Effect of Calcium Chloride and Fly ash on Stabilization of Expansive Soil

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ABSTRACT
Soil stabilization is widely applied in road and construction projects to improve weak soils. It includes mechanical, chemical, and biological methods, with chemical stabilization enhancing soil properties using additives. Effective treatment requires understanding material behavior, performance, and impacts on surrounding structures, along with factors like mixing, compaction, curing, and environmental conditions. In this study, black cotton soil was stabilized using calcium chloride and fly ash, and UCS and CBR tests were performed to identify the optimum dosages for maximum strength and subgrade performance.

Keywords: Black cotton soil, Soil stabilization, Calcium chloride, Fly ash, UCS, CBR.

I. INTRODUCTION

Soil stabilization involves the biological, chemical, or mechanical modification of soil to enhance its engineering properties. In civil engineering, it is used to improve strength, durability, permeability, compressibility, and plasticity, ensuring that soils can act as reliable foundations for buildings, roads, and airfields. While mechanical improvements are common, chemical stabilization using admixtures is often preferred to modify soil properties more effectively.

Common stabilizers include chlorides, polymers, lime, cement, fly ash, enzymes, and calcium chloride. Chlorides (magnesium and calcium) bind fines and control moisture in unpaved roads. Polymers, both synthetic and biopolymers, strengthen soils through molecular chains. Lime and cement act as binders, especially in high- plasticity soils. Fly ash, a coal byproduct, improves sub-base strength and reduces moisture. Enzymes catalyze reactions that permanently bond soil particles, while calcium chloride absorbs moisture, binds fines, and enhances load-bearing capacity.

Stabilization methods include mechanical, chemical, and biological approaches. Mechanical stabilization mixes and compacts soils to achieve a dense, well-graded material. Chemical stabilization uses additives like lime, cement, fly ash, polymers, and enzymes to enhance soil properties. Biological stabilization relies on vegetation to prevent erosion, with roots binding soil particles.

This study evaluates calcium chloride and fly ash for stabilizing expansive soils. It investigates the effects of varying dosages and curing periods on strength, plasticity, and subgrade performance, aiming to identify the most economical and effective combination through laboratory experiments and secondary research.

II. LITERATURE REVIEW

Several studies have explored soil stabilization using chemical additives and waste materials to improve the engineering properties of expansive and clayey soils. Shaoyang Han et al. (2021) investigated the stabilization of expansive soils from Gaochun, China, through calcium carbonate precipitation induced by calcium chloride and sodium carbonate. Tests on air-dried, sieved soils—including swell, compaction, UCS, and direct shear—examined the effects of curing periods and mixing methods, highlighting the impact of $CaCO_3$ formation and excessive $CaCl_2$ on soil behavior.

Jayant Singh et al. (2020) studied natural clayey soil stabilized with gypsum and 0.75% calcium chloride. Standard Proctor and CBR tests for gypsum contents of 2–8% demonstrated that combining gypsum with calcium chloride significantly enhanced soil compaction and strength compared to untreated or gypsum-only soils. Similarly, Ayushi Seeliya et al. (2018) evaluated stabilization using rice husk ash (RHA), cement clink dust, and calcium chloride on soils from LNCT Bhopal. RHA, a silica-rich pozzolanic material, reacts with calcium to form cementitious compounds, improving soil strength, plasticity, and CBR values.

Abdulla A. Sharo et al. (2018) examined high-plasticity expansive soils stabilized with calcium chloride dihydrate, assessing compaction, consistency limits, UCS, swelling, swell pressure, and CBR. Vijay Kumar Meshram et al. (2018) studied soils from LNCT Bhopal treated with 2% and 4% calcium chloride flakes, reporting increased strength, reduced optimum moisture content, and higher dry density.

While numerous studies exist on chemical or waste-based stabilization, few investigate the combined effect of calcium chloride and fly ash, highlighting the need for further research on their synergistic impact on expansive soils.

III. MATERIALS USED

Calcium chloride ($CaCl_2$) is an inorganic salt, typically a white crystalline solid, highly soluble in water and often encountered as hydrated forms ($CaCl_2 \cdot nH_2O$, n = 0, 1, 2, 4, 6). It can be produced by neutralizing hydrochloric acid with calcium hydroxide. Due to its hygroscopic and deliquescent properties, calcium chloride is widely used for de- icing, dust control, and as a desiccant. Its ability to attract and retain moisture enhances soil compaction, creating a stronger, more durable base for construction.

Fly ash, a fine by-product of pulverized coal combustion in thermal power plants, is rich in siliceous and aluminous material, making it a pozzolan. In the presence of water or lime, it forms cementitious compounds similar to Portland cement, making it useful in blended cement, tiles, hollow blocks, and soil stabilization.

