“IMPROVEMENT OF PROPERTIES OF BLACK COTTON SOIL USING POTASSIUM CHLORIDE & MICRO FINE SLAG”

A PROJECT

Submitted in partial fulfillment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision of

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By

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to

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

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HIMACHAL PRADESH INDIA

JUNE, 2016

DECLARATION

I hereby declare that the project work presented in this Project entitled “IMPROVEMENT OF PROPERTIES OF BLACK COTTON SOIL USING POTASSIUM CHLORIDE & MICRO FINE SLAG” submitted for the award of the degree of Bachelor of technology in the Department of Civil Engineering, Jaypee University of Information and Technology Wakhnaghat, is original and our own account of work. This project work is independent and its main content work has not previously been submitted for degree at any university in India or Abroad.

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CERTIFICATE

This is to certify that the work which is being presented in the project title **"IMPROVEMENT OF PROPERTIES OF BLACK COTTON SOIL USING POTASSIUM CHLORIDE & ULTRA FINE SLAG"** in partial fulfilment of the requirements for the award of the degree of Bachelor of technology and submitted in Civil Engineering Department, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by **Uday Singh Chauhan (121650) and Ashish Sharma (121667)**during a period from July 2015 to June 2016 under the supervision of **Asst.Prof.Niraj Singh Parihar**, Civil Engineering Department, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of my knowledge.

Date: - ………………………

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The topic **"IMPROVEMENT OF PROPERTIES OF BLACK SOIL USING POTASSIUM CHLORIDE & MICRO FINE SLAG"** was very helpful to us in giving the necessary background information and inspiration in choosing this topic for the project. First of all I would like to thank our head of department **Prof.Dr.Ashok Kumar Gupta** for providing us with the opportunity. Our sincere thanks to **Asst.Prof.Niraj Singh Parihar** Project Guide and **Asst. Prof. Abhilash Shukla ,** Project Coordinator for having supported the work related to this project. Their contributions and technical support in preparing this report are greatly acknowledged. I would like to extend my gratitude to all the faculty members of civil department and lab assistants for their contribution towards the completion of the project.

ABSTRACT

The improvement of soil properties is one of the main branches of geotechnical science that has been considered by researchers in different countries. In developing country like India due to the remarkable development in road infrastructure, soil stabilization has become the major issue in construction activity. Stabilization is an unavoidable for the purpose of highway and runway construction, stabilization denotes improvement in both strength and durability which are related to performance. Stabilization is a method of processing available materials for the production of low-cost road design and construction. Fine clayey soils properties due to high swelling necessitate the need to improve its geotechnical properties. When the construction work is done over problematic black cotton soil it has risks of substantial settlements, heave and low bearing capacity.

This project is an investigation carried out to study the effect of KCl, Ultra fine slag on engineering properties of the Black Cotton Soils. The properties of stabilized soil such as compaction characteristics, consistency limits were evaluated and their variations with varying KCl content is evaluated. An optimum proportion of KCl is found and mixed with varying proportions of microfine slag.

The interpretation of test results leading to various conclusion and recommendation on the use of combination of KCl and microfine slag in soil stabilization to counter the difficulty posed by black cotton soil for subgrade material is discussed**.**

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CHAPTER 1
INTRODUCTION

1.1 GENERAL INTRODUCTION

Black cotton soil is a kind of expansive soil, because of it's color & suitability for growing cotton swells when the moisture content is increased and shrinks massively when dry. Montmorillonite mineral is mainly responsible for the swell-shrink characteristic of the black cotton soil. The expansive nature decreases the bearing capacity of the soil. The black color in Black cotton soil is due to the presence of titanium oxide in small concentration. (Nyakarura, et. al, 2009)

Black cotton soil is a highly clayey soil. It is so hard that the clods cannot be easily pulverized for treatment for its use in road construction. This poses serious problems as regards to subsequent performance of the road. The softened sub grade has a tendency to up heave into the upper layers of the pavement, especially when the sub-base consists of stone soling with lot of voids. Gradual intrusion of wet Black cotton soil invariably leads to failure of the road. The roads laid on Black cotton soil bases develop undulations at the road surface due to loss of strength of the sub grade through softening during the wet season. The damage will be apparent usually several years after construction. The stability and performance of the pavements are greatly influenced by the sub grade and embankment as they serve as foundations for pavements. There is therefore need to stabilize black cotton soil in order for it to provide a good foundation material. Stabilization denotes improvement in properties of the material which are related to performance.

In most cases it is expensive to remove large volumes of unsatisfactory soils and replace them with suitable material. This brings about the need to improve the soil in place so that it serves as a good engineering construction material. The improvement of the stability of a poor soil and durability which are related to performance of the soil through mechanical, physio-mechanical and chemical methods is referred to as soil improvement. This is achieved by use of controlled compaction, proportioning and addition of suitable admixture or stabilizer. The stabilization process involves excavation of the in-situ soil, treatment of the in-situ soil and compaction of the treated soil.

Up until now in this study effects of adding KCl have been done using different concentrations on liquid limit, plastic limit and compaction properties.

On increasing the proportion of KCl added to black cotton soil the liquid limit of the soil decreses and plastic limit increases thus leading to decrease in plasticity of soil as desired. The maximum dry density of soil increases and is maximum at the optimum proportion of KCl added(1%).Thus we obtain an optimum proportion of KCl which upon adding to black cotton soil improves it's properties.

1.2 OBJECTIVE OF STUDY

- To check effect of KCL and microfine slag on compaction properties.
- To check variation in atterberg limits when percentage of KCL added to soil is varied.
- To check variation in properties on varied proportions of KCL and microfine slag.

In order to achieve the above objective, the black cotton soil has been arbitrarily reinforced with KCL. So the suitability of KCL is considered to enhance the properties of black cotton soil. A cycle of experiments such as Liquid limit test, Plastic Limit Test and compaction test is carried out on black cotton soil sample with different percentages of KCL. They are performed to study the variation in properties like liquidity and plasticity behavior and compaction behavior are also studied. These same tests are repeated with optimum percentage of KCL found with varying percentages of microfine slag.

CHAPTER 2
LITERATURE REVIEW

This study is done to evaluate the nature and engineering properties of black cotton soils, their behaviour under various seasonal conditions and finally use Ultra fine slag to stabilize the soil as a solution to the problems created by these soils in pavement subgrade construction. The physical properties of clays and most soils are often poorer than may be required for a particular project their compressibility, water content and permeability is too high. Application of RBI Grade 81 was carried out by researchers in the past.

- **Chiranjit Mishra ,July 2013** ***"Effect Of Electrolyte On The Geotechnical Properties Of Black Cotton Soil" ,***did a study to check the effect of potassium chloride compounds (KCl) on the properties of black cotton soil. The soil was tested for its liquid limit, plastic limit, optimum moisture content and swelling index. It was found that with the increase in KCl percentage the swelling behaviour of the black cotton soil reduces by about 54.54% with 2% KCL. The laboratory results show that the addition of potassium chloride compound with varying percentages of 0.5, 1.0, 1.5 and 2.0% decreases the liquid limit and increases the plastic limit with the addition of 2% KCl. With the increase in liquid limit and decrease in the plastic limit the plasticity index reduces with 2% KCl.
- **Pankaj R. Modak et al,May 2012 "*Stabilisation of Black Cotton Soil Using Admixtures*"** , conducted their studies using lime and fly ash as admixture in stabilizing black cotton soil. The improved CBR value is due to addition of Lime and Fly ash as admixtures to the BC soil. It also reduces the hydraulic conductivity of BC soil. There will be no need of drainage layer after treatment of black cotton soil as sub grade with lime and fly ash.
- **Nadgouda, K.A et al, December 2010 "*The Effect of Lime Stabilization on Properties of Black Cotton Soil*"**,carried out their studies using lime as stabilizer in expansive soil. They found that an immediate benefit obtained by the addition of lime to swelling soils is to reduce the potential for swelling upon contact with water. The plastic nature of the soil decreases and the stiffness of the soil increases as the lime content increases. For improving the properties, the optimum lime content was found to be within the range of 3.5% to 4.5%.
- **P. Venkara Muthyalu, K. Ramu and G.V.R. Prasada Raju, Jan 2012 "*Study on performance of chemically stabilized expansive soil" .*** It is observed that the liquid limit values are decreased by 57 % respectively for 1% of KCl added to the expansive clay. Marginal increase in plastic limits is observed with addition of chemical to the expansive clay.The swelling index properties decrease by 40% on addition of 1% of KCL.

CHAPTER 3
MATERIALS

Black cotton soils are organic clays of medium to high compressibility and form a major soil group in India. They are characterized by high shrinkage and swelling properties. This Black cotton soils occurs mostly in the central and western parts and covers approximately 20% of the total area of India. Because of its high swelling and shrinkage characteristics, the Black cotton soil (BC soils) has been a challenge to the highway engineers.

