SOIL STABILISATION USING TAMARIND KERNAL POWDER, EGG SHELL POWDER, WHEAT HUSK ASH AND SUGARCANE STRAW ASH

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ABSTRACT

Soil is a vital substance for all creatures in the world, soil is widely used in various parts such as agriculture, construction work, foundations, bridges, dams, buildings, canals, tunnels, etc. Soil has different classes and types of all types of soil cannot meet all the requirements of technical properties and cannot resist properties such as mechanical strength, permeability, durability, plasticity, compressibility, etc. among different classes of soil, black cotton soil is a weak soil that has less shear strength and should be stabilized. Soil stabilization is the techniques and methods to improve the engineering and other properties of black cotton soil, black cotton soil is really a problematic soil for civil engineering and other field works due to its less strength, shrinkage and swelling. Many waste materials are available for stabilization and consolidation of black cotton soil, which is economical and beneficial for the improvement of black cotton soil. We accurately analyse and incorporate this research paper based on indirect methodology and extract as many waste materials as nano silicate, white cement, fly ash grade, lime, copper slag, red mud, wheat husk ash, egg shell Powder, ash from sugarcane straw, blast furnace slag and so on are available to stabilize the black cotton soil, which is eco-friendly, economical and easily available locally and in the market. Related secondary data are processed and suitable stabilization techniques for black cotton soil are discussed.

INTRODUCTION

1.1 GENERALBACKGROUND

The basic construction material of the geotechnical engineer'sdesign foundation is the soil. In manysets of circumstances, road service layers, foundation layers and construction material cannot utilize the soil directly. The rising cost of the land, and huge demand for high rise buildings makes the improvement of soil at a site unavoidable. Therefore, it is required to revamp the quality of the soil. The expansive soil used in this research also known as black cotton soil. This soil is taken as it contains particles of montmorillonite, which absorbs water easily and thus, attains contraction and shrinking property. The humidify and scorch process of a subgrade layer comprised of Black Cotton (BC) soil which results into failure of pavements in form of colonization and rupture. Therefore, soil is binded to suppress the effect of such particle, which is responsible for the high percentage of expansiveness and cracks thus, it is dangerous for the construction. Therefore, it is important either to remove the existing soil and replace it with a non-expansive soil or to improve the important properties of the existing soil by stabilize prior to construction of a road on such subjugate. The cost-effectivepractices like explore with wastes are utilized to ameliorate the acreage of the soils having mucilage value. This is done by the process of soil stabilization. This process is mainly used where the available soil is not fit for the intended purpose, it requires to be remodel. The first experiment on soil stabilization was conducted in USA with sand or clay mixtures in 1906. Many researchers attempt to use thewastes like wheat Husk Ash (WHA), Fly Ash (FA) are used to revamp the geotechnical properties of a soil. However, the inclination of using the waste material is being used by all over the world nowadays.

1.2 OBJECTIVES

The objectives of this projects are

- For stabilisation of soil.
- Increasing the shear strength.
- Decreasing the compressibility of soil.
- For Safe disposal of waste materials.
- To reduce the construction cost

1.3 SCOPE OF THE STUDY

- Improves the stability of weak soils to achieve engineering goals.
- Long term durability of soil mixed with binder.
- Design of ground improvement.
- Development of practical, economical and environmentally safe method for soil stabilisation.

LIRERATURE SURVEY

2.1 STUDIES ON PREVIOUS LITERATURES

R. Gobinath, et.al (2022) have publishedthat, there is other problem regarding disposal of wastes to avoid environmental problem. Black cotton soil which nearly occupy 24% of the area in India as a problematic soil because of problems like less shear strength large expansion & shrinkage in volume and low bearing capacity, very less consistency of soil. Because of these demerits create obstruction for construction work, road pavements, etc. The treatment of combined by product combination with clayey soil material out turn more workable by increases the bearing ratio by 90% in soaked condition which clearly shows the soil treatment with silica material has a great impact in treating poorly graded soil. The CBR values also gives a way for use of treated clayey materials in sub-base construction of road pavement and also gives better improvement of bearing strength by reduction in the pore pressure of the soil material. And modelling in finite element tools shows the displacement of the treated soil when footing placed over the sample in field condition.

Wahidullah Safi a, Sandeep Singh (2022) have published that Soil is an extremely important reserve for the world, Soil is a vital substance for all living and non-living creatures in earth. It produces a wide range of harvests. Like it produces the human prerequisite of nourishments with development and also it could be materials which play a high and necessary role in the civil engineering field and for civil engineering structures such as highway, canals, Bridges and embankment which develop in vast areas of land. Stabilization of is a technique in civil engineering to develop the engineering and physical possessions of soil for example mechanical strength of soil, permeability of soil, compressibility of soil, durability of soil, and plasticity of clay so Soil is an extremely important and a vital matter for all living and Non-living creatures, among the different types and classes of soil clay soil is also used with some stabilizing. Brick dust and lime utilization can have superb effect on increment of CBR value. Addition of different percentage (2, 4, 6, 8, and 10%) of crushed limestone dust has positive effect on engineering belongings of clay soil, reduce plasticity of clay and significant decreased in expansion. Soil has different properties and different waste materials can affect in different property of soil, they can affect one or more than one properties of soil. Curing periods has beneficial effect on soil unconfined compression strength of soil and give strength to soil. Usage of some waste materials for soil stabilization is eco friend but some of them are harmful for environment.

MuzamilMajeed,Aman Preet Tangr(2021) have published that Soil is deposit from rocks Nowadays , plastic industries with more booming with more develop technology and researches fields. This type of technique when used maximum of waste plastic is reduced in environment. This is serious issue as it develops man-made hazard. Plastic has many good properties like durability, strength, brittle in nature, resistance in chemical attacks and heat resistance etc. In other hand the weaker soil is not able to bearing the heavy load. Soil sample collected from that area where construct the road and testing the soil for the know the geotechnical property and its index property. The study of black cotton soil is known as expansive soil. different waste use for stabilization of soil has been explain. Some waste materials are fly ash blast furnace and cement kiln these are swaste arrange problem in disposal and subsistence deposited near the industries on this review paper we study reducing the waste and improving the soil stabilizer use of waste. The fly ash is used in large scale in the stabilization soil and with aggregate to produce a condition stabilized base coarse. Cement kiln dust can be combined with soil to upgrade plastic limits or moisture content to bring the desired stabilized estate. Cement kiln dust is increasing the bearing capacity and decrease the moisture content almost all the stabilized soil mixtures produced very high CBR values (> 80%) and have the possible to be used for formation building blocks for low-cost houses and as sub base layers for road infrastructure for local people. The proposed use of balance soils should help advance sustainable evolution in the construction industry. Balanced soils possess enhanced mechanical properties such as toughness modulus of elasticity and California bearing ratio as well as tensile strength in terms of water resistance, water sportively and stealing. The liquid limit of three soils has been diminished by around (11-18%) with the expansion of 9% RHA,while the versatility file diminished by around (32- 80%).treatment with rice husk showed a general decrease in the greatest dry unit weight with the expansion in the rice husk content to least values at 9% rice husk content.

Uma Kant Gautam, Kumar Venkatesh & Vijay Kumar (2020) have published that Soil Stabilization Using Combined Waste Material The utilization of waste material in the stabilization of weak soil effectively minimizes the negative effect on the environment. Geotechnical properties of weak soil individually and in combination with varying proportion were investigated.The combination of solid waste sand beneficiation plant is very effective for stabilizing the weak soil

A Y Pratiwi, I Prasetia, Y A Perina, and R Effendi (2017) have published that There are two methods to stabilize the soil and improve its bearing capacity, mechanical and chemical. Mechanical method is applying soil reinforcement element while chemical method is by adding chemical admixture such as cementitious or viscoelastic materials. The use of cement in soil stabilization is suitable when the soil has good gradation with less porous and wide contact area. The results of stabilization of soft soil using fly ash as main stabilizing agent and cement as complement has been discussed. Increasing the fly ash content will increase CBR value which means the bearing capacity of soft soil also improve. Bearing capacity improvement caused by mixing fly ash and cement proves the increase in soil stability. CBR value of Fly ash of 20% is significantly higher compared to of 10% and 15%. Mixing fly ash and cement to soft soil is also capable to reduce the swelling value which relates to the expansion of soil. The swelling potential can be reduced to be less than 5% or the degree of expansion will be on low or medium degree.

Anoop S P, et.al (2017) have publishedthat Improvement of soil properties is necessary in the modern scenario as soils with the required properties are not readily available for construction activities. There have been a lot of issues reported when structures were constructed on weak and soft soils like problems of shear failure, excessive settlement, differential settlement etc. The alternatives left with us are making the soil at site suitable for the expected load by improving its properties or adopting a deep foundation. Egg shell powder is an ideal material to replace lime in the stabilization process due to its similar chemical composition. The chief ingredient in egg shell powder is calcium carbonate as in the case of lime. Egg shells are disposed from hotels, restaurants etc in huge quantities and they are currently facing disposal problems. Use of egg shell powder in soil stabilization reduces the disposal problems associated with egg shell generations.Egg shell powder was found to be a very good alternative in replacing the costly lime used for soil stabilization. The use of egg shell powder in soil stabilization will reduce the disposal problems of egg shell as well as make the stabilization process economically and sustainable. From the study, it was seen that egg shell powder can replace upto 25% of the lime used for stabilization process. This replacement also increased the strength of treated soil.Thus it can be concluded that egg shell powder is an ideal material to replace lime in the soil stabilization process owing to its similar chemical compositions and properties.

