Stabilization of Black Cotton Soil Using Chemical

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Abstract
Black Cotton soil, renowned for its pronounced swelling and shrinkage tendencies, poses significant challenges to construction endeavors. Over time, researchers have endeavored to stabilize this soil type through the incorporation of various additives such as lime, cement, and fly ash. With technological advancements, novel materials are being explored to enhance the efficacy of stabilization processes. This study investigates the potential of Calcium Chloride and Fly Ash as additives to ameliorate the geotechnical characteristics of Black Cotton soil. Calcium Chloride, commonly utilized as a concrete accelerator to promote rapid strength development, and Fly Ash, a by-product of thermal power plants, were employed in differing proportions – Calcium Chloride at 1%, 2%, and 3%, and Fly Ash at 20% and 30%. The specimens underwent curing for durations of 0, 7, 14, and 28 days, and were subjected to alternate wet and dry cycles to assess their swelling and shrinkage behaviors, alongside alterations in the geotechnical properties of Black Cotton Soil.

Keywords: Black Cotton Soil, Calcium Chloride, Fly Ash, Free Swell Index, Unconfined Compressive Strength.

1. Introduction

Soil stands as one of the paramount natural resources alongside air and water, holding pivotal importance in various engineering applications. Often referred to as regolith or loose rock materials within the engineering domain, soil encompasses diverse compositions and behaviors crucial for construction projects. Among these soil types, Black Cotton soils are notable for their unique characteristics, notably their propensity to expand upon contact with moisture and contract upon drying. This inherent swelling and shrinking behavior can pose significant challenges when Black Cotton soil is utilized in conjunction with engineering structures, as it introduces unpredictable movements independent of applied loads.

Given the poor engineering properties inherent to Black Cotton soil, the stabilization of this soil type becomes imperative for large-scale construction endeavors. Stabilization, in this context, refers to the process of treating soil through various chemical or physical means, often involving the utilization of stabilizers and chemical admixtures. These treatments aim to enhance or maintain the stability of the soil, thereby mitigating the adverse effects of its inherent properties.

In this study, our objective is to contribute to the understanding of improving the characteristics of Black Cotton soil through the incorporation of Calcium Chloride and Fly Ash. These additives are chosen for their potential to enhance the engineering properties of the soil and alleviate the challenges associated with its natural behavior. Through rigorous experimentation and analysis, we seek to elucidate the efficacy of Calcium Chloride and Fly Ash in stabilizing Black Cotton soil, offering insights that can inform future construction practices and infrastructure development.

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

Black Cotton Soil

The soil sample for this study was collected from a construction site in Bhopal. 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

Calcium Chloride

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

Fly Ash

Fly Ash was obtained from MPPGCL, Sarni district Betul

4. Methodology

The research process for this study involved comparing the effects of Calcium Chloride and industrial waste, specifically Fly Ash, in varying proportions under alternate wet and dry cycles. The aim was to assess the impact of different soil/calcium and soil/fly ash ratios on swelling pressure and mechanical strength. Three calcium chloride concentrations (1%, 2%, and 3%) and two different fly ash ratios were utilized.

The procedure began with thorough mixing of black cotton soil with water and the respective calcium chloride or fly ash solutions. The mixed soil was then air-dried in a controlled laboratory environment at a temperature of 21±5°C until moisture loss ceased. Subsequently, each soil specimen was rewetted using the same concentration of liquid as initially used. This process was repeated for up to five wet-dry cycles, during which the behavior of the soil was closely observed.

Laboratory experiments conducted included:

- Free Swell Index measurement to evaluate the soil's swelling potential.
- Standard Proctor's Test to determine the soil's maximum dry density and optimum moisture content.
- Unconfined Compression Test to assess the soil's mechanical strength under compression.

All experiments were conducted following the prescribed methods outlined in the relevant Indian Standard (IS) codes, ensuring adherence to established testing protocols and consistency in results.

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.

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.

