International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Effects of Calcium Chloride on Black Cotton Soil

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A B S T R A C T

Black Cotton soil is known for its high swelling and shrinkage properties. It can be very harmful to the construction done over them. Researchers have always attempted to stabilize Black Cotton soil by adding various materials such as lime, cement, fly ash, etc. As technology advances, different materials are used to increase the effectiveness of the stabilization process. In this research work, Calcium Chloride and Fly Ash were used in various proportions as additives to improve the geotechnical properties of the Black Cotton soil. In concrete, calcium chloride is used as an accelerator and to achieve high initial strength, while fly ash is used as a by-product obtained from thermal power plants. Calcium Chloride was added in 1%, 2% and 3% and Fly Ash was added in 20% and 30% and they were cured for 0, 7, 14, 28 days and subjected to alternate wet and dry cycles on the soil to understand it's swelling and shrinkage behavior and change in geotechnical properties of Black Cotton Soil.

Keywords: BCS, $CaCl_2$, FSI, UCS.

1. Introduction

Soil is one of the most significant natural resources, together with air and water. In engineering, soil is referred to as regolith or loose rock materials. Black Cotton soils are those bedrocks that increase in volume or expand as they come into contact with moisture and shrink as they dry out. Black Cotton soil when companioned with an engineering structure and in the presence of water will exhibit a propensity to swell or shrink. This will cause the structure to encounter moments that are independent of the direct consequences of loading the structure. Since Black Cotton Soil has poor engineering properties, stabilization of Black Cotton Soil becomes necessary for large-scale construction. Stabilization is the process of treating soil with chemicals or physical means, employing stabilizers and chemical admixtures to increase or maintain a soil's stability.

As part of this study, we aim to contribute to the understanding of improvements in the characteristics of Black Cotton soil mixed with Calcium Chloride and Fly Ash.

2. Literature Review

Ramdas. T.L., et al. (2012), studied the stabilization of expansive soil using calcium chloride. They used different proportions of calcium chloride and found out the strength and durability properties of the soil. They studied the behavior of the soil after adding 0.5, 1,2 and 2.5% calcium chloride and investigated the consistency limits, unconfined compressive strength, and swelling behavior. They observed that the addition of calcium chloride increases the unconfined compressive strength and decreases the swelling behavior of the soil. In addition, they observed a decrease in the liquid limit and an increase in the plastic limit. It was determined that UCS strength improved after a curing period of 14 and 28 days. Based on the results of the study, it was determined that 1% of $CaCl_2$ by dry weight of the soil is the optimal dose.

Baytar (2005), fly ash and desulphogypsum obtained from thermal power plants stabilized black cotton soils varying from 0 to 30%. Different percentages of lime (0 to 8%) were added to the expansive soil-fly ash-desulphogypsum mixture. The treated samples were cured for 7 and 28 days. It is observed that swelling pressure decreased and the rate of swelling increased with increasing stabilizer percentage. The swelling of the soil is further reduced by curing it.

EkremKalkan (2011), investigated montomorillonite as the main mineral that causes varying water percentages to have expansive behavior and shrink properties of Black Cotton soil. Additionally, it has been observed that wetting and drying cycles cause cracks in the soil, increasing its permeability, which causes distress to footings, side drainages, and clay liners for waste nuclear deposits. To reduce the effect of cycles of wet and dry, soil should be stabilized with chemicals and waste materials. In this study, black cotton soil was mixed with silica fume waste material and observed. Natural clay sample was mixed with silica fume and subjected to several wet and dry cycles leading to increased strength and a reduction in swelling.

3. Materials

3.1 Black Cotton Soil

The soil sample for this study was collected from a construction site in Jabalpur. The soil was dried and grinded to 4.75mm sieve to carry out laboratory experiments. The Properties of Black cotton soil is shown in Table 1.

