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EXPERIMENTAL INVESTIGATION ON STABILIZATION OF BLACK COTTON SOIL WITH COPPER SLAG

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ABSTRACT

In today scenario, lack of stable ground for development of infrastructure is very common. In view of this, construction of buildings on unsuitable ground is unavoidable and making a suitable ground before construction is real challenging issue for geotechnical engineers. May investigations have been carried out on clay sub-graded soil, using several types of stabilizers. Due to the increase in traffic loads and the importance of sub-grad layer in strengthening the pavement section to prevent the earlier damage. In this study the 1st step (based on the designed experimental program) sample (black cotton soil) is collected. Black cotton soil exhibit high swelling and shrinking when exposed to changes in moisture content and hence have been found to be most major soil deposits in India, so there is a need of enhancing its geotechnical properties and make it suitable for the construction purpose. There have been many methods available to control the expansive nature of soils. The stabilization of soil by adding different binding materials such as enzymes, biopolymers, emulsions, cement, lime, bitumen, etc. is the conventional and effective method for improving the geotechnical properties of soil. To overcome the difficulties experienced with black-cotton soil in geotechnical applications on one side and safe disposal of solids wastes on the other side, an attempt is made in this investigation to explore the possibilities of utilizing solid waste to improve the engineering behavior of black-cotton soil. In this, in this present investigation the type of solid waste namely Copper slag for stabilization of is selected to study the effects of same on the index and engineering characteristics of black cotton soil. The copper slag is mixed with black cotton soil in various proportions like 5% 10% 15% and 20% will be tested and the results will be compared with the properties of normal soil. The various tests such as Liquid limit, Plastic limit, Specific Gravity Of Soil by Pyconometer method, Proctor Test, Grain Size Distribution and California Bearing Ratio Test (CBR) were conducted on these proportions and optimized proportion is arrived.

Keywords: Black Cotton Soil, Copper Slag.

I.INTRODUCTION

In India, an area about one-six is occupied by black cotton soil. The area covers mostly the Deccan Trap plateau, Thus, most of soil in and around Mumbai, Madras, Gwalior, Khandwa, Indore, Nagpur and even some on the river banks is Black cotton .That means these soils are predominant in Deccan trap plateau region, i.e., in states of Andhra Pradesh, Western Madhya Pradesh, Gujarat, Maharashtra, Northern Karnataka and Tamilnadu.

Black Cotton soils are problematic for engineers everywhere in the world, and more so in tropical countries like India because of wide temperature variations and because of distinct dry and wet seasons, leading to wide variations in moisture content of soils. The following problems generally occur in black cotton soil.

Foundations in civil engineering are land-based structures requires a strong base provided by soil or rocks. Weak soil including soft clays, expansive soil, organic deposits, and loose sand are often unsuitable for construction due to their poor engineering properties .Black cotton soil is one of the major deposits of India, exhibiting high swelling and shrinkage properties in the presence and absence of moisture content respectively, resulting in deformation of the road surface and reduction of soil-bearing strength. Montimorillonite is a clay mineral, which is mainly responsible for expansive characteristics of the soil. The kaolinite group is generally non-expansive. The mica-like group that includes illites and vermiculites, can be expansive, but generally does not pose notable problems. The chief properties of a soil with which the construction engineer is concerned are volume, strength, permeability and durability.

A basic decision by a Civil Engineer among the following must, be made whether to:

1. Accept the site material as it is and design to standards, sufficient to meet the restrictions imposed by its existing quality,

2. Remove the site material and replace with a superior material and 3.Alter the properties of existing soil.

They have variable thickness and are underlain by sticky material locally known Cotton soil is one which when associated with as engineering structure and in presence of water will show a tendency to swell or shrink causing the structure to experience moments which are largely unrelated to the direct effect of loading by the structure.

Black cotton soil is not suitable for the construction work on account of its volumetric changes. It swells and shrinks excessively with change of water content. Such tendency of soil is due to the presence of fine clay particles which swell, when they come in contact with water, resulting in alternate swelling and shrinking of soil due to which differential settlement of structure takes place, so the stabilization or modification of soil is needed.

