SOIL STABILISATION USING GGBS, NANO-ZEOLITE POWDER AND COFFEE HUSK ASH

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Abstract – Soil is used as construction material in various building and civil engineering projects to provide structural supports to foundation. It is important to state that not all soils are suitable for construction in their natural states. Problematic soils could either be expansive soil or collapsible soil which in return causes low bearing capacity in building foundation, breaking and creaking of road structures. Black cotton soil is one of such problematic soils, though they are very fertile soils, they are not suitable for the foundation of roads and buildings. They are expansive clays with a high potential for shrinking or swelling as a result of changing moisture content. Building on these types of soils requires the development of techniques, such as soil stabilization, to enhance the soil. The technique used to improve the properties of problematic soil is stabilization with additives. 20% of Indian land covers the black soil, which is around 0.8msqkm. The experiments are done in the laboratory by blending the suitable % of ground granulated blast furnace slag, Nano-zeolite powder and coffee husk ash. The addition of GGBS causes flocculation of clay particles and increases the number of coarser particles. By adding GGBS compressive strength increases that means arrangement of soil particles were very closely, which reduced the voids. Nanomaterial have recently gained considerable attention in ground improvement, as they have the potential to actively interact with soil particles given their high specific surface area. This has encouraged researchers to explore the potential of nanoparticles in improving soil properties. Coffee husk ashes in this research were obtained from burned waste coffee husk which can be considered as solid waste material from the coffee processing industry which is the environment friendly element we using. In this study, we are looking for the results of the combined effect of the three additives, GGBS, Nano-zeolite and CHA. Laboratory tests are done to find out the increase in strength and physical properties of the soil after the addition of mentioned materials

INTRODUCTION

1.1 GENERALBACKGROUND

Soil is loose surface of the earth, a mixture of minerals, organic matter, gases, liquid and air. The soil quality affects the development of civil engineering infrastructures. Fundamentally, different soil types exist; one of them is expansive soil. Any earth material that has a potential for shrinking or swelling under changing moisture condition is generally termed as expansive soil. The expansive characteristic of soil is due to the presence of swelling clay minerals. As the soils get wet, the clay minerals absorb water molecules and expand; conversely, as getting dry the soils shrink and leave voids in the underground. The shrink-swell properties of soils detrimentally influence construction project design, performance and life time, especially of lightweight civil engineering infrastructures. Major engineering problems are volume changes due to cyclic swelling and shrinkage upon wetting and drying of the soils. The cyclic swelling and shrinkage of the soils can lead to differential heave, settlement and creep, instability in natural slopes, road cuts or open excavations; and difficult in workability conditions.

The usual approaches to solve the problems arise from expansive soils nature are to remove the soft soil, and replaces it with stronger materials and stabilization (mechanical and chemical). Chemical additives, lime and cement stabilization was a popular trend for decades in enhancing property of poor soils. Even though researching for new stabilization agent (effective, economical and eco-efficient) is in high importance because of increasing global demand for raw materials. Using waste materials in civil engineering infrastructure has a big role, for sustainable development. Therefore, exploring low cost materials for the improvement of soil properties to avoid damages to engineering structures is a crucial issue. Considering this, in this study, GGBS, Nano-zeolite and Coffee Husk Ash were investigated for its applicability in the treatment of expansive soil.

1.2 STATEMENT OF THE PROBLEM

Geotechnical properties of soils affect the design and cost of construction projects. Black cotton soils are known by their high expansion and shrinking properties due to a change in atmospheric conditions (wet, dry). The shrinkage behaviour of these soils leads to development of cracks. These cracks create weakness zones in a soil mass, which increase the compressibility and reduce strength. This could result in an early serious damage or even a complete collapse of civil engineering structures.

1.3 AIM

The main aim of this research is to study the potential use of GGBS, Nano-zeolite and Coffee husk ash to improve the geotechnical properties of expansive soil.

1.4 OBJECTIVES

The objectives of this projects are

- To investigate the combined effect of GGBS, Nano-zeolite and Coffee husk ash on various geotechnical properties (Atterberg limits, standard proctor test, and unconfined compressive strength) of expansive soil.
- To investigate the individual effect of GGBS, Nano-zeolite and CHA on strength of expansive soil.

1.5 SCOPE OF THE STUDY

- There are no existing projects or researches conducted by combining GGBS, Nano-zeolite and and coffee husk ash together for soil stabilisation.
- To increase the bearing capacity of expansive soil.
- To increase the strength of expansive soil

LIRERATURE SURVEY

2.1 STUDIES ON PREVIOUS LITERATURES

Chandan Kumar Behera, Satyapriya Senapati (2021)“Soil Stabilization by Industrial Waste (GGBS and Stone Dust)”. International Journal of Engineering Research & Technology (IJERT): Liquid limit of the expansive soil was 52.33%, the plastic limit was 22.45% and specific gravity was 2.6. It was observed that the OMC decreased and MDD increased by adding different percentage of GGBS and stone dust. It was observed from the laboratory investigations that the unsoaked CBR value increased up by adding GGBS and stone in different proportion. The UCS value also increased by adding GGBS and stone in different proportion. Hence, from the laboratory results, the optimum percentages of GGBS and stone dust were 30%.With increases of GGBS and stone dust percentage compressive strength increases that means arrangement of soil particles were very closely, which reduced the voids.[1]

M.K. Atahu, F. Saathoff and A. Gebissa (2018) “Strength and compressibility behaviours of expansive soil treated with coffee husk ash” Journal of Rock Mechanics and Geotechnical Engineering : This study aims to investigate the effect of CHA on compressibility and strength characteristics of black cotton soil. To examine these properties, 1D odometer and CBR tests are conducted on untreated soil and soil stabilized with different percentages (5%, 10%, 15% and 20%) of CHA.The soaked CBR value of untreated BC soil is 1%. After treated with 20% CHA, the value increased by three-fold and was 3.1%. For the unsoaked CBR test, addition of 20% CHA increases the bearing capacity from to 10.67%. From these results, it can be concluded that CHA is more effective for wet than dry condition. The results indicate that CHA improves the bearing capacity of the investigated soil.The study also reveals that the swell percentage of the BC soil decreases as the concentration of the CHA addition increases.The stabilization of BC soil using CHA improves the bearing capacity, swelling properties and compressibility behaviour of the BC soil. [2]

R P Munirwan , D Sundary , Munirwansyah, Bunyamin(2021)"Study of coffee husk ash addition for clay soil stabilization", IOP Conf. Series: Materials Science and Engineering:Thecombinations of coffee husk ashes and soil enhance the physical properties of soil and are potential materials to be used for soil stabilization.The index plasticity of treated soil exhibits a good reduction at 8.09 for 12 % of coffee husk ashes compared with 0% soil at 21.24%.The plastic limit of treated soil showed good decrement with the increasing percentage of coffee husk ashes. [3]

MeskeremKebedeAtahu(2020) "The Effect of Coffee Husk Ash on Geotechnical Properties of Expansive Soil", Geotechnical Engineering and Coastal Engineering Faculty of Agricultural and Environmental Science : In this research the potential use of CHA for the treatment of geotechnical properties (e.g. Atterberg limit, compaction characteristics, consolidation parameters, durability, strength) of expansive soil was studied in detail. In addition, the effect of the lime and CHA mixture in altering geotechnical engineering properties of the studied soil were investigated and reported.The obtained result reveals that the addition of CHA reduces the plasticity of the soil. The LL and PI decreased as the amount of CHA increased.From the compaction test results, the MDD of CHA treated samples increased and OMC decreased as the amount of CHA increased. The void ratio of CHA treated samples decreased as the amount of CHA increased due to the formation of cementitious compounds.The addition of CHA improved the bearing capacity of the BC soil.The unconfined compressive strength of samples treated with CHA increased with the increase in CHA content from 5% to 15%. Above 15% CHA (eg. 20%), decrease in the UCS value was observed.[4]

