

From the results, the liquid limit of the soil decreased steeply with the increase in the % of RHA. The maximum dry density increased in the case of addition of RHA to alluvial soil. The optimum moisture content decreased steeply for80% for clay soil and the maximum dry density increased. The undrained cohesion value of soil mixed with alluvial soil and clay soil decreased and angle of internal fraction increased for both clay and alluvial soil.

**Vishnu T.C, Raseem Rasheed, Rameesha K – Soil Stabilization Using Rice Husk Ash, Lime and Jute (2016) [11]**

The proposed project is to examine how much strength can attain by clay soil when stabilized using RHA, jute and lime. The following tests such as specific gravity determination, consistency limits, wet sieve analysis, hydrometer test, compaction test, California bearing ratio test, unconfined compressive strength test are carried out.

The material used in this project is clayey soil is taken from the paddy field. RHA was produced by burning in open air. Jute fiber was obtained from local market and used reinforce the soil. This results being obtained for the collected soil sample are that; the addition of various % of lime and RHA into the soil progressively deceases the OMC and increases MDD. The combination of 6% lime and 6% RHA was obtained as optimum. Among various combination of jute, 25 jute of aspect ratio 25 proves to be more effective as compare to lower percentages because when the length of the jute fiber increases, more and more soil particles will get bonded together precisely increased of jute fiber increases the reinforcement among the soil and jute fiber.

**P.T.Ravichandran, K.Divya Krishnan – Effect of addition of Waste Tyre Crumb Rubber on Weak Soil Stabilization (2016) [12]**

In this work, the possibility of using crumb rubber powder was an additive to improve the strength of soft soil was investigated. Two types of problematic clay soils were stabilized with various percentages of crumb rubber (5, 10, 15 and 20%).

The two soil samples A1and A2 used in the study collected at a depth of about 0.7m below the ground level from the site as disturbed but representative soils. The soil collected was air-dried and then pulverized. From the gradation analysis the sample A1 and A2 contained 97% and 94% of fine grained soils. The soil being classified as Clay of High Compressibility (CH) based on the gradation and consistency limits of soil. The crumb rubber powder was obtained from recycled rubber from automotive and truck scrap tires and the size ranges from 425micron to 600micron. Specific gravity of crumb rubber determined ranges from 0.8 to 0.9. The compaction tests on virgin soils and soils with crumb rubber powder were conducted to determine its compaction characteristics (OMC and MDD) by replacing 5%, 10%, 15%, and 20% by weight of soil. Crumb rubber powder mixed with both the soils showed improvement in CBR value with its addition up to 10% and there onwards decreased with further increase in crumb rubber powder. The use of crumb rubber as a stabilizer introduces a low cost method for stabilization.

**Dilip Shrivasthava, A.K. Singhai, R.K. Yadav – "Effect of Lime and Rice Husk Ash on Engineering Properties of Black Cotton Soil (2014) [13]**

The wide spread of black cotton soil has posed challenges in the construction activities. The black cotton soil used was collected from Jabalpur; the rice husk ash was collected from the rice mill. The black cotton soil is mixed with 5% of lime and soaked for 4 days after oven drying; the following samples are prepared by mixing different % rice husk ash to it.

A series laboratory experiments as conducted on 5% lime mixed with black cotton soil blended with rice husk ash in 5%, 10%, 15% and 20% by weight of dry soil. A significant increase in CBR and UCS strength was obtained

**Ghagte Sandeep Hambirao, Dr. P.G.Rakaraddi – "Soil Stabilization using Waste Shredded Rubber Tyre Chips" (2014) [14]**

In the present investigation, shredded rubber from waste has been chosen as the reinforcement material and cement as binding agent which was randomly included into the soil at three different percentages of fiber content i.e., 5%, 10% and 15% by weight of soil. The low strength and high compressible soft clay soils were found to improve by addition of shredded rubber and cement.

In the present investigation attempt is made to stabilize the Black Cotton Soil collected from Bagalkot city and Shedi soil collected from Haliyal road of Dharwad city with randomly distributed shredded rubber tyre chips with 5%, 10%, 15% and cement with 2% and 4%.The unconfined and CBR tests were carried out in the laboratory for different mix proportions of rubber with black cotton soil and shedi soil. An Ordinary Portland Cement (OPC) of 53 grade has be used for the treatment. The shredded tyre material was obtained from the waste generated from tyre re-threading industries Dharwad of size 10mm to 25mm in length and the shreds have a thickness ranging from 2 to 3mm and they don't contain any steel wire or nylon fibers. Considerable improvement was found in strength of black cotton soil and shedi soils for the 5% mix of rubber. The unconfined compressive strength and

California bearing ratio increases with the increase in cement content at an optimum fiber content of 5%.

The literature survey describes the experimental investigations being carried out to study the effect of various stabilizing agents such as Rice husk ash, Crumb Rubber, Fly ash, Lime, Cement, Coconut Coir fiber on the geotechnical properties of Expansive soils. The properties of stabilized soil such as compaction characteristics, unconfined compressive strength and California bearing ratio are to be evaluated.

In the present project the effective utilization of Rice husk ash and Crumb Rubber to improve the geotechnical properties of Black Cotton soil is carried out in percentages of 5, 10, 15, 20, 25, and 30 % are being adopted.

Initially the geotechnical properties of Black cotton soil are examined. Later the stabilizers are added in the above mentioned percentages and the geotechnical properties are examined further the results are to be evaluated and the appropriate proportions are to be considered.

## 2.2 OBJECTIVES OF THE PROJECT

1) To study the effect of rice husk ash and crumb rubber on the characteristics of soil and to suggest a suitable soil stabilizer.
2) The project aims to examine the geotechnical properties like specific gravity, liquid limit, plastic limit, plasticity index, flow index, compressive strength and CBR percent characteristics for soil stabilization.

# Chapter 3

# METHODOLOGY

Civil engineering projects located in areas with soft or weak soils have traditionally incorporated improvement of soil properties by using various methods. Soil stabilization is being used for a variety of engineering work, were the main object is to increase the strength or stability of soil and to reduce the construction cost by making best use of locally available material.

Soil stabilization involves the use of suitable stabilizing agent (binder material) in weak soil to improve its geotechnical properties such as compressibility, strength, permeability and durability. The components of stabilization technology include soils, soil minerals and stabilizing agent or binder (cementitious materials). The use of agricultural waste such as Rice Husk Ash and Crumb Rubber being the recycled rubber produced from automotive and truck scrap tires would reduce the environmental hazards.

## 3.1 MATERIALS

### 3.1.1 Black Cotton Soil (BCS)

The black cotton soil is brought from the Mavinalli, Indi taluk Bijapur district. BCS are derived from basaltic bedrock and behaviour is attributed to the presence of mineral montmorillonite. These soils are alkaline in nature with low potassium and nitrogen content.

***Figure 3.1.1 Black Cotton Soil procured from Indi***

These soils are residual deposit formed from the basalt and trap rocks, they are quiet suitable for growing for cotton and are of quiet high plasticity, high shrinkage and swelling characteristics, shearing and bearing capacity of soil is extremely low. The overcome these circumstance it should be treated and stabilized. The black cotton soil has posed challenges and problems to the construction activities. Black Cotton Soil is clayey soil grayish to blackish in colour. Montmorillonite is the most common of all the clay minerals in expansive clay soils. The mineral made up of sheet like units. The basic structure of each unit is made up of gibbsite sheet (i.e. octahedral sheet) sandwiched between two silica sheets. The thickness of each unit is about 10Å and the dimensions in the other two directions are indefinite. The gibbsite layer may include atoms of aluminum, iron, magnesium or a combination of these. In addition, the silicon atoms of tetrahedron may interchange with aluminum atoms. These structural changes are called amorphous changes and result in a net negative charge on clay mineral. Cat ions which are in soil water (i.e. Na+, Ca++, K+, etc.) are attracted to the negatively charged clay plates and exist in a continuous state of interchange.