3.1BLACK COTTON SOIL

Black cotton soil have the tendency to increase in volume when water is available and decrease in volume if water is removed. Black cotton soil is generally black in color. The swelling soils of India have their origin in subaqueous decomposition of basalt rocks or weathering in-situ. The mineral montmorillonite is formed under alkaline environment. The black cotton soil is mostly residual in character and the thickness of the deposit is not large- less than 4 m in most cases. In India, Black cotton soils are common in entire Deccan plateau, western Madhya Pradesh, parts of Rajasthan, Bundelkhand region in Uttar Pradesh and parts of Andhra Pradesh and Karnataka. The black cotton soil was collected from Guna , Madhya Pradesh area and transported to the lab.

Soil at the site

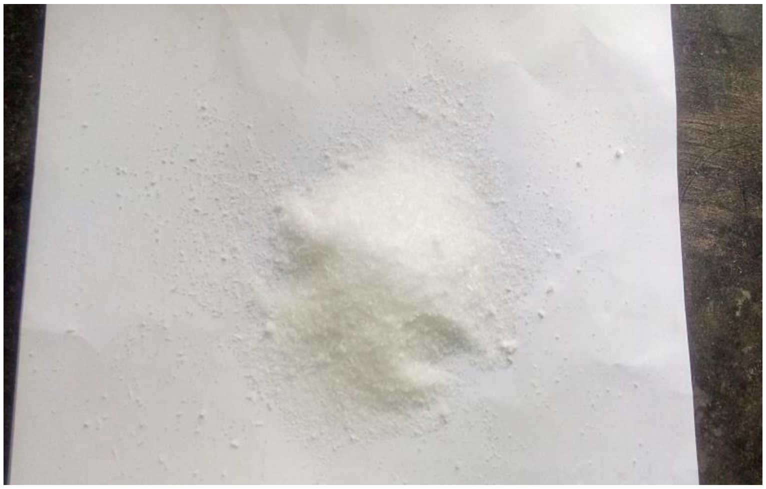
3.2 KCl

Chemical compound potassium chloride (KCl) is a metal halide salt composed of potassium and chloride. It is odourless and has a white or colourless vitrious crystal appearance. Its solid state dissolves readily in water and its solution have a salt like taste. It is extracted from minerals sylvite, carnallite and potash.Properties of KCl used are summarised as in the table given below:

Properties of KCl	
Chemical formula	KCl
Molar mass	74.5513g/mol
Appearance	White crystalline solid
Odour	Odourless
Density	1.984g/cm^3
Melting point	770^o
Boiling point	1420^o
Solubility in water	344g/L ($20^o C$)
Solubility	Soluble in glycerol, alkalies; slightly soluble i alcohol, insoluble in ether
Acidity	7
Refractive index	1.4902(589nm)

TABLE 1-properties of KCl

Hence an attempt has been made to improve the compaction properties and swell behaviour of expansive black cotton soil using KCL in this work. The various concentration of the salt used for experiment are 0.5%,1%and 1.5% respectively.



Sample of KCl

3.3 MICRO FINE SLAG

Blast-furnace slag is produced as a by-product of the iron and steel production industries. Its earthy constituents come from iron ore processing, and it consists of the same oxides as Portland cement, but in different proportions. Immediately after its production, slag is usually quenched for rapid cooling in a process known as granulation. The granulation this results in a reactive amorphous glass and avoids any crystallization.

Fine slag in this results in a reactive amorphous glass and avoids any crystallization.

Color	Specific gravity	Liquid limit	Plastic limit	Free swell index(%)
Off-white	2.82	40	Non-Plastic	zero

TABLE 2-Properties of microfine slag

Sample of microfine slag

CHAPTER 4
EXPERIMENTAL PROCEDURES

4.1LIQUID LIMIT

Liquid limit is determined using the standard liquid limit apparatus designed by Casagrande ,as conforming to IS 2720-5(1985).The test can be done by following steps:

- Soil is placed into the metal cup portion of the device and a groove is made down its center with a standardized tool of 13.5 millimetres (0.53 in) width.
- The cup is repeatedly dropped 10 mm onto a hard rubber base at a rate of 120 blows per minute, during which the groove closes up gradually as a result of the impact.
- The number of blows for the groove to close is recorded.
- The moisture content at which it takes 25 drops of the cup to cause the groove to close over a distance of 13.5 millimetres (0.53 in) is defined as the liquid limit.
- The test is has been run at several moisture contents, and the moisture content which requires 25 blows to close the groove is interpolated from the test results.
- The Liquid Limit test is defined by ASTM standard test method D 4318.
- The test method also allows running the test at one moisture content where 20 to 30 blows are required to close the groove; then a correction factor is applied to obtain the liquid limit from the moisture content.

CASAGRANDE'S APPARATUS

4.2PLASTIC LIMIT

Determining the plastic limit has these basic and simple steps as conforming to IS 2720-5(1985):

- The plastic limit (PL) is determined by rolling out a thread of the fine portion of a soil on a flat, non-porous surface.
- If the soil is at a moisture content where its behavior is plastic, this thread will retain its shape down to a very narrow diameter.
- The sample can then be remoulded and the test repeated. As the moisture content falls due to evaporation, the thread will begin to break apart at larger diameters.
- The plastic limit is defined as the moisture content where the thread breaks apart at a diameter of 3.2 mm (about 1/8 inch).

4.3 SPECIFIC GRAVITY OF SOIL

The specific gravity of soil is the ratio between the weight of the soil solids and weight of equal volume of water. It is measured by the help of a volumetric flask in a very simple experimental setup where the volume of the soil is found out and its weight is divided by the weight of equal volume of water. In accordance with the procedure in IS 2720-3-1(1980).

- Specific Gravity G = (W2-W1)/((W4-W1)-(W3-W2)).

W1- Weight of pycnometer in gm.
W2- Weight of pycnometer + Dry soil in gm.
W3- Weight of pycnometer + Soil + Water in gm.
W4- Weight of pycnometer+ Water in gm.

Specific gravity is measured at room temperature and reported to the nearest 0.1.

4.4 DETERMINATION OF MAXIMUM DRY DENSITY

- The mould and base plate is cleaned, dried and greased properly.
- Weigh of mould with the base plate is noted nearest to 1 gram.
- Collar is attached to the mould and mould is placed on a solid base.
- About 2.5kg of the processed soil is taken, and placed in the mould in 3 equal layers. About one-third the quantity first, and is compacted by giving 25 blows of the rammer. The blows should be uniformly distributed over the surface of each layer.
- The top surface of the first layer be scratched with spatula before placing the second layer. The second layer should also be compacted by 25 blows of rammer. Likewise, place the third layer and compact it.
- The amount of the soil used should be just sufficient to fill the mould ad leaving about 5 mm above the top of the mould to be struck off when the collar is

removed.

- Collar is removed and the excess soil is trimmed projecting above the mould using a straight edge.
- Base plate and the mould from outside is cleaned and weighed to the nearest gram.
- Soil is removed from the mould. The soil may also be ejected out.
- Soil samples are taken for the water content determination from middle portion. And water content is determined.

APPARATUS FOR LIGHT WEIGHT PROCTOR COMPACTION

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1Results for ordinary Black Soil

5.1.1Sieve Analysis

Dry and Wet Sieve Analysis of the soil was performed in accordance with IS 2720 (Part 4)-1985 and were classified in accordance with IS 1498-1970.and were classified in accordance with IS 1498-1970

Sieve No.	75micron
Wt of soil retained above (W1)	327 gm
Wt of soil that passed (W2)	673 gm

TABLE 3-classification of soil

Percentage of mass passing =W2/ (W1+W2)
=67.3%

Since percentage of passing through the mentioned sieve is more than 50% so it can be classified as Fine soil according to IS:1498-1970.

5.1.2Specific gravity

The specific gravity of black cotton soil has been determined in accordance with the procedure in IS 2720-3-1(1980).

Wt of empty pycnometer(W1)	461.8g
Wt of pycnometer+dry soil (W2)	1186.7g
Wt of pycnometer+dry soil+water(W3)	661.8g
Wt of pycnometer+water(W4)	1304.3g

TABLE 4- Computation of specific gravity

- Specific gravity G = (W2-W1)/((W4-W1)-(W3-W2)).

  = 2.427

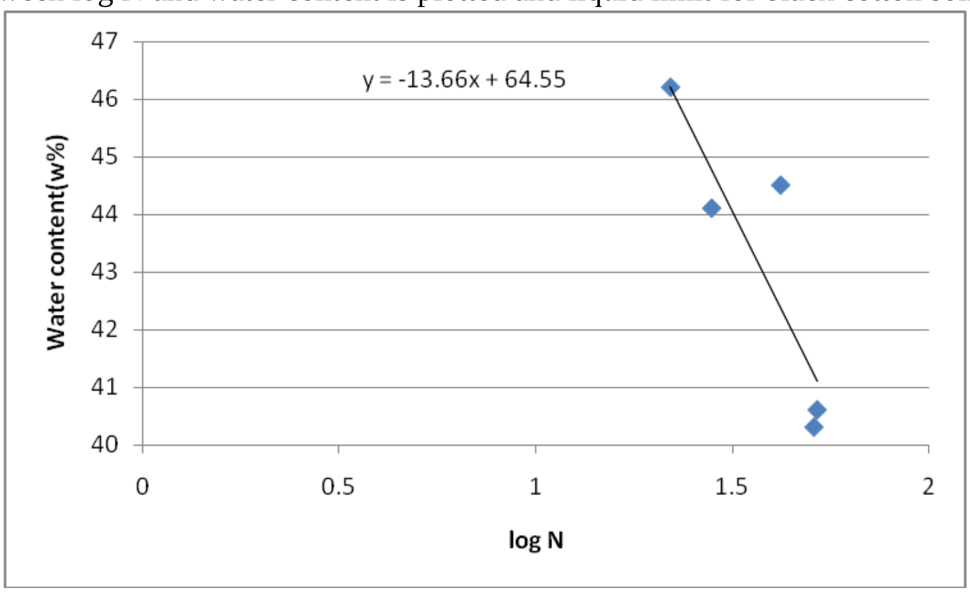
5.1.3Liquid Limit

The liquid limit was calculated by using Casagrande's apparatus. No of blows for various samples were noted with different moisture contents and the water content for these samples was calculated using oven drying method.