Table 1- Properties of Black Cotton Soil

SL. No.	Properties	Values
1	Specific Gravity	2.57
2	Liquid Limit	75%
3	Plastic Limit	27%
4	OMC	25.10%
5	MDD	1.56g/cc
6	UCS	26.58 N/cm^2
7	Natural Moisture	9.2%
8	Free Swell Index	75

3.2 Calcium Chloride

Calcium Chloride was bought from Jabalpur Market. It has molecular weight 110.47grams. It is in white crystalline powder form.

3.3 Fly Ash

Fly Ash was obtained from Sanjay Gandhi Thermal Power Station, Birsighpur, Pali, Madhya Pradesh.

4. Methodology

The following describes the research process for this study. A comparison of Calcium Chloride and industrial wastes such as Fly Ash in different proportions in alternate wet and dry cycles. To evaluate the effect of soil/calcium ratio and soil/fly ash ratio on swelling pressure and mechanical strength, three different types of calcium chloride and two different fly ash ratios were used. The calcium ratios were 1%, 2% and 3% and two different proportions of fly ash were used in the present study. The soil and fly ash were thoroughly mixed before the experiments were carried out. All tests were conducted in accordance with the IS code method.

Black cotton soil specimens were mixed with water and different proportions of calcium chloride solution compositions and different proportions of fly ash. Then the black cotton soil was left to air dry in the laboratory environment (at a controlled temperature of 21± 5C) until the loss of moisture ceased. Each black cotton soil specimen was then rewetted with the same concentration of liquid as used initially. The soil specimens were tested for up to five wet–dry cycles. In each cycle the behavior of the soil was observed.

The following experiments were conducted in the laboratory:

- Free Swell Index
- Standard Proctor's Test
- Unconfined Compression Test

5. Results and Discussions

The experimental study involves Free Swell Index, Optimum Moisture Content, Plasticity Index, Unified Compression Strength tests on soil sample with 1%, 2% and 3% of Calcium Chloride and 20% and 30% of Fly Ash as stabilizer. The results are also compared for different number of alternate wet and dry cycles.

5.1 Free Swell Index

Free Swell Index Test has been followed the code of IS: 2720(Part XL)-1977 on soil sample. Two samples passing 425µ IS sieve is taken; both the samples are poured in 100 ml capacity graduated glass cylinder. Distilled water is poured in on cylinder and kerosene in the other one. Remove the entrapped air by stirring with glass rod. Allow attainment of equilibrium state for 24 hrs. Final volume of soil in each cylinder shall be read out. This process continues for different proportion of soil and Calcium Chloride ranging from 0% to 3% and soil and Fly Ash at 20% and 30%. The F.S.I. variation with different proportions and alternate wet and dry cycles is shown in Figure 1.

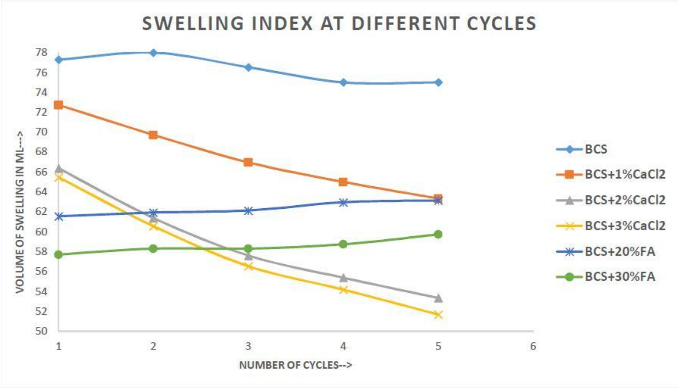

Figure 1 Swelling Pressure at different cycles

5.2 Standard Proctor's Test

Standard Proctor's Compaction tests is conducted on soil samples under different proportioning with 1%, 2% and 3% of Calcium Chloride and 20% and 30% of Fly Ash as stabilizer to determine the optimum moisture content and maximum dry density of soil sample. The optimum moisture content and maximum dry density of soil sample under different proportioning of Calcium Chloride and Fly Ash are shown in Figure 2 and the variation with alternate wet and dry cycles are shown in Figure 3 to Figure 5.