### 3.1.2 Rice Husk Ash (RHA)

The rice husk ash is obtained from RK Rice Mill, Deshihalli, Bangarpet taluk Kolar district.

***Figure 3.1.2 Rice Husk Ash procured from Bangarpet***

Rice husk is an agricultural waste obtained from milling of rice. The husk obtained is not suitable as an animal feed because of its abrasive character and almost negligible digestible protein content, its high ash and lignin content make it unsuitable as raw materials of paper manufacturing. In order to reduce such volume of a waste, rice husk is burnt either in open heaps or as a fuel in oven for rice drying, power generation etc. The rice husk consists about 7-90 % of silica present in rice husk in amorphous form and it is considered as a pozzolonic material. Cellulose ($C_5H_{10}O_5$), Lignin ($C_7H_{10}O_3$), Hemicellulose, $SiO_2$, Holocellulose is the constituents of Rice Husk. A proper quality burning of rice husk ash would remove the cellulose and rice husk components preserving the original cellular structure of the rice husk particles as the silicates are the components that give the pozzolonic reactivity capacity for rice husk ash. The rice husk ash may vary depending upon the source as well as the type of treatment. Treatment in the sense the rice husk is burned to have proper properties. The method of heating brings changes in the overall chemical composition of the ash. The silicates are one of the primary components of the rice husk ash. During the burning process, the only component left is the silicates. The rice husk ash to be more precise has the characteristics based on the components, the temperature of the burning and the time of burning. The silicates are the components that give the pozzolonic reactivity capacity for rice husk ash. In order to gain this, the silica must remain in its non-crystalline form. They should gain a highly porous structure within their microstructure. So, this makes clear that a proper quality burning of rice husk ash would remove the cellulose and rice husk components preserving the original cellular structure of the rice husk particles. The chemical composition of the Rice husk ash in general is given below:

***Table 3.1.2 Chemical composition of the Rice husk ash***

| Sl.No. | Particulars | Proportion (%) |
|---|---|---|
| 1 | Silicon Dioxide | 86.94 |
| 2 | Aluminum Oxide | 0.2 |
| 3 | Iron Oxide | 0.1 |
| 4 | Calcium Oxide | 0.3 – 2.25 |
| 5 | Potassium Oxide | 2.15 – 2.30 |
| 6 | Magnesium Oxide | 0.2 – 0.6 |
| 7 | Sodium Oxide | 0.1 – 0.8 |

The feasibility of utilization of Rice Husk Ash can be enumerated as follows:

a) Its high silica content makes it useful for strengthening building materials.
b) It resists moisture penetration and fungal decomposition, decomposes slowly, insulates well and is renewable.
c) Less expensive and more abundant than the wooden chip found in traditional board.
d) Termite-resistant because of their silica, which termites have difficulty consuming.
e) The silica benefits the environment in many ways in reducing the wastes going into landfills.

### 3.1.3 Crumb Rubber (CR)

The Crumb rubber which is used in our project is obtained from Kolar-Vemgal Rubber Retreading Centre.

Rubber does not decompose and as result an economically feasible and environmentally sound disposal method has to be followed. Utilization of crumb rubber as soil stabilizer not only soils environmental problems but also provides new resource for construction industry. As the soft soil is weak enough to stably withstand the load acting upon it the use scrap tyre powder is to stabilize the soil by reducing the environmental impact.

***Figure 3.1.3 Crumb Rubber procured from Kolar***

There are two major technologies for producing crumb rubber- Ambient Mechanical Grinding and Cryogenic Grinding. Cryogenic process is more expensive but it produces smoother and smaller crumbs. The chemical composition of the Crumb Rubber in general is according to the table3.1.2.

***Table 3.1.3 Chemical composition of Crumb Rubber***

| Sl.No. | Particulars | Test Data (%) |
|---|---|---|
| 1 | Acetone extract | 10.0 |
| 2 | Rubber hydrocarbon | 25.0 |
| 3 | Carbon black content | 30 |
| 4 | Natural rubber content | 31.0 |
| 5 | Ash content | 4.0 |

The feasibility of utilization of crumb rubber can be enumerated below:

a) Rubber crumb is sold as a feedstock for chemical devulcanization or pyrolysis process, added to asphalt for highway paving and pavement sealers, or used for the production of large number of recycled rubber containing products.
b) The application of recycled tire is a practical and ecological solution, which not only helps the environmental balance but also supplies some needs within the industrial, sports, decorative, animal and urban sectors.
c) As the soft soil is weak enough to stably withstand the loads acting upon it the use of scrap tire powder for stabilization of soil in order to reduce the environmental impact.

