

# Effect of Calcium Chloride Solution on Engineering Properties of Black Cotton Soil

Sangita Lajurkar<sup>1</sup>, Dr. Y. S. Golait<sup>2</sup>, Dr. S. R. Khandeshwar<sup>3</sup>

Research Scholar, Yeshawantrao Chavan College of Engineering, Nagpur, Maharashtra, India<sup>1</sup>

Professor Emeritus, Ramdeobaba College of Engineering and Management, Nagpur, Maharashtra, India<sup>2</sup>

Prof., Dept. of Civil Engg., Yeshawantrao Chavan College of Engineering, Nagpur, Maharashtra, India<sup>3</sup>

**ABSTRACT:** Expansive soil popularly known as black cotton soil is very problematic for Civil engineering structure. Its swell-shrink behavior with seasonal moisture content change cause serious damages to the structure founded on it. This behavior of black cotton soil necessitates in-situ ground improvement with respect to increasing the bearing capacity and reducing swelling. This paper reveals the efficacy of calcium chloride solution in improving swell and strength properties of Black Cotton Soil by physical diffusion technique.

**KEYWORDS:** Expansive soil, Swell-shrink mechanism, Physical Diffusion, Free swell ratio.

## I. INTRODUCTION

Natural expansive soils have been encountered in arid and semiarid region in the world. In India it is commonly known as Black Cotton soil because of their colour and their suitability for growing cotton. Black cotton soil is one of the major regional soil deposits in India covering about 20% of the area of country [1] [2] and are predominantly located in the Deccan trap covering the states of Maharashtra, Gujarat, Madhya Pradesh, Karnataka, Andhra Pradesh, Tamil Nadu, Uttar Pradesh and Rajasthan. Black cotton soil deposits are boon to farmer but problematic to Civil engineers due to its cyclic volumetric change with seasonal moisture fluctuation accompanied by the loss of strength with increase in moisture content [3][4]. Because of alternate swell-shrink behaviour, there is considerable damage to structures founded on them. The annual cost of damage to the civil engineering structures is estimated at £150 million in the UK, \$1000 million in the USA and many billions of pounds worldwide [5].

In the field construction activities many time civil engineer has to encounter with this expansive soils because in field either it used as construction material e.g. dams, embankment, etc. or as foundation material for transferring the structural loads through foundation elements. This necessitates proper remedial measure to modify the soil with respect to control on swelling and increase in strength. Many researchers and investigators have developed various approaches and methods of improving the undesirable characteristics of expansive soil. This paper high light on various approaches reported in available literature for reasonable solution and effect of diffusion of calcium chloride solution on swell and strength property of black cotton soil.

## II. LITERATURE REVIEW

Some of the probable methods for ensuring trouble-free performance of the structures on expansive soil are use of under reamed piles[6], provision of CNS layers or alternate cushion of other specified materials[2]. In lieu of composition specified for CNS material different alternative and better compositions of material to be used in the cushion layer (CSS) are also suggested[7], granular anchor piles (GPA)[8], use of stone columns, sand piles[9][10] etc. Expansive soil being clayey soil, techniques like grouting etc. is not feasible for the purpose. Also though various admixtures like lime, cement, fly ash etc. are very effective in soil improvement their use in in-situ ground improvement is practically impossible. Expansive soil stabilization by mixing various chemical additives prove to be effective alternative solution to overcome the undesirable swell shrink behaviour and low bearing capacity[11]. Chemical modification by adding lime has been in practice for the last three decades. The CaCl<sub>2</sub> could be an effective

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alternative to conventional lime treatment due to its ready dissolvability and to supply adequate calcium ions for exchange reactions [12],[13],[14],[15],[16],[17],[18],[19],[20],[21],[22],[23],[24]. In the available literature expansive soil was stabilized by adding chemicals but for in-situ improvement it becomes practically impossible. However the use of water soluble chemicals is considered feasible to improve expansive soil by diffusion technique in this case. Unfortunately, the review of literature on this aspect reveals that very limited work is reported and this diffusion method is inadequately investigated [25],[26],[27]. The proposed work is meant for contributing to some extent in this inadequately investigated domain of in-situ improvement of expansive clay sites by diffusion of calcium chloride solutions of different concentration.

## III. LABORTARY INVESTIGATIONS

The laboratory investigations were carried out on reconstituted expansive soil samples to study the diffusion effects of calcium chloride solution of different concentration. The diffusion effects on the final volumetric strain and unconfined compressive strength exhibited by wet soil at the end of four days diffusion were studied.

### A. Soil

Expansive black cotton soil collected from the neighborhood of Nagpur city was used. Its basic properties are: liquid limit  $w_L = 58.8\%$ , plastic limit  $w_p = 33.16\%$   $I_p = 25.64\%$ , clay and silt content 86%, Free swell ratio (FSR) = 1.522 and specific gravity = 2.69.