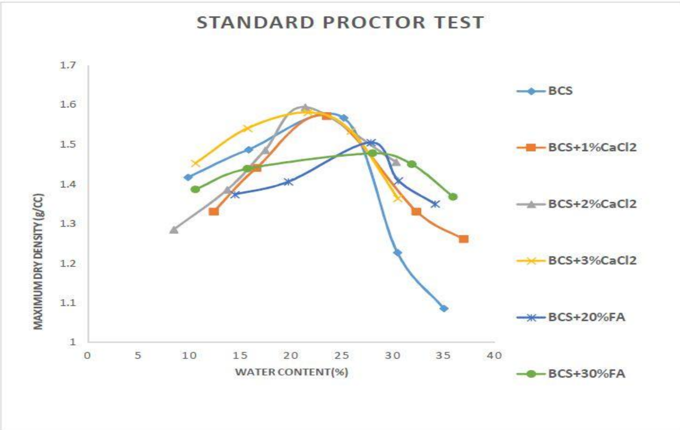

Figure 2 Standard Proctor's Test for different proportions of $CaCl_2$ and Fly Ash

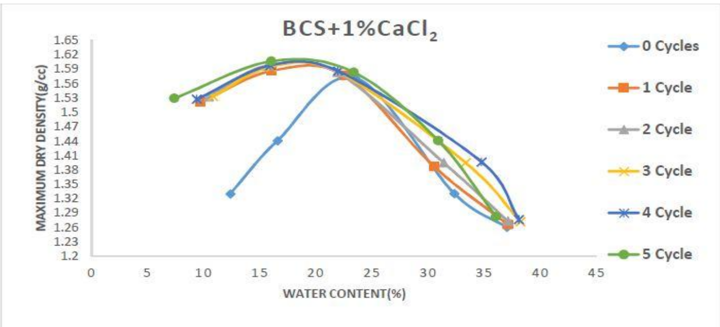

Figure 2 Standard's Proctor's Test with 1% $CaCl_2$ at different cycles

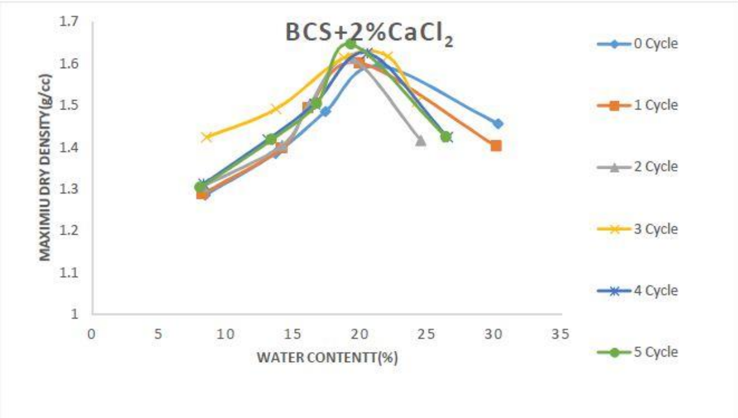

Figure 3 Standard's Proctor's Test with 2% $CaCl_2$ at different cycles

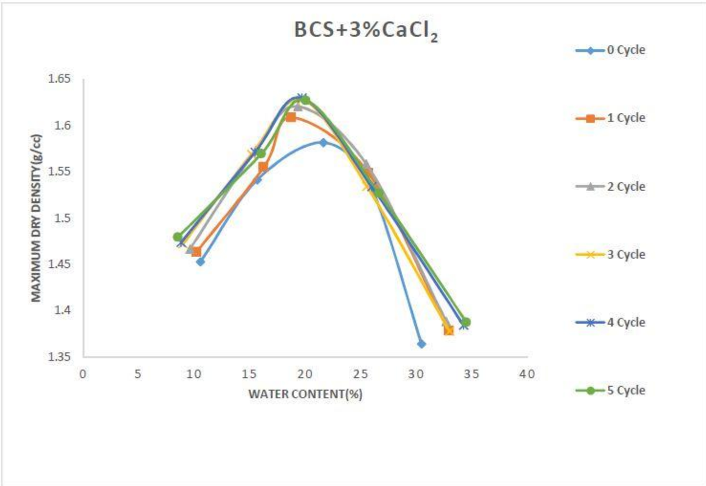

Figure 5 Standard's Proctor's Test with 3% $CaCl_2$ at different cycles

5.3 Unconfined Compressive Test

The unconfined compressive test was done in accordance with IS 2720:PART 3:1980. Unconfined Compressive strength load per unit area at which an unconfined cylindrical specimen of soil fails in Compression test. A maximum force per unit area was not reached up to 20% of the strain. During the test, we used 5 to 20 KN proving rings depending on the strength of the soil