Maninder Singh, Rubel Sharma, Abhishek (2017) have publishedthatit is important either to remove the existing soil and replace it with a non-expansive soil or to improve the important properties of the existing soil by stabilitate prior to construction of a road on such subjugate. The cost-effective practices like explore with wastes are utilized to ameliorate the acreage of the soils having mucilage value. The study reveals that the inclusion of wheat husk ash and sugarcane straw ash gives more consistent results as compared to the individual addition to the specimen. The values obtained after plethora of experimentation clears that these values are used as index for the designing and laying the base and sub base material for the infrastructure development and pavements structuring.

Muthupriya.P,Prasanth.S, Sathish kumar.S,Sandeep.S., Vasanth.M(2017)have published thatWaste materials such as waste sand, bottom sand offer a cheaper method for stabilizing marginal soils. As an added benefit, utilizing waste materials in soil stabilization applications keeps these materials from being dumped into Landfills, thereby saving already depleting landfill space. From the study it is observed that there is an appreciable improvement in the optimum moisture content and maximum dry density for the soil treated with waste. In terms of material cost, the use of less costly Admixtures can reduce the required amount of waste. Soils had the greatest improvement with all soils becoming non plastic with the addition of sufficient amounts of waste. The study after conducting several experiments revealed the following significances in using lime and waste as a stabilizing agent. The addition of lime and waste mixes to sub base increases the unconfined compressive strength value more than that by ordinary methods. The sub base stabilization with lime waste mixes improves the strength behaviour of sub base. It can potentially reduce ground improvement costs by adopting this method of stabilization.

Hitesh Sant, Shubham Jain, Rahul Meena (2016) have published that. Stabilization of soil is almost as common a technique as road construction itself. This simply refers to mixing of a foreign element in construction material for the betterment of the engineering properties and at the same time enhancing the economy of the construction project. But the biggest and most important benefit lies in the conservation of natural construction material and controlling an otherwise waste material from polluting the environment. n. Black cotton soil being a not so very strong in terms of CBR,needs some additives anyway for to become suitable as subgrade in highway construction. So, in this analysis, different proportions of Black cotton soil and bagasse ash were mixed and tested for their suitability to function as subgrade in highway construction. n. Black cotton soil being a not so very strong in terms of CBR,needs some additives anyway for to become suitable as subgrade in highway construction. So, in this analysis, different proportions of Black cotton soil and bagasse ash were mixed and tested for their suitability to function as subgrade in highway construction. CBR values have also shown a increment nature. These values were increasing up to 8% of inclusion of ash in the mix and thereafter decreasing if percentage of ash is increased further. Similar pattern was observed for UCS values with peak value of 1.72 kg/ cm2 for 8% of Ash in the mix.

Jijo James and P. Kasinatha Pandian (2013) have published that the recent methods have proved to be of great use in improving the soil and providing the scope for use of otherwise unusable land but on the other hand have had an impact on the quality of the environment. Ground improvement technology has been the driving force that has brought about this revolution in reclamation of unusable land, which has led to a sudden spurt in developmental activities. Natural materials and their use in ground improvement is one such area of potential and promise. In this study, an attempt has been made to explore the possibilities of using natural materials like Tamarind Kernel Powder (TKP), Egg Shell Powder (ESP) and Jaggery etc. for the beneficial improvement. The addition of Tamarind Kernel Powder (TKP) resulted in the increase of liquid limit of the soil. The addition of Egg Shell Powder (ESP) resulted in the decrease in the liquid limit of the soil. The swell shrink properties of the soil showed a marked improvement upon addition of ESP.

2.2 SUMMARY OF LITERATURES

Soil stabilisation is a procedure where natural or synthesized additives are used to improve the engineering properties of weak soil. Several reinforcing methods are available for stabilising soils. Therefore, the techniques of soil stabilisation can be classified into a number of categories such as physical stabilisation,chemical stabilisation, and mechanical stabilisation. Thereis a substantial history of use of soil stabilisation admixtures to improve poor subgrade soil performance by controlling volume change and increasing strength.

2.3 RESEARCH GAP

- To alter the properties of soil.
- Generally, to increase shear strength of soil.

- Prevent the crack in soil due to reduction of moisture content.
- Minimize the swelling due to wetting.
- Reduces the moisture content of soil.
- Increases the bearing capacity of soil

MATERIALS AND METHEDOLOGY

3.1 MATERIALS USED

The Following are the materials used for soil stabilisation

- Black cotton soil (BCS)
- Sugarcane straw ash (SSA)
- Egg shell powder (ESP)
- Tamarind kernel powder (TKP)
- Wheat husk ash (WHS)

3.1.1 Black Cotton Soil

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. Black soil is also known as black cotton soil or the regur soil. Black cotton soil is known as ‘tropical chernozems’ in the other parts of the world. These soils are named as black cotton soil as it is famous for the purpose of cultivation of cotton. Black soil or black cotton soil are formed from the Deccan Trap rocks known as Zonal Soils. Black cotton soil is mostly found in the Deccan trap region. Most states of India which includes Maharashtra, Madhya Pradesh, Gujarat, Andhra Pradesh and some parts of Tamil Nadu are covered by the black soil. Black cotton soil is clayey in nature and is wide. It used for the purpose of agriculture. It has high water retention capacity as it is deep and impermeable in nature. The black colour of the black soil is due to the presence of aluminium compounds, iron, and humus. Crops such as cotton, pulses, millets, linseed, tobacco, sugarcane, vegetables and citrus fruits are cultivated in the black soil for high productivity. The various properties of black cotton soil are given in table.

Table

PROPERTY	VALUE
OMC (%)	25 %
Maximum dry density(g/cc)	1.38gm/cc
Specific gravity	2.42
Liquid limit (%)	61.50 %
Plastic limit (%)	32.74 %
Plasticity index (%)	28.68 %
CBR value@2.5mmpenetration	43.8
CBR value@5mm Penetration	40.86
Moisture content	33.43 %
Unconfinedcompressivestrength (kg/cm^2)	1.44kg/cm^2

3.1:Properties of black cotton soil

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

Fig. 3.1:Black cotton soil sample

3.1.2Sugarcane Straw Ash

Sugarcane straw ash is also called bagasse ash. Sugarcane is used by many large industries and mills to make sugar by extracting juice. Sugar is used as a food product by every household person. The waste produced from these large mills creates disposal problem. There is about 30% bagasse produced from the crushed sugarcane. This bagasse is utilized by many researchers for soil stabilization due to fibrous material contained in it, which aids the soil to bind the particles of the soil together by reducing the void ratio and increasing their shear strength. The technique of using the bagasse ash of every researcher for calcination process is different.

COMPOUND	VALUE (%)
Silica (SiO_2)	70.20
Aluminium(Al_2O_3)	1.93
Iron (Fe_2O_3)	2.09
Calcium (CaO)	12.20
Magnesium (MgO)	1.95
Potassium (K_2O)	3.05
Sodium (Nao)	----

Table3.2: Chemical composition of Sugarcane Straw Ash

Fig.3.2: Sugarcane straw ash

3.1.3 Egg Shell Powder

Eggshell is a cheapest material and this is a waste product for the regular use. The eggshells have high compressive strength, polyamide has good impact strength and nylon black has good tensile strength.The use of egg shell powder in soil stabilization will reduce the disposal problems of egg shell as well as make the stabilization process economically and sustainable. Egg shell powder can replace upto 25% of the lime used for stabilization process. This replacement also increased the strength of treated soil.

Table 3.3:Chemical composition of egg shell powder

COMPOUND	VALUE (%)
Silica (SiO_2)	0.11
Aluminium(Al_2O_3)	Nill
Iron (Fe_2O_3)	Traces
Calcium (CaO)	47.49
Magnesium (MgO)	Nill
Potassium (K_2O)	Nill
Sodium (Nao)	0.14

Fig.3.3 :Egg shell powder

3.1.4 Tamarind Kernal Powder (TKP)

Tamarind Kernel Powder is derived from the plant Tamarindus Indica. Tamarind is an evergreen tree.The cotyledon or kernel in tamarind seeds is considered as a waste. However, the kernel contains starch and gum which is processed under different steps to transform into powder form. Tamarind Kernel powder has excellent water absorption property and high viscosity as well. It is applied as thickening agent in sizing process of textile industry and printing industry. It is also applied in pharma industry for its binding.

Table 3.4:Chemical composition of tamarind kernel powder.

