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COMPARATIVE STUDY ON EFFECT OF $CACL_2$ AND COMBINE INJECTION OF $CACL_2$ AND NAOH ON EXPANSIVE SOIL BY DIFFUSION TECHNIQUE

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Abstract: *An expansive soil shows high volumetric changes with changes in water content. When they imbibe water during monsoon, they expand and on evaporation thereof in summer, they shrink. Because of this alternate swelling and shrinkage, structures fonded on them are severally damaged and it also has very low strength. For civil engineer it becomes a challenge to deal with this expansive soil. Extensive research work has been done on expansive soil stabilization by various techniques. Among all these technique chemical stabilization proved to be very popular and widely accepted. This paper appreciates in-situ stabilization of clay soil deposit by using $CaCl_2$ and NaOH solution. In the present paper effect of diffusion of only $CaCl_2$ solution and $CaCl_2$ solution followed by NaOH solution were studied and compared. Two different dosages of chemicals (1.5% and 2.0%) were allowed to get diffused into the soil to study the effect of these chemicals on the compressive strength, and swell properties. For higher dosage of chemicals, improvement in the strength properties of clay soil was found to be more. It is observed that the soil treated with combination of CaCl2/NaOH not much more effective than $CaCl_2$ alone.*

Keywords: *Expansive soil, Swell-shrink mechanism, Diffusion, Free swell Ratio*

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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 encountered 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 and NaOH solution on swell and strength property of black cotton soil.

II. LITERATURE REVIEW

In field soil is used as construction material or as a foundation bed, civil engineer faces many difficulties while dealing with the site with expansive soil deposits due to its swell-shrink nature during dry-wet season and very low shear strength when imbibe water in it. Some of the probable methods for ensuring trouble-free performance of the structures on such expansive soil are, use of under reamed piles, provision of CNS (layers or alternate cushion of other specified materials, granular anchor piles (GPA), use of stone columns, sand piles etc [6,4,7,8,9,10]. Expansive soil being clayey soil, techniques like grouting etc. is not feasible for the purpose. Apart from these techniques, stabilization of expansive soils with various additives including fly ash, lime, cement and calcium chloride [10,11,15,14] has also met with considerable success but their use in in-situ ground improvement is practically impossible. However the use of water soluble chemicals is considered feasible in this case. Unfortunately, the review of literature on this aspect reveals that very limited work of preliminary nature with limited objectives is reported. The present work is meant for contributing to some extent in this inadequately investigated domain of in-situ improvement of expansive clay sites by diffusion of chemical solutions.

III. LABORATORY INVESTIGATIONS

The laboratory investigations were carried out on reconstituted expansive soil samples to study the diffusion effects of calcium chloride solution alone and sequential diffusion of CaCl2 followed by NaOH 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

The soil used in this study is a Black Cotton Soil (dark grey in colour) collected from Raut Nagar East Nagpur. The black cotton soil was collected by method of disturbed sampling after removing the top soil at 1m depth and transported in sacks to the laboratory. The soil was air dried, pulverized and sieved with Indian Standard sieve 425µ as required for laboratory investigations.

Index properties of this soil are as shown in Table 1.

Table 1: Index Properties of Expansive Soil

Soil	Physical Properties										
	Ph	G	w_L (%)	w_P (%)	I_P (%)	w_S (%)	FSR	FSI	Sand	Silt	Clay
BCS	8.66	2.71	58.80	33.16	25.64	12.29	1.522	59%	10.79	30.18	58.21

B. Calcium chloride (CaCl2)

Commercially available calcium chloride (CaCl2) was selected for the study. It consisted of Many investigators have established the effectiveness of calcium chloride for stabilization of soil when the soil is to be used as construction material [10, 11].Calcium chloride is essentially water retentive in mechanically stabilised bases and surfacing. Being hygroscopic and deliquescent the salt absorbs moisture from the atmosphere and retains it. It 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 to take place. It lowers the vapour pressure and increases the surface tension. Besides, it acts as soil flocculent.