Black cotton soil, rich in titaniferous magnetite, is fertile for cotton cultivation but problematic for engineering due to high swelling and shrinkage. Combining $CaCl_2$ and fly ash improves its compaction, strength, and durability, providing a stable subgrade for construction.

IV. DETAIL EXPERIMENTAL PROGRAM

Table 1. Detailed experimental programme

Sr. No.	Conditions	Tests	Remarks
1	Untreated Soil (BC Soil)	Atterberg's limits Compaction test, CBR (Soaked, Unsoaked). UCS test	The classification of soil was carried out as per IS classification system.
2	Soil + Calcium chloride ($CaCl_2$)	Compaction test	To study the dosages of Cacl2 on compaction characteristics of soil.
3	Soil + Calcium chloride ($CaCl_2$)	UCS test 1, 7 and 14 day of curing	The test was carried out for the optimum dosage of calcium chloride.
4	Soil + Fly ash	UCS test 7 Days of curing	The test was carried out for the optimum dosage of Fly ash.
5	Soil + Fly Ash + Calcium chloride	UCS test 1, 7 and 14 day of curing	To find compressive strength of soil with optimum dosages of fly ash and calcium chloride
6	Soil + Calcium chloride ($CaCl_2$)	CBR (Unsoaked) 1,7 and 14 days of curing	To find the subgrade strength of soil by using optimum percentages of stabilizers.
7	Soil + Fly Ash + Calcium chloride	CBR (Soaked and unsoaked) 1,7 and 14 days of curing	To find the subgrade strength of soil by using optimum percentages of stabilizers.

V. DISCUSSION OF RESULTS

The experimental results of soil treated with Fly ash and Calcium Chloride for various laboratory experiment are discussed in this section.

1. Effect of Fly ash on Unconfined Compression Strength:

The samples which are kept for curing 7 days after treated with Fly ash, it is sealed with plastic so that there will be no moisture loss while treating the sample. Fig. 1 shows the variation of UCS of soil with varying percentage of flyash for 7 days of curing period. It is observed that UCS Strength increases after adding 15% of Fly ash and thereafter the increase in UCS is marginal. Hence, we can conclude that 15% Fly ash is optimum for further experimental investigation.

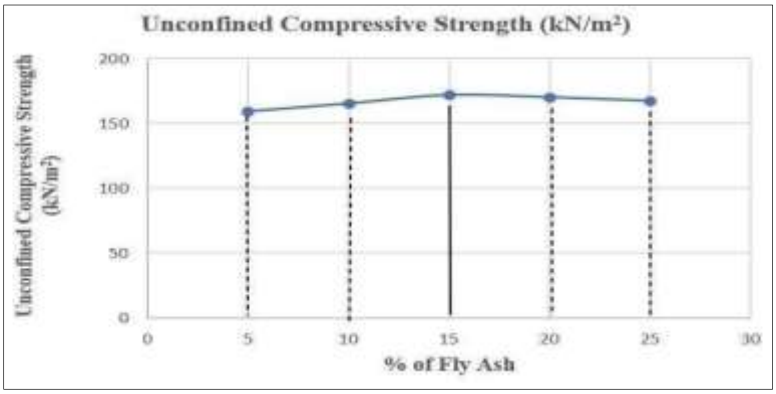

Fig. 4.15 Variation of UCS of Soil with varying percentage of Fly Ash for 7 days curing period

2. Effect of Calcium Chloride on Unconfined Compression Strength:

The variation of UCS of soil with varying percentage of Calcium Chloride with natural soil is obtained. From the result it can be concluded that 12% Calcium Chloride gives the maximum UCS value after 14 days of curing. Fig. 2 shows the Stress v/s Strain graph of 12% Calcium Chloride for 1, 7, 14 days respectively. Therefore 12% Calcium Chloride is adopted as optimum percentage for further experimental investigation.