specimen we used as soil samples from freshly developed soil samples and laid the samples in a constant water content desiccator for seven days. Knowing the volume of the mould, the soil will be packed into the mold to a maximum dry density and optimum moisture content. Then after compacting the soil soil specimen will be removed from the mould which having 5 cm diameter and 10cm height. The soil sample was placed in a compressive testing machine without any side confinement and the stress and strain values were recorded. The percentage change of UCS and number of alternate wet and dry cycles for different proportions of Calcium Chloride and Fly Ash at different curing days are shown in figure 5 to figure 8.

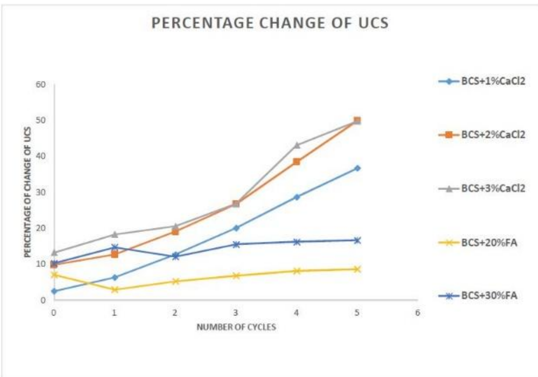

Figure 5 Change in percentage of UCS and Number of cycles for different percentage of $CaCl_2$ and Fly Ash at 0 Days