## 3.2 METHODOLOGY

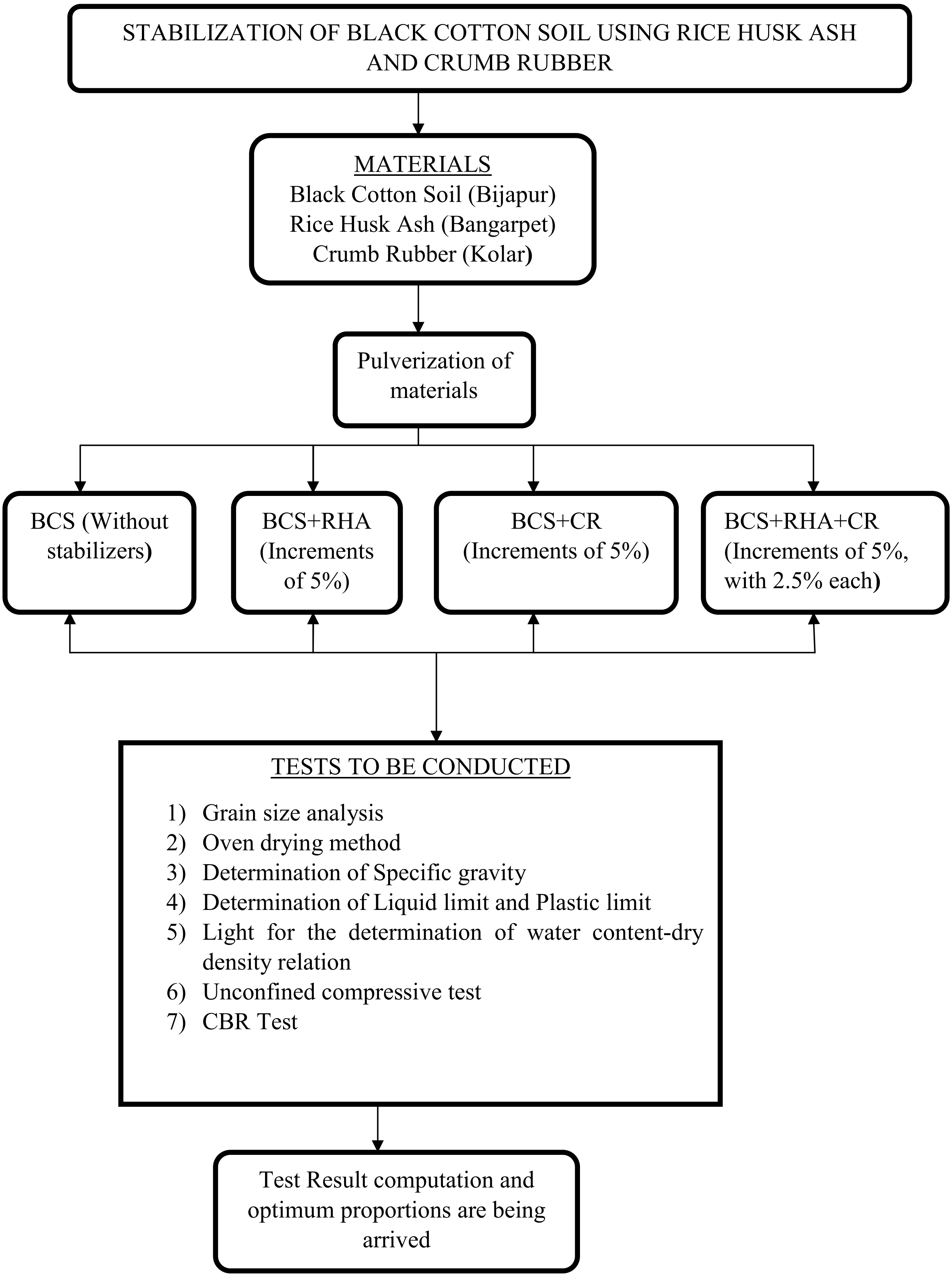


***Figure 3.2 Methodological framework of the project***

## 3.3 TESTS CONDUCTED

The below are the tests to be conducted is on the black cotton soil without the stabilizers initially for the determination of the geotechnical properties further by the addition of the stabilizers in increments of 5% to 30% properties of the stabilized samples are being assessed.

### 3.3.1 Grain Size Analysis

This method is for the quantitative determination of grain size distribution in soils. Wet sieving shall be applicable to all soils due to the presence of considerable amount of clay. The grain size distribution is found by mechanical analysis. The test is conducted according to IS 2720 (Part 4) – 1985.

The different apparatus used for test were, sieves confirming to IS: 460(part I) - 1978,4.75 mm, 2 mm, 425µ, 75µ, Oven to maintain temperature between 105˚C to 110˚C, trays or buckets, brushes, mechanical sieve shaker.

Suitable quantity of soil about 1000 g passing through 4.75 mm sieve is taken in 75µ sieve and is washed thoroughly using clean water until clear water appears and retained portion of soil is kept for oven drying. Retained sample is sieved using either mechanical sieve shaker or manually sieved. Set of IS sieves as 4.75mm, 2.36mm, 1.18mm,600µ, 425 µ, 300µ, 75µ were used. Sieve the soil in a mechanical sieve shaker for 10 minutes. Weigh the material retained on each sieve. Percentage of soil passing 75µ is considered as combination of silt and clay, soil retained above 75µ is coarse sand, medium or fine sand. Particles retained above 2.36mm sieve are considered as gravel portion of soil under investigation.

### 3.3.2 Determination of Specific Gravity

This standard lays down the methods of test for the determination of specific gravity of soil particle of fine grained soils. The test is conducted according to IS: 2720 Part 3 – 1980.Specific gravity is defined as the ratio of the mass/weight of a given volume of dry soil solids at a given temperature to the mass/weight of an equal volume of distilled water at that temperature, both weights being taken in air. It gives an idea about the suitability of the soil as a construction material, higher value of specific gravity gives more strength for Roads and Foundations.

### 3.3.3 Determination of Liquid Limit

Liquid limit is generally determined by the mechanical method using Casagrande's apparatus. As per this method the liquid limit is defined as the moisture content at which 25 blows or drops in standard liquid limit apparatus will just close a groove of standardized dimensions cut in the sample by the grooving tool by a specified amount.

Casagrande apparatus is a mechanical device, consisting of a cup and arrangement for raising and dropping through a specified height of 10mm. There are two standard grooving tools. Other apparatus required include spatula, evaporating dish, moisture containers, balance of capacity 200 grams and sensitivity to 0.01 g and thermostatically controlled drying oven to maintain 105˚C to 110˚C.

About 120 g of dry soil sample passing 425 micron IS sieve is weighed and mixed thoroughly with distilled water in the evaporating dish to form a uniform thick paste. The liquid limit device is adjusted to have a free fall to cup exactly through 10 mm. The paste should have a fairly stiff consistency such that in the trial run, 30-35 blows or drops of the cup are required to close the standard groove for a specified length of 12 mm at the bottom. The soil paste is remixed and a portion of the paste is placed in the cup of the apparatus above the lowest spot and squeezed down with the spatula to have a horizontal surface. The soil paste is trimmed by firm strokes of the spatula in such a way that the maximum depth of soil sample in the cup is 10 mm. The soil sample in the cup is divided along the diameter through the centre line of the cam followed by firm strokes of the grooving tool so as to get a clean sharp groove. The V shaped grooving tool is used only in clayey soils free from sand particles or fibrous materials. The crank is rotated at the rate of 2 revolutions per second so that the test cup is lifted and dropped as specified. This is continued till the two halves of the soil cake flows slowly under the blows and come into contact at the bottom of the groove for a length of 12 mm and the number of blows given is recorded.

In the next trial, additional small quantity of water is added to the soil paste in the dish, mixed well using a spatula and the required quantity of paste is placed in the test cup and the operations are repeated to determine the number of blows required in this trial. As the water content in the paste is increased, the number of blows required to close the groove decreases. The process is repeated for more trials with slightly increased water contents each time, noting the number of blows so that there are at least 4 to 6 uniformly distributed readings of number of blows between 15 and 35.

### 3.3.4 Determination of Plastic Limit

Plastic limit (PL) is the water content at which the soil rolled into thread of smallest diameter possible starts crumbling and has a diameter of 3 mm. Evaporating dish of about 120 mm diameter, spatula, ground glass plate, moisture containers, rod of 3 mm diameter, balance sensitivity to 0.01g, drying oven controlled at temperature 105˚C to 110˚C.

About 30 g of dry soil sample passing through 425 micron IS sieve is weighed out. The soil is mixed thoroughly with distilled water in the evaporating dish till the soil paste is plastic enough to be easily moulded with fingers.

A small ball (of about 8 g weight) is formed with the fingers and this is rolled between the fingers and the ground glass plate to a thread throughout its length. The pressure just sufficient to roll into a thread of uniform diameter should be used. The rate of rolling should be between 80 to 90 strokes per minute counting a stroke as one complete motion of hand forward and back to the starting position again. The rolling is done till the diameter of the thread is 3 mm. Then the soil is kneaded together to a ball and rolled again to form thread. During this process of alternate rolling and kneading there will be loss in water content in the soil sample and it gradually become stiffer. The process of kneading and rolling into thread is continued until the thread starts crumbling under the same pressure required for rolling, when the thread just reaches a diameter of 3 mm and the soil sample can no longer be rolled into thread of smaller diameter.

By trial, the thread which starts crumbling at 3 mm diameter under normal rolling pressure should be obtained and the pieces of the crumbled thread of soil sample should be immediately transferred to an air tight moisture container, lid tightly placed quickly and weighed to find the wet weight of the thread. Any delay in transferring the sample of thread to the container or closing with the lid tightly could result in considerable loss in the moisture due to rapid evaporation. The container with the soil specimen is kept in the oven for about a day and dry weight is found. The water content of the soil thread is determined which is plastic limit of the soil. The above process is repeated three to four more times so as to get at least three consistent values of plastic limit.