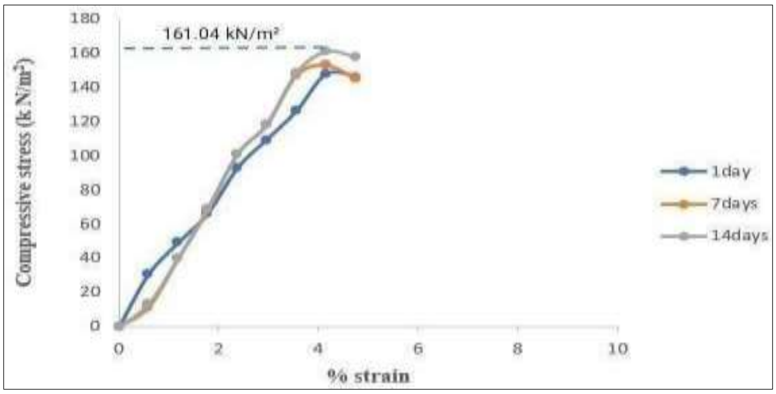

Fig. 2 Stress v/s Strain graph of Soil sample treated with 12% of $CaCl_2$

3. Effect of Combination of 12% Calcium Chloride and 15% Fly Ash on Unconfined Compression Strength Test:

The variation of UCS of soil with combination of 12% CaCl2 and 15% Fly ash with natural soil was obtained. From the results it can be concluded that 12% CaCl2 and 15% Fly ash gives the maximum UCS value after 14 days of curing. Fig. 3 shows the stress v/s strain graph of 12% calcium chloride and 15 % fly ash for 1, 7, 14 days respectively. Therefore 12% Calcium and 15% fly ash is adopted as optimum percentage for further experimental investigation.

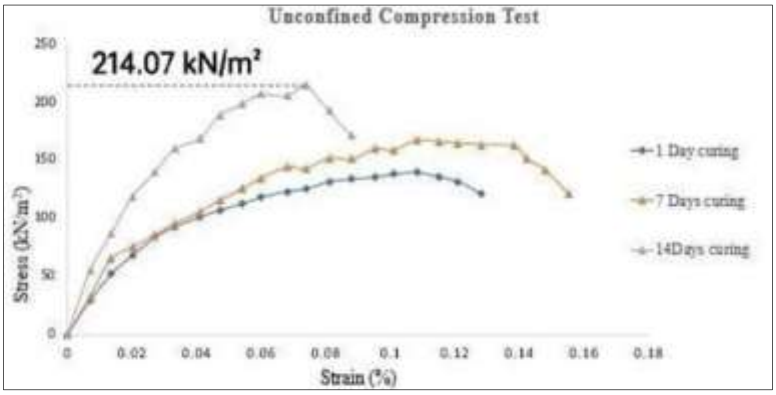

Fig. 3 UCS graph of untreated soil and treated soil with combination of 12% $CaCl_2$ & 15% Fly Ash for curing period of 1, 7, 14 days respectively.

4. Effect on Subgrade (CBR) Strength of Soil:

The California Bearing Ratio (Soaked and Unsoaked) test was conducted on the untreated sample and treated sample with optimum dosages of Fly ash and Calcium Chloride and the combination of the same to check the subgrade strength characteristics of the soil. The 12% Calcium Chloride was added into the soil sample to determine the California Bearing Ratio. The sample is prepared in laboratory and cured for 1,7 and 14 days respectively for unsoaked condition. Table 2 and Fig. 4 shows the CBR values for treated soil sample with 12% Calcium Chloride after 1,7 and 14 days of curing.

Table 2. CBR Unsoaked value for treated soil sample with 12% Calcium Chloride after 1,7 and 14 days of curing.

Sr. No.	Penetration	CBR Value (%)		
		1 day	7 days	14 days
1	2.5	5.22	5.73	7.36
2	5	4.32	5.01	6.15

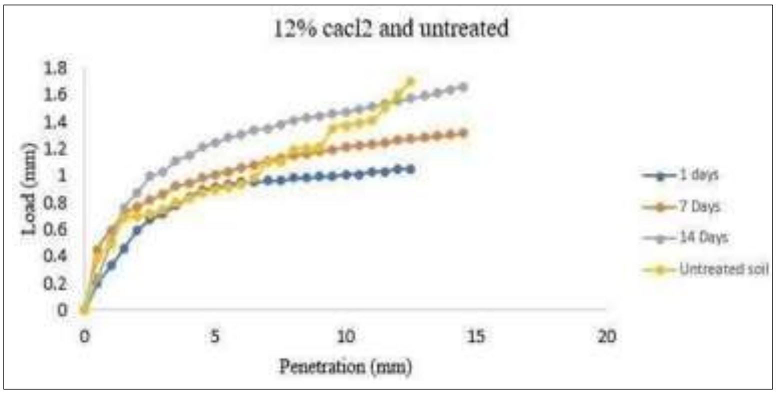

Fig. 4 shows the Load v/s penetration curve for untreated soil sample and treated soil sample with optimum percentage of calcium chloride for 1, 7 and 14 days of curing.

5. Percentage increase in CBR (Unsoaked and soaked) of soil due to stabilization of soil (Fly ash, calcium chloride)

Table 3 shows percentage increase in CBR (Soaked and Unsoaked) of soil due to stabilization of soil by

various stabilization i.e., optimum doses of calcium chloride and fly ash and only dosage of calcium chloride.
It is observed that when the soil is treated with combination of optimum doses of calcium chloride (12%) and fly ash (15%), it gives higher CBR (Unsoaked and Soaked) values as compared to untreated soil i.e., it is increased by 110.75% for unsoaked and 88.39% for soaked during 14 days of curing period.