S.No.	Empty container	Container+MS	Weight of dry sample	Water content%	No of blows
	W1(g)	W2(g)	W3(g)	(W2-W3)/(W3-W1) (g)	N
1	28.6	56.8	48.7	40.3	51
2	27.6	45.9	40.3	44.1	28
3	25.8	47.6	41.3	40.6	52
4	27	40.6	36.3	46.2	22
5	28.1	51.8	44.5	44.5	42

TABLE 5:This table contains values for determination of liquid limit for black cotton soil.

Graph between log N and water content is plotted and liquid limit for black cotton soil is determined.



GRAPH 1: Graph between log N and water content

The liquid limit as obtained from graph above corresponding to 25 blows is 45.45%.

5.1.4Plastic Limit

Empty container		Container+MS	Weight of dry sample	Water content%
S.No.	W1(g)	W2(g)	W3(g)	(W2-W3)/(W3-W1)
1	27.5	30.6	29.9	29.1
2	29.3	31	30.5	41.6
3	28.6	31.5	30.8	31.8

TABLE 6: This table contains values for determination of plastic limit of black cotton soil.

The plastic limit of the sample soil is determined by averaging three values obtained in above table .

Plastic limit of the soil as determined from above table is 34.16%.

According to unified soil classification system (USCS) the soil comes under category CL, that is clay of low plasticity.
It can be concluded from the calculation that black cotton soil has the high swelling potential because plasticity limit comes out to be in the range of 20-35.

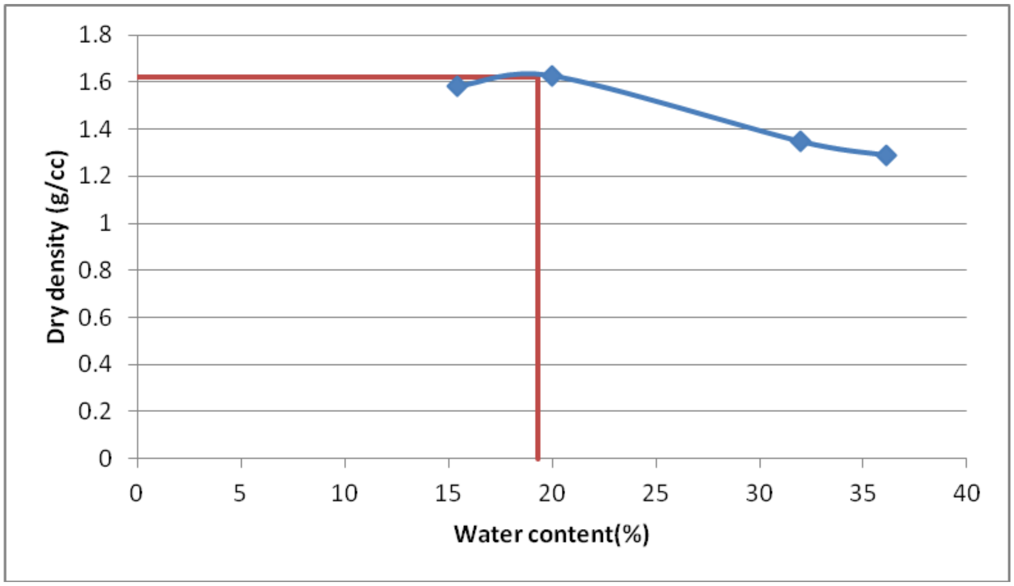
5.1.5Standard Proctor test

The Standard Proctor test was performed on black cotton soil and the result was plotted on graph between dry density and water content.

- Empty mould weight=4319.1g
- Volume of mould=1000cc.
- MS-Moist sample.

S.No.	Mould +MS	Weight of MS (W1)	Density of MS (W1/V)	w%	Dry density $\gamma_d = \frac{\gamma}{1+w}$
	g	g	g/cc		g/cc
1	6144.2	1825.1	1.8251	15.4	1.5815
2	6268.6	1949.5	1.9495	20	1.6245
3	6100	1780.9	1.7809	31.97	1.3494
4	6076	1756.9	1.7569	36.11	1.2907

TABLE 7:This table contains values for determination of maximum dry density and OMC for black cotton soil.



GRAPH 2: Graph of (γ_d)dry density vs (w)water content.

The graph 2 shows variation of dry density with changing water content of soil.

The maximum dry density as obtained from graph above is 1.62g/cc and OMC is 19.3%.

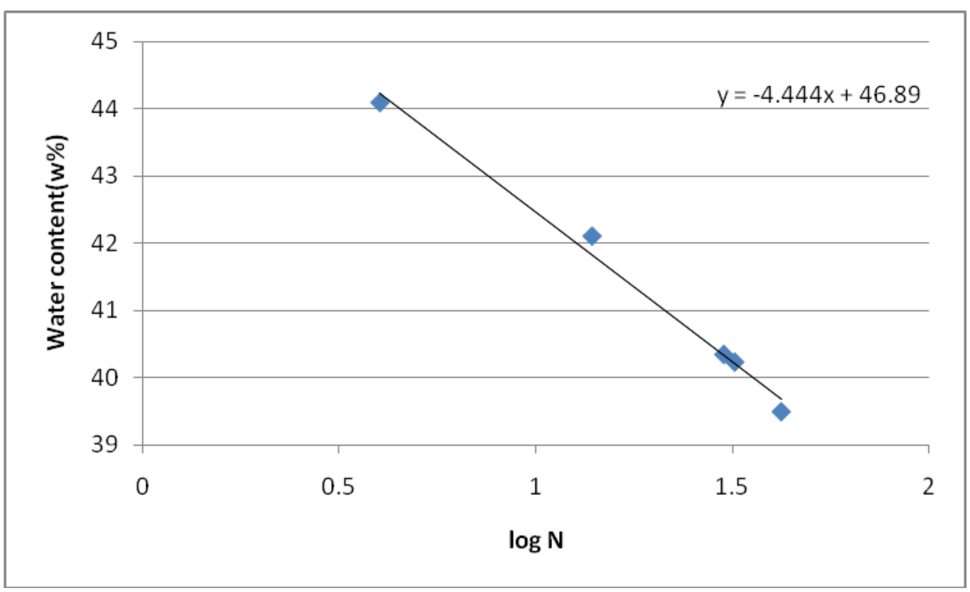
5.2Results for Black Soil with 0.5% KCL

5.2.1 Liquid Limit:

The liquid limit was calculated by using Cassagrande's apparatus. No of blows for various samples was noted with different moisture contents and the water content for these samples was calculated using oven drying method. Results are tabulated below:

S.No.	Empty container	Container+MS	Weight of dry sample	Water content%	No of blows
	W1(g)	W2(g)	W3(g)	(W2-W3)/(W3-W1)	N
1	19.9	43.6	36.8	40.236	32
2	18.7	46.6	38.7	39.5	42
3	20.6	34	29.9	44.086	4
4	19.1	40.7	34.3	42.105	26
5	27.9	43.9	39.3	40.35	30

TABLE 8:This table contains values for determination of liquid limit for black cotton soil mixed with 0.5% KCl.



GRAPH 3: Graph between log N and water content for black cotton soil mixed with 0.5% KCl is plotted and liquid limit is determined corresponding to 25 blows.

The liquid limit as obtained from graph 3 corresponding to 25 blows is = 40.67 %.
The liquid limit of black cotton soil on mixing with 0.5% KCl decreases from a value of 45.45% for normal black cotton soil to 40.67% as obtained from graph 3.

5.2.2Plastic Limit of clay sample with 0.5% KCL:

S.No.	Empty container	Container+MS	Weight of dry sample	Water content%
	W1(g)	W2(g)	W3(g)	(W2-W3)/(W3-W1)
1	27	30.3	29.3	43.47

TABLE 9: This table contains values for determination of plastic limit of black cotton Soil mixed with 0.5% KCl.

Plastic limit of the soil as determined from above table is 43.47%.

The plastic limit of black cotton soil on mixing with 0.5% KCl increases from a value of 34.16% for normal black cotton soil to 43.47% as obtained from table 9.