### 3.3.5 Determination of Water Content, Dry Density relation using Light Compaction

This method is for the determination of the relation between the water content and the dry density of soil using light compaction. In this test 2-6 kg rammer falling through a height of 310 mm is used. The test is conducted according to IS: 2720 Part 7 – 1980.

The Standard Proctor Test is conducted to study the density of soil and its corresponding optimum moisture content. Compaction of soil is a mechanical process by which the soil particles are constrained to be packed more closely together by reducing the air voids. Soil compaction causes decrease in air voids and consequently an increase in dry density. This may result in increase in shearing strength.

Mould of capacity 1000 cm3 with diameter of 100 mm and height 127.3 mm, metal rammer of 50 mm diameter, 2.6 kg weight with a free drop of 310 mm, IS sieve 4.75 mm. Other accessories like moisture containers, spatula, trowel, balances of capacity 10 kg and200 g, drying oven, and measuring cylinder.

Take about 2.5 kg of air dried soil sample passing through 4.75 mm IS sieve. Add required water to it and mix thoroughly and keep it for soaking in an air tight container for about 16-20 hours. Find the mass of the empty and clean cylindrical mould along with the base plate fixed to it. Attach the collar and apply grease to the inside of mould and collar.Mix the matured soil thoroughly and fill the soil in 1000cc mould.

For light compaction, compact the moist soil in three equal layers, each layer being given 25 blows from the rammer weighing 2.6 kg with a drop of 310 mm for 1000cc mould by distributing the blows evenly. Each layer of the compacted soil should be scratched with the spatula before putting the soil for next layer. The amount of soil should be just sufficient to fill the mould leaving about 5 mm to be struck off when the collar is removed. Remove the collar, trim the excess soil using a straight edge, clean the mould from outside and take the mass of the mould with base plate and compacted soil. Eject out the soil from the mould and take a representative sample for water content determination. Repeat the above procedure for 5 to 6 time with increasing water content.

### 3.3.6 Determination of Unconfined Compressive Strength

This method is for the determination of compressive strength of clayey soil, remoulded or compacted, using controlled rate of strain. Unconfined compressive strength defines the load per unit area at which an unconfined cylindrical specimen of soil will fail in the axial compressive test. The test is conducted according to IS: 2720 Part 10 – 1991.

The shear strength of the soil is determined by conducting unconfined compression test. Unconfined compression tests are carried out on cohesive soil specimen. The cylindrical test specimen may be directly placed in a compression testing machine and the compressive load applied. Strain controlled compression testing machine with proving ring assembly to measure load applied, dial gauge to measure deformation and moulds and tools to prepare test specimen.

Take 1000 g of dry soil sample passing through 425 micron IS sieve. Add optimum water to it and mix thoroughly. The specimen of required size is obtained using sampling tube. Measure the initial length and diameter of the specimen. Put the specimen on the bottom plate and raise it to make contact with the upper plate. Adjust the compression dial gauge and load dial gauge to zero. Compress the specimen to produce an axial strain rate of 0.5-0.2% per minute. Record both the dial gauge readings at suitable time intervals or at least at every 1 mm deformation of the specimen. Compress the specimen till the cracks is definitely developed or stress strain curve is well past its peak or 20% of vertical deformation is reached whichever occurs earlier. Sketch the failure pattern and measure failure angle α with horizontal, if possible, and if specimen is homogeneous and partially saturated.

### 3.3.7 Determination of CBR

The laboratory method is for the determination of California Bearing Ratio (CBR). The ratio expressed in percentage of force per unit area required to penetrate a soil mass with a circular plunger of 50 mm diameter at the rate of 1.25 mm/min to that required for corresponding penetration in a standard material. The test is conducted according to IS: 2720 Part 16 – 1987.

The CBR test denotes a measure of resistance to penetration of a soil or flexible pavement material, of standard plunger under controlled test conditions.CBR test equipment consists of a motorized loading machine fitted with the plunger which penetrates at the specified rate into the test specimen placed in the CBR mould.

Hollow cylindrical mould of inner diameter 150 mm and height 175 mm, spacer disc, compaction rammer of 4.89 kg with a drop of 450 mm, metal weights i.e., two discs weighing 2.5 kg each. Other accessories like IS sieve 19 mm, tray, mixing bowl, straight edge, filter paper, weight balance, measuring jar.

Take 5 kg of dry soil sample passing through 19 mm IS sieve. Add optimum amount of water to it and mix thoroughly. Apply grease to the inner surface of the CBR mould, place the spacer disc at the bottom of the mould and keep a filter paper over it and fill the soil sample into the mould in five layers with each layer being tamped for 56 blows using 4.89kg rammer with a free fall of 450 mm, to obtain the required density. Keep the surcharge weight of 5 kg i.e., two discs weighing 2.5 kg each. Test the samples in unsoaked condition are tested for CBR using motorized loading machine.

The mould with the specimen is clamped over the base plate and the same number of surcharge weights is placed on the specimen centrally such that the penetration test could be conducted. The mould with base plate is placed under the penetration plunger of the loading machine. The penetration plunger is seated at the centre of the specimen and is brought in contact with top surface of the soil sample by applying a seating load of 4 kg. The dial gauge for measuring the penetration values of the plunger is fitted in position and the penetration dial gauge is set to zero.

The dial gauge of the proving ring for load readings (or the load cell reading) is also set to zero, not considering the seating load. The load is applied through the penetration plunger of the motorized loading machine at a uniform rate of 1.25 mm per minute. The load readings are recorded at penetration readings of 0.0, 0.5, 1, 1.5, 2, 2.5, 3, 4, 5, 7.5, 10 and 12.5 mm. In case the load readings start decreasing before 12.5 mm penetration, the maximum load value and the corresponding penetration value are recorded. After the final reading, the load is released and the mould is removed from the loading machine.

## Chapter 4

# EXPERIMENTAL RESULTS & DISCUSSION

Wet sieve Analysis, Atterberg limits, Compaction tests, Unconfined Compressive Strength and CBR percent tests are conducted on Black Cotton Soil to determine the initial characteristics. The tests are further conducted by the addition of stabilizers Rice Husk Ash with Black Cotton Soil, Crumb Rubber with Black Cotton Soil and combination of the RHA and CR with Black Cotton Soil in the increments of 5% to 30%. The analysis has been discussed below.