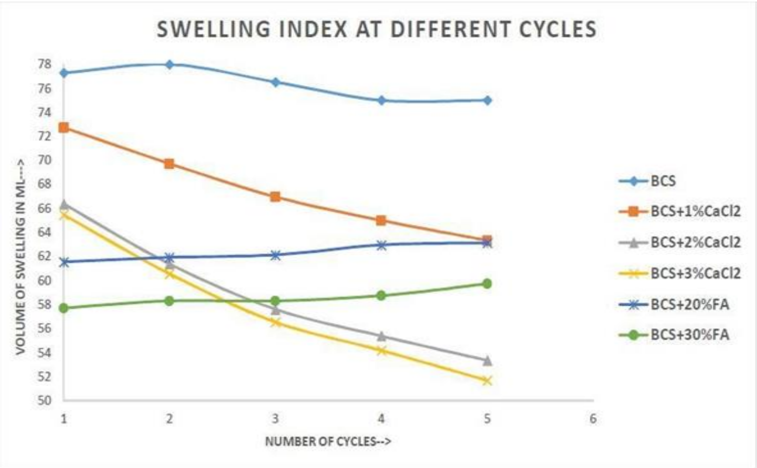


Figure 1 Swelling Pressure at different cycles

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.

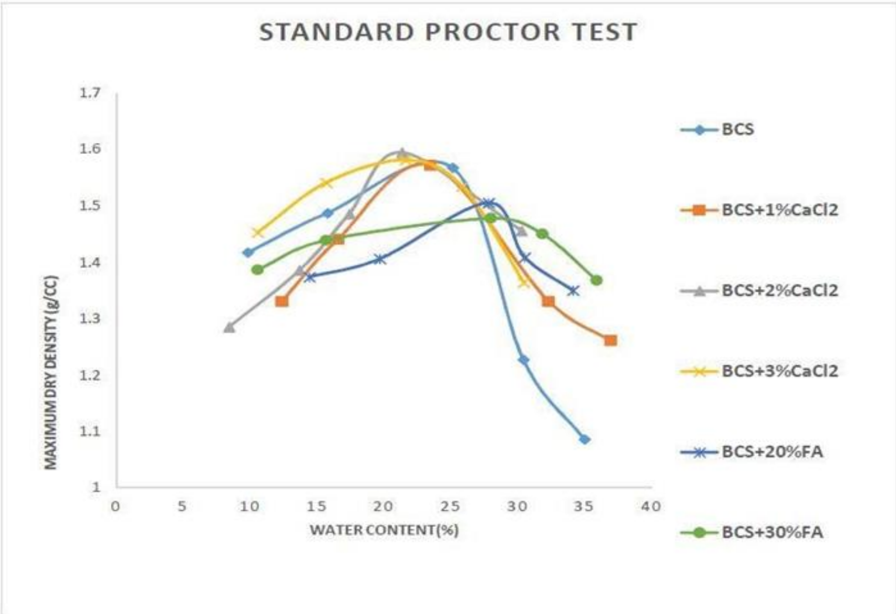


Figure 2 Standard Proctor's Test for different proportions of CaCl2 and Fly Ash

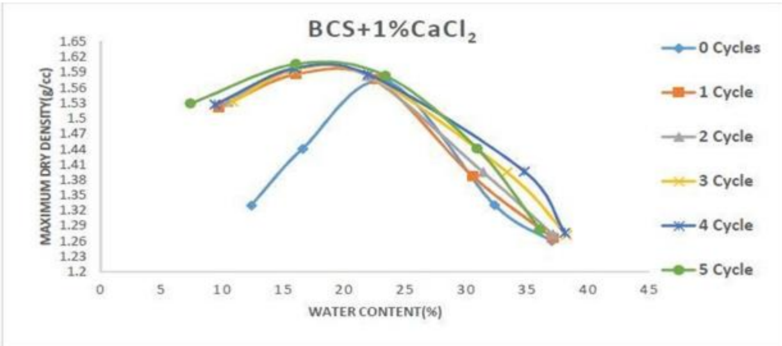
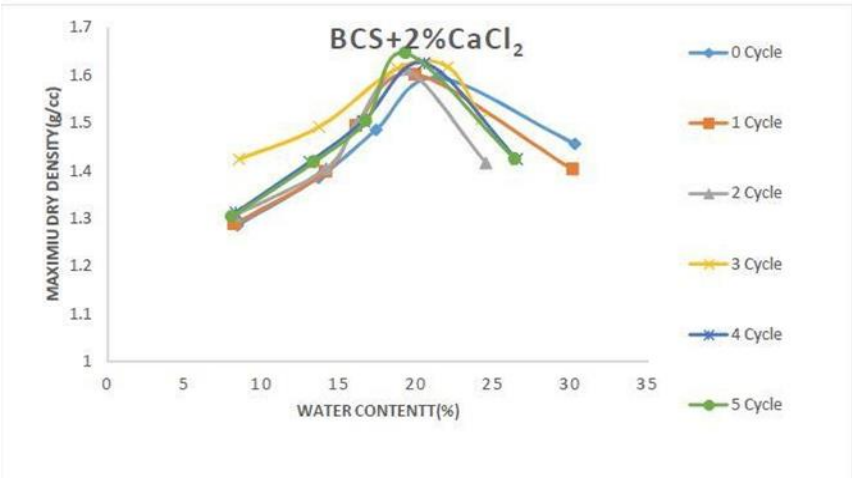