Reza PahleviMunirwan, MohdRaihanTaha, AizatMohdTaib, and MunirwansyahMunirwansyah(2022) "Shear Strength Improvement of Clay Soil Stabilized by Coffee Husk Ash"MDPI Journal of Applied Science:Stabilization of CHA in the clay soil significantly enhances the soil engineering properties, including their physical, and mechanical performance. This research indicates that CHA is not only cost-effective and practical in construction but also an approach to accomplishing sustainability and addressing climate change and environmental challenges. The liquid limit, plasticity index, and optimum water content all decrease as the CHA increases.However, maximum dry density and plastic limit increases.With the addition of CHA content, the OMC decrease and the MDD increase.[5]

Ruqayah Al-khafaji, Hassnen M Jafer, AnmarDulaim, W. Atherton, and ZahraaJwaida(2017) "Soft soil stabilisation using ground granulated blast furnace slag"Research Gate:This study has been carried out to investigate the effect of GGBS on the physical and engineering properties of the soft soil. The soft soil was mixed with GGBS at different percentages (0, 3, 6, 9 & 12%). The results indicate that the use of GGBS gave an improvement in the physical and strength characteristics of the soil.With the addition of GGBS to the soil, the Plasticity Index decreased while MDD and OMC increased and decreased respectively. Based on the UCS tests, the optimum amount of GGBS was 6% as it increased the strength by about 80% of that of soft soil.GGBS is a latent hydraulic material and needs an activator to break its glassy phase.[6]

Ashish Kumar Pathak, Dr. V. Pandey, Krishna Murari and J.P.Singh(2014) "Soil Stabilisation Using Ground Granulated Blast Furnace Slag"Int. Journal of Engineering Research and Applications: With the increases of GGBS percentage optimum moisture content goes on decreasing while maximum dry density goes on increasing, hence compactibility of soil increases and making the soil more dense and hard.Specific gravity goes on increasing, thus making the soil denser.With the increases of GGBS percentage, percentage finer goes on decreases, which strengthens the soil.Liquid limit, plastic limit and plasticity index decreases. With the increases of GGBS percentage compressive strength increases that means arrangement of soil particles are very closely, which reduces the voids.[7]

Bhanu Prakash Darsi, Kumar Molugaram ,andSaisantoshVamshiHarshaMadiraju (2021)"Subgrade Black Cotton Soil Stabilization Using Ground Granulated

Blast-Furnace Slag (GGBS) and Lime, an Inorganic Mineral"MDPI Environmental science proceedings: Liquid Limit, plastic limit, and plasticity index of soil decreased with the addition of Lime and GGBS. The addition of GGBS causes flocculation of clay particles and increases the number of coarser particles which helps in reducing the Atterberg limits.The MDD was increased by 9.9% and the OMC of Block Cotton Soil was by decreased 41.17%.Unconfined compressive strength of Soil-Lime and GGBS specimen increased by 84.16% with the increase in Lime content and GGBS and found maximum UCS value at proportions 6% of Lime and GGBS 10% of GGBS. The liquid and plastic limits of the expansive soil taken for the study are 58.2 and 32.95 respectively and the plasticity index was 25.25. The soil sample was classified as clay of high compressibility. [8]

Aaqib Ali, Bashir Ahmed Mir, Nadeem Gul, Fiza Zahoor Malik (2022) "Strength and Microstructural Behaviour of Soft Soil Treated with Zeolite Nanoparticles"Transportation Infrastructure Geotechnology: This current study ofers an overview of the uses of nanomaterial (nano-zeolite) additives for the stabilization of soft soils for their bulk use in geotechnical engineering applications.The test results indicated that the addition of 0.2%, 0.4%, 0.6%, 0.8%, and 1% of nano-zeolite by dry weight of soil, yielded 1-day UCS values of 109.67 kPa, 121.37 kPa, 147.69 kPa, 175.47 kPa, and 212.04 kPa, respectively. The unconfined compression strength of stabilized samples with 1% nano-zeolite was 10.2 and 16.7 times that of untreated soil after 7 and 28 days of curing, respectively. These results indicate that the addition of nano-zeolite to soft soil increases the strength.There was a progressive development of strength with curing age, indicating a time-dependent trend in strength.The addition of nano-zeolite increased the cohesion and friction angle of soil, which increased with further addition of the nanomaterial. Also, with an increase in nano-zeolite percentage, the sample ductility decreased as the samples failed at relatively lesser strains.[9]

2.2 SUMMARY OF LITERATURES

Previous researches were conducted on expensive and soft soils with the addition of GGBS, Nano-zeolite and coffee husk. The soil stabilisation additives on each of these researches were either alone or with incorporating other materials. The results have been effective because of the increased efficiency in strength and physical properties. Based on these reviews, it can be made sure that the addition of these materials will indeed increase the strength and physical properties of expansive soil in terms of stabilisation.

2.3 RESEARCH GAP

There are no existing researches where GGBS, Nano-zeolite powder and coffee husk ash has combined together for soil stabilisation. This research is done to make sure that this combination of materials can work well in soil stabilisation. Including GGBS and coffee husk, which are nothing but waste materials that can harm the environment can also be used for better infrastructure,

2.4 NEED FOR STUDY

Even though these researchers exists, there is still need of new methods and new materials to increase the stability of expansive soil, since it is a day to day challenge of a civil engineer working with expansive soil. So more researches are need to be done to find more additives and combination of such materials in the field of soil stabilisation.

MATERIALS AND METHODS

3.1 MATERIALS

Materials used in this project are expansive soil, GGBS, Nano-zeolite powder and Coffee husk.

3.1.1 BLACK COTTON SOIL

Black cotton soil was collected from Kozhinjampara area, Palakkad dist.

Black Cotton Soil is a cohesive soil. It is considered difficult or problematic soil for civil engineers. It possesses the characteristics of swelling during the rainy and shrinking during summer. In both situations, it poses difficulties. Swelling caused in Black Cotton Soil during the rainy season, the structure has uplift pressure and generates heave in the foundations, plinth beams, ground floors of the buildings and canals, roads surfaces, etc and on shrinkage in the summer season, cracks created in walls, slabs, plinth protection, floors, etc

Fig 3.1: Black cotton soil sample

3.1.2 GGBS

GGBs or Ground Granulated Blast-furnace Slag) is a cementitious material whose main use is in concrete and is a by-product from the blast-furnaces used to make iron.GGBS improves the quality of soil and increases strength and thereby stabilize soil better

Fig3.2: GGBS

3.1.3 NANO-ZEOLITE POWDER

In this study, nano-zeolite (Na2Al2Si2O8) in powdered form with a purity of greater than 99.9% supplied by Global Earths, Karnataka, India, was used as a chemical additive. The size of particles ranged between 30 and 50 nm.Table 3.1 shows the chemical composition of nano-zeolite.