COMPOSITION	VALUE
Calcium (CaO)	109.25 mg
Iron (Fe_2O_3)	247.51 mg
Sodium (Nao)	nil
Potassium (K_2O)	1245.11mg
Magnesium (MgO)	247.51 mg

Fig. 3.4:Tamarind Kernel Powder

3.1.5 Wheat Husk Ash (WHS)

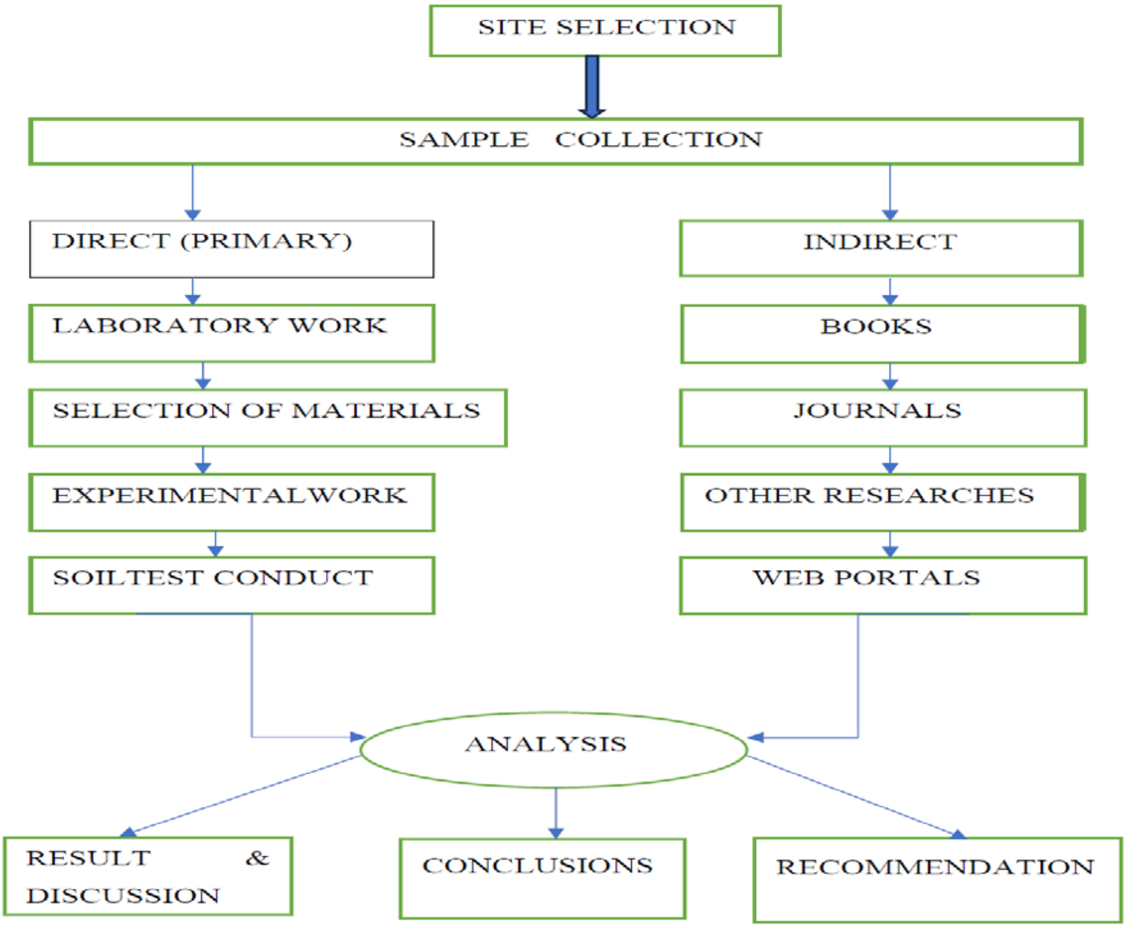
WHA has a good pozzolanic property. It is used for various purposes. It is the staple food produced in large quantity for living and non-living beings. It has high calorific value of about 3.5 kcal/g. Its by-product is often found in the fields because waste is burned by the farmers after extracting grains. In this research, the effect of WHA on the soil is studied. Wheat husk is taken from the agriculture fields and burned at 600°C to convert into fine ash. This ash has highest amount of silica which helps in fertility of soil. Wheat husk ash, basically a waste material, is produced by burning crops waste while processing wheat from paddy. About 20 – 22% wheat husk is generated from paddy and about 25% of this total husk become ash when burn. It is non – plastic in nature. Its properties also varied depending on its burning temperature. Wheat husk has a high ash content varying from 20-22% and Silica is the major constituent of Wheat husk ash varying from 60-65%. With such large silica content in the Wheat husk it becomes economical to extract silica from the ash, which has wide market and also takes care of ash disposal.Wheat husks contain 36% cellulose, 18% hemicellulose, 16% lignin, 9% starch, 6% protein and 5% fat. Due to their high cellulose content and fibrous structure, the husks have the potential to be used in cellulose-based composites.

Fig. 3.5:Wheat husk ash.

Table 3.5: Chemical properties of WHA at 600℃.

COMPOUND	VALUE (%)
Silicon Oxide(SiO_2)	43.22
Pottasium Oxide (K_2O)	11.30
Magnesium Oxide(MgO)	0.99
Iron Oxide (Fe_2O_3)	0.84
Sodium Oxide (Na_2O)	0.16
Chromium oxide(Cr_2O_3)	0.0004

3.2 METHODOLOGY



TESTING PHYSICAL PROPERTIES OF MATERIALS

4.1 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 (M1) 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 (M2).
4. Unscrew the cap and fill it up with water to the Pycnometer. Take its mass (M3).
5. Empty the Pycnometer. Clean it and wipe it dry.
6. Fill the Pycnometer with water only. Screw on the cap up to the mark. Wipe it dry.

Take its mass (M4).

Specific gravity is found using the equation,

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

Fig. 4.1:Pycnometer jar.

Determination of Specific Gravity.

The main steps observation in the procedure was,

1. Weight of dry clay = 10g
2. Weight of bottle (W1) = 29.22g
3. Weight of bottle + Weight of dry clay (W2) = 39.22g
4. Weight of bottle + dry clay + Water (W3) = 85.02g
5. Weight of bottle + Water (W4) = 79.13g

Formula for finding the specific gravity is, G=(W2-W1)/(W2-W1) *(W3-W4).

Specific gravity is 2.42

4.2 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 ofwatercontained in a material, such assoil,rock,ceramics,crops, orwood. 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'porosityat saturation. It can be given on a volumetric or mass(gravimetric)basis.

4.2.1 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

Table 4.1:Observations and calculations of natural moisture content

SL no:	Ww (gm)	Wd (gm)	Naturalwater content (Ww/Wd)*100(%)	MeanNatural Water content (%)
1	18	49	36.73	34.19
2	20	58	34.48	
3	16	51	31.37	

Average of 3 samples = 34.19%

4.3ATTERBERG 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 remoulded 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 behaviour 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.

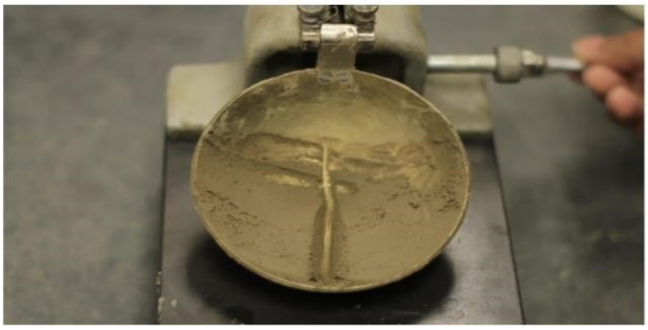


Fig. 4.2: Soil sample in Casagrande apparatus.

4.3.1 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.
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 blows vs water content %, which is called the "flow curve".

Table 4.2:Observations and calculations of Atterberg Limit

Observation no:	Sample 1	Sample 2	Sample 3
Weight of container w_1	31	32	31
Weight of container + wet clay w_2	235	235	236
Weight of container + dry soil w_3	233.33	233	233.33
Weight of moisture	204	204	204
water content	40	51	65
Number of blows	49	35	22

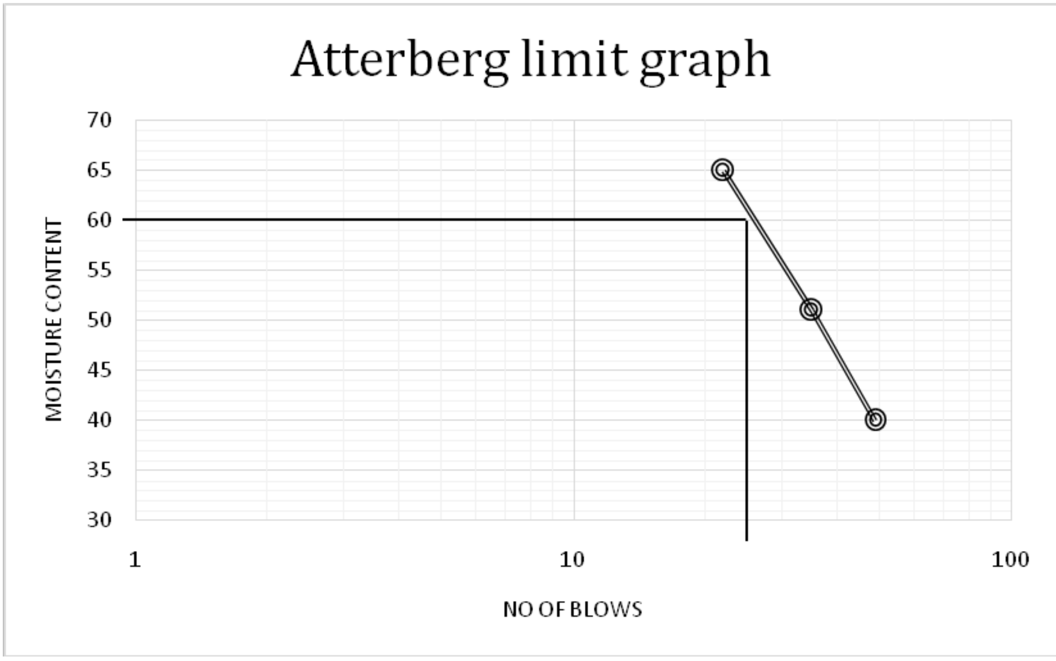


Fig. 4.3: Graph between number of blows and water content.

