STUDY ON PERFORMANCE OF CHEMICALLY STABILIZED EXPANSIVE SOIL

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ABSTRACT

Expansive soils, such as black cotton soils, are basically susceptible to detrimental volumetric changes, with changes in moisture. This behaviour of soil is attributed to the presence of mineral montmorillonite, which has an expanding lattice. Understanding the behaviour of expansive soil and adopting the appropriate control measures have been great task for the geotechnical engineers. Extensive research is going on to find the solutions to black cotton soils. There have been many methods available to controlling the expansive nature of the soils. Treating the expansive soil with electrolytes is one of the techniques to improve the behaviour of the expansive ground. Hence, in the present work, experimentation is carried-out to investigate the influence of electrolytes i.e., potassium chloride, calcium chloride and ferric chloride on the properties of expansive soil.

KEYWORDS: *Expansive soil, Calcium Chloride, Potassium Chloride, Ferric Chloride*

I. INTRODUCTION

Expansive soil is one among the problematic soils that has a high potential for shrinking or swelling due to change of moisture content. Expansive soils can be found on almost all the continents on the Earth. Destructive results caused by this type of soils have been reported in many countries. In India, large tracts are covered by expansive soils known as black cotton soils. The major area of their occurrence is the south Vindhyachal range covering almost the entire Deccan Plateau. These soils cover an area of about 200,000 square miles and thus form about 20% of the total area of India. The primary problem that arises with regard to expansive soils is that deformations are significantly greater than the elastic deformations and they cannot be predicted by the classical elastic or plastic theory. Movement is usually in an uneven pattern and of such a magnitude to cause extensive damage to the structures resting on them.

Proper remedial measures are to be adopted to modify the soil or to reduce its detrimental effects if expansive soils are indentified in a project. The remedial measures can be different for planning and designing stages and post construction stages. Many stabilization techniques are in practice for improving the expansive soils in which the characteristics of the soils are altered or the problematic soils are removed and replaced which can be used alone or in conjunction with specific design alternatives. Additives such as lime, cement, calcium chloride, rice husk, fly ahs etc. are also used to alter the characteristics of the expansive soils. The characteristics that are of concern to the design engineers are permeability, compressibility and durability. The effect of the additives and the optimum amount of additives to be used are dependent mainly on the mineralogical composition of the soils. The paper focuses about the various stabilization techniques that are in practice for improving the expansive soil for reducing its swelling potential and the limitations of the method of stabilization there on.

Modification of BC soil by chemical admixture is a common method for stabilizing the swell-shrink tendency of expansive soil [5]. Advantages of chemical stabilization are that they reduce the swell-shrink tendency of expansive soils and also render the soils less plastic. Among the chemical stabilization methods for expansive soils, lime stabilization is mostly adopted for improving the swell-shrink characteristics of expansive soils. The reaction between lime and clay in the presence of water can be divided in to two distinct processes [20]. The use of calcium chloride in place of lime, as calcium chloride is more easily made into calcium charged supernatant than lime [40]. The electrolytes like potassium chloride, calcium chloride and ferric chloride can be effectively used in place of the conventionally used lime, because of their ready dissolvability in water and supply of adequate cations for ready cation exchange ([55],[56],[42]).

Calcium chloride is known to be more easily made into calcium charged supernatant than lime an helps in ready cation exchange reactions [44]. The $CaCl_2$ might be effective in soils with expanding lattice clays [33]. The stabilization to the in-situ soil using KOH solution was made and revealed that the properties of black cotton soils in place can be altered by treating them with aqueous solution of KOH [27]. The laboratory tests reveals that the swelling characteristics of expansive soils can be improved by means of flooding at a given site with proper choice of electrolyte solution more so using chloride of divalent or multivalent cations [19]. The influence of $CaCl_2$ and KOH on strength and consolidation characteristics of black cotton soil is studied [55] and found an increase in the strength and reduction in the settlement and swelling. 5% $FeCl_3$ solution to treat the caustic soda contaminated ground of an industrial building in Bangalore [55]. In this work an attempt made to study the effect of electrolytes like KCl, $CaCl_2$ and $FeCl_3$ on the properties of expansive soil.

The bibliography on stabilization of soil and calcium chloride giving its wide use in highways[58]. [30],[18], [53] has stated that $CaCl_2$ enjoyed its wide use as dust palliative and frost control of subgrade soil.

When lime stabilization is intended to modify the in-situ expansive soil bed it is commonly applied in the form of lime piles ([24],[6],[23],[7],[1],[10],[65],[18],[51]) or lime slurry pressure injection (LPSI) ([66],[63],[36],[58],[26],[9],[3],[59]).