### B. Calcium chloride ( $\text{CaCl}_2$ )

Commercially available calcium chloride ( $\text{CaCl}_2$ ) was selected for the study.  $\text{CaCl}_2$  was used as chemical to stabilize the soils. Six different concentrations of  $\text{CaCl}_2$  solutions (0.5% to 3.0% with increment of 0.5%) were used in this study and distilled water is indicated as 0%. Many investigators have established the effectiveness of calcium chloride when the soil is to be used as construction material [7, 8]. Calcium chloride is highly soluble in water and calcium cations can easily replace other adsorbed cations in the adsorption complex of clay particles thereby facilitating the Base Exchange phenomenon take place.

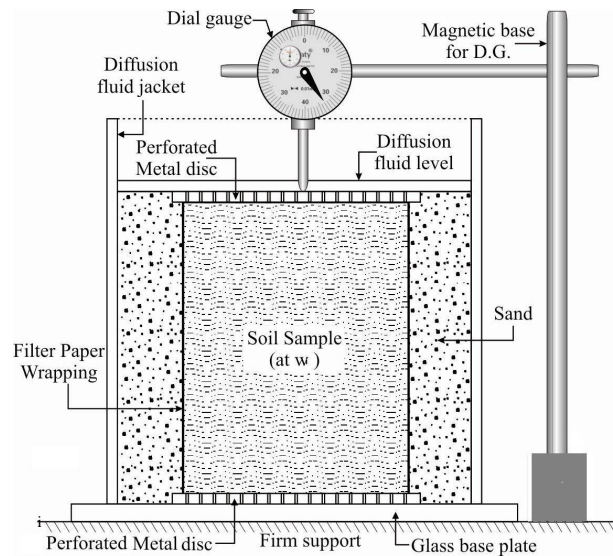
### C. Procedure

Pulverized black cotton soil passing through 425 $\mu$  was mixed with distilled water to attain its water content at approximately 40-45 percent (midway between its plastic limit  $w_p$  and liquid limit  $w_L$ ). Wet mass was kept in airtight plastic bag for minimum ten hours for uniform distribution of water. Wet soil was then pressed into fifteen PVC open ended tubes each of 4.5cm inside diameter and 9 cm height for getting identical wet cylindrical soil samples. All the samples were air dried in shade, making them upside down frequently. Drying of initially fully saturated plastic soil sample caused its gradual shrinking (without development of cracks within) and consequent reduction in its water content and the degree of saturation. Eight samples were dried for 7 days. Out of the eight samples one was tested for determining its initial water content and dry unit weight. The remaining seven were kept for diffusion of fluids (i.e. water, and solutions of seven different concentrations) for 4 days in separate test assemblies as shown in Fig. 1. The test assembly ensured laterally confined state of sample at all stages. The increase in height of sample ( $\Delta h$ ) with respect to its initial height ( $h$ ) was observed from the dial gauge readings during 4 days of diffusion period. Samples were then taken out and after removal of circumferential wrapping, they were tested for UCS.

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**Fig. 1** Experimental Setup

## IV. RESULTS AND DISCUSSION

The laterally confined soil samples when immersed in seven different concentration calcium chloride solution caused diffusion laterally. During diffusion and simultaneous interaction of chemicals with clay particles, the increase in water content and vertical swell took place. The maximum change in water content ( $\Delta w$ ) and the maximum increase in the length of the samples were noted. The maximum volumetric strain due to swelling is expressed as  $\Delta h/h$ . After completion of diffusion process the unconfined compressive strengths of samples were determined. These results are presented in Table 1.

**TABLE 1** RESULTS OF VOLUMETRIC STRAIN (SWELLING) AND UNCONFINED COMPRESSIVE STRENGTH

Sample	Concentration of $\text{CaCl}_2$	Initial Water Content before diffusion	Final Water content after diffusion	Change in water content $\square w\%$	Swelling	% Reduction in swelling	UCS $\text{Kg/cm}^2$	% increase in UCS
S1	0% $\text{CaCl}_2$ (Water)	23.88%	39.55%	16%	12.987	---	0.34	--
S2	0.5 % $\text{CaCl}_2$		36.76%	13%	10.209	21.391	0.57	67.01543
S3	1.0 % $\text{CaCl}_2$		36.03%	12%	9.596	26.110	0.60	76.95002
S4	1.5 % $\text{CaCl}_2$		33.09%	9%	8.515	34.433	0.64	87.74845
S5	2.0 % $\text{CaCl}_2$		32.86%	9%	9.095	29.968	0.72	113.1328
S6	2.5% $\text{CaCl}_2$		38.06%	14%	11.196	13.790	0.49	44.05478
S7	3.0 % $\text{CaCl}_2$		38.52%	15%	12.427	4.316	0.41	19.8776

In Table no.1, 0% concentration represent water and the concentration of solution were ranging from 0.5% to 3.0%.