Table 3.1: Chemical Composition of Nano-zeolite powder provided by Global Earths

Constituents	%
SiO_2	40-60
Al_2O_2	12-22
Fe_2O_3	2-3
CaO	12-18
MgO	2-5
Na_2O	1-2

Fig 3.3: Nano-zeolite powder

3.1.4 COFFEE HUSK ASH

Coffee husk ashes in this research were purchased from Amazon. These are industrial waste material from the coffee industry.Every 1 kg of coffee bean production will result in around 1 kg of coffee husk waste. In geotechnical engineering, the expansive soil behaviour of compressibility and strength after stabilising with coffee husk showed good strength paramaters.

Fig 3.4: Coffee husk ash

3.2 METHODOLOGY

The methodology consists of 5 steps from the collecting of expansive soil to result analysis and comparison of the physical properties. Main steps involved in our projects are shown in Fig 3.5. And we have successfully done the first two steps and is in the process of the third step.

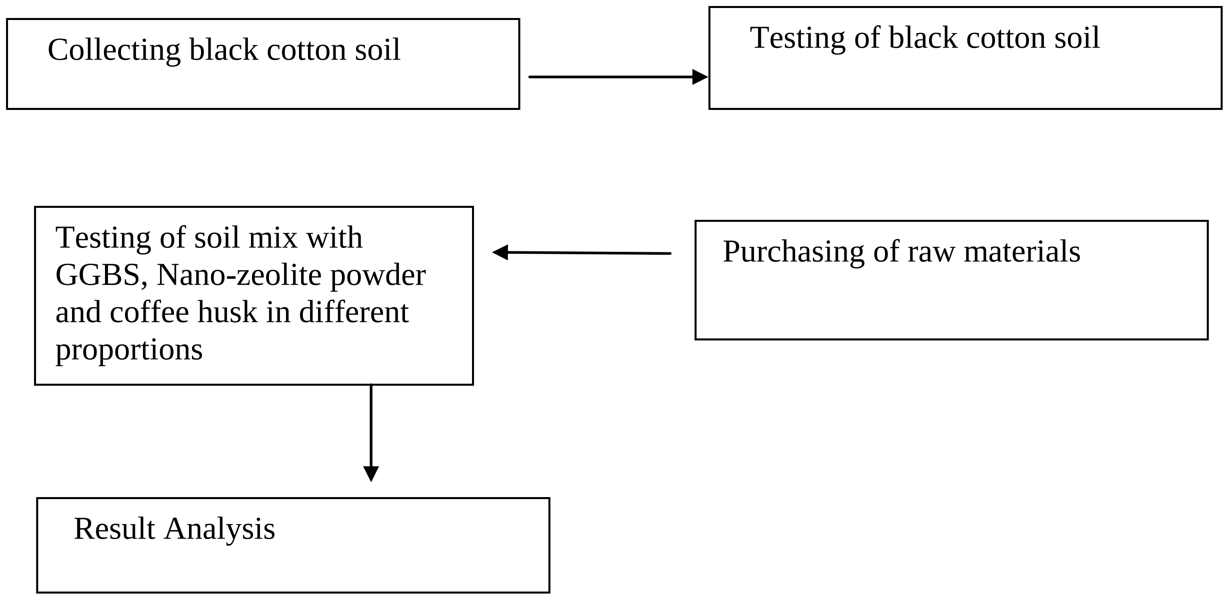

Fig 3.5: Flow Chart

3.3 DETERMINATION OF SPECIFIC GRAVITY

The specific gravity of the soil was found using pycnometer.

PROCEDURE

1. Clean and dry the Pycnometer. Tightly screw its cap. Take its mass (M_1) to the nearest of 0.1 g.
2. Mark the cap and Pycnometer with a vertical line parallel to the axis of the Pycnometer to ensure that the cap is screwed to the same mark each time.
3. Unscrew the cap and place about 200 g of oven dried expansive soil in the Pycnometer. Screw the cap. Determine the mass (M_2).
4. Unscrew the cap and fill it up with water to the Pycnometer. Take its mass (M_3).
5. Empty the Pycnometer. Clean it and wipe it dry.
6. Fill the Pycnometer with water only. Screw on the cap upto the mark. Wipe it dry. Take its mass (M_4).

Specific gravity is found using the equation,

$$G = (M2 - M1)/(M2 - M1) - (M3 - M4)$$

Fig 3.6:Pycnometer jar

3.4 DETERMINATION OF NATURAL WATER CONTENT

The natural water content also called the natural moisture content is the ratio of the weight of water to the weight of the solids in a given mass of soil. This ratio is usually expressed as percentage. Water content or moisture content is the quantity of water contained in a material, such as soil, rock, ceramics, crops, or wood. Water content is used in a wide range of scientific and technical areas, and is expressed as a ratio, which can range from 0 (completely dry) to the value of the materials' porosity at saturation. It can be given on a volumetric or mass(gravimetric)basis.

PROCEDURE

1.Soil sample is taken and weigh it.(Ww).

2.Dry the sample for 24 hrs in oven(Wd).

3.Using the equation (Ww/Wd)×100, natural water content is determined. 4. Mean Natural water content is calculated.

3.5 DETERMINATION OF ATTERBERG LIMIT

The Atterberg limit refers to the liquid limit and plastic limit of soil. These two limits are used internationally for soil identification, classification, and strength correlations. When clay minerals are present in fine-grained soil, the soil can be remolded in the presence of some moisture without crumbling. This cohesiveness is caused by the adsorbed water surrounding the clay particles. At a very low moisture content, soil behaves more like a solid; at a very high moisture content, the soil and water may flow like a liquid. Hence on an arbitrary basis, depending on the moisture content, the behavior of soil can be divided into the four basic states: solid, semisolid, plastic, and liquid.The percent of moisture content at which the transition from solid to semi-solid state takes place is defined as the shrinkage limit (SL). The moisture content at the point of transition from semi-solid to plastic state is the plastic limit (PL), and from plastic to liquid state is the liquid limit (LL). These parameters are also known as Atterberg limits. The liquid and plastic limits of a soil and its water content can be used to express its relative consistency or liquidity index. It is done in casagrande apparatus.

Fig 3.7: Soil sample in casagrande apparatus

PROCEDURE FOR DETERMINING LIQUID LIMIT (LL)

1. Determine the mass of each of the three moisture cans (W1).
2. Calibrate the drop of the cup, using the end of the grooving tool not meant for cutting, so that there is consistency in the height of the drop.
3. Put about 250 g of air-dried soil through a # 40 sieve into an evaporating dish and with a plastic squeeze bottle, add enough water to form a uniform paste.
4. Place the soil in the Casagrande's cup and use a spatula to smooth the surface so that the maximum depth is about 8mm
5. Using the grooving tool, cut a groove at the centre line of the soil cup
6. Crank the device at a rate of 2 revolutions per second until there is a clear visible closure of 1/2" or 12.7 mm in the soil pat placed in the cup. Count the number of blows (N) that caused the closure. (Make the paste so that N begins with a value higher than 35.)
7. If N= 15 to 40, collect the sample from the closed part of the cup using a spatula and determine the water content weighing the can + moist soil (W2). If the soil is too dry, N will be higher and will reduce as water is added.
8. Do not add soil to the sample to make it dry. Instead, expose the mix to a fan or dry it by continuously mixing it with the spatula.
9. Perform a minimum of three trials with values of N-15 to 40, cleaning the cap after each trial.
10. Determine the corresponding w% after 24 hours (W3) and plot the Number of blowsvs water content %, which is called the "flow curve".

