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Effect Of Electrolyte On The Geotechnical Properties Of Black Cotton Soil

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Abstract
Black Cotton soil is one of the major soil deposits of India. They exhibit high swelling and shrinkage when exposed to change in moisture content and hence they have been found to be most troublesome from engineering conditions. Various studies are going on to find the solution for black cotton soil. One among the remedial measure for this problem is stabilization of soil using some stabilizing agents. The studies show that electrolytes like chlorides can also be used as stabilizing agent instead of conventional materials like lime, fly ash etc. The present work illustrates the efficient use of potassium chloride with varying percentages in improving the various properties of black cotton soil.
Keywords: *Black Cotton Soil, Potassium Chloride (KCL), MDD, OMC, UCS.*

1. Introduction

The rapid growth of industries and urbanization has focused a lot in improving the soil strength. The term soil improvement is used generally to improve the strength (index properties) of the weak soils. This weak soil contains a mineral known as montmorilloniate which makes the soil to swell and shrink excessively with the change in water content. Such changes of the soil are due to the present of fine clay particles which when comes in contact with water, they swell and when the water is dried they tend to shrink. For centuries mankind was wondering at the instability of the earth materials, especially expansive soil. One day they are dry and hard, and the next day wet and soft. Expansive soil cover large tracts of several world nations and in India these deposits are known by the name “black cotton soils” which occupy about 20% of its surface area. Black cotton soil represents a well known category of problematic from civil engineering point of view. The swelling and shrinkage tendency of the soil causes differential settlement of the structures. The phenomena of expansive soil can be stabilized by the addition of small percentage by weight of lime. Lime enhances many engineering properties of the soil. These techniques have proved an enhanced engineering property and hence it is used in constructions purposes, highway, railroad and airport construction to improve sub grade and sub base of soils.

2. Materials Used

2.1 Black Cotton Soil

Black cotton soils are those soils, which have tendency to increase in volume when water is available and to decrease in volume when water is removed. These volume changes in swelling soils are the cause of many problems in structures that come into their contact or constructed out of them.

The soil used for investigation is obtained at 1.5m depth from Lakkya, Chikkamagalur district, Karnataka State, India. Both disturbed and undisturbed samples (Using core cutter) are collected from the site and tested in the laboratory.

Fig 1 Collection of Black Cotton Soil

2.2 Potassium Chloride

The chemical compound potassium chloride (KCl) is a metal halide salt composed of potassium and chlorine. In its pure state, it is odorless and has a white or colorless vitreous crystal appearance, with a crystal structure that cleaves easily in three directions. Potassium chloride crystals are face-centered cubic. Potassium chloride was historically known as "muriate of potash". For the present study 0.5%, 1.0%, 1.5% and 2.0% of potassium chloride is added by the weight of the soil and various index and Engineering properties has been studied.

3. EXPERIMENTAL INVESTIGATIONS

3.1 BLACK COTTON SOIL:

The various properties of natural black cotton soil is shown below

Table 1 Properties of Black Cotton Soil

Soil properties	Values
Field moisture content (%)	34.77
Liquid limit (%)	66
Plastic limit (%)	24.4
Plasticity index (%)	41.6
Specific gravity	2.47
Permeability (cm/sec)	$6.05*10^{-4}$
Maximum dry density(kN/m^3)	13.7
Optimum moisture content (%)	16.3
Unconfined compression strength (kN/m^2)	432.65
Free swell index (%)	73.33

3.2 DETAILS OF TESTS CONDUCTED

3.2.1 Specific gravity

Specific gravity of a substance denotes the number of times that substance is heavier than water. In simpler words we can define it as the ratio between the mass of any substance of a definite volume divided by mass of equal volume of water.

3.2.2 Atterberg limit test

Atterberg limits were conducted to determine the Liquid limit, Plastic limit and Shrinkage limit. Liquid limit tests were carried out using Casagrande's method.

3.2.3 Differential free swell (DFS) index

Free swell index is used for the classification of the expansive soils on the basis of degree of expansiveness. Differential free swell index of soil sample was determined by Indian standard specification.

3.2.4 Compaction characteristics

Light (standard Proctor) test were carried out to determine the maximum dry density (MDD) and optimum moisture content (OMC) for both untreated and treated soil as per Indian standard specifications. The MDD and OMC are very necessary for the determination of load carrying capacity of foundation, embankment etc.

3.2.5 Unconfined Compression Strength (UCS) test

Unconfined compression tests were conducted on soil and treated soils as per Indian Standards. Samples were prepared in split mould at MDD and optimum moisture content (OMC). The cylindrical specimen of untreated and treated soil was tested under normal vertical load. The UCS value of every sample was determined by dividing the maximum load at which the failure takes place and the corrected cross sectional area of the specimen.