The improvement of soil can be classified into several categories, modification or stabilization or both. The modification can be conducted by compaction or replacement of the original soil or mixing soil with another. While stabilization is the treatment of soils to enable their strength and durability to be improved such that they become totally suitable for construction. Stabilization of pavement sub grade soils has traditionally relied on treatment with lime, cement, or waste materials such as fly ash, slags, silica fume, etc. Many researchers have been looking for waste and economical materials to employee soil stabilization.

The soil stabilization process enhances the physical properties of expansive soils with respect to strength, durability, or other geotechnical properties. Soils can be stabilized by mixing the correct proportion of sandy and clay soil or by mechanical compaction of natural soil, which increases the strength and cohesion. This is an important factor for road construction, and other problems related to the building and maintenance of infrastructure. Blending a binder into the soil to increase its strength and stiffness through chemical reactions is referred to as chemical stabilization .Waste &industrial byproducts utilization in the soil stabilization for road and civil constructions has become common research idea.

1.1 Expansive soil-Origin, Occurrence, Properties & Damage:-

Expansive soils creates greatest hazard in arid regions. Expansive soils contain clays and fine silts swells and shrinks as their moisture content changes. These expansive soils created problems for the structures, mainly lightweight structures and the structures most commonly damaged are small buildings, roadways, pipelines and irrigation canals.

Clay mineral is that the key component that passes on swelling characteristics to any standard non-swelling soils. Montmorillonite has the utmost swelling potential among many varieties of clay minerals. The origin of such soil is sub aqueous decomposition of blast rocks, or weathering in situ formation of vital clay mineral takes place under alkaline environments. If there is an adequate supply of magnesium of ferric or ferrous oxides and alkaline environments along with adequate silica and aluminum attributable to weathering condition, it will favor the formation of Montmorillonite.

Expansive soils contain clay or other minerals that cause them to expand when absorbing water. These soils often expand by 10% or more during a rainfall. When the soils dry out, they shrink back to their original size.

Causes of Damage: 1.Expanding

2. Contracting

1.2 Objectives :-

The following are the objectives of the project. They are:-

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- The primary objective of this work is to study the interaction of black cotton soils with Copper Slag.
- To improve the Geo-Technical and Engineering Properties of the Black-Cotton soil.
- To study the behavior of strength gain in black cotton soil using Copper Slag Stabilization.
- To use the industrial waste as a stabilizing material.
- To know the percentage of copper slag can be utilized in the stabilization process.
- To evaluate the suitable blend that can be used in the stabilization of black cotton soil.

1.3 Scope of Project:-

In remote rural villages, the development of road network is of vital importance in the socio- economic development. Especially the rural villages having black cotton soil as subgrade is very difficult to lay the pavement. As the copper slag is an industrial waste from cane mills, the optimum usage of this material in subgrade soil stabilization will bring down the construction cost of the pavements. In our study an attempt is made to stabilize black cotton soil with addition of copper slag. The strength parameters like CBR, MDD are determined to know the suitability of material.

1.4 Soil Stabilization:-

Soil stabilization in its general meaning considers every physical and chemical method employed to make a soil suitable for its required engineering purpose. In its specific meaning in road engineering, soil stabilization is a process to improve the soil strength by using additives in order to use as a base or sub base courses and carry the expected traffic and pavement loads.

Types of Stabilization:-

There are different types of stabilization, each having its own benefits and potential problems. The types described below are those most frequently used.

1.4.1 Mechanical Stabilization:-

The most basic form of mechanical stabilization is compaction, which increases the performance of a natural material. The benefits of compaction however are well understood and so they will not be discussed further in this report. Mechanical stabilization of a material is usually achieved by adding a different material in order to improve the grading or decrease the plasticity of the original material.