4.3.2 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.

Plastic Limit: -

Weight of container (W1) = 18 gm

Water content Wp = W2-W3/ W2-W1

PL Plastic limit = 32.74%

Index property Ip = WL–WP = 61.50 %- 32.74% = 28.68%

4.3 CALIFORNIA BEARING RATIO (CBR)

CBR value is used to check the shear strength and bearing capacity of the soil. Two types oftestsare performed to calculate the CBR value. In this test, soaked sample is used, which gives the revamped CBR values. At low energy levels bearing ratio is very less and therefore less water is available for controlling the hydration process. But as the percentage of ashes increases there is increase in CBR value. It again decreases at certain optimum value.CBR is the ratio expressed in percentage of force per unit area required to penetrate a soil mass with a standard 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 ratio is usually determined for penetration of 2.5 and 5 mm.The CBR is expressed as a percentage of the actual load causing the penetrations of 2.5 mm or 5.0 mm to the standard loads on crushed stone. A load penetration curve is drawn. CBR test results for soil should correctly be expressed as a percentage, e.g., CBR 2.5%. The test compares the penetration resistance of the tested soil to that of a standard high quality compacted granular material, in which typical results show a high percentage denotes a hard surface

Table 4.3:CBR Calculation

Penetration (mm)	No of division on proving ring	load
0	0	0
0.5	3	185.1
1	14	864.20
1.5	39	2407.41
2	64	3950.62
2.5	78	4814.81
4	109	6728.40
5	124	7654.32
7.5	155	9567.90
10	178	10987.65
12	200	12345.68

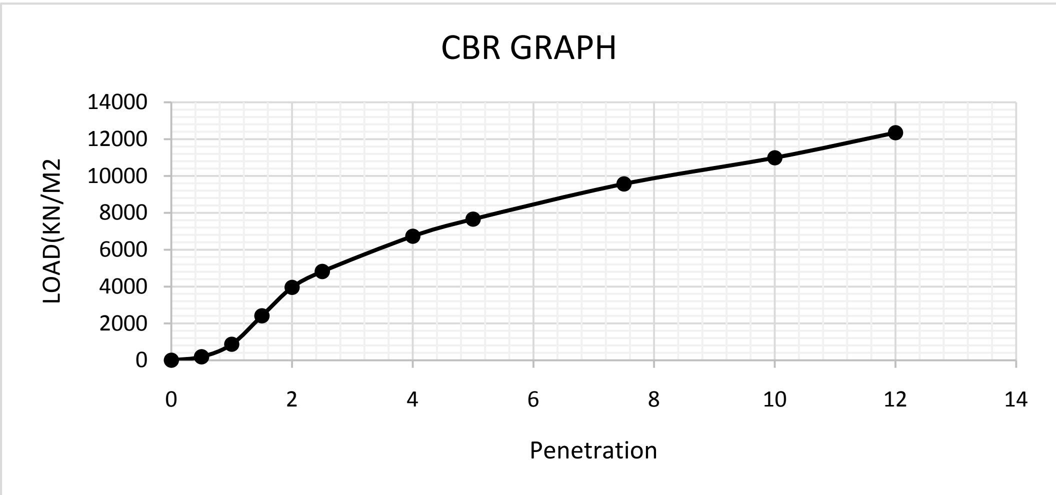


Fig 4.4:Load vs penetration graph

Load vs penetration graph indicates that the soil is of high strength.

From the load – penetration curve,

CBR corresponding to 2.5 mm penetration = 43.8

CBR corresponding to 5mm penetration = 40.86

From the above inference, it can be concluded that clay is having high strength.

4.4STANDARD 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 number 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. 4.5: Proctor compaction test apparatus

4.5.1 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.

Fig. 4.6: Mould after the filling of soil

Table 4.4:Observation table for compaction test

Parameters	Sample 1	Sample 2	Sample 3	Sample 4
Water Content	0.163	0.243	0.342	0.837
Dry Density	1.16	1.39	1.28	1.17

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 = Ɣ/1+w

Ɣ is the bulk density of soil.

W is the water content of soil

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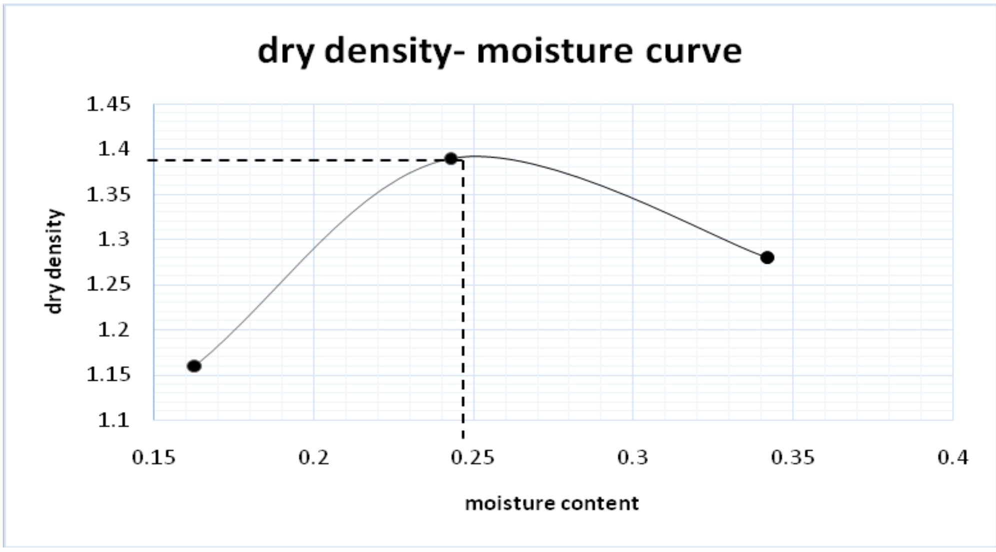

Fig 4.7:Dry density -moisture curve

From the above graph we can easily find out the optimum moisture content and maximum dry density of the clay soil. The Optimum moisture content of the sample is 25% and the maximum dry density is 1.38gm/cc.

4.5UNCONFINED COMPRESSIVE STRENGTH TEST

The Unconfined Compression Test is a laboratory test used to derive the Unconfirmed Compressive Strength (UCS) of a rock specimen. Unconfirmed Compressive Strength (UCS) stands for the maximum axial compressive stress that a specimen can bear under zero confining stress. Unconfined Compressive Strength (UCS) stands for the maximum axial compressive stress that a cohesive soil specimen can bear under zero confining stress. It is used to determinethe 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.

Fig. 4.8: Unconfined Compression test apparatus.

Unconfined compression test is one of the fastest and cheapest methods of measuring shear strength of clayey soil. 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. A cylinder of soil without lateral support is tested to failure in simple compression, at a constant rate of strain. The compressive load per unit area required to fail the specimen as called Unconfined compressive strength of the soil. 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 xUnconfined compressive strength.

4.6.1 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.

The angle between the failure surface and the horizontal is measured if possible.

Table 4.5:Observation Table for Unconfined Compression Test

Dial Gauge	Proving Ring	Deformation	Load (kg)	Strain	Corrected area	Compressive Stress
0	0	0	0	0	11.34	0
50	5.2	0.5	11.81	0.0065	11.41	1.03
100	7.3	1	16.59	0.013	11.49	1.44
150	7.3	1.5	16.59	0.019	11.56	1.43
200	7.3	2	16.59	0.026	11.64	1.42