## 4.1 WET SIEVE ANALYSIS

Wet sieve analysis on Black Cotton Soil collected from Indi, Bijapur was carried out in order to classify the soil. The following observations are being made:

Sample taken (passing 4.75mm sieve before washing) = 1000g

Sample retained on 0.075mm sieve after washing and drying = 115g

***Table 4.1 Wet Sieve Analysis on Black Cotton Soil***

| Sl.No. | IS sieve size(Particle size-D)mm | Individual weight of sieve (g) | Mass of soil retained (g) | Mass of soil (g) | %Mass of soil retained | Cumulative % retained C | % Finer N=100-C |
|---|---|---|---|---|---|---|---|
| 1 | 4.75 | 332 | 332 | 0 | - | - | 100 |
| 2 | 2.36 | 336 | 342 | 6 | 5.3 | 5.3 | 94.7 |
| 3 | 1.18 | 326 | 363 | 37 | 32.74 | 38.04 | 61.96 |
| 4 | 0.600 | 326 | 335 | 9 | 7.96 | 46 | 54 |
| 5 | 0.425 | 172 | 187 | 15 | 13.27 | 59.27 | 40.73 |
| 6 | 0.300 | 224 | 241 | 17 | 15.04 | 74.31 | 25.69 |
| 7 | 0.075 | 224 | 253 | 29 | 25.66 | 99.97 | 0.03 |
| 8 | Pan | 280 | 280 | 0 | 0 | 99.97 | 0.03 |

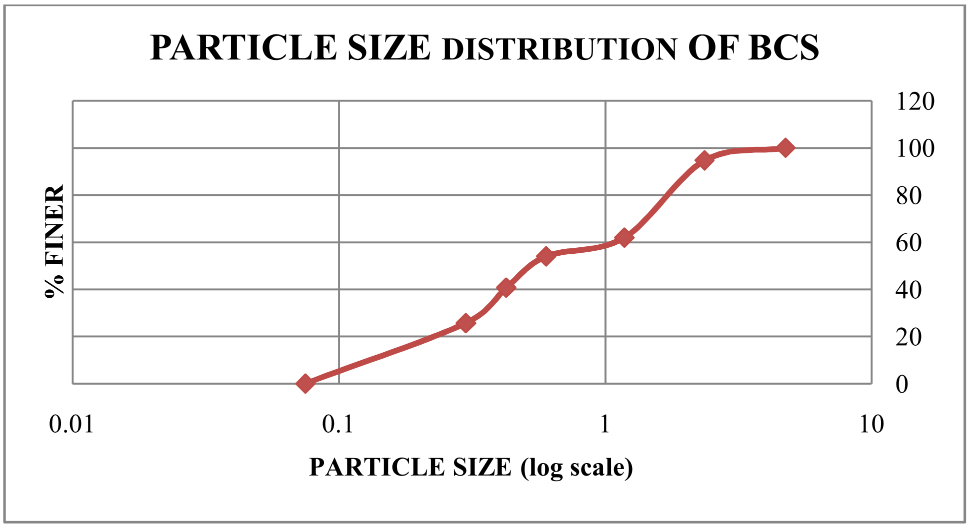


*Figure 4.1 Grain Size Analysis of Black Cotton Soil*

## 4.2 PROPERTIES OF BLACK COTTON SOIL

*Table 4.2 Properties of Black Cotton Soil from Indi, Bijapur*

| Sl. No. | Properties | Values |
|---|---|---|
| 1. | Specific Gravity | 2.78 |
| 2. | Liquid Limit (%) | 69 |
| 3. | Plastic Limit (%) | 37.5 |
| 4. | Flow Index (%) | 65 |
| 5. | Plasticity Index (%) | 31.5 |
| 6. | Standard Proctor Compaction test | |
| | a)Maximum Dry Density(MDD) (g/cc) | 1.7 |
| | b)Optimum Moisture Content (OMC)(%) | 24 |
| 7. | Unconfined Compressive Strength(UCS)(kN/m$^2$) | 44.14 |
| 8. | CBR Percent | 2.2 |

## 4.3 TESTS CONDUCTED ON BCS TREATED WITH SOIL STABILZERS – RHA, CR, combination of RHA & CR

### 4.3.1 Liquid Limit

*Table 4.3.1Variation of Liquid Limit of BCS treated with varying percentages of stabilizers*

| LIQUID LIMIT (%) | | | |
|---|---|---|---|
| % of Soil Stabilizer | BCS+RHA | BCS+CR | BCS+RHA+CR |
| 0 | 69 | 69 | 69 |
| 5 | 41 | 61 | 44 |
| 10 | 34 | 52 | 43 |
| 15 | 33 | 35 | 39 |
| 20 | 45 | 40 | 34 |
| 25 | 60.4 | 45 | 52 |
| 30 | 62 | 62.5 | 60.4 |

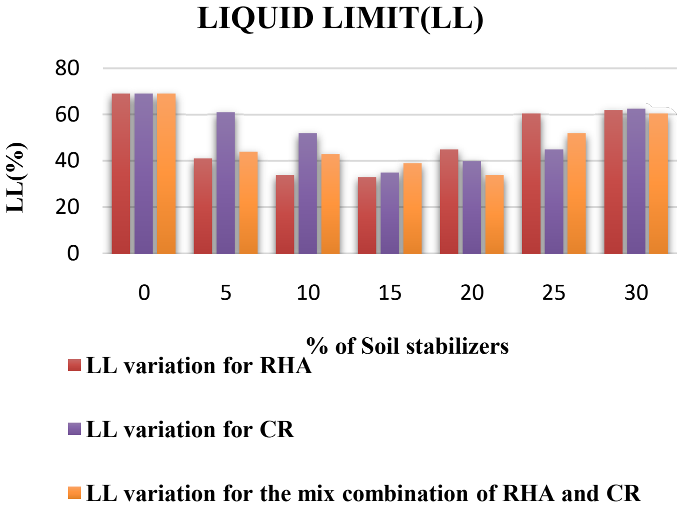


*Figure 4.3.1 Variation of Liquid Limit of BCS treated with varying percentages of stabilizers*

**OBSERVATION & DISCUSSION:**

1. Liquid Limit for Black Cotton Soil alone is found to be 69%.
2. LL of BCS on addition of 15% RHA is found to be 33% which yields better results. There is a subsequent decrease of LL upto 15% addition of CR and further LL increases on increasing percentage of CR.
3. LL of BCS on addition of 15%CR is found to be 35% which yields better results. There is a subsequent decrease of LL upto 15% addition of CR and further LL increases on increasing percentage of CR.

4. LL of BCS on addition of 20%RHA+CR is found to be 34% which yields better results. There is a subsequent decrease of LL upto 20% addition of RHA+CR and further LL increases on increasing percentage of RHA+CR.
5. LL is the minimum water content at which the soil mass is still in liquid state but has enough shearing strength to prevent flowing.
6. A high LL normally indicates a high compressibility and high shrinkage or swelling potential, thus the decrease of LL is to be assured by the utilization of stabilizers.

### 4.3.2 Plastic Limit

*Table 4.3.2 Variation of Plastic Limit of BCS treated with varying percentages of stabilizers*

| PLASTIC LIMIT (%) | | | |
|---|---|---|---|
| % of Soil Stabilizer | BCS+RHA | BCS+CR | BCS+RHA+CR |
| 0 | 37.5 | 37.5 | 37.5 |
| 5 | 33 | 42 | 32.65 |
| 10 | 25 | 62.5 | 22.2 |
| 15 | 23.3 | 32.65 | 16.7 |
| 20 | 32.65 | 75 | 36.6 |
| 25 | 42 | 76.5 | 43 |
| 30 | 54.22 | 80.2 | 52.2 |