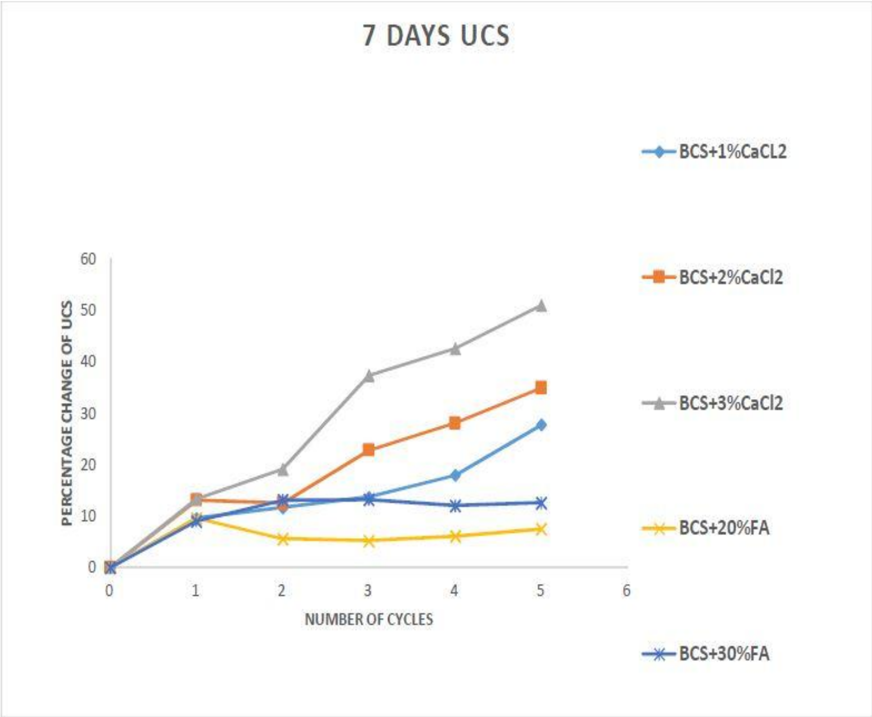

Figure 6 Change in percentage of UCS and Number of cycles for different percentage of $CaCl_2$ and Fly Ash at 7 days

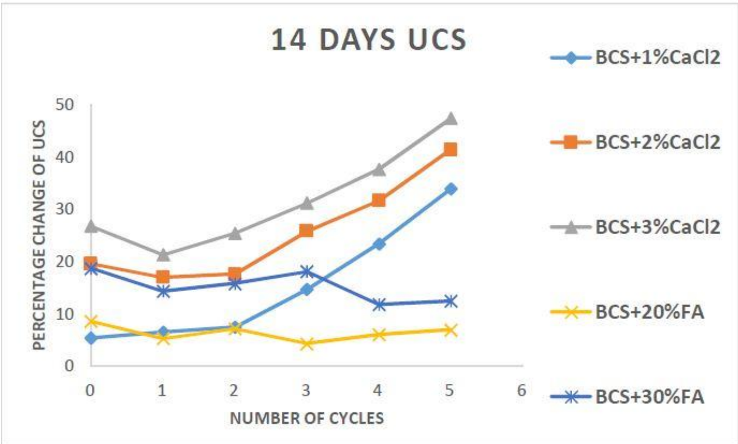

Figure 7 Change in percentage of UCS and Number of cycles for different percentage of $CaCl_2$ and Fly Ash at 14 Days

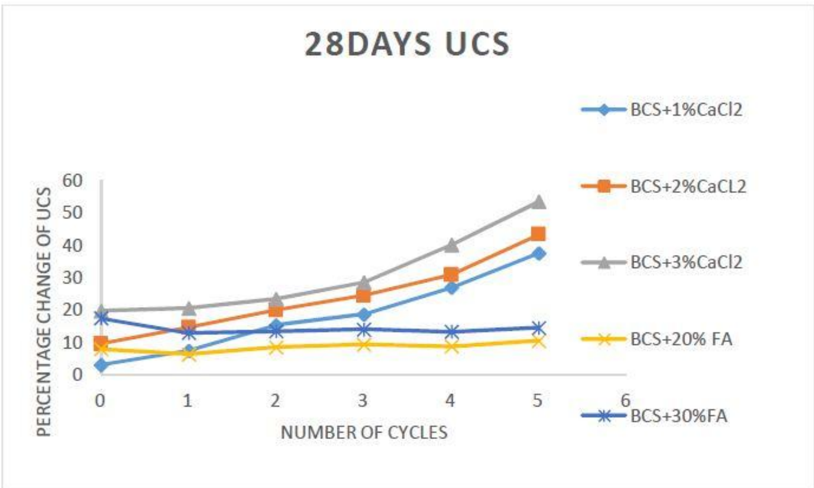

Figure 8 Change in percentage of UCS and Number of cycles for different percentage of $CaCl_2$ and Fly Ash at 28 Days

6. Conclusions

Based on experimental study and analysis, the following conclusions were made:

- The Free Swell Index of Black Cotton soil decreases with increase in Calcium Chloride content and alternate wet and dry cycles.
- The Maximum Dry Density increases and the Optimum Moisture Content decreases with increase in Calcium Chloride content.
- The Unconfined Compressive Strength increases with increase in Calcium Chloride content.
- Unconfined Compressive Strength increases with increase in number of days of curing and also with increase in alternate wet and dry cycles.
- The change due to 2% and 3% Calcium chloride are comparable. Hence, 2% Calcium Chloride is recommended from economical perspective.

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