Application of Black Cotton Soil:-

Soil Stabilization can be utilized on roadways, parking areas, site development projects, airports and many other situations where sub-soils are not suitable for construction. Stabilization can be used to treat a wide range of sub-grade materials, varying from expansive clays to granular materials.

II.LITERATURE SURVEY

Stabilization, in a broad sense, incorporates method employed for modifying the properties of soil to improve its engineering performances. Stabilization is being used for variety of engineering works, the most common application being in the construction of roads and air-field pavements, where the main objective is to increase the strength or stability of soil and to reduce the construction cost by making best use of locally available materials. Method of stabilization may be grouped under two main types: a) modification or improvement of soil property of existing soil without any admixture, b) modification of properties with the help of admixtures. Compaction and drainage are examples of the first type. Mechanical stabilization, stabilization with cement, lime, bitumen and chemicals, etc are examples of second type.

There are many attempts made in stabilizing soils with the use of wastes and additives, here are some of the research works carried on stabilizing soil with use of wastes.

Prof. Ranjendrakumar (2017) had studied about the Black cotton soil blended with copper slag and fly- ash which are added in different percentages. The soil properties like liquid limit, plastic limit, plasticity index, free swell, compaction test and CBR (unsoaked) were determined. The results indicated that the dry density, CBR values were improved and swelling was reduced due to addition of copper slag 30% and fly ash 10% (% by weight of soil) in the soil.

Prof. Ramesh babu (2017) had investigated about the behaviour of black cotton soil with addition of copper slag and steel slag. The soil samples are tested by compaction test, unconfined compression test and CBR. It is concluded that CBR, optimum moisture content, maximum dry density and shear strength are increased when the soil is added with 20% of copper slag and steel slag.

Prof. Wajid Ali Butt (2016) had investigated about the Strength Behaviour of Clayey soil stabilized with sawdust ash. The soil properties were determined by computing the Liquid limit, plastic limit, plasticity index, specific gravity, UCC and CBR. He observed that the property of soil showed an acceptable value up to 4% replacement of sawdust ash. He had discovered that sawdust ash acceptably act as a cheap stabilizing material for road pavement.

III.MATERIALS & METHODOLOGY

3.1 Materials:-

3.1.1 Black Cotton Soil:-

Basaltic rocks are dark black colored rocks solidified from lava and on weathering form black cotton soils. Hence, they are very dark

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in colour. They develop cracks during the dry period and swell during the wet period hence they are self-tilling in nature, fertile and can hold water for along time. This capacity is used for cotton cultivation. Hence, they are also called as Regur or Black Cotton Soil. The Black cotton soil is poorly graded soil. Montimorillonite is the clay mineral responsible for expansive properties of black cotton soil. The black colour in the black cotton soil is due to the presence of titanium oxide in small concentration. These are inorganic clays of medium to high compressibility. The soil sample was collected from a site in local village (Kandlakoya), Hyderabad at 1.5m depth from the ground level. About 60kg of soil was used for conducting the experiments.

Fig.1 Black Cotton Soil

3.1.2 Copper Slag:-

Copper slag is an industrial waste by product obtained by the manufacture process it is mettle smelting and reefing of copper. Present it is used in sand blasting, rail road ballast and also in cement and concrete industries. The copper slay is used for replacement of fine aggregated in concrete as in up to 15%by weight of copper slay is used as fly ash replacement together with up to 1.5% . The multiple extraction leading tests indicate that the elements present in the slag are stable and are not leachable even through repetitive leaching under acid rain in a natural environment the highest concentration of all the elements is for below the prescribed limits .It has been estimated that approximately24.6million tons of slay are generated from the world of copper industry. Although copper slag is widely used in the sand blasting in and in the manufacturing of abrasive tools, the reminder is disposed of without any further reuse or reclamation. Copper slag possesses mechanical and chemical character to the copper slays C Copper slag procured from sterlite industries, tuticorin, and tamilnadu. The physical &chemical properties of the copper slag as provided by the manufacture are presented n the below tables respectively.