PROCEDURE FOR DETERMINING PLASTIC LIMIT (PL)

1. Mix approximately 20 g of dry soil with water from the plastic squeeze bottle.
2. Determine the weight of the empty moisture can, (W1).
3. Prepare several small, ellipsoidal-shaped masses of soil and place themin the plastic limit device. Place two fresh sheets of filter paper on either face of the plates.
4. Roll the upper half of the device which has a calibrated opening of 3.18 mm with the lower half plate.
5. If the soil crumbles forming a thread approximately the size of the opening between the plates (around 3 mm diameter), collect the crumbled sample, and weigh it in the moisture can (W2) to determine the water content. Otherwise, repeat the test with the same soil, but dry it by rolling it between your palms.
6. Determine the weight of the dry soil + moisture can, (W3).
7. The water content obtained is the plastic limit.

- Weight of container, W1
- Weight of container + wet soil, W2
- Weight of container + dry soil, W3
- Water content(%) = W2– W3/ W3-W1

3.6 SIEVE ANALYSIS

Particle size distribution is found by sieve analysis of the soil sample.

PROCEDURE

1. Clean the sieves of sieve shaker using cleaning brush if any particles are struck in the openings.
2. Take oven dried soil sample of 1kg.
3. Arrange the sieves in order as the smaller openings sieve to the last and larger openings sieve to the top.
4. Allow the shaker to work 10-5 minutes.
5. Remove the sieve stack from the shaker and record the weight of each sieve and receiving pan separately.

3.7 STANDARD PROCTOR TEST

The Proctor compaction test is a laboratory method of experimentally determining the optimal moisture content at which a given soil type will become most dense and achieve its maximum dry density.These laboratory tests generally consist of compacting soil at known moisture content into a cylindrical mould with a collar of standard dimensions of height and diameter using a compactive effort of controlled magnitude. The soil is usually compacted into the mould to a certain amount of equal layers, each receiving a number of blows from a standard weighted hammer at a specified height. This process is then repeated for various moisture contents and the dry densities are determined for each. The graphical relationship of the dry density to moisture content is then plotted to establish the compaction curve. The maximum dry density is finally obtained from the peak point of the compaction curve and its corresponding moisture content, also known as the optimal moisture content.

Fig 3.8:Proctor compaction test apparatus

PROCEDURE

1. Obtain about 3 kg of soil.
2. Pass the soil through the No. 4 sieve.
3. Weight the soil mass and the mould without the collar (Wm).
4. Place the soil in the mixer and gradually add water to reach the desired moisture content (w).
5. Apply lubricant to the collar.
6. Remove the soil from the mixer and place it in the mould in 3 layers or 5 layers depending on the method utilized (Standard Proctor or Modified Proctor). For each layer, initiate the compaction process with 25 blows per layer.
7. Carefully remove the collar and trim the soil that extends above the mould with a sharpened straight edge.
8. Weight the mould and the containing soil (W).
9. Extrude the soil from the mould using a metallic extruder, making sure that the extruder and the mould are in-line.
10. Measure the water content from the top, middle and bottom of the sample.
11. Place the soil again in the mixer and add water to achieve higher water content, w.

Fig 3.9: Mould after the filling of soil

Compaction is the process of densification of soil by reducing air voids. The degree of compaction of a given soil is measured in terms of its dry density. The dry density is maximum at the optimum water content. A curve is drawn between the water content and the dry density to obtain the maximum dry density and the optimum water content.

Dry density of the soil is determined by using the formula of

Dry density = $\gamma/1+w$

γ is the bulk density of soil.

W is the water content of soil.

3.8 DETERMINATION OF UNCONFINED COMPRESSIVE STRENGTH

It is used to determine the unconfined compressive strength of soil in the laboratory. According to the ASTM standard, the unconfined compressive strength (qu) is defined as the compressive stress at which an unconfined cylindrical specimen of soil will fail in a simple compression test. The unconfined compression test is the most popular method of soil shear testing because it is one of the fastest and least expensive methods of measuring shear strength. It is used primarily for saturated, cohesive soils recovered from thin-walled sampling tubes. The test is not applicable to cohesionless or coarse-grained soils.

Fig3.10:Mould on Unconfined Compression test apparatus

The primary purpose of Unconfined Compression Test is to determine the unconfined compressive strength, which is then used to calculate the unconsolidated shear strength of the clay under unconfined conditions. For soils, the undrained shear strength is necessary for the determination of bearing capacity of soils, the dams, etc. The undrained shear strength of clays is commonly determined from an unconfined compression test. The undrained shear strength (su) of a cohesive soil is equal to one half the unconfined compression strength (qu) when the soil is under the f = 0 condition (f = the angle of internal friction). The most critical condition for the soil usually occurs immediately after construction, which represents undrained conditions, when the undrained shear strength is basically equal to the cohesion (c). It is expressed as c=1/2* unconfined compressive strength.

PROCEDURE

1. The soil specimen is prepared at the desired water content and density in the large mould.
2. Taking 250g of expansive soil and optimum moisture content 14%.
3. The soil sample in the sampling tube is saturated by a suitable method.
4. The split mould is lightly coated with a thin layer of grease. The mould is weighed.
5. The sample is extracted out of the sampling tube by a suitable method into the split mould, using the sample extractor and the knife.
6. The two ends of the specimen are trimmed off in the split mould.
7. The length and diameter of the specimen is measured with Vernier callipers.
8. The specimen is placed on the bottom plate of the compression machine.
9. The upper plate is adjusted to make contact with the specimen
10. The dial gauge and the proving ring gauge is adjusted to zero.
11. The compression load is applied to cause an axial strain at the rate of ½ to 2% per minute.
12. The dial gauge reading is recorded and the proving ring after every 60 seconds for a strain between 6% to 12% after every 2 minutes or so beyond 12%.
13. The test is continued until failure surfaces have clearly developed or until an axial strain of 20% is reached.
14. The angle between the failure surface and the horizontal is measured if possible.

RESULTS AND DISCUSSIONS

4.1 INITIAL PROPERTIES OF BLACK COTTON SOIL

Results for physical properties like specific gravity, Atterberg limits and sieve analysis were obtained initially. Followed by tests done for finding the strength of raw expansive soil sample.

Table 4.1:Soil Characteristics

Properties	**Values**
PlasticLimit	36%
LiquidLimit	58%
Plasticity,Index	22%
Co-efficient of Curvature	1.07
Uniformity Coefficient	9.23
Moisture Content	34%
Specific Gravity	2.4
Optimum Moisturem Content (OMC)	14%

Maximum Dry Density (MDD)	1.64gm /cm^3
Unconfined Compressive strength	5KN/m^2

4.2 PROPERTIES AFTER TREATMENT

Soil is treated with additive GGBS, Nano-zeolite and CHA. In order to assess the individual effect of additives on black cotton soil, we have conducted test by adding additives individually. Tests were done for soil by combining GGBS, Nano-zeolite and CHA in the proportions. The materials were added in these composition to the soil.

Sample (i)20% GGBS, 0.6% Nano-zeolite and 6% CHA Sample (ii) 25% GGBS, 0.8% Nano-zeolite and 8% CHA Sample (iii) 30% GGBS, 1% Nano-zeolite and 10% CHA

4.2.1 STANDARD PROCTOR TEST

Standard proctor test was done to find the OMC of the soil mix. Black cotton soil with 20% GGBS, 0.6% Nano-zeolite and 6% CHA was taken for the test. The test was conducted only on sample (i) due to the stiffness seen when adding higher percentages.