Unconfined Compression Strength = 1.44kg /cm2 Cohesion = 0.72kg/cm2

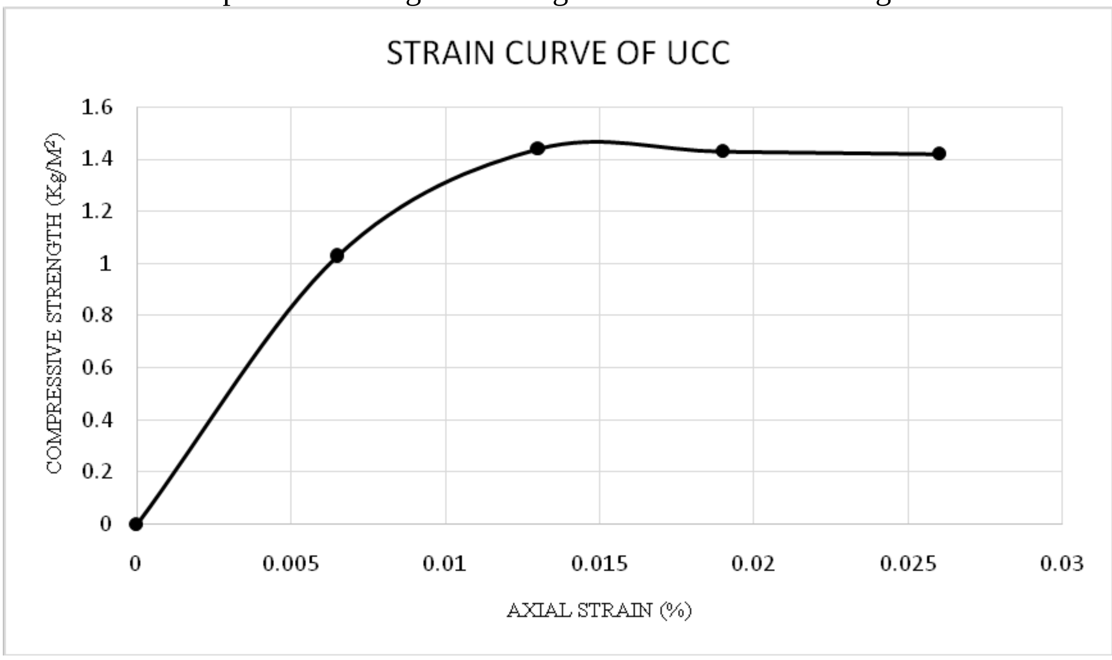

Fig 4.9: strain curve of UCC

4.6PHYSICAL PROPERTIESOF MATERIALS

Table 4.6: Physical properties of materials

Sl.No	Egg Shell Powder	Tamarind Kernal Powder	WheatHusk Ash	Sugarcane Straw Ash
Specific Gravity	1.86	2.40	2.45	2.35
Fineness	50 µm-90µm	60 µm-100µm	43µm - 63µm	55µm -75µm
Moisture Content	0.2%-0.4%	6.0% -7.0%	7.7% -9.5%	45% -55%
Size Of Particle	90µm	100µm	63µm	BELOW 75µm

CHAPTER 5

TEST ANALYSIS

5.1 MIXING PROPORTIONS

Tests were done on black cotton soil with different proportions of Sugarcane Straw Ash, Wheat Husk Ash, Tamarind Kernal Powder and Egg shell powder. Three mixes were taken with

(I) [1.5:1:1:1] [Sugarcane Straw Ash:Wheat Husk Ash: Tamarind Kernal Powder: Egg shell powder]

(II) [1:1.5:1:1] [Sugarcane Straw Ash: Wheat Husk Ash: Tamarind Kernal Powder: Egg shell powder]

(III) [1:1:1.5:1] [Sugarcane Straw Ash: Wheat Husk Ash: Tamarind Kernal Powder: Egg shell powder]

5.2 ANALYSIS OF LABORATORY TEST

5.2.1Atterberg Limit

The plasticity of the soil is the ability of the soil to mould into many shapes when the soil is wet. This is basically due to the presence of clay minerals. So, when the soil is wet it is attracted towards water molecules. So, this plasticity is due to adsorbed water. The Atterberg limits show that soil having plasticity and it has clay minerals and purely suitable for the embankments as shown in Fig 3.

I.Black cotton soil is mixed variouswastes (SCSA, ESP, WHS &TKP) in 0.5%, 1%,,1.5% and 2% by weight of dry soil with Black cotton soil.[1.5:1:1:1.].

Table 5.1:Result of Atterberg limit[1.5:1:1:1.].

% of Waste	Blackcotton soil+different percentages of WHA,SCSA ,ESP &TKP			
	Liquid Limit	Plastic Limit	Plasticity Index	Average plasticity index
0.5	43.50	42.03	1.476	2.90
	48.50	44.17	4.33	
1	52.5	50.98	1.62	4.28
	62.5	55.95	6.95	
1.5	61.0	54.64	3.13	3.51
	66.50	61.15	3.90	
2	67.50	62.64	4.87	4.8
	65.50	60.78	4.72	

II. The proportion of adding wastes (SSA: ESP: WHS: TKP) is 1:1.5:1:1

Table 5.2:Result of Atterberg limit 1:1.5:1:1.

Percentage of Enhancement (%)	Black cotton soil+ different percentages of WHA, SCSA, ESP &TKP			
	Liquid Limit	Plastic Limit	Plasticity Index	Average plasticity index
0.5	48.52	44.56	3.96	2.99
	47.65	45.60	2.03	
1	51.30	48.38	1.52	3.7
	60.42	53.41	5.89	
1.5	43.50	42.03	1.476	2.90
	48.50	44.17	4.33	
2	48.23	45.56	2.67	1.85
	46.65	45.62	1.03	

III The proportion of adding wastes (SSA: ESP: WHS: TKP) is 1:1:1.5:1.

Table 5.3:Result of Atterberg limit 1:1:1.5:1.

Percentage of Enhancement (%)	Black cotton soil+ different percentages of WHA, SCSA, ESP &TKP			
	Liquid Limit	Plastic Limit	Plasticity Index	Average plasticity index
0.5	43.50	42.03	1.476	2.90
	48.50	44.17	4.33	
1	50.21	47.21	1.45	3.68
	59.18	52.91	5.92	
1.5	48.52	44.56	3.96	3.04
	47.62	45.5	2.12	
2	42.56	41.03	1.53	
	44.61	43.56	1.05	

5.2.2Unconfined Compressive Strength Test

The compressive strength was conducted to calculate the undrained shear strength. This is basically equal to the half of the undrained shear strength. The soil sample prepared for the test are analysed based on the given table 6. The different percentages of the wheat husk and sugar cane straw ash was mixed with the raw soil to revamp its quality. This compressive strength was used to calculate the undrained shear strength.

I. Black cotton soil is mixed various wastes (SCSA, ESP, WHS &TKP) in 0.5%, 1%,1.5% and 2% by weight of dry soil with Black cotton soil. [1.5:1:1:1.].

Table 5.4: Result of UCC[1.5:1:1:1.].

Percentage of Enhancement (%)	Black cotton soil + different percentages of WHA and SCSA + ESP +TKP	
	Unconfined Compressive strength (UCS values)	Cohesion (kg/ m^2)
0.5	2.2	1.1
1	2.37	1.85
1.5	2.32	1.22
2	2.1	1.17

II. The proportion of adding wastes (SSA: ESP: WHS: TKP) is 1:1.5:1:1

Table 5.5: Result of UCC [1:1.5:1:1.].

Percentage of Enhancement (%)	Black cotton soil + different percentages of WHA and SCSA + ESP +TKP	
	Unconfined Compressive strength (UCS values)	Cohesion (kg/ m^2)
0.5	2.15	1.51
1	2.31	1.79
1.5	2.28	1.68
2	2.2	1.42

III The proportion of adding wastes (SSA: ESP: WHS: TKP) is 1:1:1.5:1.

Table 5.6: Result of UCC [1:1:1.5:1].

Percentage of Enhancement (%)	Black cotton soil + different percentages of WHA and SCSA + ESP +TKP	
	Unconfined Compressive strength (UCS values)	Cohesion (kg/ m^2)
0.5	2.29	1.54
1	2.33	1.82
1.5	2.27	1.54
2	2.00	1.39

5.2.3 California Bearing Ratio (CBR) Test

CBR value is used to check the shear strength and bearing capacity of the soil.

I. Black cotton soil is mixed various wastes (SCSA, ESP, WHS &TKP) in 0.5%, 1%,1.5% and 2% by weight of dry soil with Black cotton soil. [1.5:1:1:1.].

Table5.7: Result of CBR[1.5:1:1:1.].

Percentage of Enhancement (%)	Black cotton soil + different percentages of WHA and SCSA + ESP +TKP	
	CBR of 2.5mm penetration	CBR of 5mm penetration
0.5	47.3	45.73
1	48.1	46.73
1.5	47.9	45.89
2	47.6	45.82

II. The proportion of addingwastes (SSA: ESP: WHS: TKP) is 1:1.5:1:1

Table5.8: Result of CBR[1:1.5:1:1]

Percentage of Enhancement (%)	Black cotton soil + different percentages of WHA and SCSA + ESP +TKP	
	CBR of 2.5mm penetration	CBR of 5mm penetration
0.5	40.69	43.65
1	46.13	45.38
1.5	45.69	44.36
2	43.69	43.96

III The proportion of adding wastes (SSA: ESP: WHS: TKP) is 1:1:1.5:1.

Table5.9: Result of CBR [1:1:1.5:1.]

Percentage of Enhancement (%)	Black cotton soil + different percentages of WHA and SCSA + ESP +TKP	
	CBR of 2.5mm penetration	CBR of 5mm penetration
0.5	47.69	42.57
1	46.12	44.83
1.5	46.12	43.34
2	45.26	43.29

5.2.4Standard 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.

I. Black cotton soil is mixed various wastes (SCSA, ESP, WHS &TKP) in 0.5%, 1%,1.5% and 2% by weight of dry soil with Black cotton soil. [1.5:1:1:1.].

Table 5.10:Result of Standard Proctor Test [1.5:1:1:1.].

Percentage of Enhancement (%)	Black cotton soil + different percentages of WHA and SCSA + ESP +TKP	
	Optimum moisture content	Maximum dry density (gm/cc)
0.5	24.7	1.22
1	23	1.31
1.5	24.7	1.22
2	24.7	1.22

II The proportion of adding wastes (SSA: ESP: WHS: TKP) is 1:1.5:1:1.