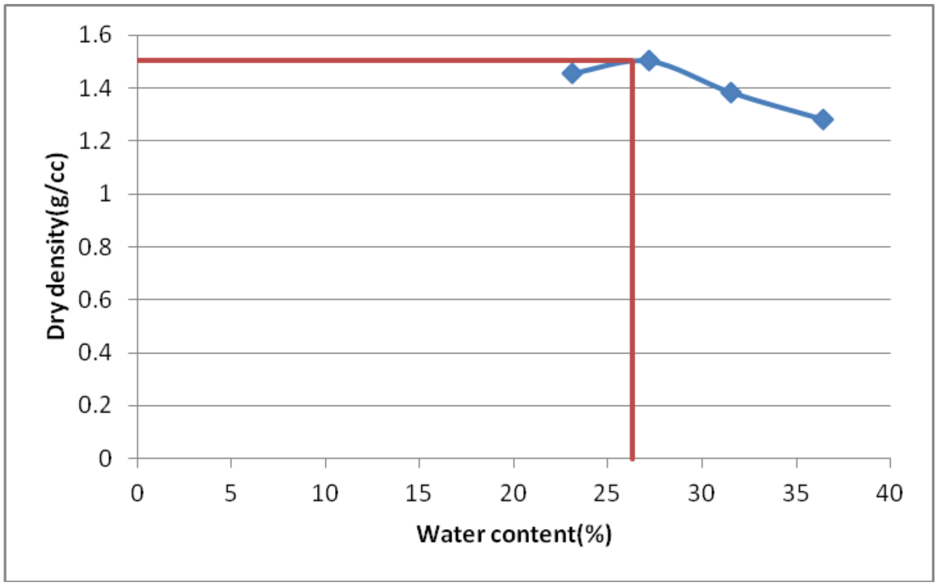
5.2.3Standard Proctor Test on clay sample with 0.5%KCL

The Standard Proctor test was performed on black cotton soil with 0.5% KCL and the result was plotted on graph between dry density and water content.

- Empty mould weight =4317.8g
- Volume of mould (V) =1000cc.
- MS-Moist sample

S.No.	Mould +MS	Weight of MS (W1)	Density of MS(W1/V) γ	w%	Dry density $\gamma_d = \frac{\gamma}{1+w}$
	g	g	g/cc		g/cc
1	6139.8	1822	1.822	31.5	1.385
2	6067.2	1749.4	1.7494	36.4	1.2825
3	6229.2	1911.4	1.9114	27.19	1.5027
4	6112.4	1794.6	1.7946	23.13	1.457

TABLE 10:Contains value for determination of max dry density and OMC for black cotton soil mixed with 0.5% KCl.



GRAPH 4: Graph showing variation of (γ_d) dry density on changing water content of black cotton soil when mixed with 0.5% KCl.

The maximum dry density as obtained from graph 4 is 1.5027g/cc and OMC is 26.3%.

The maximum dry density of black cotton soil as obtained from graph 2 was 1.62g/cc.There was a decrease in dry density on mixing with 0.5% KCl to black cotton soil as obtained from graph 4 and OMC increased from 19.3% to 26.3%.

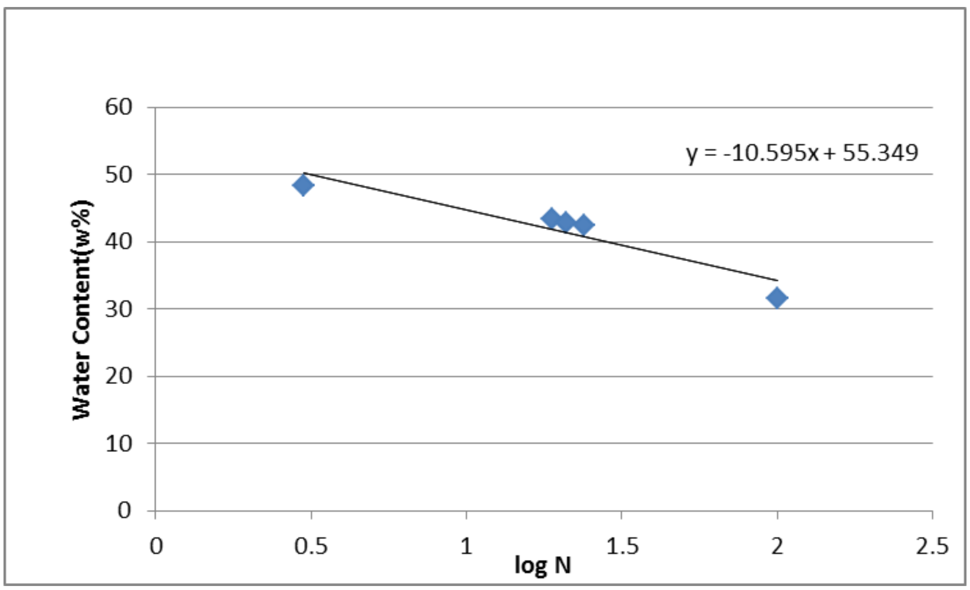
5.3Results for Black Soil with 1% KCL

5.3.1Liquid Limits

The liquid limit was calculated by using casagrande's apparatus. No of blows for various samples was noted with different moisture contents and the water content for these samples was calculated using oven drying method. Results are tabulated as shown below:

S.No.	Empty container	Container+MS	Weight of dry sample	Water content%	No of blows
	W1(g)	W2(g)	W3(g)	(W2-W3)/(W3-W1) (g)	N
1	28.6	48.3	42.4	47.014	21
2	27	54.5	47.9	31.578	100
3	25.9	55.7	46	48.258	3
4	27.5	53.7	45.9	42.391	24
5	28.3	48.8	42.6	43.356	19

TABLE 11: Contains value for determination of liquid limit of black cotton soil when mixed with 1% KCl.



GRAPH 5: Graph between log N and water content for black cotton soil mixed with 1% KCl is plotted and liquid limit is determined corresponding to 25 blows.

The liquid limit as obtained from graph 5 corresponding to 25 blows is 40.53%

The liquid limit of black cotton soil on mixing with 1% KCl decreases from a value of 45.45% for normal black cotton soil to 40.53% as obtained from graph 5.

5.3.2Plastic limit

Empty container	Container+MS	Weight of dry sample	Water content%
W1(g)	W2(g)	W3(g)	(W2-W3)/(W3-W1)
28.6	29.8	29.4	50

TABLE 12: This table contains value for determination of plastic limit for black cotton soil mixed with 1% KCl.

Plastic limit of the soil as determined from above table is 50%.

The plastic limit of black cotton soil on mixing with 1% KCl increases from a value of 34.16% for normal black cotton soil to 50% as obtained from table 12.

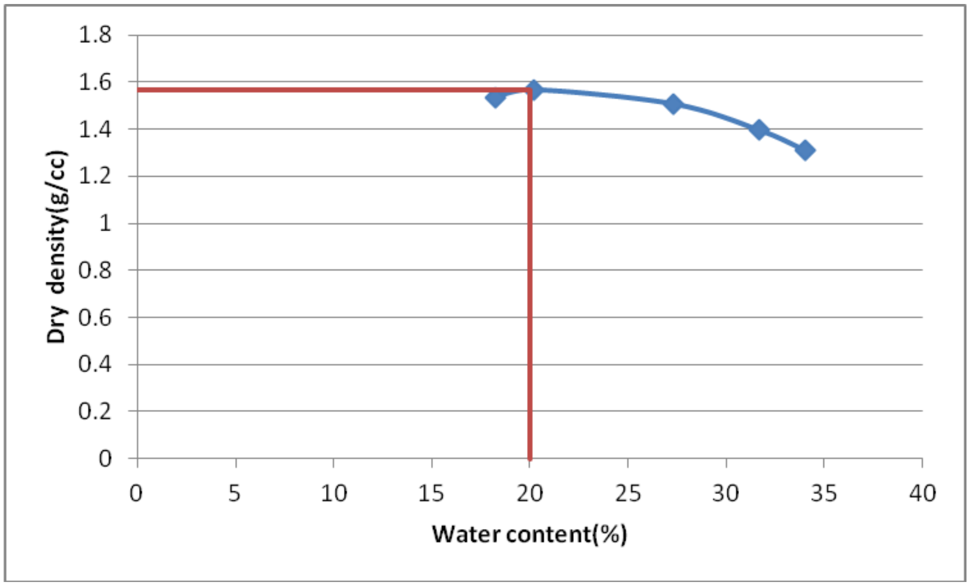
5.3.3 Standard Proctor Test on clay sample with 1%KCL

The Standard Proctor test was performed on black cotton soil with 1% KCL and the result was plotted on graph between dry density and water content.

- Empty mould weight= 4317.8g
- Volume of mould (V) =1000cc.
- MS- Moist sample.

S.No.	Mould +MS	Weight of MS (W1)	Density of MS(W1/V) γ	w%	Dry density $\gamma_d = \frac{\gamma}{1+w}$
	g	g	g/cc		g/cc
1	6158	1840.2	1.8402	31.68	1.3974
2	6076.6	1758.8	1.7588	34.06	1.312
3	6235.5	1917.7	1.9177	27.33	1.506
4	6200.4	1882.6	1.8826	20.19	1.566

TABLE 13: Contains value for determination of max dry density and OMC for black cotton soil mixed with 1% KCl.