Fig 4.1: Standard proctor test

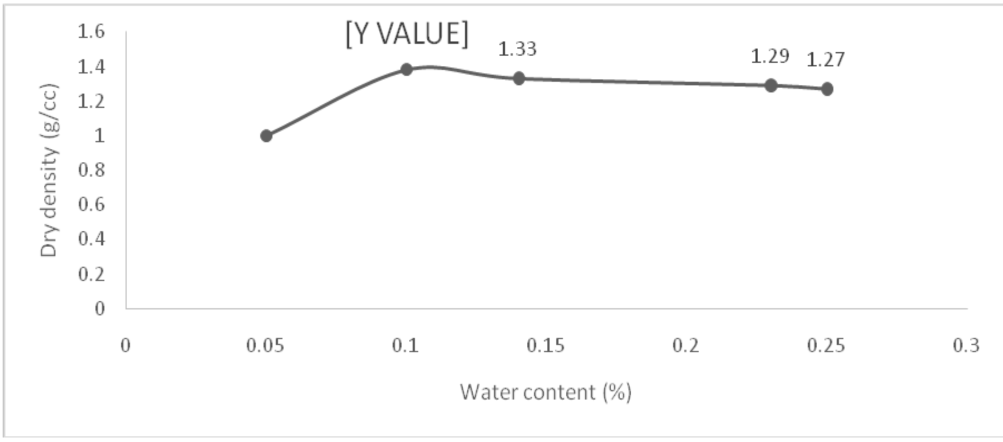

Fig 4.2: Graph between dry density and water content

The OMC was found out to be 10%. And MDD was found out to be 13.53 kN/m³ or 1.38g/cc.

4.2.2 PLASTIC LIMIT

Fig 4.3: Soil threaded for plastic limit test

Table 4.2: Observations of plastic limit of soil mixes

Proportions	Plastic Limit (%)
20% GGBS, 0.6% Nano-zeolite and 6% CHA	23
25% GGBS, 0.8% Nano-zeolite and 8% CHA	22
30% GGBS, 1% Nano-zeolite and 10% CHA.	18

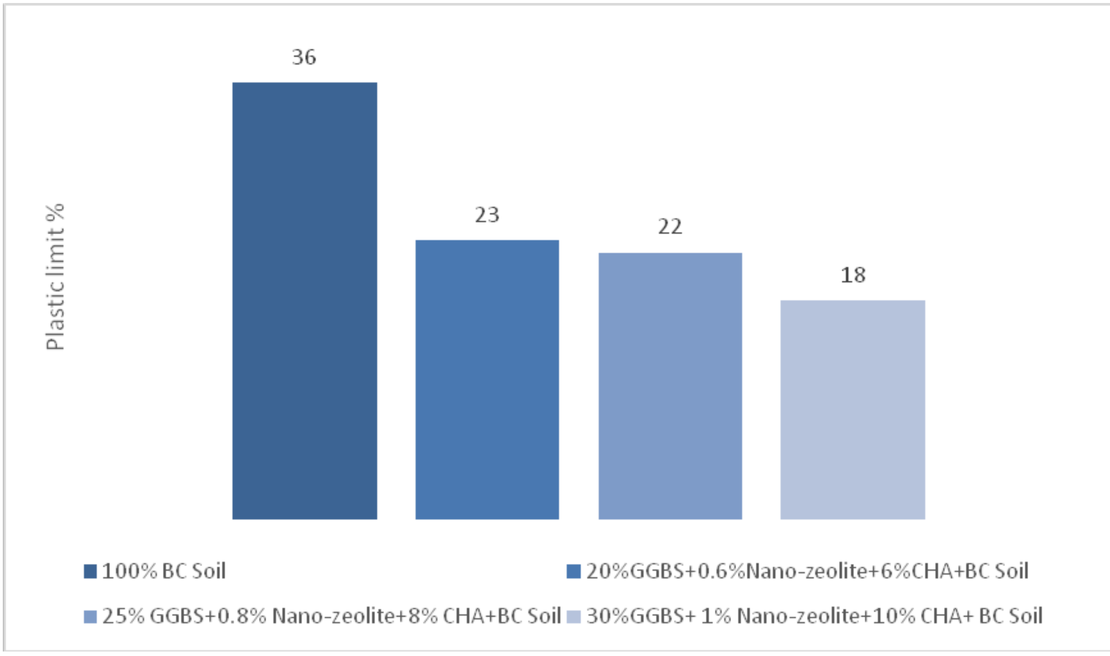

Fig 4.4: Plastic limit values of soil mixes

All samples were tested to find the plastic limit. It was observed from the results that the black cotton soil mixed with different percentages of GGBS, Nano-zeolite and CHA, the plastic limit values are 23%, 22% and 18% for 20% GGBS+0.6% Nano-zeolite+6% CHA, 25% GGBS+0.8% Nano-zeolite+8% CHA and 30% GGBS+1% Nano-zeolite+10% CHA respectively.

4.2.3 UNCONFINED COMPRESSIVE STRENGTH

Unconfined compressive strength of soil with GGBS, Nano-zeolite and CHA was done individually and together in different proportions.

4.2.3.1 INDIVIDUAL EFFECTS OF ADDITIVES

In order to assess the improvement by each additives we have conduced individual test for soil with GGBS in the proportion 20%, 25% and 30%. Similarly done with 0.6%, 0.8% and1% Nano-zeolite and with 6%, 8% and 10% CHA individually.

4.2.3.1.1EFFECT OF GGBS

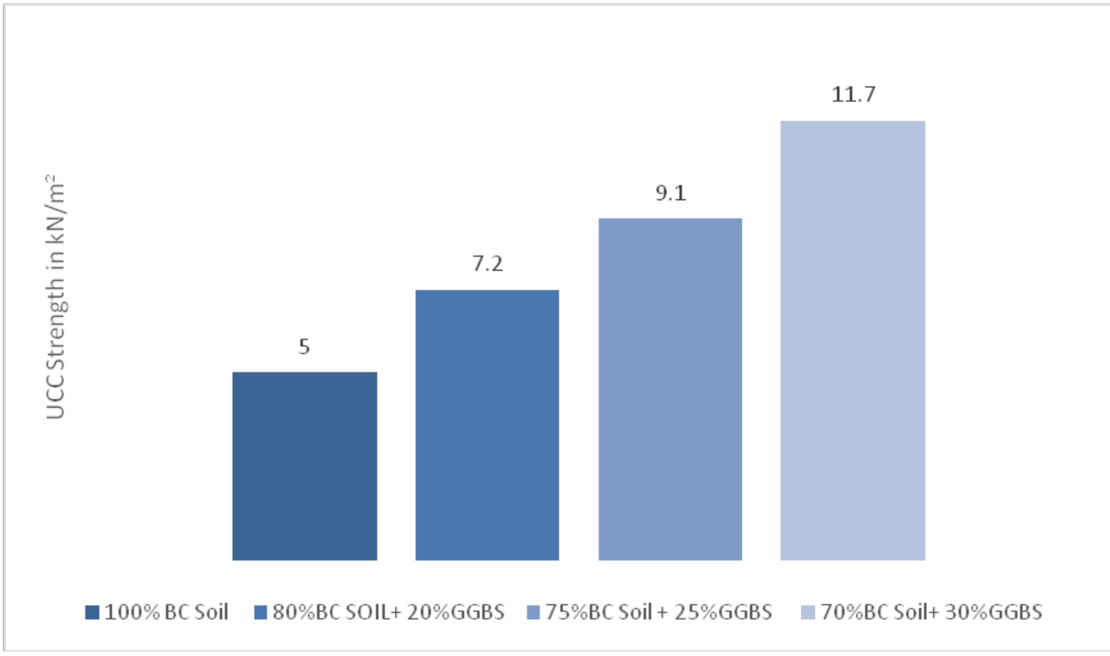

Fig 4.5: UCS of soil with GGBS in 20%, 25% and 30% proportions

Black cotton soil samples were tested for unconfined compressive strength. It was observed that the black cotton soil mixed with different percentage of GGBS, the UCS values are 7.2 kN/m², 9.1 kN/m² and 11.7 kN/m² for 20%, 25% and 30% of GGBS respectively.