Figure 3 Standard's Proctor's Test with 1% CaCl2 at different cycles



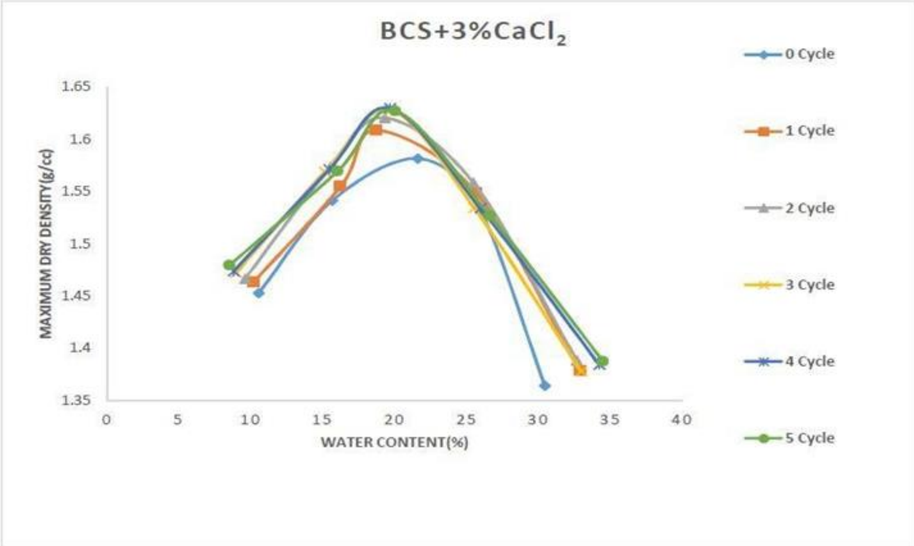


Figure 3 Standard's Proctor's Test with 2% CaCl2 at different cycles

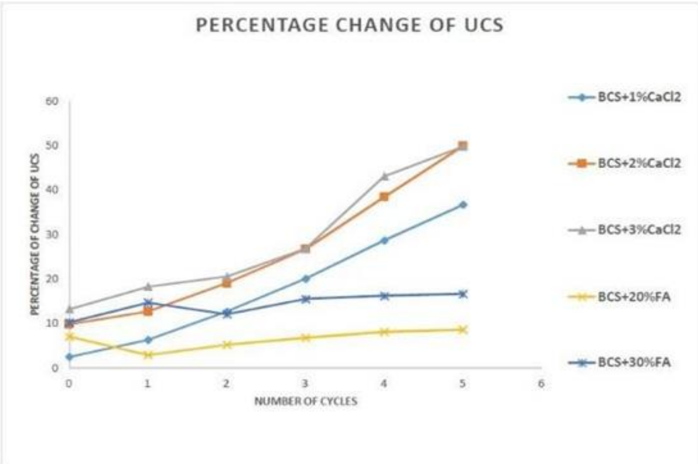


Figure 5 Standard's Proctor's Test with 3% CaCl2 at different cycles

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 CaCl2 and Fly Ash at 0 Days