Numerous investigators,([20], [34], [64], [43], [15], [41], [35], [45], [29], [37], [45], [4], [22], [2], [31], [39], [32]), have studied the influence of lime, cement, lime-cement, lime-flyash, lime –rice-husk-ash and cement – flyash mixes on soil properties, mostly focusing on the strength aspects to study their suitability for road bases and subbasess. As lime and cement are binding materials, the strength of soil-additive mixtures increases provided the soil is reactive with them. However, for large-scale field use, the problems of soil pulverization and mixing of additives with soil have been reported by several investigators ([20],[58],[9],[5],[44]).

It is an established fact that, whenever a new material or a technique is introduced in the pavement construction, it becomes necessary to experiment it for its validity by constructing a test track, where the loading, traffic and other likely field conditions are simulated. Several test track studies ([38],[49],[54],[50],[12],[25],[8],[14],[17],[52]), have been carried out in many countries to characterize the pavement materials and to assess the effectiveness of remedial techniques developed to deal with the problematic condition like freeze-thaw, expansive soil and other soft ground problems.

Recent studies ([60],[28]), indicated that $CaCl_2$ could be an effective alternative to conventional lime used due to its ready dissolvability in water and to supply adequate calcium ions for exchange reactions. [13] Studied the use of KCl to modify heavy clay in the laboratory and revealed that from engineering point of view, the use of KCl as a stabilizer appears potentially promising in locations where it is readily and cheaply available. In the present work, the efficiency of Potassium Chloride (KCl), Calcium Chloride ($CaCl_2$) and Ferric Chloride ($FeCl_3$), as stabilizing agents, was extensively studied in the laboratory for improving the properties of expansive soil.

The experiences of various researchers in the field as well as laboratory chemical stabilization have been presented briefly in the above section. Experimental study methodologies for laboratory are presented in the following section.

II. EXPERIMENTAL STUDY

2.1. Soil

The black cotton soil was collected from Morampalem, a village nearer to Amalapuram of East Godavari District in Andhra Pradesh in India. The physical properties of the soil are given in Table 1.

Table.1: Physical Properties of Expansive Soil

Property					
Grain Size Distribution	Sand (%)	Silt (%)	Clay (%)		
	2	22	76		
Atterberg Limits	Liquid limit (%)	Plastic limit (%)	Plasticity Index	Shrinkage Limit (%)	
	85	39	46	12	
Classification	CH	Specific Gravity	2.68	Free Swell Index	140 %
Compaction properties	Maximum Dry Density (g/cc)	Optimum moisture Content (%)	Soaked CBR of sample prepared at MDD & OMC	2	
	1.42	26.89			
Permeability of the sample prepared at OMC & MDD	1.89×10^{-7} cm/sec	Shear Strength Parameters of the sample prepared at OMC & MDD	Cohesion (C) (kg/cm²)	Angle of internal friction (ø)	
			0.56	2^0	

2.2. Chemicals

Three chemicals of commercial grade, KCl, $CaCl_2$ and $FeCl_3$ are taken in this study. The quantity of the chemical added to the expansive soil was varied from 0 to 1.5% by dry weight of soil.

2.3. Test Program

Electrolytes like KCl, $CaCl_2$ and $FeCl_3$ are mixed in different proportions to the expansive soil and the physical properties like liquid limit, plastic limit, shrinkage limit and DFS of the stabilized expansive soil are determined to study the influence of electrolytes on the physical properties of the expansive soil. Then stabilized expansive soil with different percentage of electrolytes are tested for engineering properties, like permeability, compaction, unconfined compressive strength and shear strength properties to study the influence of electrolytes on expansive soil.

In this section the details of laboratory experimentation were presented. Analysis and discussion of test results will be presented in the next section.

III. RESULTS AND DISCUSSION

3.1. Effect of Additives on Atterberg's Limits

The variation of liquid limit values with different percentages of chemicals added to the expansive soil is presented in the Fig. 1. It is observed that the decrease in the liquid limit is significant upto 1% of chemical added to the expansive clay for all the chemicals, beyond 1% there is a nominal decrease. Maximum decrease in liquid limit for stabilized expansive clay is observed with the chemical $FeCl_3$, compared with other two chemicals, KCl and $CaCl_2$. Nominal increase in plastic limit of stabilized expansive clay is observed with increase the percentage of the chemical (Fig. 2).

Fig. 3 shows the variation of plasticity index with the addition of chemicals to expansive clay. The increase in the plastic limit and the decrease in the liquid limit cause a net reduction in the plasticity index. It is observed that, the reduction in plasticity indexes are 26%, 41% and 48% respectively for 1 % of KCl, $CaCl_2$ and $FeCl_3$ added to the expansive clay. The reduction in plasticity index with chemical treatment could be attributed to the depressed double layer thickness due to cation exchange by potassium, calcium and ferric ions.