4.2.3.1.2 EFFECT OF NANO-ZEOLITE

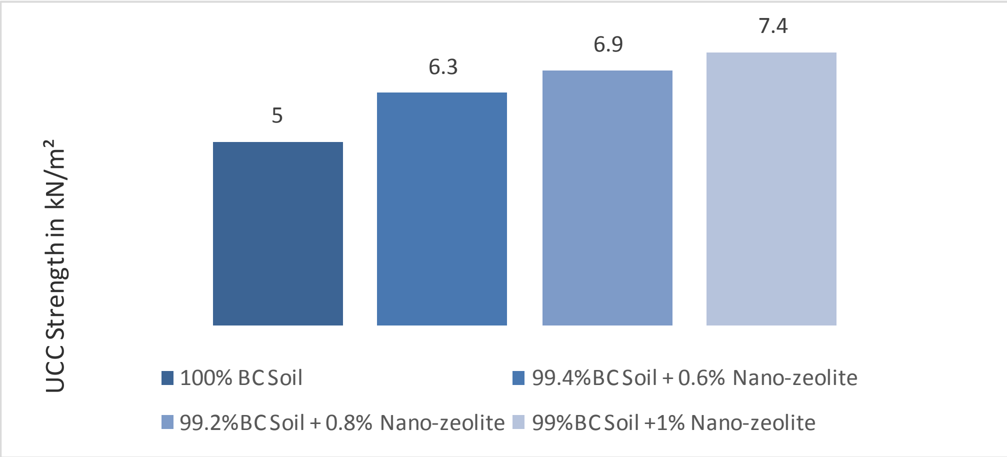

Fig 4.6: UCS of soil with Nano-zeolite in 0.6%, 0.8% and 1% proportions

All samples were tested for unconfined compressive strength. It was observed that the black cotton soil mixed with different percentage of Nano-zeolite, the UCS values are 6.3 kN/m², 6.9 kN/m² and 7.4 kN/m² for 0.6%, 0.8% and 1% of Nano-zeolite respectively.

4.2.3.1.3 EFFECT OF COFFEE HUSK ASH

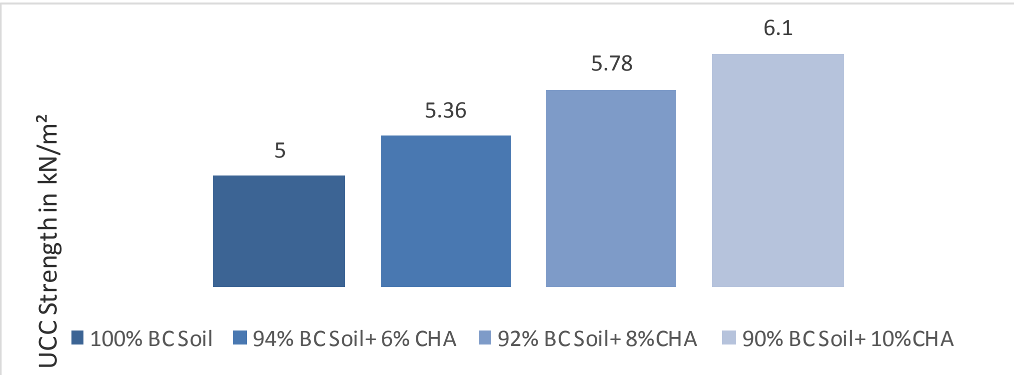

Fig 4.7: UCS of soil with CHA in 6%, 8% and 10% proportions

All samples were tested for unconfined compressive strength. It was observed that the black cotton soil mixed with different percentage of CHA, the UCS values are 5.36kN/m², 5.78kN/m² and 6.1kN/m² for 0.6%, 0.8% and 1% of Nano-zeolite respectively.

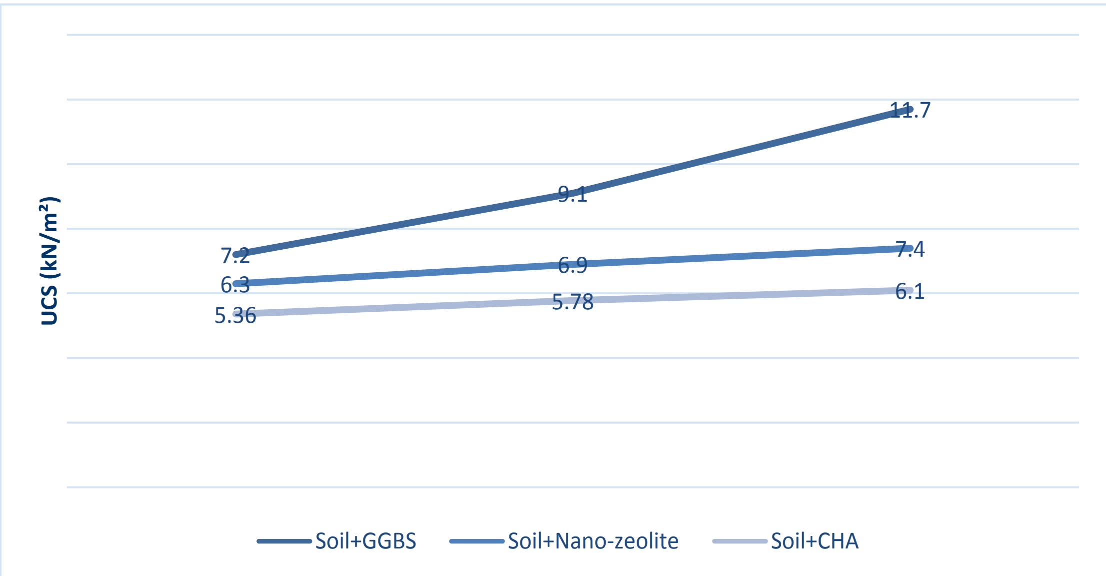

Fig 4.8: Comparison of UCS with different additives

For the selected percentages of additives, the UCS value of black cotton soil is getting increased. If we increase the percentage of the corresponding additives the value will also increase. We found the greater increase in value when added GGBS. It can be because of the property of GGBS to control swelling of soil and increasing stress by reducing the voids.

4.2.3.2 COMBINED EFFECT OF GGBS, NANO-ZEOLITE AND CHA

Unconfined compressive strength of all 3 samples were found by doing the tests on unconfined compressive strength testing machine. The additives were added to the soil in the proportions 20% GGBS, 0.6% Nano-zeolite and 6% CHA; 25% GGBS, 0.8% Nano-zeolite and 8% CHA; 30% GGBS, 1% Nano-zeolite and 10% CHA

The graphs between stress and strain of all three samples are shown below.