Fig .2 Copper Slag

Table-1 Physical properties of copper slag:-

Properties	Values
Colour	Black, glassy
Grain Shape	Angular, multifaceted
Grain Size	0.2-2.4mm
Bulk Density	1.87g/cc
Moisture Content	<0.1%

Table-2 Chemical properties of copper slag:-

Constituent	%weight
Silica sio2	26-30
Free silica	<0.5
Alumina Al2O3	1-3
Iron oxide Feo	42-48
Calcium oxide Cao	0.8-1.5
Magnesium oxide Mgo	0.8-1.5
Copper oxide cuo	0.6-0.7

3.2 Methodology:-

Tests viz., Atterberg limits (liquid limit and Plastic limit tests),Vane shear test, free swell index test, California bearing ratio test and compaction tests were performed as described by the standard protocols IS 2720 (Part 5)-1970,IS 2720 (Part 7)-1980, IS 2720 (Part XL) – 1977, IS 2720 (Part 16)-1987 and IS 2720 (Part 30)-1980. These tests were first conducted on untreated soil (100%) and compared with that of treated soil (with different percentages of (BC+CS).

Table 3: Different proportions of mix used in each tests:

Test Number	Soil (% by weight)	Copper slag (% by percentage)
1	100	-
2	90	10
3	80	20
4	70	30
5	60	40

IV.EXPERIMENTAL METHODS

The laboratory tests carried out first was on the black cotton soil which includes following tests California bearing ratio (CBR), Liquid limit, Plastic limit, Specific gravity and Proctor test.

4.1 SPECIFIC GRAVITY TEST (IS 2720 PART-3 1980) OBJECTIVE :-

Determine the specific gravity of soil fraction passing 4.75 mm I.S sieve by pycnometer method.

NEED AND SCOPE :-

The knowledge of specific gravity is needed in calculation of soil properties like void ratio, degree of saturation etc.

DEFINITION :-

Specific gravity G is defined as the ratio of the weight of an equal volume of distilled water at that temperature both weights taken in air.

APPARATUS REQUIRED :-

1. Pycnometer of 1000 ml with stopper having capillary hole.

2. Balance to weigh the materials (accuracy 10gm).

3. Wash bottle with distilled water.

4. 4.75mm size sieve

PROCEDURE :-

1. Clean and dry the pycnometer

a. wash the pycnometer with water and allow it to drain.

b. Wash it with alcohol and drain it to remove water.

c. Wash it with ether, to remove alcohol and drain ether.

2. Weigh the empty pycnometer with stopper (W1).

3. Take about 300-350gms of oven soil sample which is cooled in a desiccator. Transfer it to the pycnometer. Find the weight of the bottle and soil (W2).

4. Put 300ml of distilled water in the pycnometer to allow the soil to soak completely. Leave it for about 2 hours.

5. Again fill the pycnometer completely with distilled water put the stopper and keep the pycnometer under constant temperature water baths.

6. Take the pycnometer outside and wipe it clean and dry note. Now determine the weight of the pycnometer and the contents (W3).

7. Now empty the pycnometer and thoroughly clean it. Fill the bottle with only disttiled water and weigh it. Let it be W4 at temperature.

8. Repeat the same process for 2 to 3 times, to take the average reading of it.

9. Similarly determine the specific gravity of soil by adding different percentages of copper slag(10%, 20%, 30%, 40%).

Formula:-

Specific gravity of soil = Density of water at 27 C / weight if water of equal volume:

= (W2 – W1) (W4 – W1) – (W3 – W2)

Where,

W1 = Weight of empty pycnometer W2 = Weight of pycnometer + Dry soil

W3 = Weight of pycnometer + Dry soil +Distilled Water W4 = Weight of pycnometer + Distilled Water.

Fig.3 Pycnometer

These are the pictures have been taken by performing experiment.