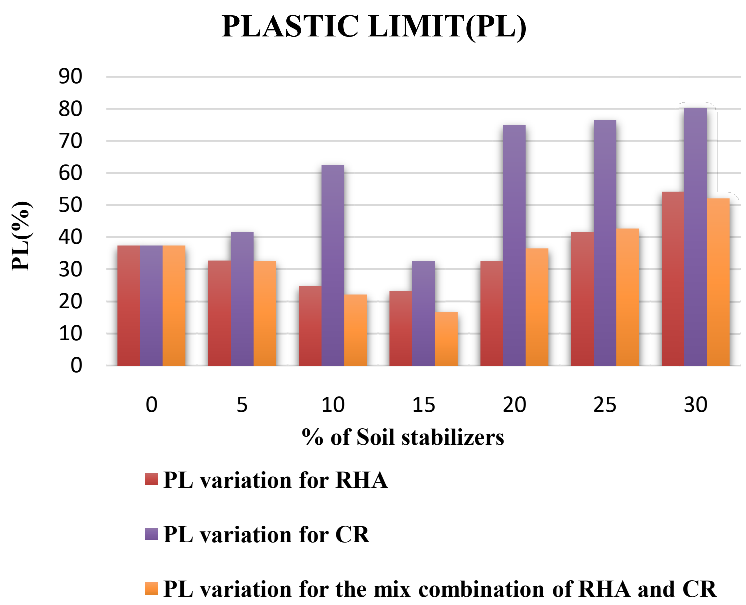


*Figure 4.3.2 Variation of Plastic Limit of BCS treated with varying percentages of stabilizers*

**OBSERVATION & DISCUSSION:**

1. Plastic Limit for Black Cotton Soil alone is found to be 37.5%.
2. PL of BCS on addition of 15% RHA is found to be 23.3% which yields better results. There is a subsequent decrease of PL, upto 15% addition of RHA and further PL increases on increasing percentage of RHA.
3. PL of BCS on addition of 15%CR is found to be 32.65% which yields better results. There is a subsequent decrease of PL upto 15% addition of CR and further PL increases on increasing percentage of CR.
4. PL of BCS on addition of 15% RHA+CR is found to be 16.7% which yields better results. There is a subsequent decrease of PL upto 15% addition of RHA+CR and further PL increases on increasing percentage of RHA+CR.
5. PL is the water content at which the soil will just begin to crumble when rolled into a thread of approximately 3mm diameter. Fine Grained soils become plastic as their moisture content is increased, leading to loss in shear strength and durability.
6. The clay content in the soil influences the PL wherein, higher the percentage of clay in soil higher would be its PL and higher would be the surface for water absorption.

## 4.3.3 Plasticity Index

***Table 4.3.3 Variation of Plasticity Index of BCS treated with varying percentages of stabilizers***

| PLASTICITY INDEX (%) | | | |
|---|---|---|---|
| % of Soil Stabilizer | BCS+RHA | BCS+CR | BCS+RHA+CR |
| 0 | 31.5 | 31.5 | 31.5 |
| 5 | 18.4 | 19.34 | 22.3 |
| 10 | 9.1 | 10.5 | 20.8 |
| 15 | 9.7 | 2.35 | 11.35 |
| 20 | 7.78 | 35 | 2.6 |
| 25 | 12.35 | 31.5 | 8.2 |
| 30 | 23.85 | 47.7 | 9 |

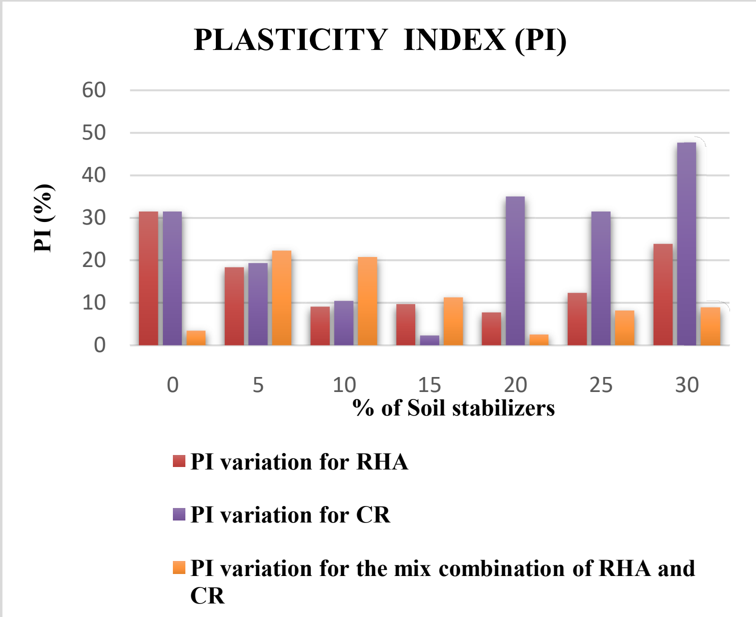


***Figure 4.3.3 Variation of Plasticity Index of BCS treated with varying percentages of stabilizers***

**OBSERVATION & DISCUSSION:**

1. Plasticity Index for Black Cotton Soil alone is found to be 31.5%.
2. PI of BCS on addition of 20% RHA is found to be 7.78% which yields better results. There is a subsequent decrease of PI, upto 20% addition of RHA and further PI increases on increasing percentage of RHA.
3. PI of BCS on addition of 15%CR is found to be 2.35% which yields better results. There is a subsequent decrease of PI upto 15% addition of CR and further PI increases on increasing percentage of CR.
4. PI of BCS on addition of20% RHA+CR is found to be 2.6% which yields better results. There is a subsequent decrease of PI upto 15% addition of RHA+CR and further PI increases on increasing percentage of RHA+CR.
5. As PI is the measure of plasticity of soil, higher the PI value higher would be its suspicion to the increase of swelling and shrinkage property.

## 4.3.4 Flow Index

***Table 4.3.4 Variation of Flow Index of BCS treated with varying percentages of stabilizers***

| FLOW INDEX (%) | | | |
|---|---|---|---|
| % of Soil Stabilizer | BCS+RHA | BCS+CR | BCS+RHA+CR |
| 0 | 65 | 65 | 65 |
| 5 | 56 | 56 | 60 |

| | | | |
|---|---|---|---|
| 10 | 46 | 35 | 43 |
| 15 | 33 | 30 | 22 |
| 20 | 50 | 23 | 56 |
| 25 | 60 | 45 | 64 |
| 30 | 65 | 52 | 70 |

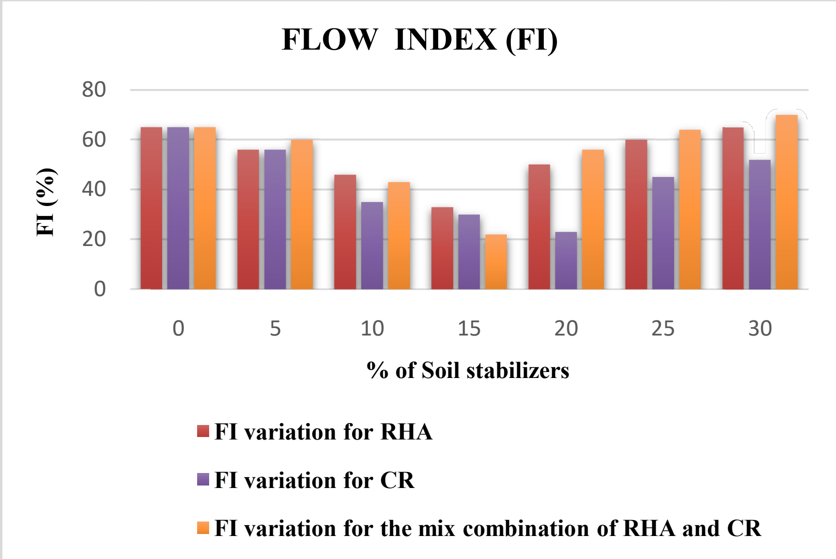


*Figure 4.3.4 Variation of Flow Index of BCS treated with varying percentages of stabilizers*

## OBSERVATION & DISCUSSION:

1. Flow Index for Black Cotton Soil alone is found to be 65%.
2. FI of BCS on addition of 15% RHA is found to be 33% which yields better results. There is a subsequent decrease of FI, upto 15% addition of RHA and further FI increases on increasing percentage of RHA.
3. FI of BCS on addition of 20%CR is found to be 23% which yields better results. There is a subsequent decrease of FI upto 20% addition of CR and further FI increases on increasing percentage of CR.
4. FI of BCS on addition of 15% RHA+CR is found to be 22% which yields better results. There is a subsequent decrease of FI upto 15% addition of RHA+CR and further FI increases on increasing percentage of RHA+CR.
5. FI is a measure of the rate at which a soil mass loses its shear strength with an increase in water content. Soil with lower value of FI has higher shear strength.