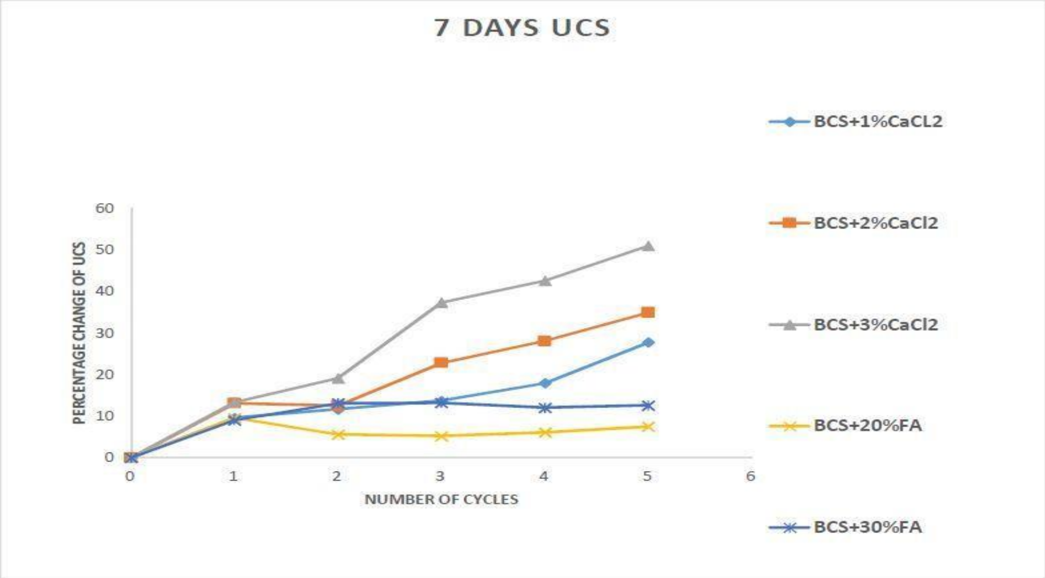


Figure 6 Change in percentage of UCS and Number of cycles for different percentage of $CaCl_2$ and Fly Ash at 7 days

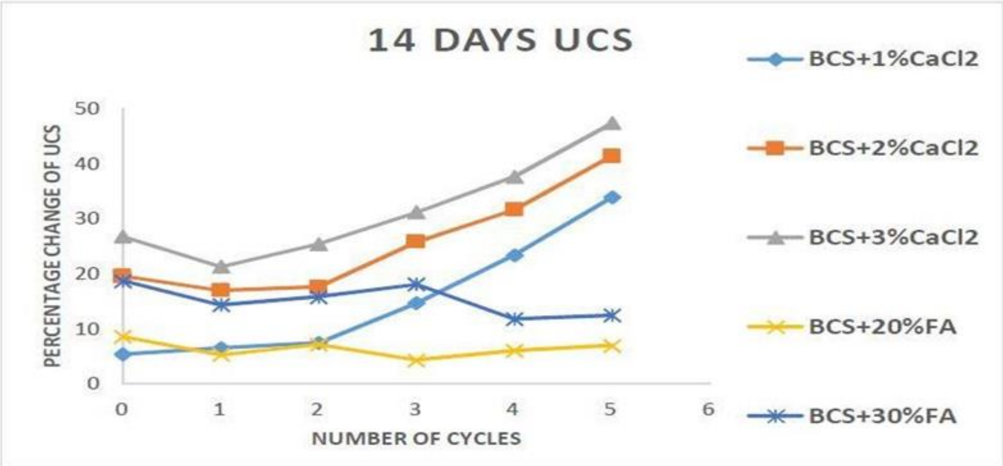


Figure 7 Change in percentage of UCS and Number of cycles for different percentage of $CaCl_2$ and Fly Ash at 14 Days