4.2 SIEVE ANALYSIS TEST (IS 2720 PART-4 1985)

Grain size analysis expresses quantitatively the proportions by mass of various sizes of particles present in the soil. The results of a grain size analysis may be represented in the form of a Grain Size Distribution (GSD) curve/ Particle Size Distribution (PSD) curve/ Gradation curve. The grain-size distribution is universally used in the engineering classification of the soils.

OBJECTIVE:-

a) Select sieves as per I.S specifications and perform sieving.

b) Obtain percentage of soil retained on each sieve.

c) Draw graph between log grain size of soil and % finer.

NEED AND SCOPE OF EXPERIMENT:-

The grain size analysis is widely used in classification of soils. The data obtained from grain size distribution curves is used in the design of filters for earth dams and to determine suitability of soil for road construction, air field etc. Information obtained from grain size analysis can be used to predict soil water movement although permeability tests are more generally used.

APPARUTUS:-

1. Balance

2. I.S sieves

3. Mechanical Sieve Shaker

The grain size analysis is an attempt to determine the relative proportions of different grain sizes which make up a given soil mass.

KNOWLEDGE OF EQUIPMENT

1. The balance to be used must be sensitive to the extent of 0.1% of total weight of sample taken.

2. The sieves for soil tests: 4.75 mm to 75 microns.

PROCEDURE:-

1) For soil samples of soil retained on 75 micron I.S sieve

a) The proportion of soil sample retained on 75 micron I.S sieve is weighed and recorded weight of soil sample is as per I.S 2720.

b) I.S sieves are selected and arranged in the order as shown in the table.

c) The soil sample is separated into various fractions by sieving through above sieves placed in the above mentioned order.

d) The weight of soil retained on each sieve is recorded.

e) The moisture content of soil if above 5% it is to be measured and recorded.

2) No particle of soil sample shall be pushed through the sieves.

3) Also determine the fineness modulus of soil.

Fineness modulus of soil = ∑ cumulative percentage retained / 100

4) After determining the percentage finer of soil draw the graph.

• Percentage finer in Y- axis.

• Size of sieve in X- axis .

5) From the grading curve in the graph gives the D10, D30, D60 values which is to determine the coefficient of uniformity and coefficient of curvature.

6) Cu and Cc are used to classify the soil based on percentage finer.

Fig .4 set of sieves arranged in descending order.

Coefficient of Uniformity:-

Uniformity Coefficient (Cu) which is a measure of the uniformity of grain size in the soil and is defined as the ratio of the 60% finer size (D60) to D10. which indicates a relatively uniform soil (sometimes referred to as poorly graded).

V.RESULTS AND DISCUSSION

1.1 Specific Gravity Test Results:-

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Table-4 Specific Gravity Values For Different Percentages of Copper slag:

Sl.no	Description	Specific Gravity (Gs)
1	Soil	2.25
2	Soil+10% C.S	2.34
3	Soil+20%C.S	2.43
4	Soil+30%C.S	2.51
5	Soil+40%C.S	2.46

Note :

With the increase in 10% to 30% of Copper Slag, Specific Gravity increase from 2.25 to 2.51. The percentage increase in specific gravity of soil is 11%

1.2 Sieve Analysis Test Result:-

Table-5 Sieve Analysis Tabular Form

Sl.no	Sieve size (mm)	Soil Retained (Grams)	% Retrained	Cumulative % Retrained	%fin
1	4.75	48	4.8	4.8	95.2
2	2.36	18	1.8	6.6	93.2
3	1.18	50	5.0	11.6	88.4
4	0.6	83	8.3	19.9	80.1
5	0.3	187	18.70	39.6	61.4
6	0.15	176	17.6	56.2	43.8
7	0.075	33	3.3	59.5	40.5
8	Pan	405	40.5	100	0