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## Swelling Behaviour during Diffusion

The sample at the initial water content of 23.88% immersed in different concentration calcium chloride solution finally attained water content 39.55%, 36.76%, 36.03%, 33.09%, 32.86%, 38.06% and 38.52% with  $\Delta w$  of 15.67%, 12.88%, 12.15%, 9.21%, 8.98%, 14.18% and 14.64% as shown in Fig. 2. which result maximum swelling expressed by  $\Delta h/h\%$  values are 12.99%, 10.21%, 9.6%, 8.52%, 9.1%, 11.2% and 12.43% respectively as shown in Fig 3. Comparing to all concentration, the diffusion of 1.5% & 2% concentration solutions caused much smaller values of  $\Delta w$  and  $\Delta h/h$ . Increase in water content after diffusion of soil in different concentration of calcium chloride solution is as shown in Fig 2. It is to be observed from Table 1 and Fig 2 sample diffused in pure water i.e. 0% conc. attain high value of final water content whereas for sample diffused in 1.5% and 2% concentration  $\text{CaCl}_2$  solution shows much smaller value of final water content after diffusion and thus resulting maximum swelling.

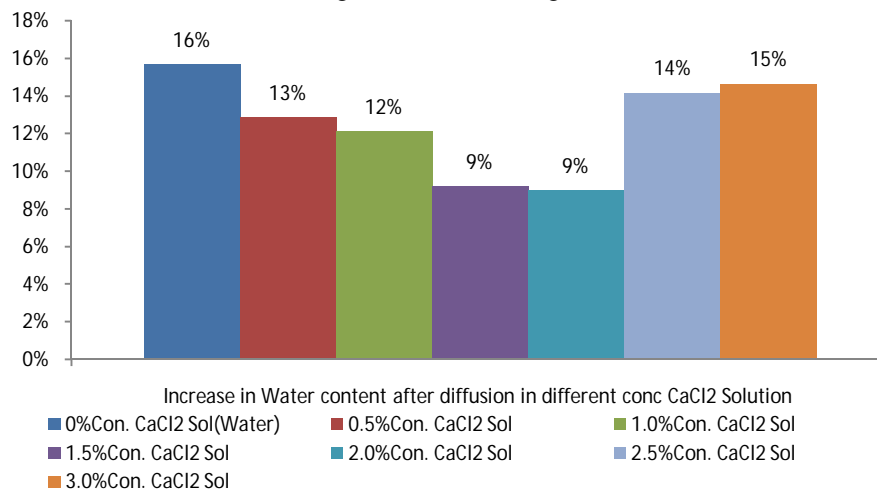


Fig. 2 Increase in water content after diffusion in different concentration  $\text{CaCl}_2$  solutions

From the above Fig. 2 it is to be observed that there is highest increment in water content i.e. 16 % for sample diffused in water and lowest increment in water content i.e. approximately 9% for the sample diffused in 2% concentration calcium chloride solution.

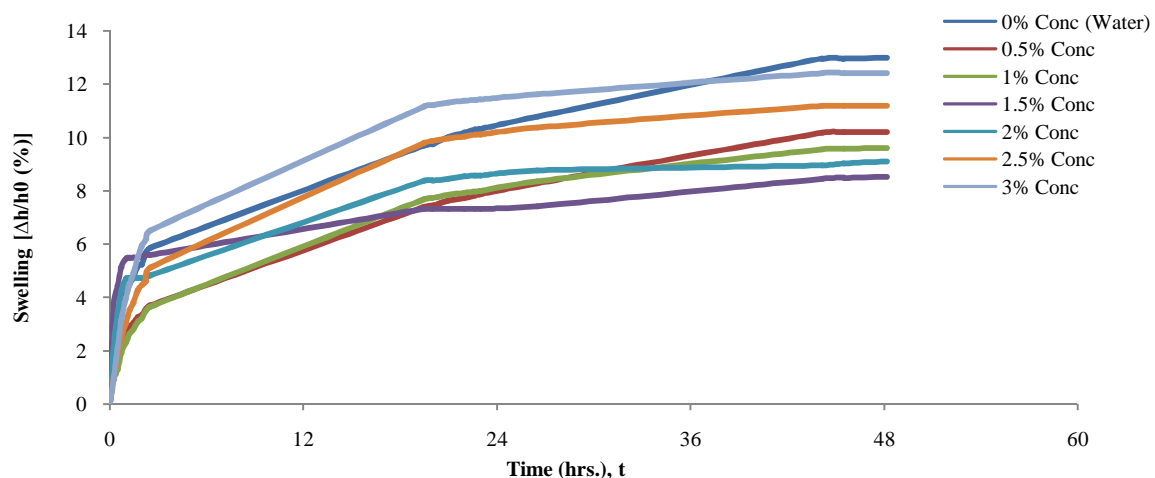


Fig. 3 Swelling behaviour of soil during diffusion in different concentration  $\text{CaCl}_2$  solutions