GRAPH 6: Graph showing variation of (γ_d) dry density on changing water content of black cotton soil when mixed with 1 % KCl.

The maximum dry density as obtained from graph 6 is 1.566 g/cc.and OMC is 20%.

The maximum dry density of black cotton soil as obtained from graph 2 was 1.62g/cc for normal black cotton soil.There was a decrease in dry density on mixing with 0.5% KCl to black cotton soil as obtained from graph 4 and OMC increased from 19.3% to 26.3%.On further increase of proportion of KCl being added resulted in increase of dry density to 1.566 g/cc as obtained from graph 6.

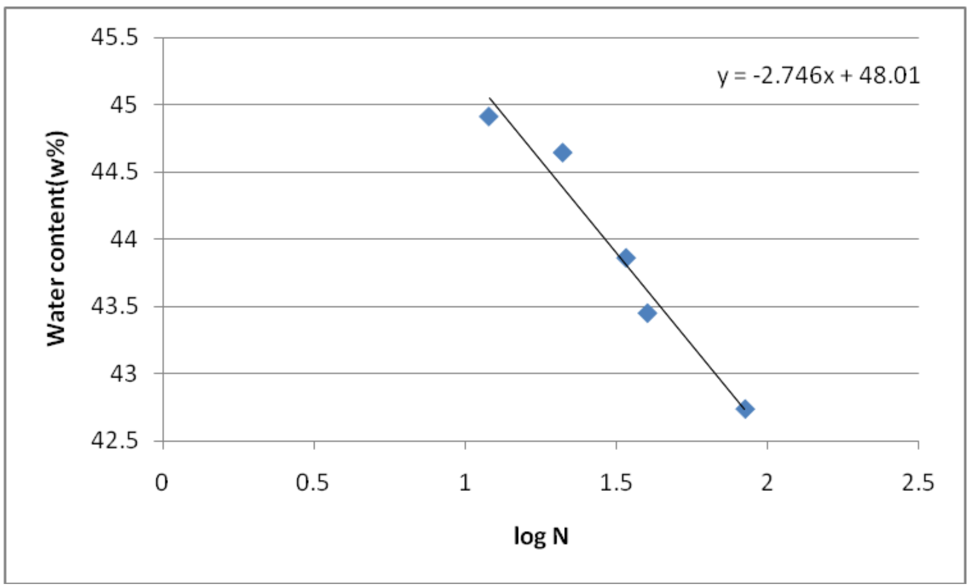
5.4 Results for Black Soil with 1.5% KCL

5.4.1Liquid Limit

The liquid limit was calculated by using Casagrande's apparatus. No of blows for various samples was noted with different moisture contents and the water content for these samples was calculated using oven drying method.

S.No.	Empty container	Container+MS	Weight of dry sample	Water content%	No of blows
	W2(g)	W2(g)	W3(g)	(W2-W3)/(W3-W1)	N
1	29.3	53.9	46.4	43.859	34
2	26.7	50.9	43.4	44.9102	12
3	28.4	44.6	39.6	44.642	21
4	27.6	44.3	39.3	46.729	84
5	27.8	48.6	42.3	43.448	40

TABLE 14: Contains value for determination of liquid limit of black cotton soil when mixed with 1.5% KCl.



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GRAPH 7: Graph between log N and water content for black cotton soil mixed with 1.5% KCl is plotted and liquid limit is determined corresponding to 25 blows.

The liquid limit as obtained from graph 7 corresponding to 25 blows is 44.17%.

The liquid limit of black cotton soil on mixing with 1.5% KCl decreases from a value of 45.45% for normal black cotton soil to 44.17% as obtained from graph 5.But the value seems to be more than that obtained from graph 5 for 1% KCl added.

5.4.2Plastic Limit

S.No.	Empty container	Container+MS	Weight of dry sample	Water content%
	W1(g)	W2(g)	W3(g)	(W2-W3)/(W3-W1)
1	26.8	29.3	28.5	47.058

TABLE 15:This table contains values for determination of plastic limit of black cotton soil mixed with 1.5% KCl.

Plastic limit of the soil as determined from above table is 47.058 %.

Plastic limit of black cotton soil decreases from a value of 50% for 1% KCl added to 47.058% for 1.5% KCl added to the soil.

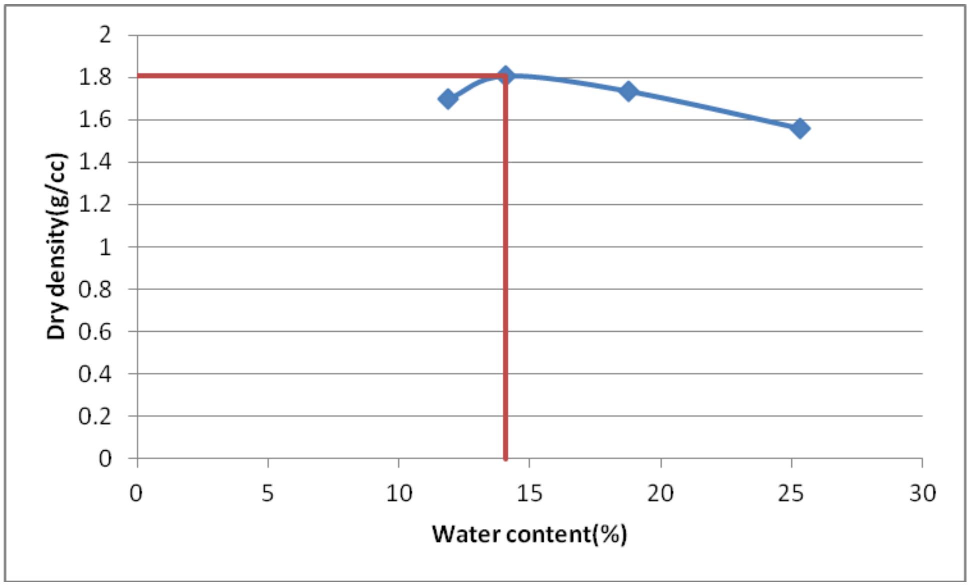
5.4.3 Standard Proctor Test on clay sample with 1.5%KCL

The Standard Proctor test was performed on black cotton soil with 1.5% KCL and the result was plotted on graph between dry density and water content.

- Empty mould weight= 4317.8g
- Volume of mould (V) =1000cc.
- MS- Moist sample.

S.No.	mould +MS	weight of MS (W1)	density of MS(W1/V)	w%	dry density
	g	g	g/cc		g/cc
1	6200.1	1882.3	1.8823	0.226	1.535318108
2	6011.7	1693.9	1.6939	0.149	1.474238468
3	6124.3	1806.5	1.8065	0.1867	1.5222887
4	6197.3	1879.5	1.8795	0.241	1.514504432
5	6150.5	1832.7	1.8327	0.281	1.430679157

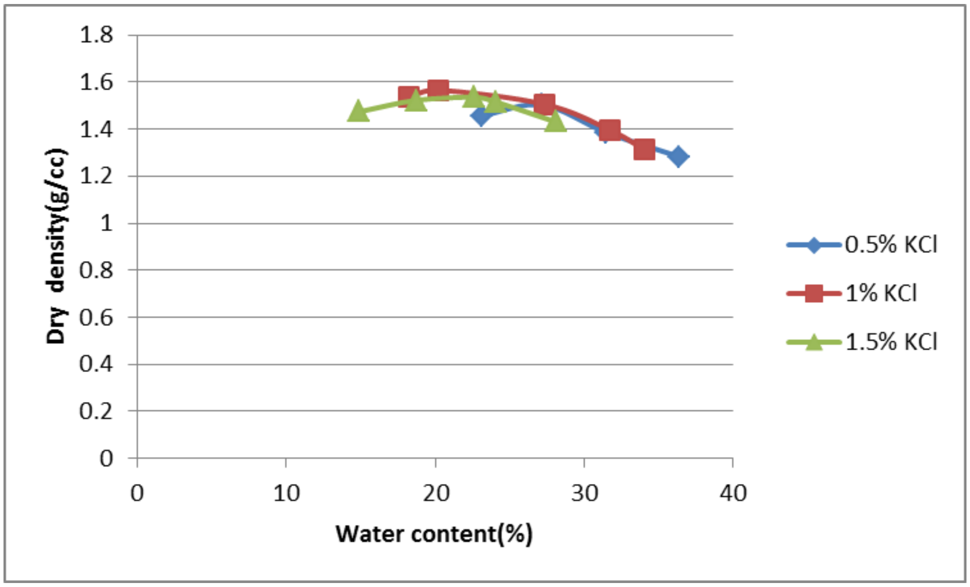
TABLE 16:Contains value for determination of max dry density and OMC for black cotton soil mixed with 1.5% KCl.



GRAPH 8: Graph showing variation of (γ_d) dry density on changing water content of black cotton soil when mixed with 1.5 % KCl.

The maximum dry density as obtained from graph 8 is 1.53g/cc and OMC is 22.6%.