Table 5.11:Result of Standard Proctor Test [1:1.5:1:1]

Percentage of Enhancement (%)	Black cotton soil + different percentages of WHA and SCSA + ESP +TKP	
	Optimum moisture content	Maximum dry density (gm/cc)
0.5 %	25.6	1.25
1%	23	1.31
1.5%	25.8	1.29
2%	26	1.32

III. The proportion of adding wastes (SSA: ESP: WHS: TKP) is 1:1:1.5:1.

Table 5.12: Result of Standard Proctor Test [1:1:1.5:1]

Percentage of Enhancement (%)	Black cotton soil + different percentages of WHA and SCSA + ESP +TKP	
	Optimum moisture content	Maximum dry density (gm/cc)
0.5	28.6	1.56
1	23	1.31
1.5	25.6	1.25
2	25.7	1.27

5.2.5 Specific Gravity

Specific gravity is a fundamental property of soils and other construction materials. This dimensionless unit is the ratio of material density to the density of water and is used to calculate soil density, void ratio, saturation, and other soil properties

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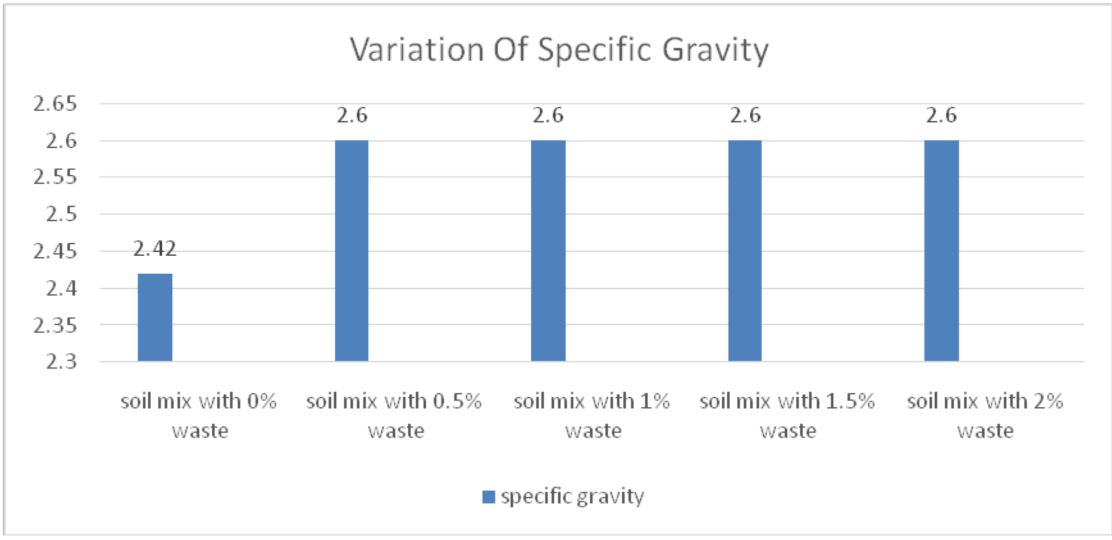

Fig. 5.1: Variation of Specific Gravity with % waste.

Hence there is no variation with other proportion, the specific gravity can be concluded as 2.6.

RESULTS AND DISCUSSIONS

6.14.1INITIAL PROPERTIES OF BLACK COTTON SOIL

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

TABLE 6.1:Properties of Soil

PROPERTY	VALUE
OMC (%)	25
Maximum Dry Density(g/cc)	1.38
Specific Gravity	2.42
Liquid Limit (%)	61.50
Plastic Limit (%)	32.74
Plasticity Index (%)	28.68
CBRvalue at 2.5mmpenetration	43.8
CBR valueat5mm penetration	40.86
Moisture Content	33.43
Unconfined Compressive Strength (Kg/ Cm2)	1.44

4.2 PROPERTIES AFTER TREATMENT

In this study we have mixed various wastes [SCSA, ESP, WHS and TKP] in 0.5%, 1%,1.5% and 2% by weight of dry soil with Black cotton soil. Various tests were done for finding the strength of stabilized soil sample in order to study the effect of these wastes with soil mix. The physical characteristics of Free Black cotton soil and Black cotton soil with different % of wastes are given in the table below.

6.1 STANDARD PROCTOR TEST

Standard proctor test was done to find the OMC of the soil mix. Black cotton soil is mixed various wastes (SCSA,ESP, WHS&TKP) in 0.5%, 1% ,1.5% and 2% by weight of dry soil with Black cotton soil in different proportions.

Analysis of proportion

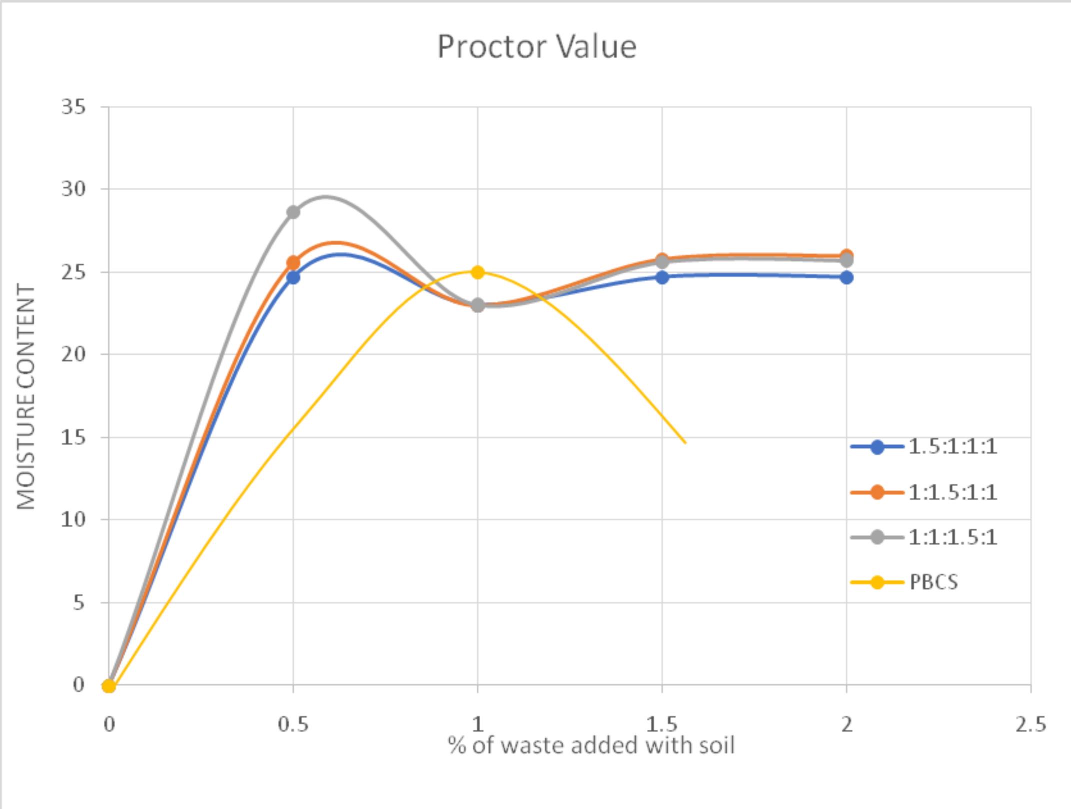

Fig6.1:Proctor Test Analysis

The moisture content and dry density relationship of stabilised soil is presented in the Fig. 6.2. it may be observed that with the percentage increase in stabiliser content optimum moisture content (OMC) of admixed soil decreases gradually and maximum dry density (MDD) decreases. The cause of decrease in MDD may also be attributed to coating of the soil particles by WHA which results in larger particles with larger voids and hence lesser density.

Optimum moisture content ofPure black cotton soil is 25% and here we had obtained 23% moisture content while adding admixtures.

6.2 ATTERBERG LIMIT

Based on theresults the graphs were plotted for different soil characteristics for varying proportion are given below:

The proportion of adding wastes (SSA: ESP: WHS: TKP) is 1.5:1:1:1

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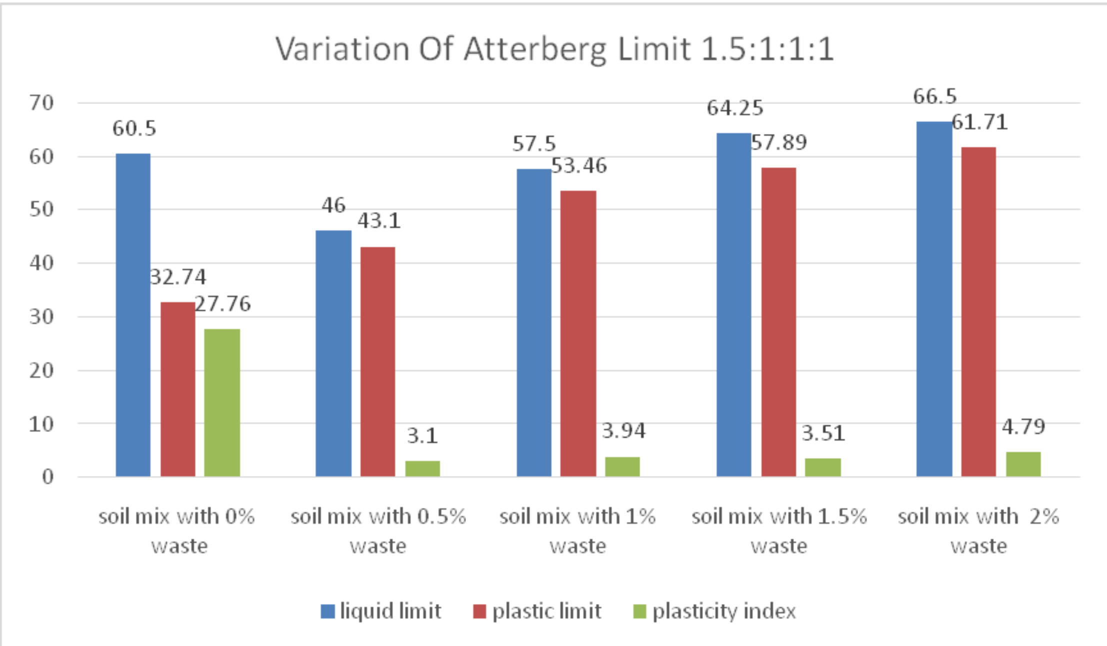

Fig. 6.2: Variation ofAtterbergLimit with Different Percentage of Waste in 1.5:1:1:1.