4.2.3.2.1 UCS OF SAMPLE (i)

Table 4.3: Observation and calculation for 20 %GGBS, 0.6% Nano-zeolite, 6% CHA

Dial gauge reading	**Proving ring reading**	**Deformation**	**Load (kg)**	**Strain**	**Corrected area (cm²)**	**Compressive stress (kg/cm²)**
0	0	0	0	0	0	0
20	22	0.2	1.57	0.049	117.9	0.014
40	57	0.4	3.81	0.115	126.79	0.034
60	112	0.6	6.73	0.15	132.01	0.06
80	170	0.8	10.21	0.215	142.9	0.091
100	265	1	15.93	0.26	151.6	0.142
120	210	1.2	22.12	0.28	155.54	0.142

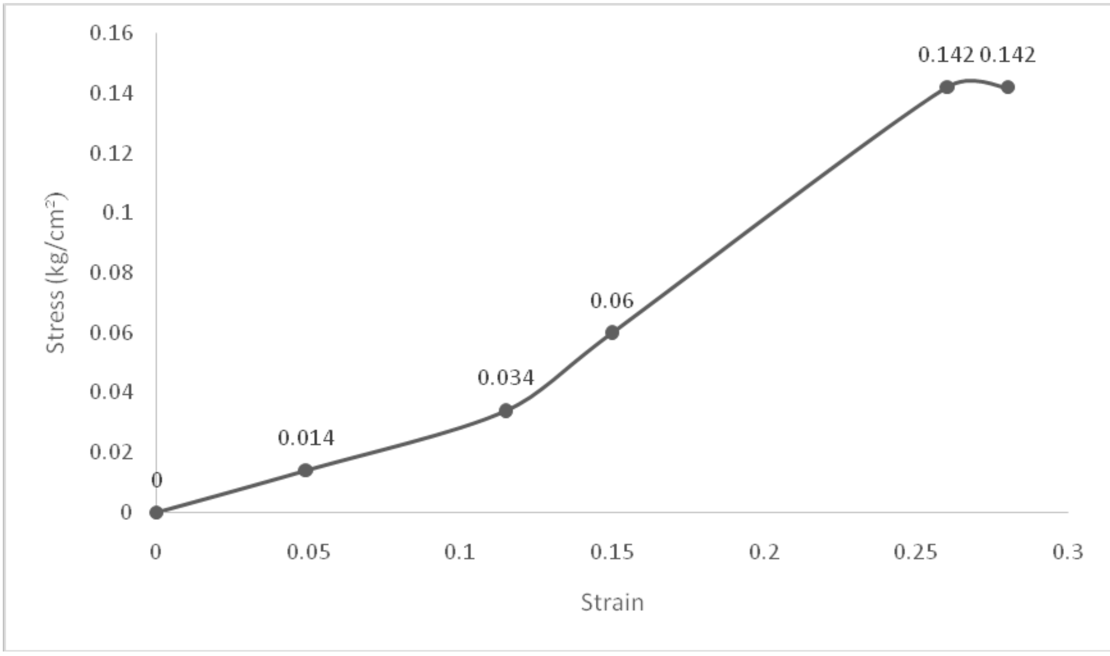

Fig 4.9: Graph between stress and strain of sample (i)

From the graph, the unconfined compressive stress of soil with 20% GGBS, 0.6% Nano-zeolite and 6% CHA is found to be 0.142 kg/cm² which is equal to 13.92kN/m².

4.2.3.2.2 UCS OF SAMPLE (ii)

Dial gauge reading	**Proving ring reading**	**Deformation**	**Load (kg)**	**Strain**	**Corrected area (cm^2)**	**Compressive stress (kg/cm^2)**
0	0	0	0	0	0	0
20	52	0.2	3.53	0.045	117.49	0.0315
40	75	0.4	4.95	0.0652	120.03	0.0442
60	83	0.6	5.50	0.12	127.51	0.0491
80	140	0.8	9.22	0.146	131.39	0.0822
100	197	1	13.01	0.175	136.01	0.116
120	232	1.2	15.37	0.231	145.91	0.137
140	268	1.4	17.72	0.245	148.62	0.158
160	294	1.6	19.41	0.273	154.34	0.173
180	244	1.8	26.84	0.281	156.06	0.172
200	240	2	27.47	0.311	162.6	0.169

Table 4.4: Observation and calculation for 25% GGBS, 0.8% Nano-zeolite, 8% CHA

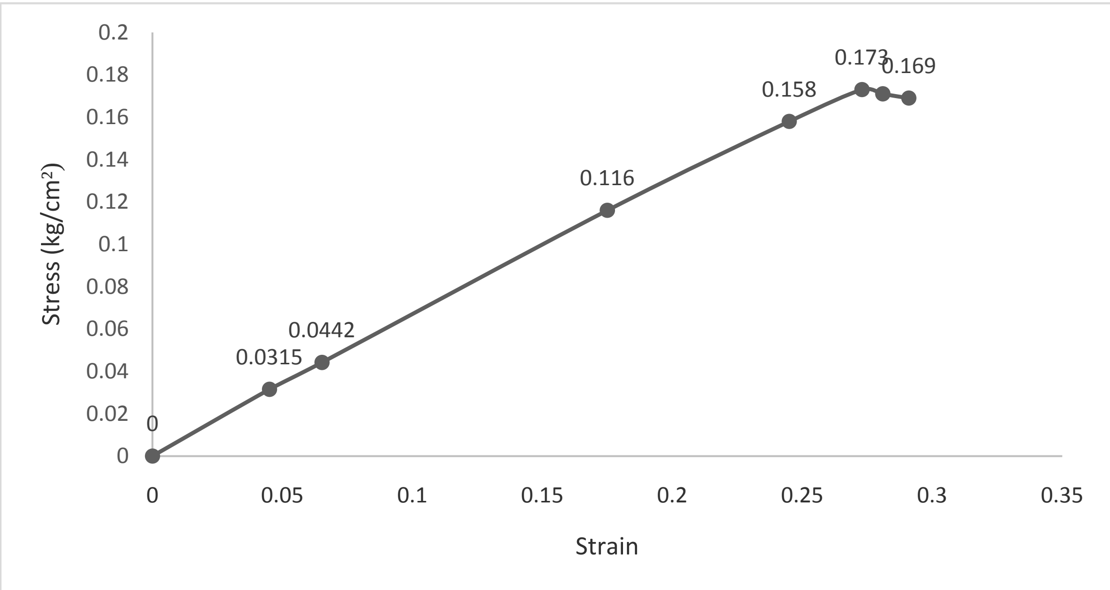

Fig 4.10: Graph between stress and strain of sample (ii)

From the graph, the unconfined compressive stress of soil with 25% GGBS, 0.8%Nano-zeolite and 8% CHA is found to be 0.173 kg/cm^2 which is equal to 16.96kN/m^2.