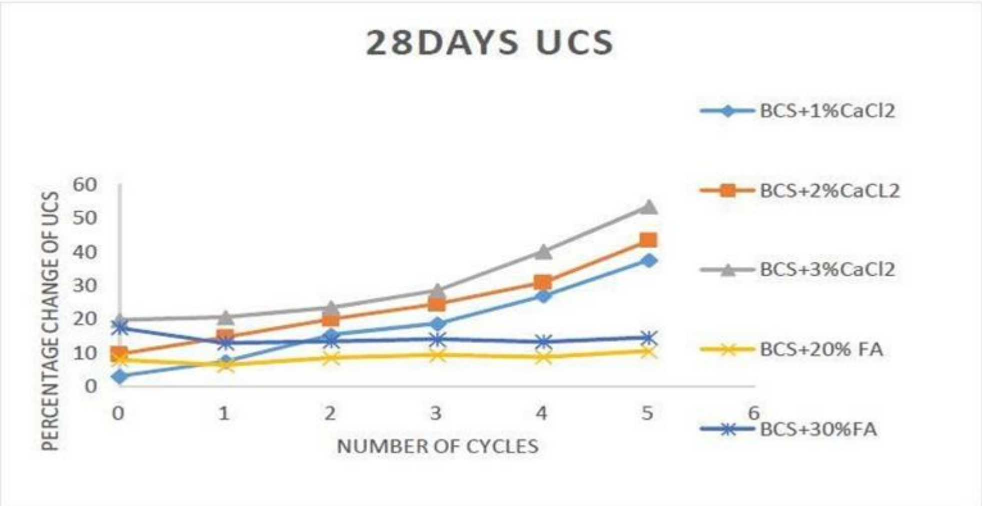


Figure 8 Change in percentage of UCS and Number of cycles for different percentage of $CaCl_2$ and Fly Ash at 28 Days

6. Conclusions

Based on the experimental study and analysis conducted, several key conclusions can be drawn regarding the effects of Calcium Chloride on Black Cotton soil:

1. The Free Swell Index of Black Cotton soil demonstrates a consistent decrease with an increase in Calcium Chloride content and alternate wet and dry cycles. This indicates that the soil's swelling potential diminishes as Calcium Chloride concentration rises.
2. The Maximum Dry Density of the soil shows an upward trend, while the Optimum Moisture Content decreases with an increase in Calcium Chloride content. This suggests that Calcium Chloride addition enhances soil compaction, resulting in higher density and lower moisture content requirements for optimal compaction.
3. The Unconfined Compressive Strength exhibits a positive correlation with Calcium Chloride content. As Calcium Chloride concentration increases, the soil's strength improves, indicating better load-bearing capacity.
4. Furthermore, the Unconfined Compressive Strength demonstrates an increase with both the number of days of curing and alternate wet and dry cycles. This implies that prolonged curing periods and repeated wetting and drying cycles contribute to further enhancement of the soil's compressive strength.
5. Notably, the observed changes induced by 2% and 3% Calcium Chloride concentrations are comparable. Therefore, from an economic standpoint, it is recommended to utilize 2% Calcium Chloride, as it offers similar benefits to the higher concentration while being more cost-effective.

In summary, the experimental findings suggest that the incorporation of Calcium Chloride effectively mitigates the swelling potential, enhances compaction characteristics, and improves the overall strength of Black Cotton soil. These conclusions provide valuable insights for engineering applications aimed at soil stabilization and construction projects.

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