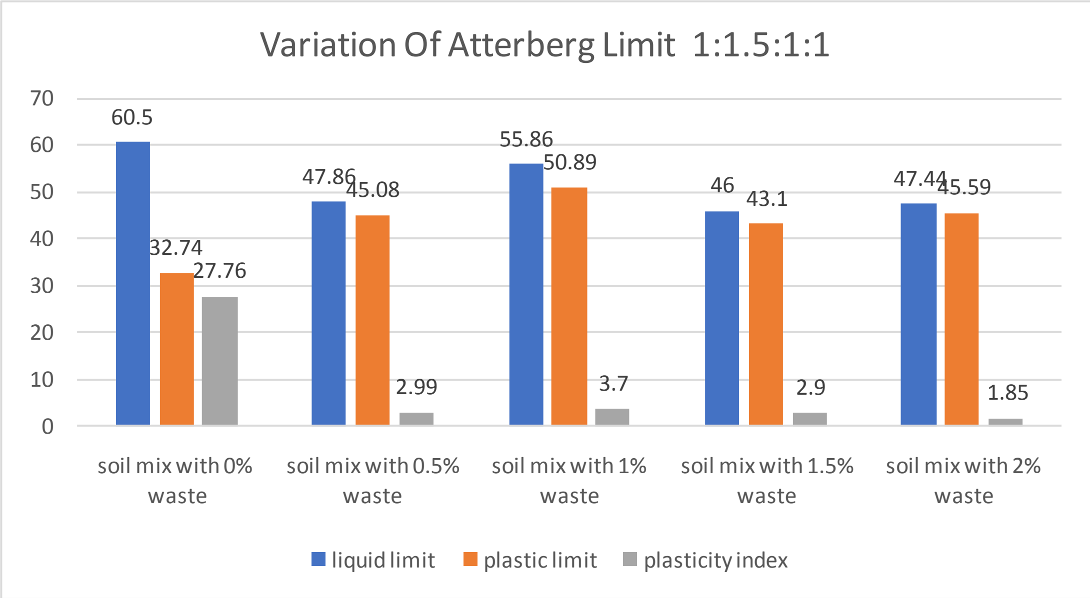

Fig. 6.3: Variation of Atterberg Limit with Different Percentage of Waste in 1:1.5:1:1

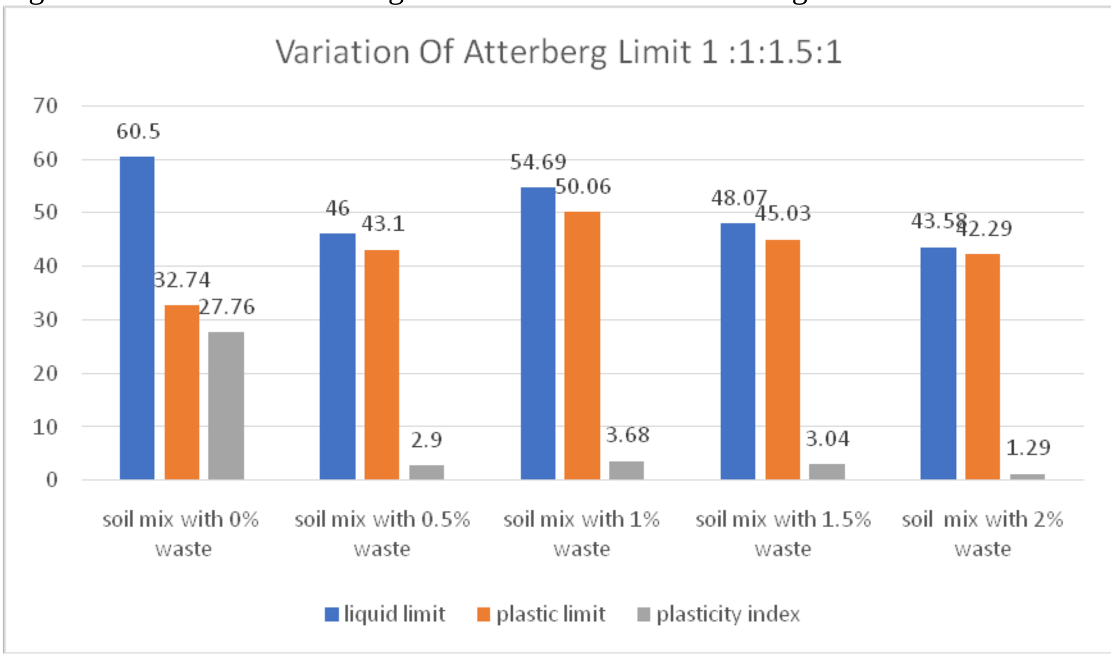

Fig. 6.4: Variation of Atterberg Limit with Different Percentage of Waste in 1:1:1.5:1.

The plasticity of the soil is the ability of the soil to mould into many shapes when the soil is wet. This is basically due to the presence of clay minerals. So, when the soil is wet it is attracted towards water molecules. So, this plasticity is due to adsorbed water. The Atterberg limits show that soil having plasticity and it has clay minerals and purely suitable for the embankments.The plastic limit of black cotton soil ranges from 20-40%, Here we had 27.76 % in black cotton soil.Variation of Atterberg limit with different percentage of waste added. When the soil is stabilised with wastes, the value of P.L. of mixed soil increases sharply and the value of L.L decreases but at the same time the value of P.I. of mixed soil decreases.

6.3 CALIFORNIA BEARING RATIO

CBR value is used to check the shear strength and bearing capacity of the soil. Two types of tests are performed to calculate the CBR value. In this test, soaked sample is used, which gives the revamped CBR values.

The graph 6.5 shows that at low energy levels bearing ratio is very less and therefore less water is available for controlling the hydration process. But as the percentage of ashes increases there is increase in CBR value. It again decreases at certain optimum value. Thus, it is clear that 1% addition of ashes gives more consistent results.

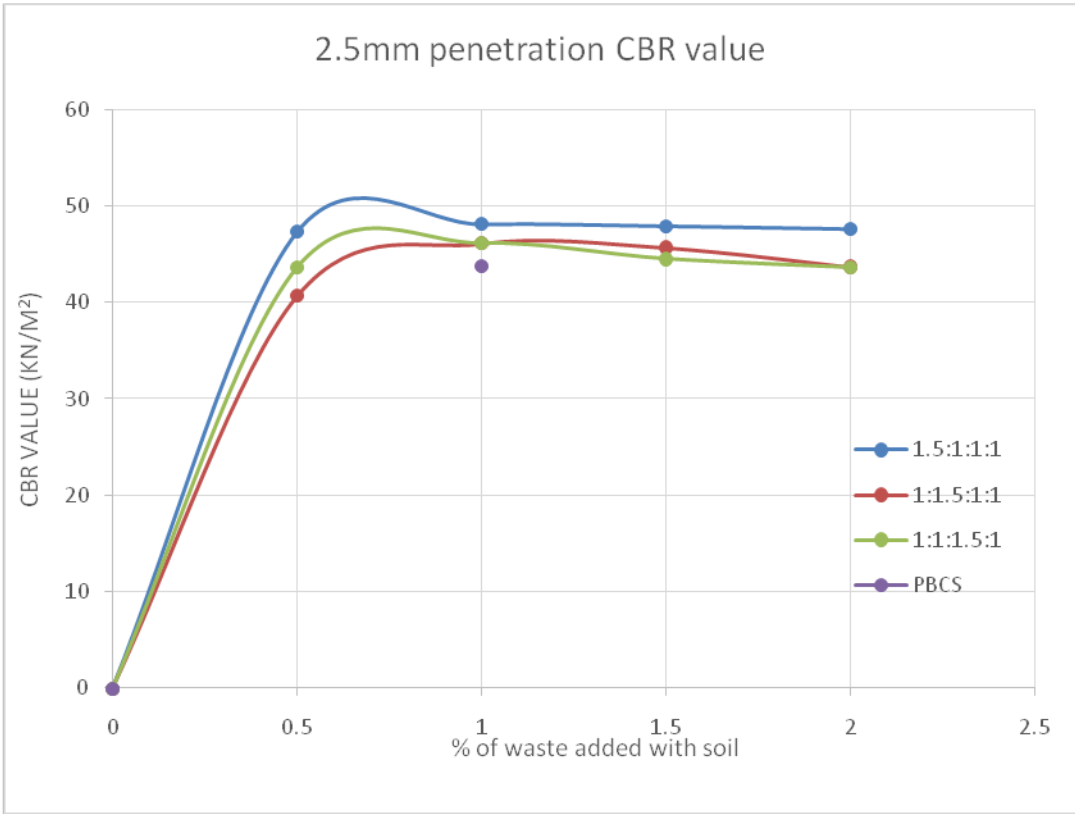

Fig. 6.5: Variation of CBR Value (2.5mm penetration)