4.2.3.2.3 UCS OF SAMPLE (iii)

Table 4.5: Observation and calculation for 30% GGBS, 1% Nano-zeolite, 10% CHA

Dial gauge reading	Proving ring reading	Deformation	Load (kg)	Strain	Corrected area (cm²)	Compressive stress (kg/cm²)
0	0	0	0	0	0	0
20	54	0.2	3.47	0.042	117.12	0.031
40	96	0.4	6.306	0.065	120.01	0.0562
60	122	0.6	8.07	0.135	129.7	0.072
80	190	0.8	12.56	0.16	133.5	0.112
100	258	1	17.05	0.212	142.39	0.152
120	295	1.2	19.52	0.22	143.85	0.174
140	331	1.4	21.88	0.235	146.6	0.195
160	366	1.6	24.23	0.281	156.06	0.216
180	360	1.8	34.28	0.293	158.71	0.216

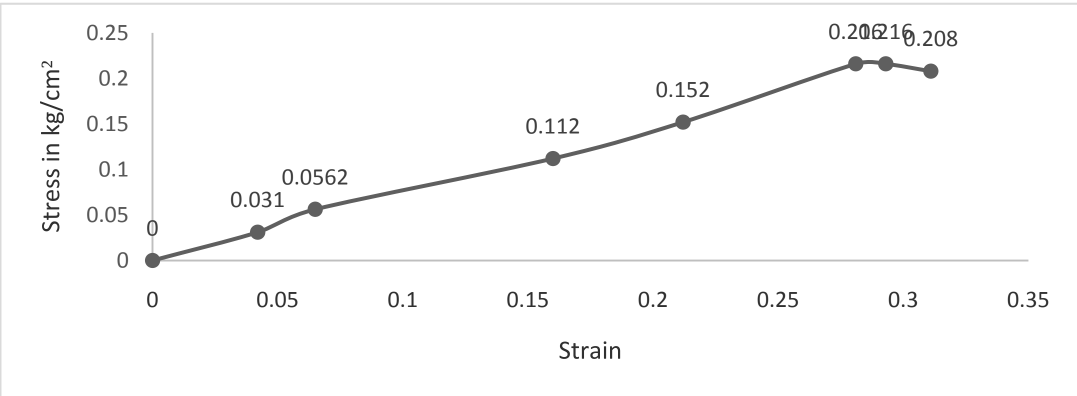

Fig 4.11: Graph between stress and strain of sample (iii)

From the graph, the unconfined compressive stress of soil with 30% GGBS, 1% Nano-zeolite and 10% CHA is found to be 0.216 kg/cm² which is equal to 21.18kN/m².

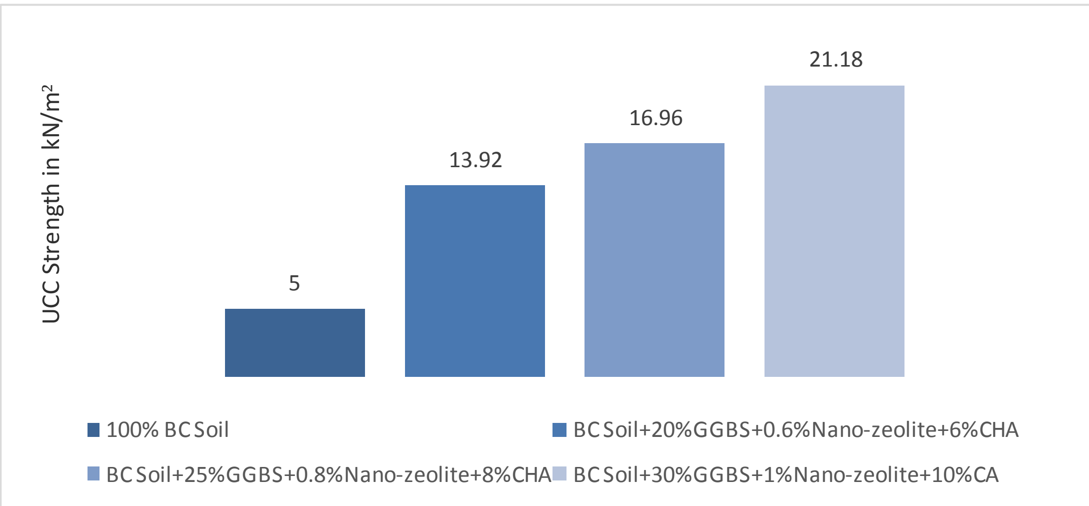

Fig 4.12: UCS of soil mixes with different proportions

All samples were tested for unconfined compressive strength. Graphs drawn between axial strain and compressive stress for every percentage. It was observed from the expansive soil or black cotton soil mixed with different percentage of GGBS, Nano-zeolite and CHA the UCS values are 13.92kN/m², 16.96kN/m² and 21.18kN/m² for soil mixed with20% GGBS, 0.6% Nano-zeolite and 6% CHA, 25% GGBS, 0.8% Nano-zeolite and 8% CHA and 30% GGBS, 1% Nano-zeolite and 10% CHA respectively.

CONCLUSION

The following conclusions were drawn based on the laboratory studies carried out. Liquid limit of the black cotton soil was 58%, the plastic limit was 36% and specific gravity was 2.4. It was observed that the OMC and MDD decreased by adding GGBS, Nano-zeolite and CHA. The OMC decreased by 28% and MDD decreased by 15%. The plastic limit of soil added with these materials decreased by 36% on sample (i) and decreased by 50% when taken sample (iii). The UCS value increased by adding GGBS, Nano-zeolite and CHA. The UCS value increased when additives where added individually and all together. Adding GGBS provided the highest increase in UCS by 170%. Adding all additives combined, gave and increase by 323%.The GGBS and CHA were easily available across the country and Nano-zeolite was available in labs. With increase of GGBS and nano-zeolite percentage, compressive strength increases that means arrangement of soil particles were very closely, which reduced the voids. The property of GGBS that increased the strength was due to its own strength increasing capacity. The plastic limit was able to reduce due to the property of CHA, in addition the potential use of this waste material as a stabilisation agent has a positive effect on reducing the cost related to stabilisation, and furthermore, it can address the associated disposal problems and environmental concerns. Thereby, this study was helpful to realise the stabilising properties of GGBS, Nano-zeolite and CHA.

REFERENCES

[1] Chandan Kumar Behera, Satyapriya Senapati,“Soil Stabilization by Industrial Waste (GGBS and Stone Dust),” International Journal of Engineering Research & Technology (IJERT), 2021.

[2] M.K. Atahu, F. Saathoff and A. Gebissa, “Strength and compressibility behaviours of expansive soil treated with coffee husk ash,” Journal of Rock Mechanics and Geotechnical Engineering, 2018.

[3] R P Munirwan , D Sundary , Munirwansyah, Bunyamin, “Study of coffee husk ash addition for clay soil stabilization”, IOP Conf. Series: Materials Science and Engineering,2021.

[4] MeskeremKebedeAtahu, “The Effect of Coffee Husk Ash on Geotechnical Properties of Expansive Soil”, Geotechnical Engineering and Coastal Engineering Faculty of Agricultural and Environmental Science,2020.

[5] Reza PahleviMunirwan, MohdRaihanTaha, AizatMohdTaib, and MunirwansyahMunirwansyah, “Shear Strength Improvement of Clay Soil Stabilized by Coffee Husk Ash,” MDPI Journal of Applied Science,2022.

[6] Ruqayah Al-khafaji, Hassnen M Jafer, AnmarDulaim, W. Atherton, and ZahraaJwaida, “Soft soil stabilisation using ground granulated blast furnace slag,” Research Gate, 2017.

[7] Ashish Kumar Pathak, Dr. V. Pandey, Krishna Murari and J.P.Singh, “Soil Stabilisation Using Ground Granulated Blast Furnace Slag,” Int. Journal of Engineering Research and Applications,2014.

[8] Bhanu Prakash Darsi, Kumar Molugaram ,and SaisantoshVamshiHarshaMadiraju, “Subgrade Black Cotton Soil Stabilization Using Ground Granulated Blast-Furnace Slag (GGBS) and Lime, an Inorganic Mineral,” MDPI Environmental science proceedings, 2021.

[9] Aaqib Ali, Bashir Ahmed Mir, Nadeem Gul, Fiza Zahoor Malik, “Strength and Microstructural Behaviour of Soft Soil Treated with Zeolite Nanoparticles”, Transportation Infrastructure Geotechnology, 2022.