Table 2 Indian Standard codes used to perform laboratory tests

Specific gravity	IS: 2720 (Part 3) – 1980
Atterberg limit test	IS: 2720 (Part 5) – 1985
Differential free swell index	IS: 2720 (Part 40) – 1977
Standard Proctor compaction test	IS: 2720 (Part 7) – 1980
Unconfined compressive strength test	IS: 2720 (Part 10) – 1991

3.3 TEST RESULTS AND DISCUSSION

3.3.1 Specific Gravity

In case of soils, specific gravity is the number of times the soil solids are heavier than equal volume of water.

Table 3 Specific Gravity Variation for KCL

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Materials (KCL)	**Specific Gravity**
BC Soil	2.47
BC Soil+0.5% KCl	2.30
BC Soil+1% KCl	2.27
BC Soil+1.5% KCl	2.10
BC Soil +2% KCl	2

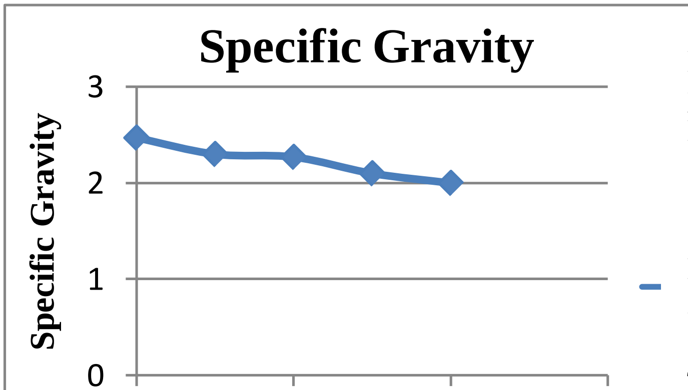

Fig 2 Variation of Specific Gravity due to addition of KCL

From table 3 it has been observed that the specific gravity is greatly affected by the addition of KCl with the increase in percentage of KCl with respect to dry weight of soil the specific gravity value decreases. When 1.5% KCl is added the specific gravity reduces to 2.1 compared to 2.27 for 1% KCl.

3.3.2 Atterberg limit test

Table 4 and 5 Atterberg Limit Variation for KCL

Materials	**Liquid Limit (%)**	**Plastic limit (%)**
BC	66	24.4
BC Soil+0.5% KCl	59	27.8
BC Soil+1% KCl	54	30.9
BC Soil+1.5% KCl	51.2	32.4
BC Soil +2% KCl	47	33

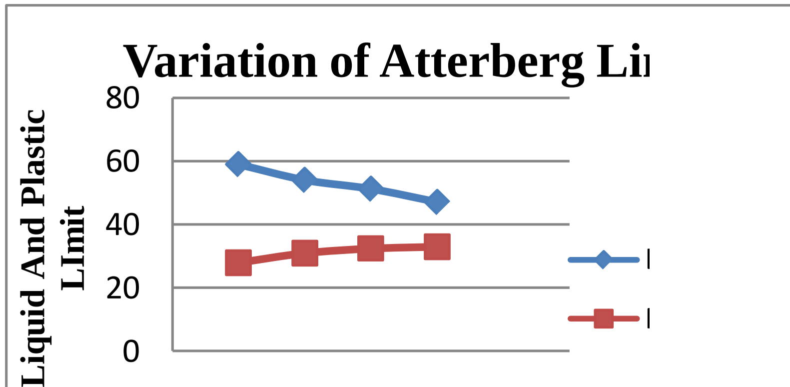

Fig 3 Variation of Atterberg due to addition of KCL

From table 4 & 5, it has been observed that the liquid limit values goes on decreases with increase in percentage of KCl added vice versa effect for plastic limit. The increase in the plastic limit is attributed to cation exchange and the chloride concentration since KCL is completely soluble in water. Since there is decrease in the liquid limit and increase in the plastic limit the overall value reduction in the plasticity index from 41.6% to 14%

3.3.3 .Differential free swell index

Table 6 Free Swell index Variation for KCL

Materials	**Free swell index (%)**
BC Soil	73.33
BC Soil+0.5% KCl	62.5
BC Soil+1% KCl	50
BC Soil+1.5% KCl	37.5
BC Soil+2% KCl	33.33