## 4.3.5 Compaction Test

***Table 4.3.5 Variation of OMC & MDD when BCS treated with varying percentage of stabilizers***

| % of Stabilizer | BCS+RHA | | BCS+CR | | BCS+RHA+CR | |
|---|---|---|---|---|---|---|
| | OMC (%) | MDD(g/cc) | OMC (%) | MDD(g/cc) | OMC (%) | MDD(g/cc) |
| 0 | 24 | 1.7 | 24 | 1.7 | 24 | 1.7 |
| 5 | 22 | 1.72 | 22.2 | 1.65 | 23 | 1.7 |
| 10 | 20 | 1.74 | 14 | 1.72 | 20 | 1.72 |
| 15 | 19.5 | 1.75 | 18 | 1.7 | 18 | 1.73 |
| 20 | 18.18 | 1.4 | 32.5 | 1.32 | 38.1 | 1.2 |
| 25 | 32.5 | 1.3 | 36 | 1.3 | 10.55 | 1.3 |
| 30 | 42 | 1.2 | 40.2 | 1.2 | 36 | 1.3 |

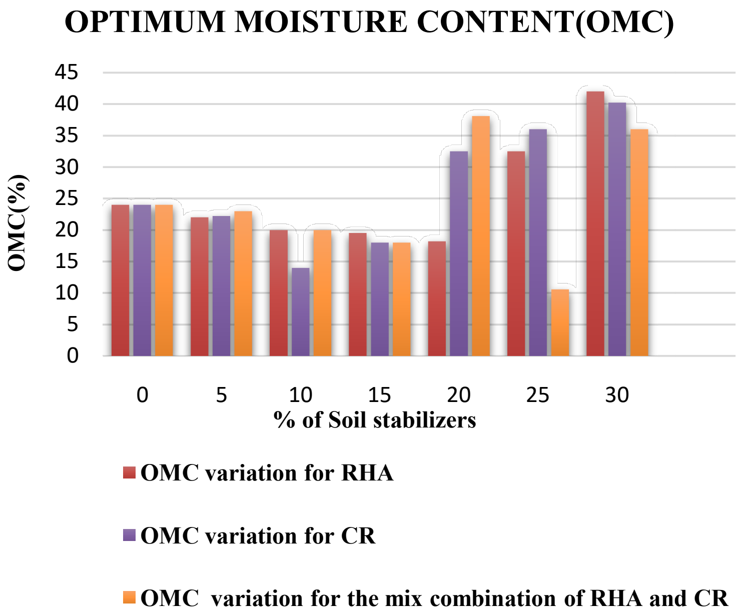


***Figure 4.3.5(a) Variation of Optimum Moisture Content of BCS treated with varying percentages of stabilizers***

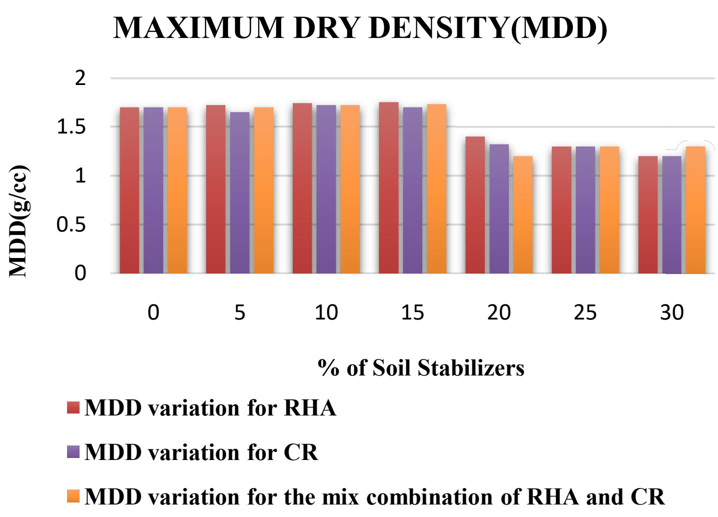


*Figure 4.3.5(b) Variation of Maximum Dry Density of BCS treated with varying percentages of stabilizers*

## OBSERVATION& DISCUSSION:

1. Optimum Moisture Content and Maximum Dry Density for Black Cotton Soil alone are found to be 24% and 1.7g/cc respectively.
2. MDD of BCS on addition of 15% RHA is found to 1.75g/cc and corresponding OMC for 15% RHA is found to be 19.5% which yield better results. There is a subsequent increase of MDD and consequent decrease of OMC upto 20% addition of RHA and further MDD decreases and its corresponding OMC increases on increasing percentage of RHA.
3. MDD of BCS on addition of 10% CR is found to be 1.72g/cc and corresponding OMC for 10% CR is found to be 14% which yield better results. There is a subsequent increase of MDD and consequent decrease of OMC upto 10% addition of CR and further MDD decreases and its corresponding OMC increases on increasing percentage of CR.
4. MDD of BCS on addition of 15% RHA+CR is found to be 1.73g/cc and corresponding OMC for 15% RHA+CR is found to be 18% which yield better results. There is a subsequent increase of MDD and consequent decrease of OMC upto 15% addition of RHA+CR and further MDD decreases and its corresponding OMC increases on increasing percentage of CR.
5. As the particles come closer, the voids are reduced and this causes the increase in dry density. The MDD occurs at an OMC. A greater compactive effort reduces the OMC and increases the MDD.
6. OMC/ MDD are important to achieve suitable compaction, primarily in order to reduce the susceptibility of soil to a settlement.

### 4.3.6 Unconfined Compression Test

*Table 4.3.6 Variation of UCS when BCS treated with varying percentages of stabilizers*

| UNCONFINED COMPRESSION STRENGTH (kN/m$^2$) | | | |
|---|---|---|---|
| % of Soil Stabilizer | BCS+RHA | BCS+CR | BCS+RHA+CR |
| 0 | 44.14 | 44.14 | 44.14 |
| 5 | 51.012 | 48.06 | 66.4 |
| 10 | 55.19 | 53.6 | 56.89 |
| 15 | 68.67 | 23.74 | 85.34 |
| 20 | 60.22 | 22.44 | 68.67 |
| 25 | 48.06 | 20.3 | 55.9 |
| 30 | 23.74 | 19.8 | 53.6 |