The maximum dry density of black cotton soil as obtained from graph 2 was 1.62g/cc for normal black cotton soil. There was a decrease in dry density on mixing with 0.5% KCl to black cotton soil as obtained from graph 4 and OMC increased from 19.3% to 26.3%.On further increasing proportion of KCl to 1.5% decrease in value of dry density to 1.53 g/cc as obtained from graph 8.



GRAPH 9: Graph showing variation of dry density on different proportions of KCl

The maximum dry density of soil is 1.52 g/cc,1.566 g/cc and 1.53 g/cc at KCl contents of 0.5%,1% and 1.5% respectively. Hence from these results it can be interpreted that the optimum content of KCl to improve the properties of black cotton soil is 1%.

As can be seen from the results obtained the liquid limit is minimum while plastic limit of the soil is maximum as desired on addition of 1% KCl to the black cotton soil. At 1.5% of KCl the liquid limit again increases. The maximum dry density of soil is 1.52 g/cc,1.566 g/cc and 1.53 g/cc at KCl contents of 0.5%,1% and 1.5% respectively. Hence from these results it can be interpreted that the optimum content of KCl to improve the properties of black cotton soil is 1%. Which is in accordance with previous results as obtained from International Journal of Innovative Science, Engineering & Technology, Issue 10, December 2014.

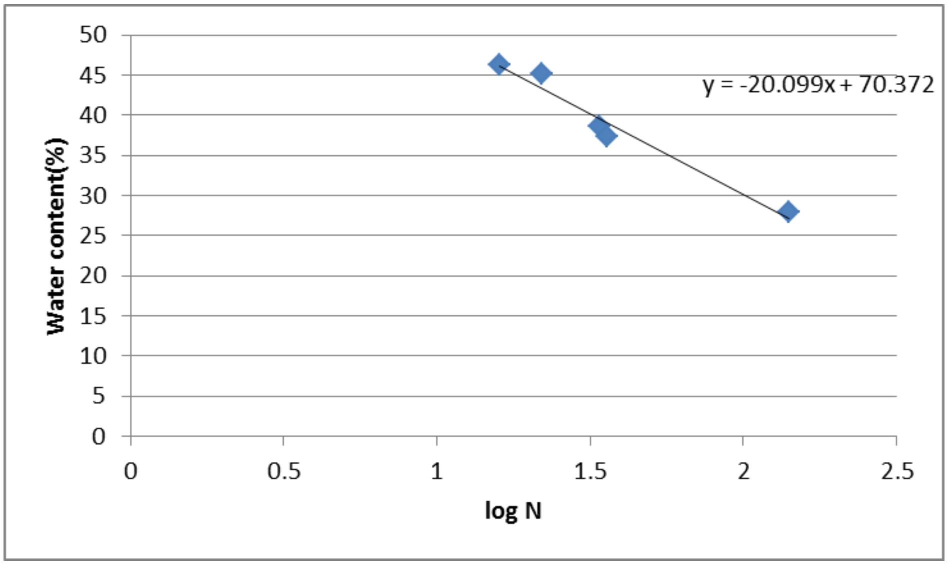
5.5 Results for Black Soil with 1% KCL and 5%microfine slag

5.5.1Liquid Limit

The liquid limit was calculated by using Casagrande's apparatus. No of blows for various samples was noted with different moisture contents and the water content for these samples was calculated using oven drying method.

S.No	Empty container	Container +MS	Weight of dry sample	Water content%	no of blows
	g(W1)	g(W2)	g(W3)	(W2-W3)/(W3-W1)	N
1	26	38	34.2	46.34146	16
2	28.6	43.7	39	45.19231	22
3	27	42.8	38.4	38.59649	34
4	26.8	44.8	39.9	37.40458	36
5	26.8	40.1	37.2	27.88462	141

TABLE 17: Contains value for determination of liquid limit of black cotton soil when mixed with 1% KCl and 5% microfine slag.



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GRAPH 10: Graph between log N and water content for black cotton soil mixed with 1% KCl and 5% microfine slag is plotted and liquid limit is determined corresponding to 25 blows.

The liquid limit as obtained from graph 9 corresponding to 25 blows is 42.27%.

The liquid limit of black cotton soil on mixing with 1% KCl and 5% microfine slag decreases from a value of 45.45% for normal black cotton soil to 42.27% as obtained from graph 10.

5.5.2Plastic Limit

S.No.	Empty container	Container+MS	Weight of dry sample	Water content%
	W1(g)	W2(g)	W3(g)	(W2-W3)/(W3-W1)
1	26.7	30.8	29.9	28.12
2	7.9	10.6	9.9	35

TABLE 18:This table contains values for determination of plastic limit of black cotton soil mixed with 1% KCl and 5% microfine slag.

Plastic limit of black cotton soil on mixing with 1%KCl and 5% microfine slag is 31.56%

The plastic limit of black cotton soil on mixing with 1% KCl and 5% microfine slag decreases from a value of 34.16% for normal black cotton soil to 31.56% as obtained from table 18.

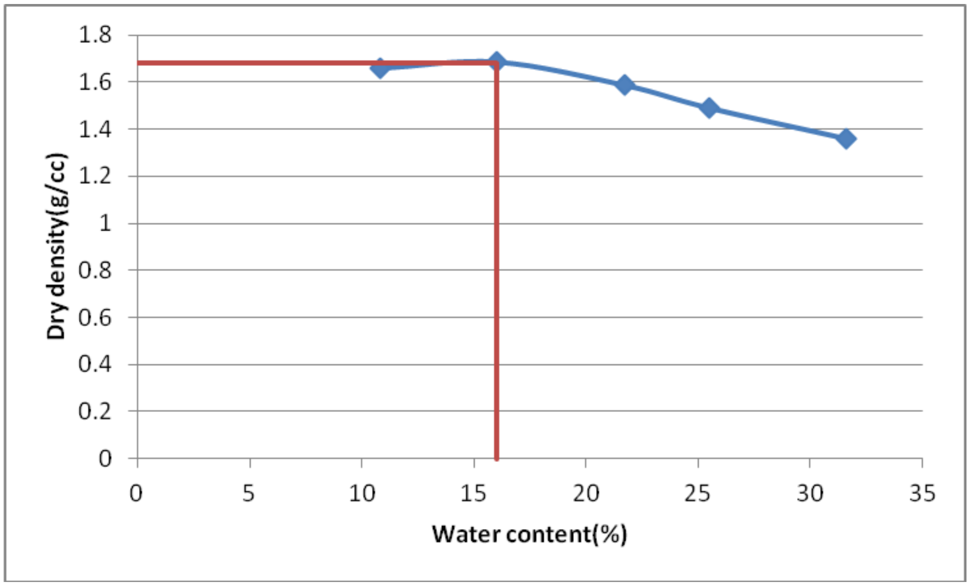
5.5.3 Standard Proctor Test on clay sample with 1%KCL and 5% microfine slag

The Standard Proctor test was performed on black cotton soil with 1% KCL and 5% microfine slag and the result was plotted on graph between dry density and water content.

- Empty mould weight= 4317.8g *MS- Moist sample.
- Volume of mould (V) =1000cc.

S.No.	mould +MS	weight of (W1)	density of MS(W1/V)	w%	dry density
	g	g	g/cc		g/cc
1	6157.4	1839.6	1.8396	10.84	1.65969
2	6275.2	1957.4	1.9574	16.03	1.686978
3	6250.8	1933	1.933	21.7	1.588332
4	6188.6	1870.8	1.8708	25.5	1.490677
5	6107.5	1789.7	1.7897	31.6	1.359954

TABLE 19:Contains value for determination of max dry density and OMC for black cotton soil mixed with 1% KCl and 5% microfine slag.



GRAPH 11: Graph showing variation of (γ_d) dry density on changing water content of black cotton soil when mixed with 1% KCl and 5% microfine slag.

The maximum dry density as obtained from graph 11 is 1.68 g/cc and OMC is 16.03%**.**

The maximum dry density of black cotton soil as obtained from graph 2 was 1.62g/cc for normal black cotton soil.There was an increase in dry density on mixing with 01% KCl and 5% microfine slag to black cotton soil as obtained from graph 11 and OMC decreased from 19.3% to 16.03%.