Table 3. Percentage increase in CBR (Unsoaked and Soaked) due to stabilization of soil by Calcium chloride and fly ash

Sr. No.	Stabilizer (in %)	Curing Period in Days	% Increase in CBR
1	Unsoaked Only 12% CaCl2	1	No change
		7	10.47
		14	38.86
2	Unsoaked CaCl2 (12%) and fly ash (15%)	1	82.33
		7	34.33
		14	110.75
3	Soaked CaCl2 (12%) and fly ash (15%)	1	No change
		7	32.34
		14	88.39

VI. CONCLUSIONS

Based on the experimental investigation, following conclusion are drawn:

1. Maximum MDD is achieved after treating the soil sample with 9% Calcium Chloride and the percent increase is 35.23% as compared with untreated soil sample.
2. The Unconfined compressive strength of soil treated with Calcium chloride (12%) is increased by 20.83% as compared to untreated soil.
3. Addition of fly ash and Calcium Chloride improved the workability of the soil considerably. Due to addition of fly ash and calcium chloride the physical properties of the black cotton soil are improved.
4. The Unconfined compressive strength of soil treated with fly ash is increased by 28.76% as compared with untreated soil.
5. The Unconfined compressive strength of soil treated with combination of calcium chloride (12%) and fly ash (15%) is increased by 60.62% as compared to untreated soil.
6. The increase of compressive strength in certain percent was observed when the soil was treated with combination of 15% Fly ash and 12% Calcium Chloride is maximum in both UCS and C.B.R (soaked and unsoaked).
7. The CBR value of soil can be improved with application of fly ash and calcium chloride.
8. The CBR value (unsoaked) of soil treated with combination of calcium chloride (12%) and fly ash (15%) is increased by 110.75%.
9. The CBR value (soaked) of soil treated with combination of calcium chloride (12%) and fly ash (15%) is increased by 88.39%.

REFERENCES

1. Seeliya. A. and Mittal. S. K., “An experimental study of black cotton soil stabilized with rice

husk ash, cement clink dust and calcium chloride‖, International Journal of Advance Research, Ideas and Innovations in Technology, ISSN: 2454-132X ,Impact factor: 4.295 (Volume 4, Issue 5) (2018),728-732, www.ijariit.com.

2. Sharo, A.A., Alhowaidi. Y and Al-Tawaha M. S. (2018), ―Feasibility of Calcium Chloride Dehydrate as Stabilizing Agent for Expansive Soil‖, Journal of Engineering Science and Technology Review 11 (6) (2018) 156-161, www.jestr.org
3. Chhangani. A, Meshram, K.V and Dangi. N., ―Use of calcium chloride for soil stabilization and dust suppression of unpaved roads‖, International Journal of Advance Research, Ideas and Innovations in Technology, ISSN: 2454-132X Impact factor: 4.295(Volume 4, Issue 3), (2018),1402-1406, www.ijestr.org.
4. Purnanandam, K. and Renuka, G., ―A laboratory study on the stabilization of expansive soil using marble powder and calcium chloride‖, Journal of Emerging Technologies and Innovative Research (JETIR), ISSN-2349-5162 Volume 5, Issue 8, (2018),679-686, www.jetir.org.
5. Kumar, J. Sharma, A. and Sharma, N., ―Experimental Study of Clayey Soil Stabilized with Rice husk ash and Calcium Chloride‖, International Journal of Advance Research, Ideas and Innovations in Technology, Vol. 8, Issue 4, April 2019,3893-3899, Visit: www.ijirset.com.
6. Saravanakumar, K., Kandasamy, G. Karthikeyan, S., Kaviyarasan. M. and Mohan Raj, M. Assistant Professor, ―An experimental study on the soil stabilization method by adding the calcium chloride and the sodium chloride‖, international journal of current engineering and scientific research,ISSN (PRINT): 2393-8374, (ONLINE): 2394-0697, VOLUME-6, ISSUE-3, 2019,119-124 ,www. Ijcesr.com.
7. Singh, J., Singh, U.K. and Singh, R.K., ―Stabilization of Clayey Soil using Gypsum and Calcium Chloride‖, International Journal of Advance Research, Ideas and Innovations in Technology, ISSN: 2277- 3878 (Online), Volume-9 Issue-2,668-673, www.ijestr.org.
8. Han, S., Wang, B, Gutierrez, G., Shan, Y. and Zhang Y., ―Laboratory Study on Improvement of Expansive Soil by Chemically Induced Calcium Carbonate Precipitation‖,**MDPI** (Multidisciplinary Digital Publishing Institute),(2021),1-23, https://www.mdpi.com/journal/materials