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The swelling characteristic with respect to time as shown in Fig 3 indicates that although the maximum values of  $\Delta h/h$  are significantly different for seven solutions. The swelling behaviour of the investigated soil is almost identical. The swelling for diffusion of six concentration solutions is compared with swelling affected by water. The decrease in volumetric strain is found to maximum in 1.5% and 2% concentration solution.

## Strength Characteristics of Treated Soil

The values of unconfined compressive strength of samples after diffusion of fluids are given in Table 1. The value of UCS is observed to be increases as the concentration of chemical increases up to the concentration 2%. But it is observed that the value of UCS is start decreasing after 2.0% concentration solution. Thus 2%  $\text{CaCl}_2$  was proved to be the effective in improving strength of expansive soil. The increase in UCS was observed as 67.02%, 76.95%, 87.74%, 113.13%, 44.05% and 19.88% for treatments with different concentration solutions of  $\text{CaCl}_2$  respectively. The Fig.4 shows this stress strain behaviour of treated soil samples for different concentration.

Desai and Oza [13] and some other investigators reported that  $\text{CaCl}_2$  works not only by cation exchange but also by intercalation whereby  $\text{CaCl}_2$  enters into the intermiscellar spaces of clay mineral structure, thus bringing about significant modification in clay behavior. Numerous laboratory studies in the past [22][26] have revealed positive effects of  $\text{CaCl}_2$  and lime on improvement of strength of expansive soil. The study presented in this paper substantiates this generally established fact in respect of in-situ expansive ground improvement by diffusion process also.

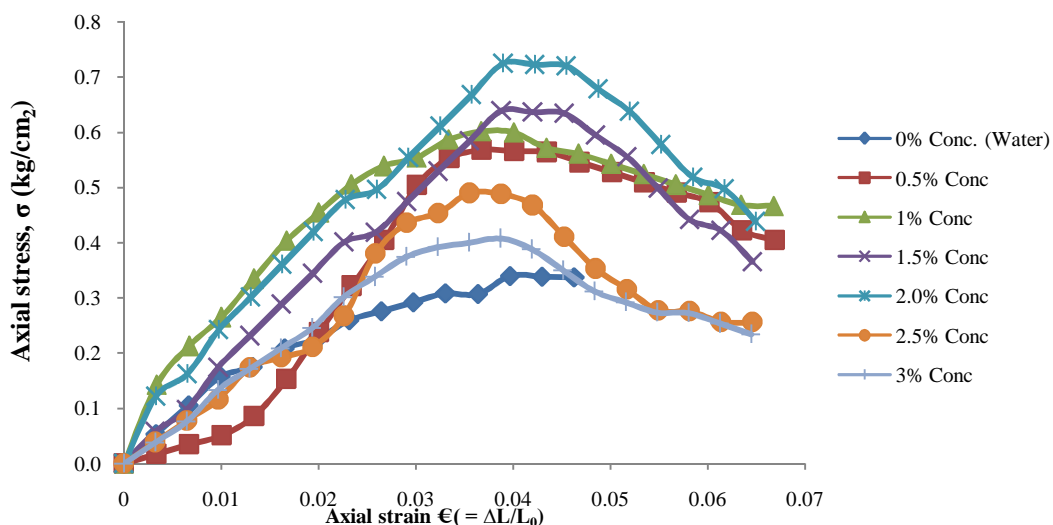


Fig. 5 Increase in UCS treated samples by  $\text{CaCl}_2$  solutions of different concentration.

Above Fig. 5 indicate stress-strain behaviour of sample treated with different concentration solutions. After treatment soil become stiffer and shows greater strength comparing to non treated sample (i.e. sample diffused in water). From Fig.4 it is to be observed that sample treated by 1.5% & 2% concentration solution attain stiffness earlier than other five concentrations and also achieve higher UCS value.

## V. CONCLUSION

The following important conclusions are drawn from the laboratory investigations:

- The diffusion of chemical solution in expansive soil is possible and it develops the positive effects in respect of improving the strength characteristics and reducing the swelling behaviour.
- Different concentrations of calcium chloride have different effects on these values of volumetric strain  $\Delta h/h$  and UCS.

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- Significant improvement in UCS value was observed up to 2% concentration of  $\text{CaCl}_2$  solution and thereafter it will start decrease.

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