The variation of shrinkage limit with the percentage of chemical added to the expansive soil is presented in the Fig. 4. With increase in percentage of chemical added to the expansive soil the shrinkage limit is increasing. With 1.5 % chemical addition, the shrinkage limit of stabilized expansive clay is increased from 12% to 15.1%, 15.4% and 16% respectively for KCl, $CaCl_2$ and $FeCl_3$.

3.2. Effect of Additives on DFS

The variation of DFS of stabilized expansive clay with addition of different percentages of chemicals is shown in the Fig.5. It is observed that the DFS is decreasing with increasing percentage of chemical added to the expansive soil. Significant decrease in D.F.S. is recorded in stabilized expansive clay with addition of 1% of chemical. The reductions in the DFS of stabilized expansive clay with addition of 1% chemical are 40%, 43% and 47% for KCl, $CaCl_2$ and $FeCl_3$ respectively compared with the expansive clay. The reduction in DFS values could be supported by the fact that the double layer thickness is suppressed by cation exchange with potassium, calcium and ferric ions and with increased electrolyte concentration.

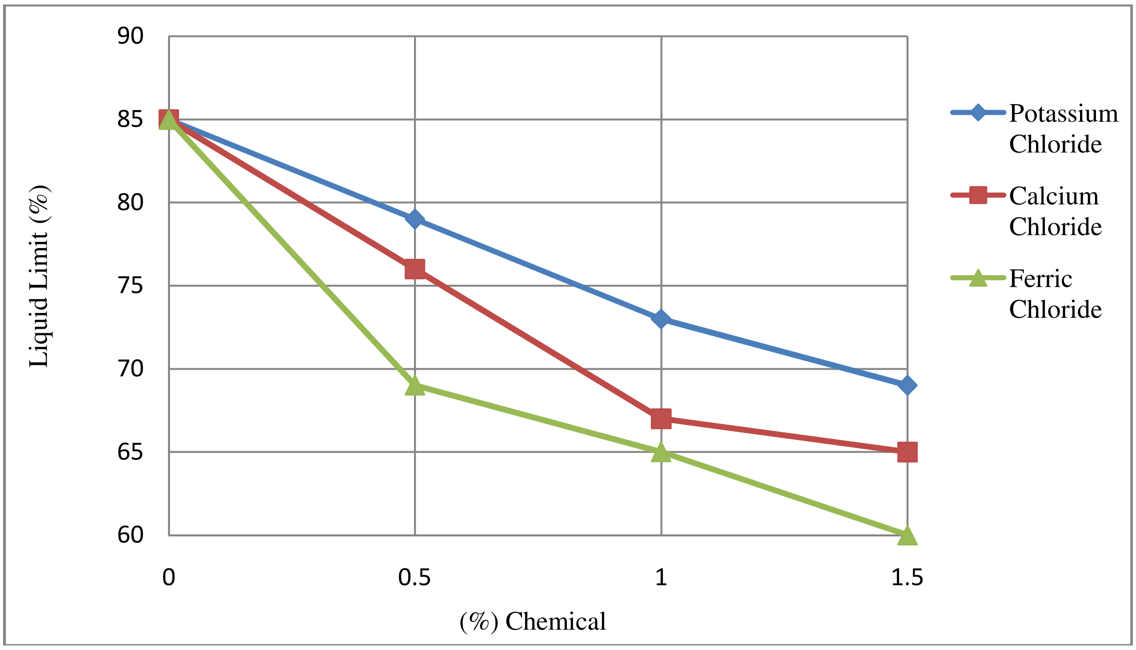