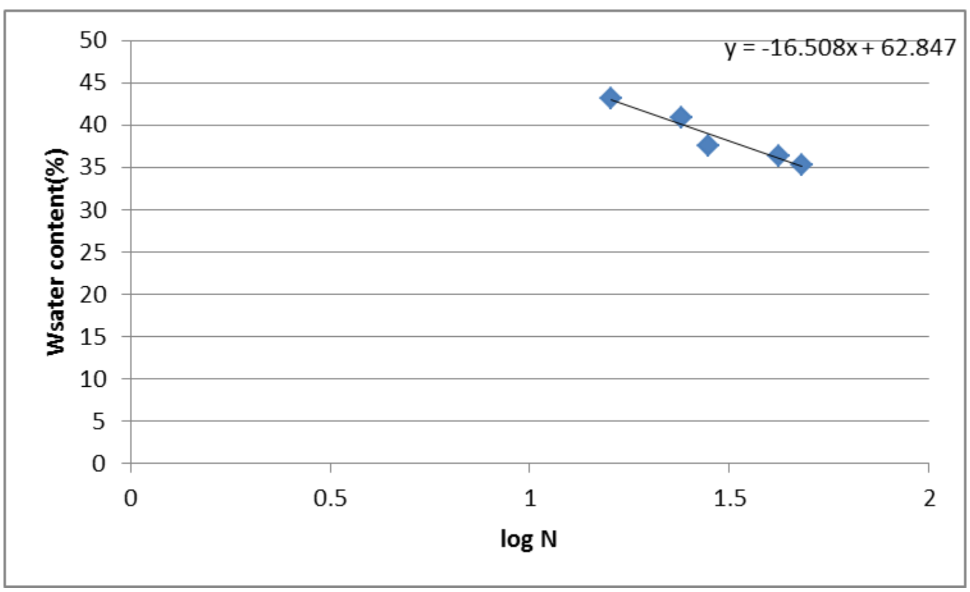
5.6 Results for Black Soil with 1% KCL and 10%microfine slag

5.6.1Liquid Limit

The liquid limit was calculated by using Casagrande's apparatus. No of blows for various samples was noted with different moisture contents and the water content for these samples was calculated using oven drying method.

S.No	Empty container	Container +MS	Weight of dry sample	Water content%	no of blows
	g(W1)	g(W2)	g(W3)	(W2-W3)/(W3-W1)	N
1	28.4	49.3	43	43.15068	16
2	27.8	44	39.3	40.86957	24
3	27.3	42.7	38.5	37.5	28
4	28.3	42.2	38.5	36.27451	42
5	27.5	43.2	39.1	35.34483	48

TABLE 20: Contains value for determination of liquid limit of black cotton soil when mixed with 1% KCl and 10% microfine slag.



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GRAPH 12: Graph between log N and water content for black cotton soil mixed with 1% KCl and 10% microfine slag is plotted and liquid limit is determined corresponding to 25 blows.

The liquid limit as obtained from graph 12 corresponding to 25 blows is 39.77%.

The liquid limit of black cotton soil on mixing with 1% KCl and 5% microfine slag decreases from a value of 45.45% for normal black cotton soil to 42.27% as obtained from graph 10.On further increase of proportion of slag to 10%,there was a decrease in liquid limit to 39.77%

5.6.2Plastic Limit

S.No.	Empty container	Container+MS	Weight of dry sample	Water content%
	W1(g)	W2(g)	W3(g)	(W2-W3)/(W3-W1)
1	8.8	12.7	11.7	34.48
2	8.1	10.6	10	31.57

TABLE 21:This table contains values for determination of plastic limit of black cotton soil mixed with 1% KCl and 10% microfine slag.

Plastic limit of black cotton soil on mixing with 1%KCl and 10% microfine slag is 33.025%

The plastic limit of black cotton soil on mixing with 1% KCl and 5% microfine slag decreases from a value of 34.16% for normal black cotton soil to 31.56% as obtained from table 18.On further increase of proportion of slag to 10% plastic limit increases to 33.025%.

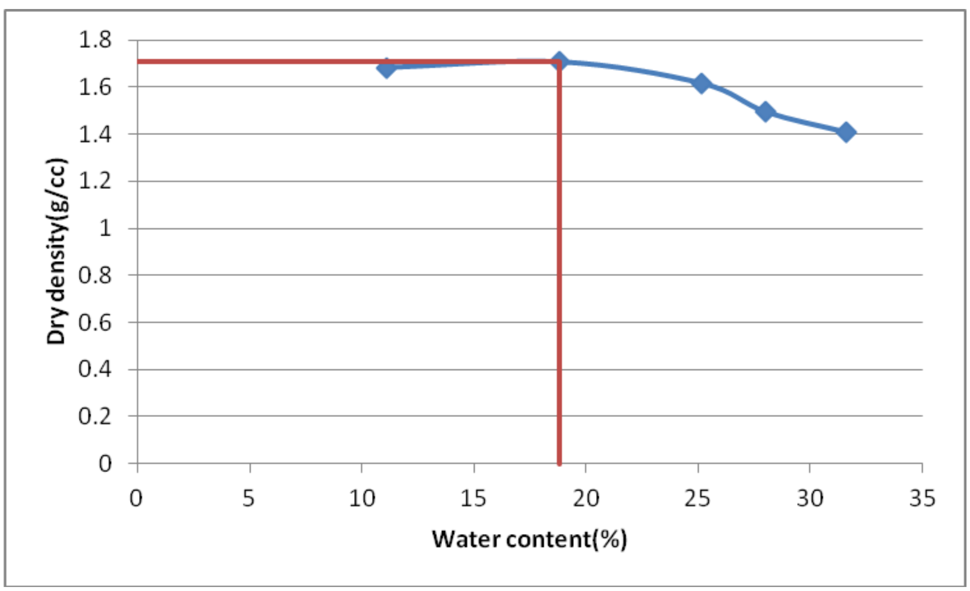
5.6.3 Standard Proctor Test on clay sample with 1%KCL and 10% microfine slag

The Standard Proctor test was performed on black cotton soil with 1% KCL and 10% microfine slag and the result was plotted on graph between dry density and water content.

- Empty mould weight= 4317.8g
- Volume of mould (V) =1000cc.
- MS- Moist sample.

S.No.	mould +MS	weight of (W1)	density of MS(W1/V)	w%	dry density
	g	g	g/cc		g/cc
1	6188	1870.2	1.8702	11.1	1.68318
2	6346.9	2029.1	2.0291	18.84	1.707413
3	6340.7	2022.9	2.0229	25.14	1.616473
4	6229.8	1912	1.912	28.03	1.493453
5	6170.5	1852.7	1.8527	31.59	1.407889

TABLE 22:Contains value for determination of max dry density and OMC for black cotton soil mixed with 1% KCl and 10% microfine slag.



GRAPH 13: Graph showing variation of (γ_d) dry density on changing water content of black cotton soil when mixed with 1% KCl and10% microfine slag.

The maximum dry density as obtained from graph 13 is 1.707g/cc and OMC is 18.84%.

The maximum dry density of black cotton soil as obtained from graph 2 was 1.62g/cc for normal black cotton soil.There was an increase in dry density on mixing with 1% KCl and 5% microfine slag to 1.68g/cc.Which further increased on increasing the proportion of slag to 1.707g/cc.

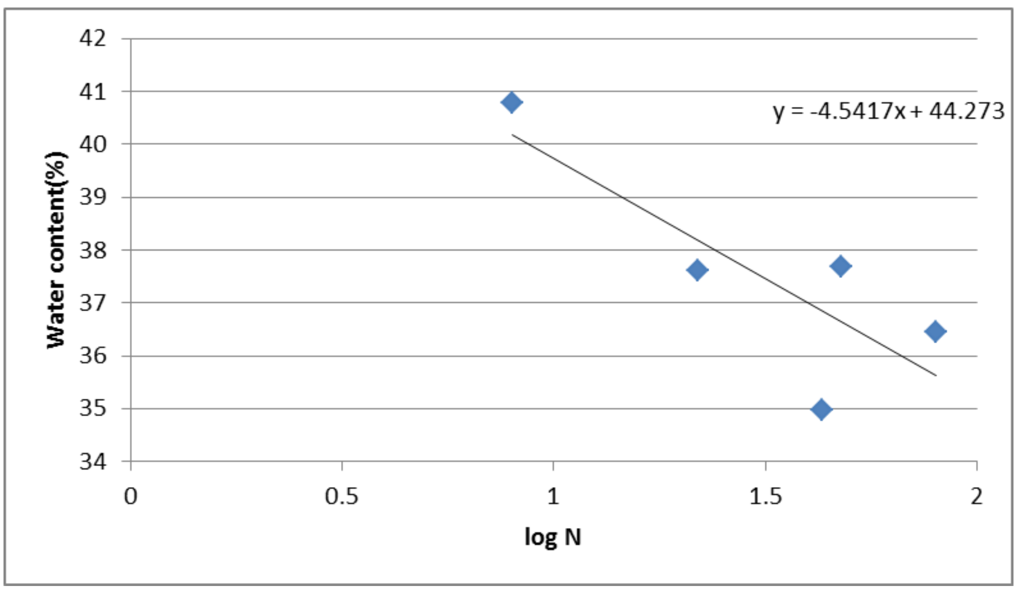
5.7 Results for Black Soil with 1% KCL and 15%microfine slag

5.7.1Liquid Limit

The liquid limit was calculated by using Casagrande's apparatus. No of blows for various samples was noted with different moisture contents and the water content for these samples was calculated using oven drying method.

S.No	Empty container	Container +MS	Weight of dry sample	Water content%	no of blows
	g(W1)	g(W2)	g(W3)	(W2-W3)/(W3-W1)	N
1	27.7	46	40.7	0.407692	8
2	27.3	43.4	39	0.376068	22
3	27.5	46.8	41.8	0.34965	43
4	26.8	36.3	33.7	0.376812	48
5	27.3	41.9	38	0.364486	80

TABLE 23: Contains value for determination of liquid limit of black cotton soil when mixed with 1% KCl and 15% microfine slag.