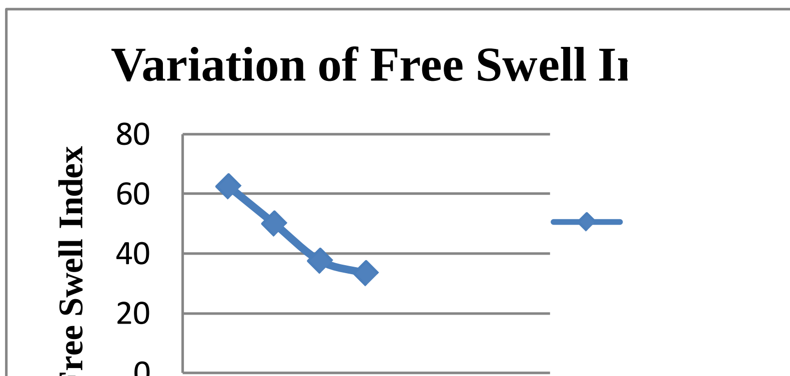

Fig 4 Variation of Free Swell index due to addition of KCL

From table 6 it has been observed that swelling property of the black cotton soil is greatly reduced with increase in the percentage of chemical added. The reduction in swelling is maximum upto 1.5% addition of KCL thereafter the percentage reduction of swelling reduces with increase in percentage of KCL.

3.3.4 .Standard Proctor compaction test

Table 7 Dry density and Optimum Moisture Content Variation for KCL

Materials	Max Dry Density (kN/m^3)	OMC (%)
BC Soil	13.7	16.3
BC Soil+0.5% KCl	16.3	15.4
BC Soil+1% KCl	19.62	15.2
BC Soil+1.5% KCl	21.23	14.7
BC Soil+2% KCl	23.79	14.3

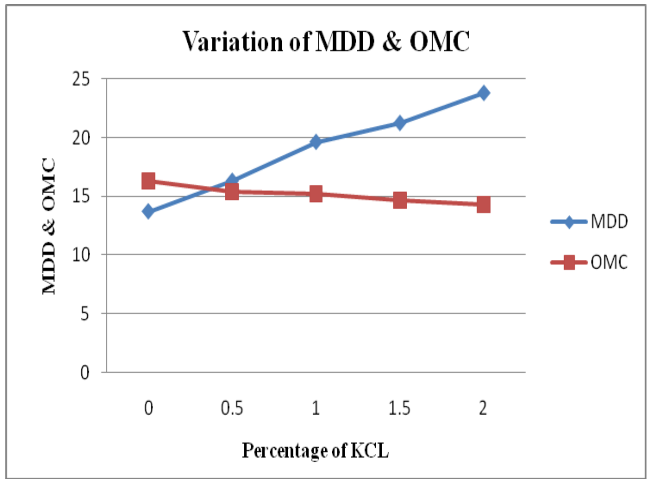

Fig 5 Variation of MDD & OMC due to addition of KCL

From table 7 it has been observed that the maximum dry density and optimum moisture content values increases with increase in the percentage of chemical added. The increase in Maximum dry density shows the increase in the strength characteristics of the soil.

3.3.5. Unconfined compressive strength test

Table 8 Unconfined compressive strength Variation for KCL

BC Soil		BC Soil+.5%KCl		BC Soil+1%KCl		BC Soil+1.5%KCl		BC Soil+2%KCl	
Strain	Stress (kN/m^2)	Strain	Stress (kN/m^2)	Strain	Stress (kN/m^2)	Strain	Stress (kN/m^2)	Strain	Stress (kN/m^2)
0	0	0	0	0	0	0	0	0	0
$8.18*10^{-3}$	17.76	$8.18*10^{-3}$	17.76	$8.18*10^{-3}$	35.52	$8.18*10^{-3}$	53.29	$8.18*10^{-3}$	53.29
$16.37*10^{-3}$	35.23	$16.37*10^{-3}$	52.85	$16.37*10^{-3}$	123.32	$16.37*10^{-3}$	70.47	$16.37*10^{-3}$	88.08
$24.55*10^{-3}$	87.36	$24.55*10^{-3}$	139.78	$24.55*10^{-3}$	157.26	$24.55*10^{-3}$	87.36	$24.55*10^{-3}$	122.31
$32.74*10^{-3}$	173.17	$32.74*10^{-3}$	207.8	$32.74*10^{-3}$	242.43	$32.74*10^{-3}$	121.21	$32.74*10^{-3}$	173.17
$40.92*10^{-3}$	223.30	$40.92*10^{-3}$	257.66	$40.92*10^{-3}$	292.01	$40.92*10^{-3}$	154.59	$40.92*10^{-3}$	223.3
$49.11*10^{-3}$	289.68	$49.11*10^{-3}$	357.84	$49.11*10^{-3}$	408.96	$49.11*10^{-3}$	187.44	$49.11*10^{-3}$	221.52
$57.3*10^{-3}$	338.09	$57.3*10^{-3}$	422.61	$57.3*10^{-3}$	524.04	$57.3*10^{-3}$	304.20	$57.3*10^{-3}$	304.28
$65.48*10^{-3}$	368.97	$65.48*10^{-3}$	486.37	$65.48*10^{-3}$	620.55	$65.48*10^{-3}$	352.2	$65.48*10^{-3}$	335.43
$73.67*10^{-3}$	432.65	$73.67*10^{-3}$	515.85	$73.67*10^{-3}$	715.54	$73.67*10^{-3}$	399.37	$73.67*10^{-3}$	366.09
		$81.85*10^{-3}$	528.37	$81.85*10^{-3}$	776.04	$81.85*10^{-3}$	429.3	$81.85*10^{-3}$	379.76
		$90.04*10^{-3}$	557.07	$90.04*10^{-3}$	835.61	$90.04*10^{-3}$	507.92	$90.04*10^{-3}$	393.23