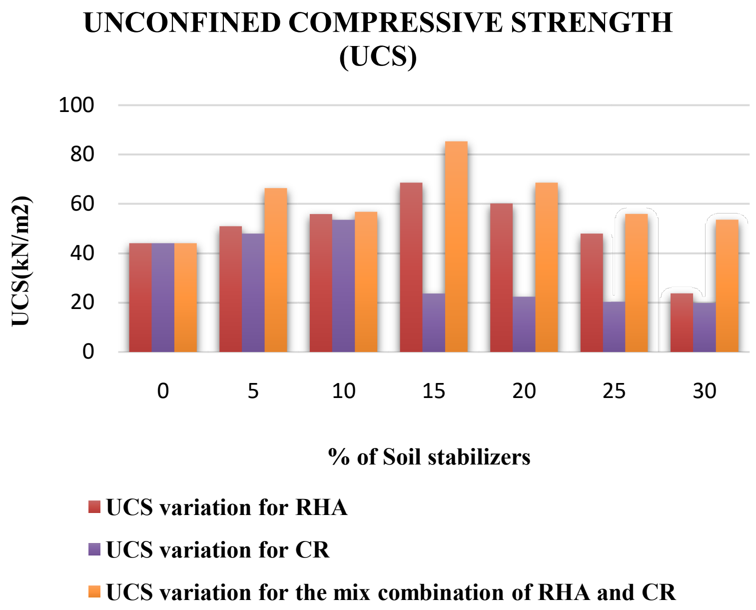


*Figure 4.3.6 Variation of UCS of BCS treated with varying percentages of stabilizers*

**OBSERVATION & DISCUSSION:**

1. Unconfined Compressive Strength for Black Cotton Soil alone is found to be 44.14kN/m$^2$.
2. UCS of BCS on addition of 15% RHA is found to be 68.67kN/m$^2$ which yields better results. There is a subsequent increase of UCS upto 15% addition of RHA and further UCS decreases on increasing percentage of RHA.
3. UCS of BCS on addition of 10% CR is found to be 53.06kN/m$^2$ which yields better results. There is a subsequent increase of UCS upto 10% addition of CR and further UCS decreases on increasing percentage of CR.

4. UCS of BCS on addition of 15% RHA+CR is found to be 85.34kN/$m^2$ which yields better results. There is a subsequent increase of UCS upto 15% addition of RHA+CR and further UCS decreases on increasing percentage of RHA+CR.
5. The brittle behavior of BCS is decreased thus, increasing the stiffness of stabilized soil with the inclusion of Crumb Rubber. The measurement of the shearing strength of cohesive soil.

### 4.3.7 CBR Percent characteristics

***Table 4.3.7 Variation of CBR of BCS treated with varying percentages of stabilizers***

| CBR (%) | | | |
|---|---|---|---|
| % of Soil Stabilizer | BCS+RHA | BCS+CR | BCS+RHA+CR |
| 0 | 2.2 | 2.2 | 2.2 |
| 5 | 2.8 | 2.0 | 2.3 |
| 10 | 2.9 | 3.27 | 2.76 |
| 15 | 2.6 | 2.3 | 2.915 |
| 20 | 1.02 | 1.1 | 2.8 |
| 25 | 1.1 | 1.1 | 2.6 |
| 30 | 0.72 | 1.82 | 2.4 |

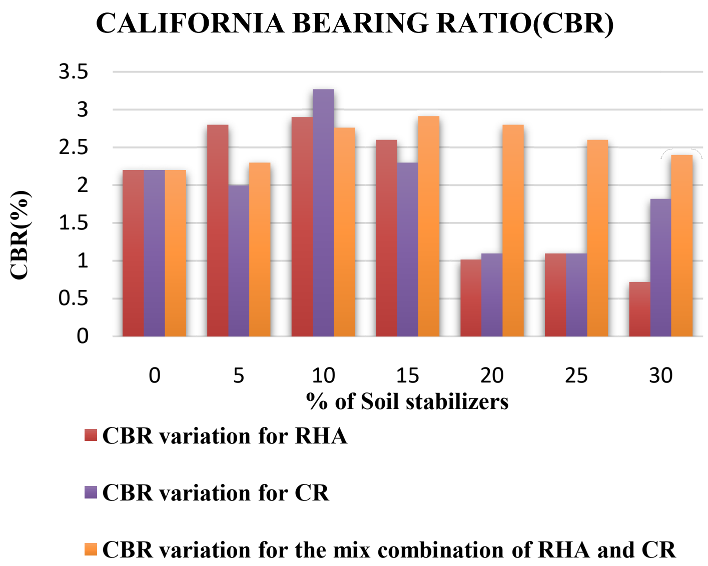


***Figure 4.3.7 Variation of CBR of BCS treated with varying percentages of stabilizers***

**OBSERVATION & DISCUSSION:**

1. California Bearing Ratio percent for unsoaked condition of Black Cotton Soil alone is found to be 2.2%.

2. CBR of BCS on addition of 10% RHA is found to be 2.9% which yields better results. There is a subsequent increase of CBR upto 10% addition of RHA and further CBR value decreases on increasing percentage of RHA.
3. CBR of BCS on addition of 10% CR is found to be 3.27% which yields better results. There is a subsequent increase of CBR upto 10% addition of CR and further CBR value decreases on increasing percentage of CR.
4. CBR of BCS on addition of 15% RHA+CR is found to be 2.915% which yields better results. There is a subsequent increase of CBR upto 15% addition of RHA+CR and further CBR value decreases on increasing percentage of RHA+CR.
5. The increase in CBR percentage increases the bearing capacity of Black Cotton Soil and also significant reduces in the pavement thickness can be considered in the design process.

## Chapter 5

# CONCLUSIONS

On the basis of present experimental study the following conclusions are drawn:

1. It is observed that for stabilized Black Cotton soil the Liquid Limit, Plastic Limit, Plasticity Index, Flow Index is found to be decreasing with an optimum proportion of 15% RHA+CR when compared with BCS alone and thus, it reduces the potential towards swelling and shrinkage and also the loss in shear strength of soil is minimized.
2. Based on the Plasticity chart of Soil Classification IS: 1498-1970 the Black Cotton Soil being utilized in the experimental study is of clayey soil having high Plasticity and is inorganic in nature.
3. It is observed that for the stabilized Black Cotton soil the Optimum Moisture Content is found to be decreasing and there is a consequent increase in Maximum Dry Density for the optimum proportion of 15% RHA+CR when compared with BCS alone thus, this reduces the susceptibility of soil to settlement.
4. It is observed that for stabilized Black Cotton soil the Unconfined Compressive strength is found to be increasing for an optimum proportion of 15% of RHA+CR when compared with BCS alone thus, this increases the stiffness of the Black Cotton Soil.
5. It is observed that for stabilized Black Cotton soil the CBR percentage is found to increase for the optimum proportion of 15% RHA+CR when compared with BCS alone thus, this increases the bearing capacity of soil.
6. The investigations demonstrates that Rice Husk Ash and Crumb Rubber can be made used in treating expansive soil to a certain extent in solving the environmental problem of waste tyre and agricultural waste disposal.

## 5.1 SCOPE FOR FURTHER STUDY

1. The determination of Shrinkage limit, Triaxial Compression test, Direct Shear test, Permeability test for the varying proportions of soil stabilizers are to be carried out.
2. Field determination of the geotechnical properties of Black Cotton Soil can be implemented and studied.
3. CBR percent characteristics for the varying curing period are to be carried out.
4. Extensive research can be carried out by blending the Black Cotton soil with other materials like Flyash, Burnt Brick Dust, Crushed Glass, Cement Dust, Bitumen etc, in their varying proportions which can partially solve the disposal problem and reduce its environmental impact.
5. The cost estimation for a particular practical case is to be carried.

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