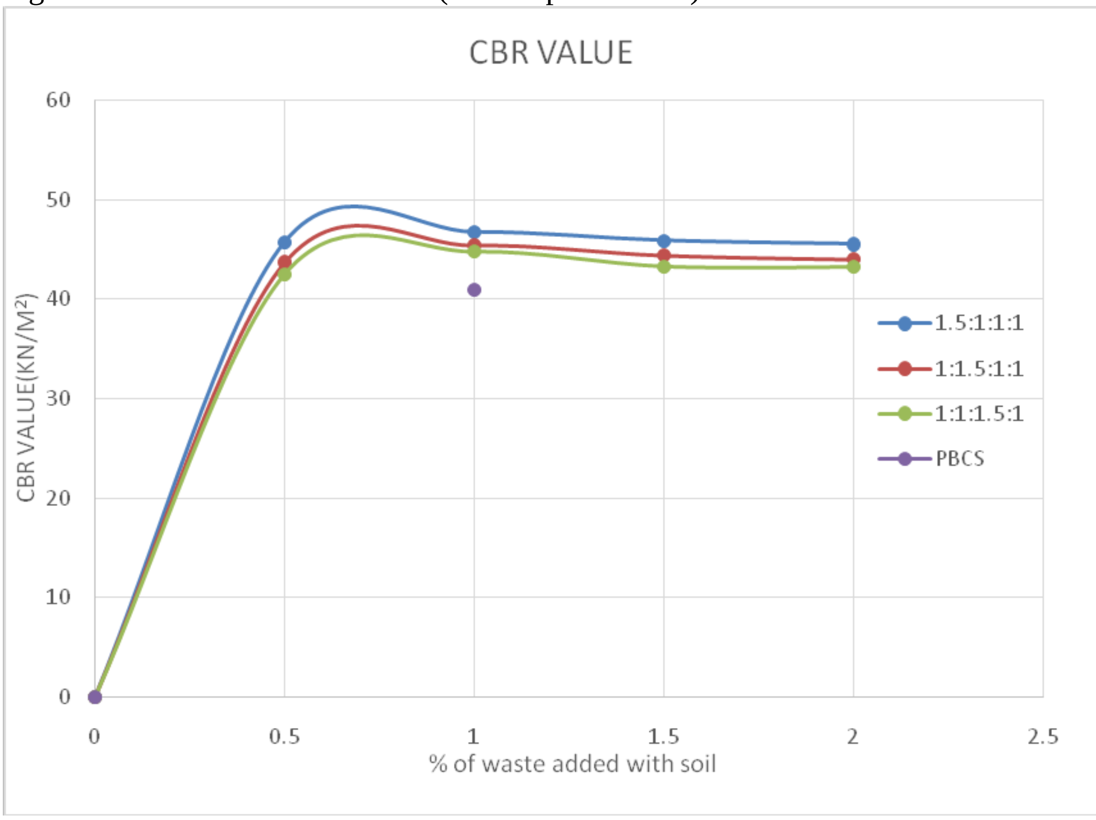

Fig. 6.6:Analysis of CBR Value (5mm penetration)

CBR value is greater for soil mix with 1% of waste with 1.5:1:1:1 which gives more consistent results.

6.4 UNCONFINED COMPRESSIVE TEST

The compressive strength was conducted to calculate the undrained shear strength. This is basically equal to the half of the undrained shear strength. The soil sample prepared for the test are analysed based on the given graph. The different percentages of the wheat husk, egg shell powder, tamarind kernel powder and sugar cane straw ash was mixed with the raw soil to revamp its quality. It is seen in the given graph 4 that maximum strength was obtained at 1% in 1.5:1:1:1 proportion which was about 2.37. This compressive strength was used to calculate the undrained shear strength.

It shows that Unconfined compressive strength increases with increasing percentage of stabiliser added. It again decreases at certain optimum value. Thus, it is clear that 1% addition of ashes in 1.5:1:1:1gives more consistent results.

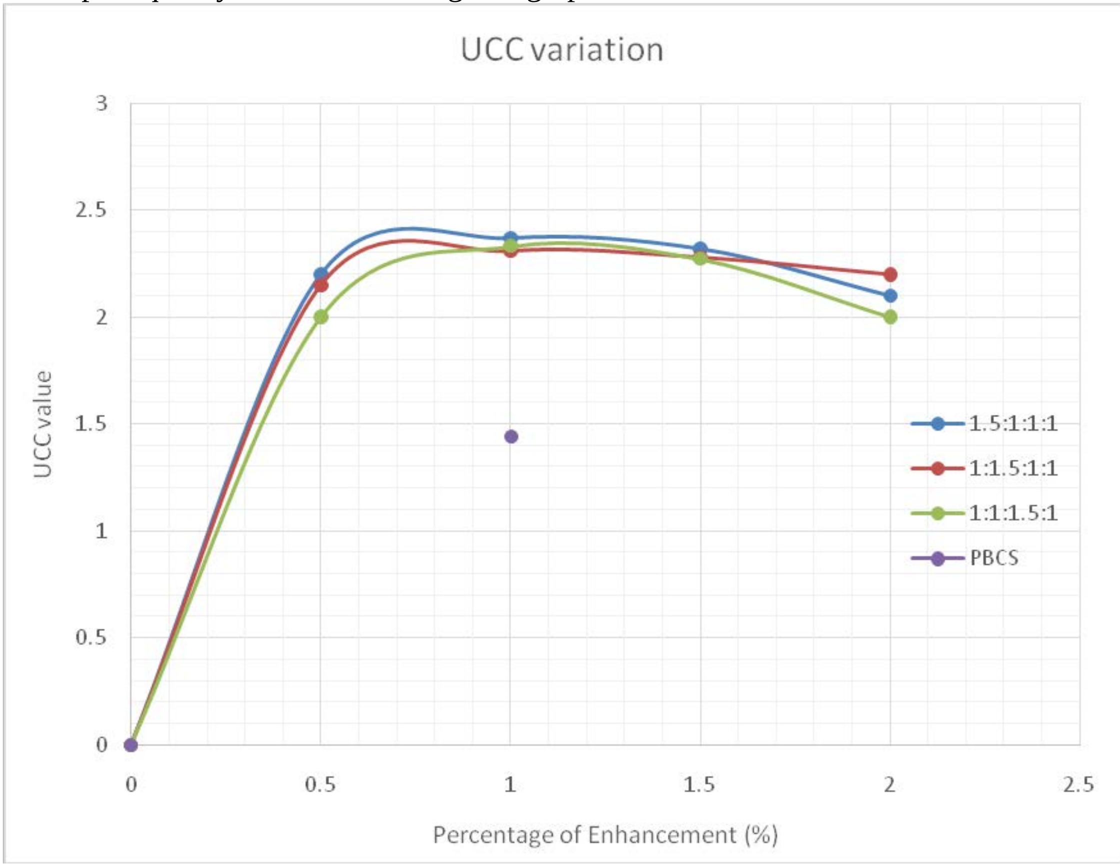

Fig .6.7:Variation of UCC Value

UCC value is greater for soil mix with 1% of wastewith1:1.5:1:1

CONCLUSIONS

The study reveals that the inclusion of Wheat Husk Ash, SugarcaneStraw Ash, Egg Shell Powder and Tamarind Kernal Powder gives more consistent results as compared to the individual addition to the specimen. The research determines the following investigations carried out in the laboratory are as given below: -

• The collected black cotton soil has specific gravity is very less. This is basically due to fibrous nature of the soil. The mixing of different proportions of ashes to the black cotton soil shows that there is improvement in the specific gravity in addition of 1% ash which is considered as an indication of high strength

• The mixing of different proportions of ashes to the black cotton soil shows that there is improvement MDD in addition of 1%and then further decreases due to stiffness of the soil.

• The optimum moisture content was attained at 1% and then further there is sharp decline. This OMC is used as an index to mix the quantities together for various projects.

• The Atterberg limits of pure black cotton soil shows that the collected soil is highly plastic in nature as its plasticity index is more than 17. The differ in percentages of enhancement at 1 % addition of ashes renders that soil shows clayey nature. This nature is fruitful to the applying soil for the pavements.

• CBR value is used as index parameter to determine the bearing capacity and shear strength of the soil. It is maximum at 1 percent enhancement level and then further decreases.

This decline is basically due to certain increase and decrease in OMC which is responsible for decrease in CBR value.

• The UCS test gives the shear strength as an index to structuring the buildings by various engineers. It is clear from the above results that the strength increases slowly.

• Increase in Optimum moisture content of soil, plays an important role in compaction as well as the durability and strength of compacted soil.

• The values obtained after the experimentation clears that these values are used as index for the designing and laying the base and sub base material for the infrastructure development and pavements structuring

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