Percentage of gravel =100-95.2

= 4.8%

Percentage of sand =95.2 - 40.5

= 54.7

Percentage of slit and clay = 40.5%

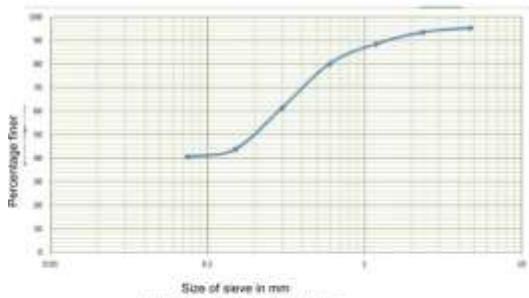


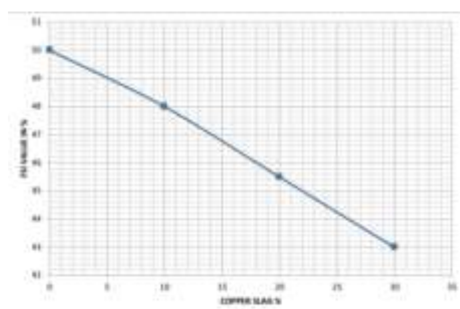
Fig 8 Grain Size Distribution Curve

1.3 Differential Free Swell Index Results :-

Table-6: FSI Value Of Soil For Differential Percentages Of Copper Slag

Description	FSI %	Result
Bare soil	50%	-
Soil+10% Copper slag	46%	Decreases
Soil+20% Copper slag	41%	Decreases
Soil+30% Copper slag	35%	Decreases
Soil+40% Copper slag	33%	Decreases

Fig 9. Variation in FSI of soil with Copper slag



1.4 Fineness modulus of Copper Slag Result:-

Table-7: Fineness modulus Tabular Form

Is sieve size (mm)	Weight Retained(gm)	%o weight Retained	Cumulative%weightRetained	Cumul veweig of pass
4.75	0	0	0	10
2.36	1.04	52	52	48
1.18	0.75	37.5	89.5	10.
0.6	0.18	9	98.5	1.5
0.3	0.015	0.75	99.25	0.7
0.15	0.01	0.5	99.75	0.2

Fineness modulus =. Cumulative% Retrained/100

=. 439 / 100

= 4.39.

1.5 Atterberg Limits Result:-

Table-8: variation in Atterberg Limits

Slno	Description	Liquid limit%	Plasticity limit %	Plasticity index Ip	Classification of specimen
1	Soil	60	36	24	MH
2	Soil+10% Copper slag	54	35	19	MH
3	Soil +20% copper slag	46	29	17	CI
4	Soil+ 30% copper slag	39	24	16	CI
5	Soil +40% copper slag	32	-	32	CL