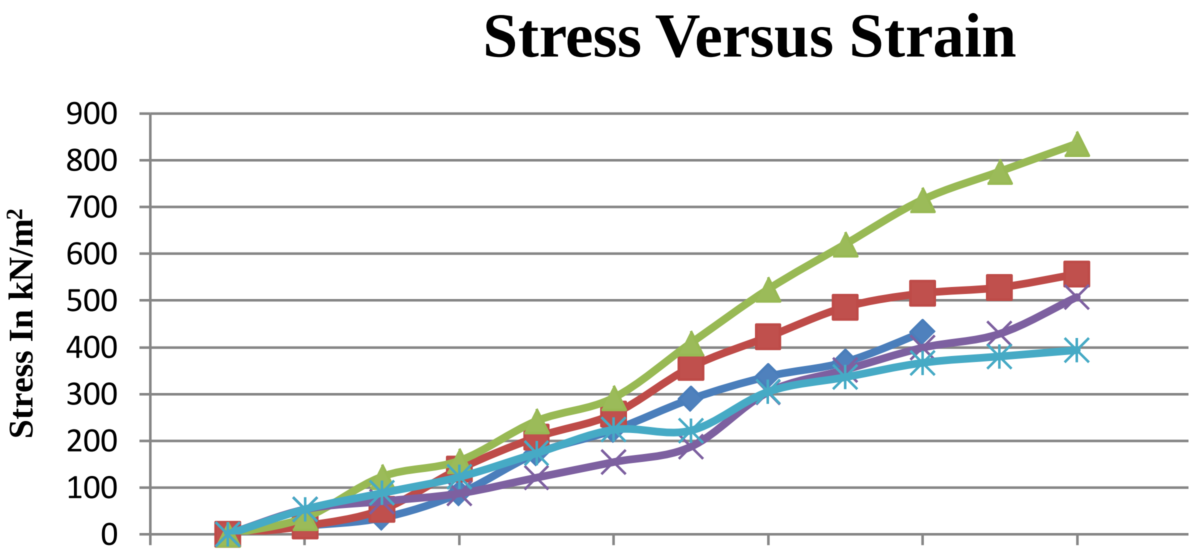

Fig 6 Variation of Unconfined compressive strength due to addition of KCL

From table 8 it has been observed that there is a significant improvement in the UCS values up to 1% Chemical, after that UCS values get reduced. The increase in the strength is mainly due to the increase in pore water ion concentration which in term reduces the repulsion and increases the cohesion between the soil particles. But further increase of the KCL concentration above 1% shows slight decrease in the strength of the soil from 835.61, 507.92 and 393.23 kN/m^2 at 1, 1.5, and 2% respectively. This is mainly due to the increase in the electrolyte concentration which reduces the tendency of the soil particles to attract each other.

4. Conclusions

An attempt was made to study the effect of potassium chloride compounds (KCl) on the properties of black cotton soil. The soil was tested for its liquid limit, plastic limit, maximum dry density, optimum moisture content, unconfined compressive strength and swelling index. 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 by 28.78% and increases the plastic limit upto 35.24% with the addition of 2% KCl. With the increase in liquid limit and decrease in the plastic limit the plasticity index reduces by 66.34% with 2% KCl. The maximum dry density was 13.7 kN/m^3 for 0% KCl which significantly increases to 23.79 kN/m^3 when 2% KCl is added. The increase in MDD shows a positive sign of increase in the strength properties of soil. The compressive strength of the soil increased with the addition of chloride compounds only up to 1% by about 93.13% but above 1% increased in KCl the compressive strength of the black cotton soil reduces. With the above results it is obvious that 1% KCl by the weight of soil can be effectively used to increase the strength of the black cotton soil. Further it is remarkable to note that with the increase in KCl percentage the swelling behaviour of the black cotton soil reduces by about 54.54% with 2% KCL. This will help in reducing swelling characteristics and also helps in improving soil strength and other soil properties. From the laboratory results it was observed that, with increase in % of KCl there is a change in several properties of black cotton soil. Properties like free swell index, MDD and plasticity index vary significantly, whereas compressive strength of black cotton soil increases impressively upto 1% KCl and thereafter strength decreases.

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