C. Sodium hydroxide (NaOH)

Laboratory based NaOH was used for the laboratory investigations. NaOH is a white, odorless, nonvolatile material. It reacts with water and generates high heat, but not combustible due to this heat broken bond between particles and change the property of clayey soil. Its advantage are that it can easily react with water which a results into a powerful compaction aid and giving a higher density for same comp active effort, soil is react with NaOH highly due to rich in aluminum.[20]

IV. PROCEDURE

Pulverized black cotton soil passing through 425µ was mixed with distilled water to attain its water content at approximately 40-45 percent (midway between its plastic limit wp and liquid limit wL). 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. Six samples were dried for 7 days. Out of the six samples one was tested for determining its initial water content and dry unit weight. The remaining four were kept for diffusion of fluids (i.e. water, and solutions of chemical of different concentrations) for 4 days in separate test assemblies as shown in Fig. 1. In this diffusion test series out of five samples, one sample was allowed to diffuse in water, two samples were in CaCl2 solution of 1.5% and 2%. Remaining two samples were get diffused for first five day with 1.5 % and 2% Cacl2 solutions and thereafter it was followed by 1.5% and 2% NaOH solution respectively. The test assembly ensured laterally confined state of sample at all stages. The increase in height of sample (Δh) with respect to its initial height (h) was observed from the dial gauge readings during 10 days of diffusion period. Samples were then taken out and after removal of circumferential wrapping, they were tested for UCS.

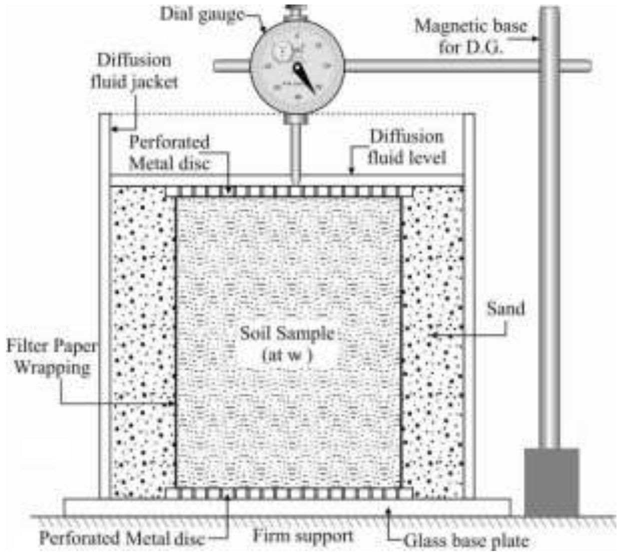


Fig. 1 The Experimental Setup

V. RESULTS AND DISCUSSION

The laterally confined soil samples when immersed in different diffusion media 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

(Δw) 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 2 Results of Volumetric Strain (Swelling) and Unconfined Compressive Strength

Samp le	Concentration of Chemical	w_i (%)	w_f (%)	Δw (%)	Dry Unit Wt γ_{di} gm/cm^3	γ_{df} gm/cm^3	Swelling $\Delta h/h_0$ (%)	UCS Kpa
A	Water		37.67	13.7	1.522	1.362	5.986	36.838
B	1.5 % $CaCl_2$		32.00	8.03	1.522	1.457	3.155	94.006
C	2.0 % $CaCl_2$	23.97	32.00	8.03	1.522	1.463	3.154	101.936
	1.5 % $Cacl_2$ +		32.43	8.46	1.522	1.403		

D	1.5%NaOH					3.719	58.723
E	2.0 % $CaCl_2$ + NaOH	32.67	8.7	1.522	1.444	3.611	86.453

Swelling Behaviour during Diffusion

The samples at the initial water contents of 23.97% immersed in water finally attained 37.67% with Δw of 13.7%. The resulting maximum swelling as expressed by Δh/h values 5.986 %. As compared to this the diffusion of chemical solutions caused much smaller values of Δw and Δh/h as shown in Table 1. It is cleared from the result for 1.5% and 2% CaCl2 solution considerable reduction in swelling i.e. was observed as compared to water, this swelling characteristic as shown in Fig 2 indicates that although the maximum values of Δh/h are significantly different for different concentration of CaCl2 and combine CaCl2 and NaOH solutions .