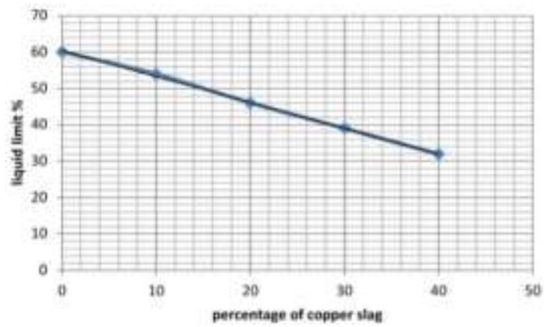


Fig 10.Variation of LL of soil with Copper slag

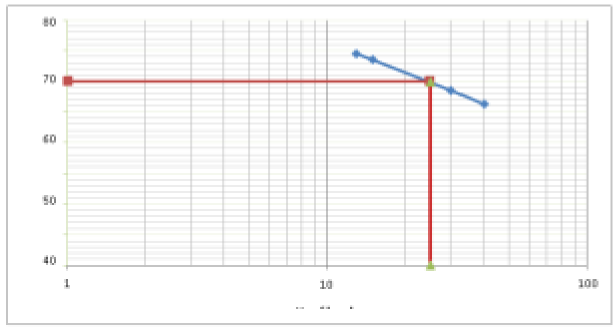


Fig.11.1Liquid limit graph for soil with 10% of copper slag

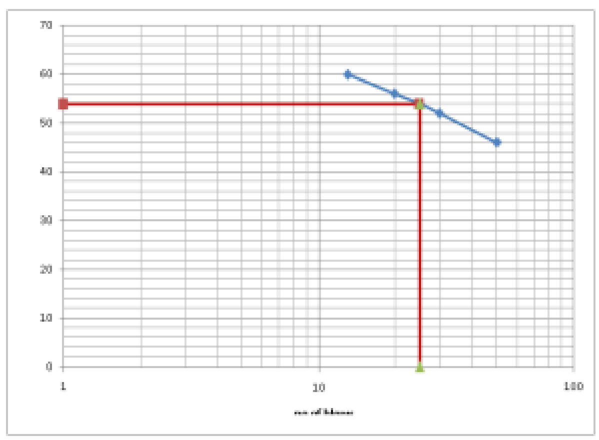


Fig .11.2 Liquid limit graph for soil with 20% of copper slag

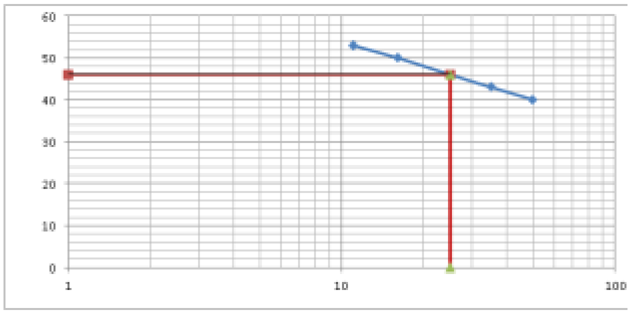


Fig.11.3 Liquid limit graph for soil with 30% of Copper Slag1

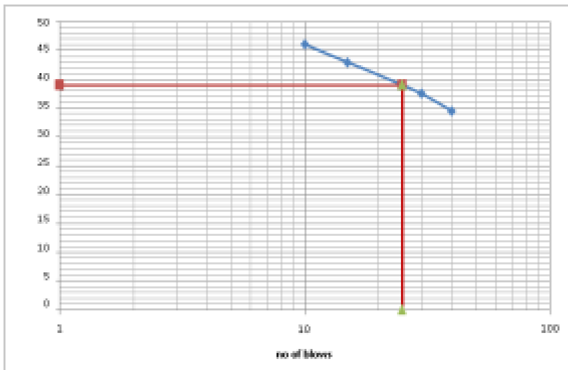


Fig .11.4 Liquid limit graph for soil with 40% of Copper Slag

VI.CONCULISON

Based on the investigation distributed during this study, the following conclusions are drawn:

From the results of the current study, it's complete that, the soil stabilization victimization of copper dross could be a terribly effective method for the strengthening of soil. Since copper dross could be a low-value material obtains high strength and makes the structure strong and sturdy. The check has been conducted on black cotton soils. because of the stabilization of the soil, the bearing capability of the soil gets increasing and any foundation is constructed within the soil.

1. By mixing copper slag along with Black cotton soil by varying the Copper slag the Liquid limit consistency has increases gradually up to 6 to 8% and the max obtained Liquid limit is 67.54 at 10% mixing of copper slag with the soil

2. When the Copper slag is varied along with the Black cotton soil constant the plastic limit goes higher value and increases its strength. The Plastic Limit increased to 4% higher with the highest value of 43.05 at the copper slag mix of 10%

3. The shrinkage limit consistency also increases with varying the copper content in the black cotton soil by 5 to 8% with the highest value of 10.9883 at the 10% copper mix into the B.C soil.

4. The compaction value of the Black cotton soil has gone higher value up to 8% has increased when 20% of copper slag is mixed along with it

5. As the compression strength is the key factor incorporated in the UCS check hence it has drastically increased its value by 12% when the copper slag is added by 30%

6. The California bearing Ratio is also increased by 9% in the unsoaked CBR and in the soaked CBR the value is increased by 10% compared to the Black cotton soil.

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