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GRAPH 14: Graph between log N and water content for black cotton soil mixed with 1% KCl and 15% microfine slag is plotted and liquid limit is determined corresponding to 25 blows.

The liquid limit as obtained from graph 13 corresponding to 25 blows is 37.92%.

The liquid limit of black cotton soil on mixing with 1% KCl and 5% microfine slag was 42.27%which decreased to 39.77% on increasing the slag to 10%.There was a further decrease in liquid limit on increasing slag to 15% value being 37.92%.

5.7.2Plastic Limit

S.No.	Empty container	Container+MS	Weight of dry sample	Water content%
	W1(g)	W2(g)	W3(g)	(W2-W3)/(W3-W1)
1	27.5	29.9	29.1	50
2	27.5	30.1	29.4	36.84

TABLE 24:This table contains values for determination of plastic limit of black cotton soil mixed with 1% KCl and 15% microfine slag.

Plastic limit of black cotton soil on mixing with 1%KCl and 15% microfine slag is 43.42%

The plastic limit of black cotton soil on mixing with 1% KCl and 15% microfine slag increases from a value of 33.025% for normal black cotton soil with 1% KCl and 10% slag to 43.42% on increase of slag content to 15%.

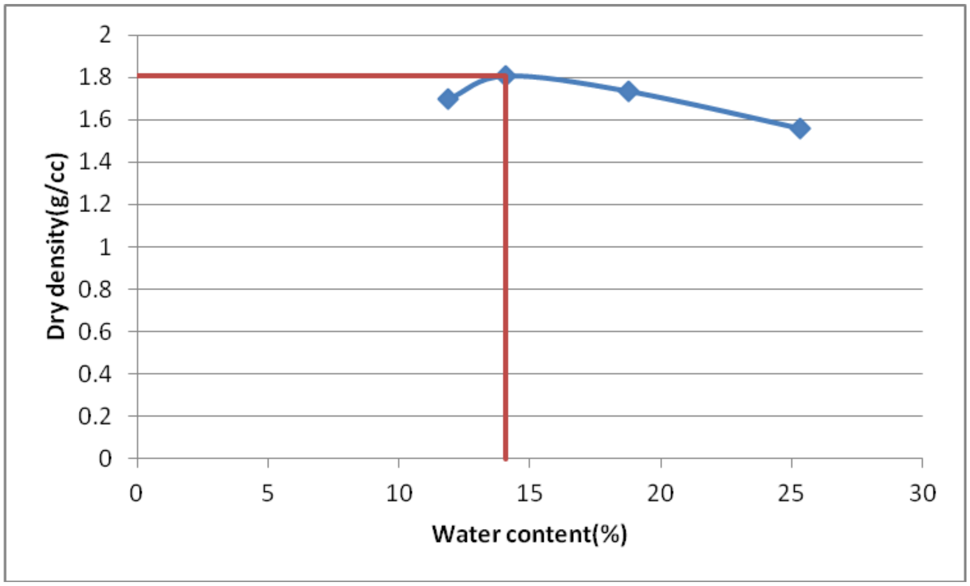
5.7.3 Standard Proctor Test on clay sample with 1%KCL and 15% microfine slag

The Standard Proctor test was performed on black cotton soil with 1% KCL and 15% microfine slag and the result was plotted on graph between dry density and water content.

- Empty mould weight= 4317.8g
- Volume of mould (V) =1000cc.
- MS- Moist sample.

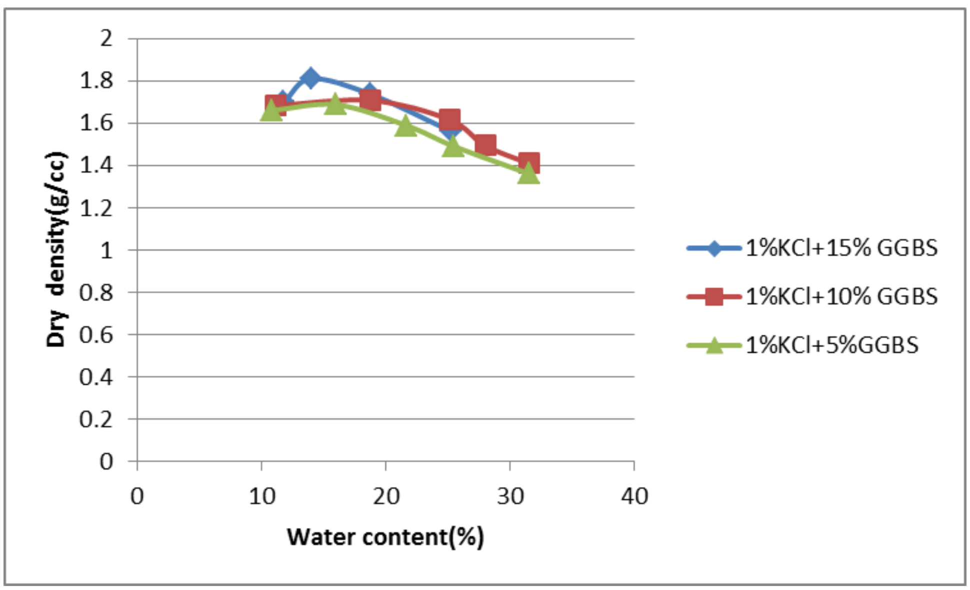
S.No.	mould +MS	Weight of (W1)	density of MS(W1/V)	w%	dry density
	g	g	g/cc		g/cc
1	6217.4	1899.6	1.8996	11.86	1.699105546
2	6381	2063.2	2.0632	14.06	1.809824561
3	6380.7	2062.9	2.062	18.78	1.736447811
4	6273.8	1956	1.956	25.31	1.561053472

TABLE 25:Contains value for determination of max dry density and OMC for black cotton soil mixed with 1% KCl and 15% microfine slag.



GRAPH 15: Graph showing variation of (γ_d) dry density on changing water content of black cotton soil when mixed with 1% KCl and 15% microfine slag.

The maximum dry density as obtained from graph 14 is 1.809 g/cc and OMC is 14.06%.
The maximum dry density of soil was 1.707g/cc on addition of 1%KCl and 10% microfine slag to soil as obtained from graph 13.Which further increased to 1.809g/cc on increasing the slag content to 15%.



GRAPH 16: Graph showing variation of dry density on different proportions of microfine slag and 1% KCl

The maximum dry density of soil is 1.686 g/cc,1.707 g/cc and 1.809 g/cc at optimum KCl content of 1% . and varying proportion of microfine slag.5%,10% and 15% respectively.

The maximum dry density is maximum on 15% slag+1% KCl addition with a value of 1.809 g/cc at an optimum moisture content of 14.06%.

CONCLUSIONS

- Addition of KCl to black cotton soil resulted in decrease of liquid limit and increase in the plastic limit resulting in decrease of plasticity index as desired for improvement of properties of black cotton soil.

- The liquid limit is minimum while plastic limit of the soil is maximum as desired on addition of 1% KCl to the black cotton soil.

- At 1.5% of KCl the liquid limit again increases. The maximum dry density of soil is 1.52 g/cc, 1.566 g/cc and 1.53 g/cc at KCl contents of 0.5%, 1% and 1.5% respectively.

- Hence from these results it can be interpreted that the optimum content of KCl to improve the properties of black cotton soil is 1%. Which is in accordance with previous results as obtained from International Journal of Innovative Science, Engineering & Technology, Issue 10, December 2014.

- Addition of microfine slag and KCl together resulted in much more effective results.The liquid limit is minimum while plastic limit of the soil is maximum as desired on addition of 1% KCl (optimum) along with 15% microfine slag to the black cotton soil.

- The liquid limit keeps on decreasing with increasing percentages of microfine slag with values 42.27%,39.77% and 37.92% at slag contents of 5%,10% and 15% respectively alongwith 1% KCl.

- The maximum dry density of soil is 1.686 g/cc,1.707 g/cc and 1.809 g/cc at optimum KCl content of 1% . and varying proportion of microfine slag.5%,10% and 15% respectively. The dry density is maximum on addition of 15% microfine slag with 1% KCl, with a value of 1.809 g/cc at an optimum moisture content of 14.06%.

- KCl improves the properties of black cotton soil through base exchange mechanism and microfine slag has a totally different approach by formation of cementitious material when mixed with black cotton soil and water thus leading to improvement of properties of black cotton soil.

- The effects of addition of both the agents for improvement of properties of black cotton soil and the outcome has been as desired leading to much effective results.

FUTURE SCOPE OF STUDY

There are ways of keeping expansive soils from either expanding or shrinking too much when used as a subgrade. These help minimize the problems associated with black cotton soil. The challenges of construction on clay were carried out and their effect on the pavement looked into. When KCL and microfine individually used, have proven to improve the properties of black cotton soil as is seen from the earlier studies thus increasing its acceptance to be used as a foundation material for pavement subgrade construction and foundation design .

When KCl and microfine slag mixed in different proportions to the black cotton soil, the effect on improvement in properties is much pronounced as compared to individual addition of these two components.

The project has vast scope in future in the form of identification of swelling potential and strength parameters of black cotton soil when mixed with agents in the experiment respectively.

The data is analyzed so as to obtain the best design for the local conditions.

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