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

It was observed from the test result, combine injection of CaCl2 and NaOH indicated relatively smaller reduction in swelling as compared to that for CaCl2 solutions.

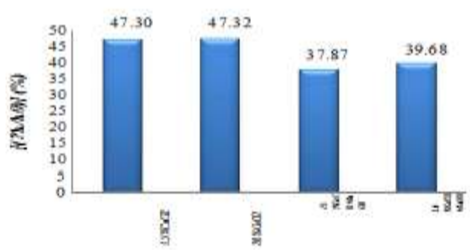


Fig. 2 Decrease in swelling during diffusion of chemical solutions

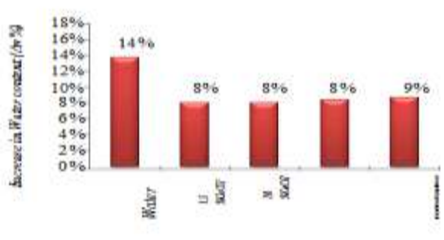


Fig. 3 Increase in water content during diffusion of different diffusion media

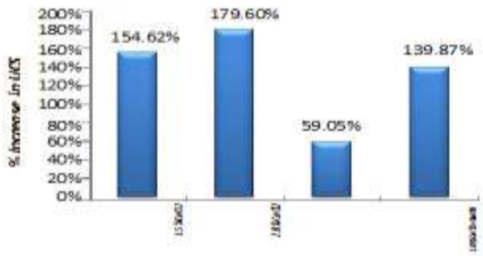
Strength Characteristics of Treated Soil

The values of unconfined compressive strength of samples after diffusion of fluids are given in Table 2. The value of UCS is observed to be higher for 2% CaCl2 concentration. But value of UCS for combine injection of CaCl2 and NaOH was less as compared to CaCl2. From the result 2% CaCl2 was proved to be the effective in improving strength of expansive soil. The increase in UCS was observed as 154.62%, 179.60%, 59.05% and139.87% for treatments with 1.5% CaCl2 , 2.0%

CaCl2, 1.5% CaCl2 + NaOH and 2.0% CaCl2+ NaOH solutions respectively as shown in Figure 4. The Figure 5 shows this stress strain behaviour of untreated and chemically treated soil samples.

Desai and Oza [11] and some other investigators reported that CaCl2 works not only by cation exchange but also by intercalation whereby CaCl2 enters into the intermiscellar spaces of clay mineral structure, thus bringing about significant modification in clay behavior. Numerous laboratory studies in the past [7] have revealed positive effects of CaCl2 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.

As reported by Thygraj and Sudhakar [21], Bhuvaneshwar and Thygraj [22] on sequential mixing of CaCl2 and NaOH cause precipitation of lime which results in increase in unconfined compressive strength. The present research also reveal the similar findings on diffusion CaCl2 and NaOH but comparing to effect of CaCl2 alone it is marginally less effective.



'ig. 4 Percentage increase in UCS of treated samples by different chemical solutions as a diffusion media.

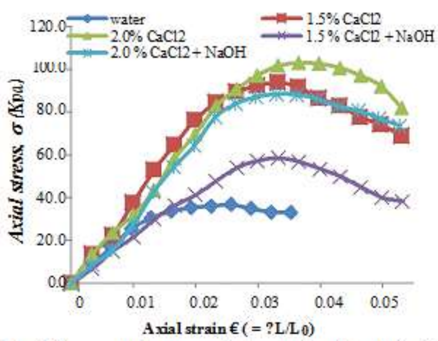


Fig. 5 Stress-strain curve of untreated and treated soil specimen with different chemicals

VI. 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 behavour.

Different concentrations of calcium chloride have similar effect on the values of volumetric strain Δh/h but different effect on value of UCS.

Significant improvement in UCS value was observed for 2% concentration of CaCl2 solution.

The combine injection of CaCl2 + NaOH can also help in reducing Δh/h value and improvement in value of UCS.

Volumetric strain and UCS results show that the diffusion of CaCl2 than the sequential diffusion of CaCl2 followed by NaOH .

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