Fig.1: Variation of liquid limit with addition of percentage Chemical

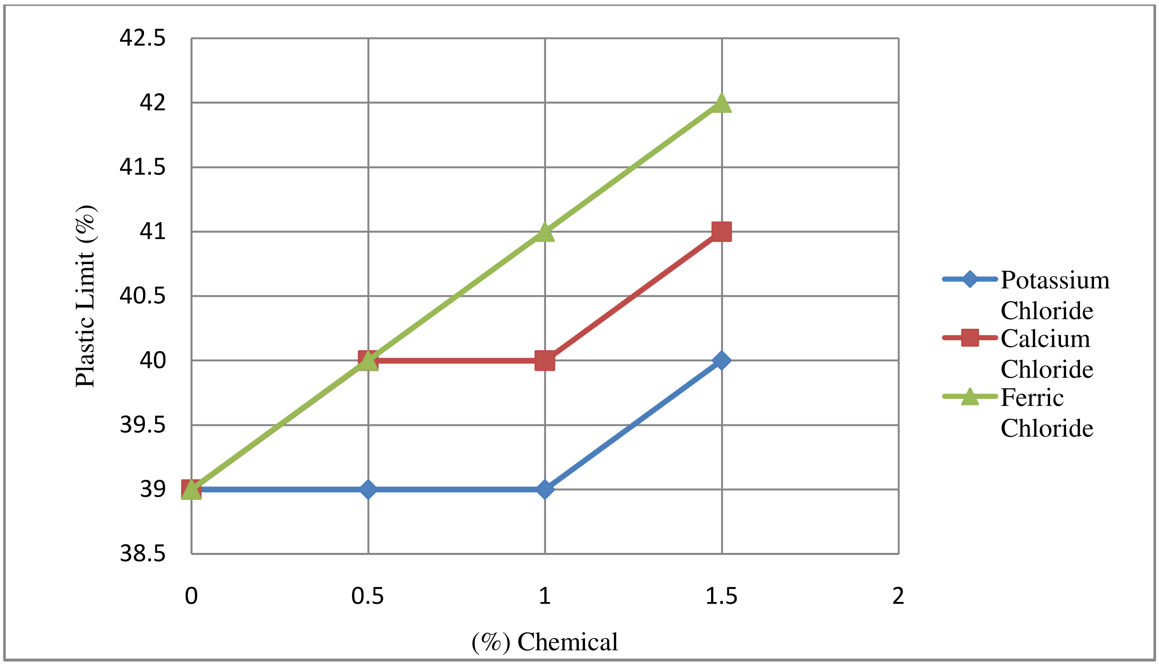

Fig.2: Variation of Plastic limit with addition of percentage Chemical

3.3. Effect of Additives on CBR

Fig. 6 shows the variation of CBR of stabilized expansive clay with addition of different percentages of chemicals. It is can be seen that the CBR is increasing with increasing percentage of chemical added to the expansive soil. Significant increase in CBR is recorded in stabilized expansive clay with addition of chemical upto 1%, beyond this percentage the increase in CBR is marginal. The increase in CBR values of stabilized expansive clay with addition of 1% chemical are 80%, 99% and 116% for KCl, $CaCl_2$ and $FeCl_3$ respectively compared with the expansive clay. The increase in the strength with addition of chemicals may be attributed to the cation exchange of KCl, $CaCl_2$ & $FeCl_3$ between mineral layers and due to the formation of silicate gel. The reduction in improvement in CBR beyond 1% of chemicals KCl, $CaCl_2$ & $FeCl_3$, may be due to the absorption of more moisture at higher chemical content.

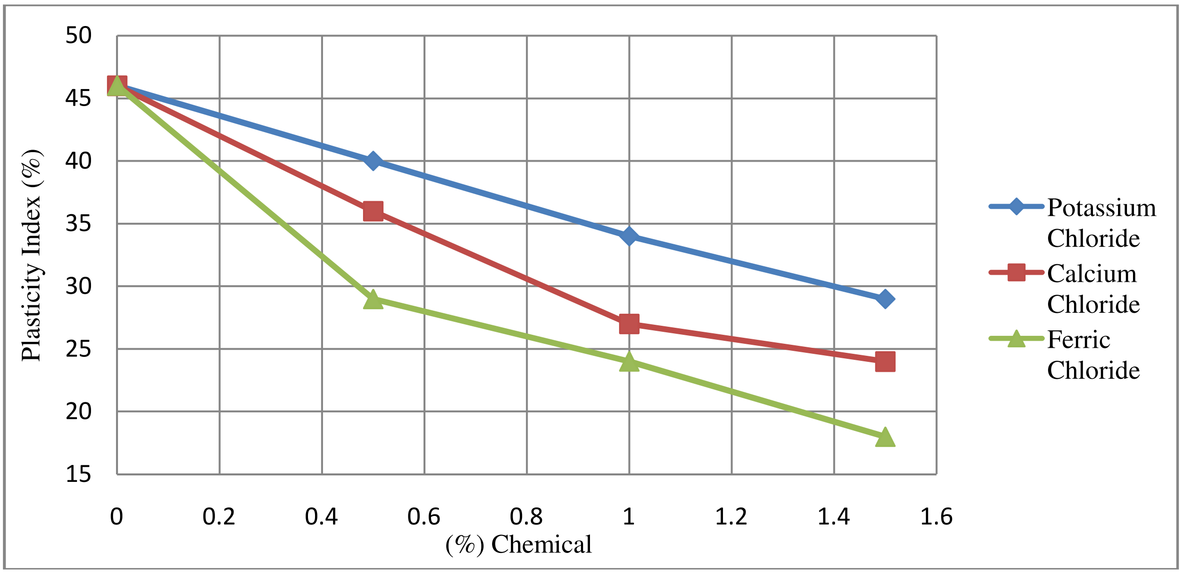

Fig.3: Variation of plasticity index with addition of percentage Chemical

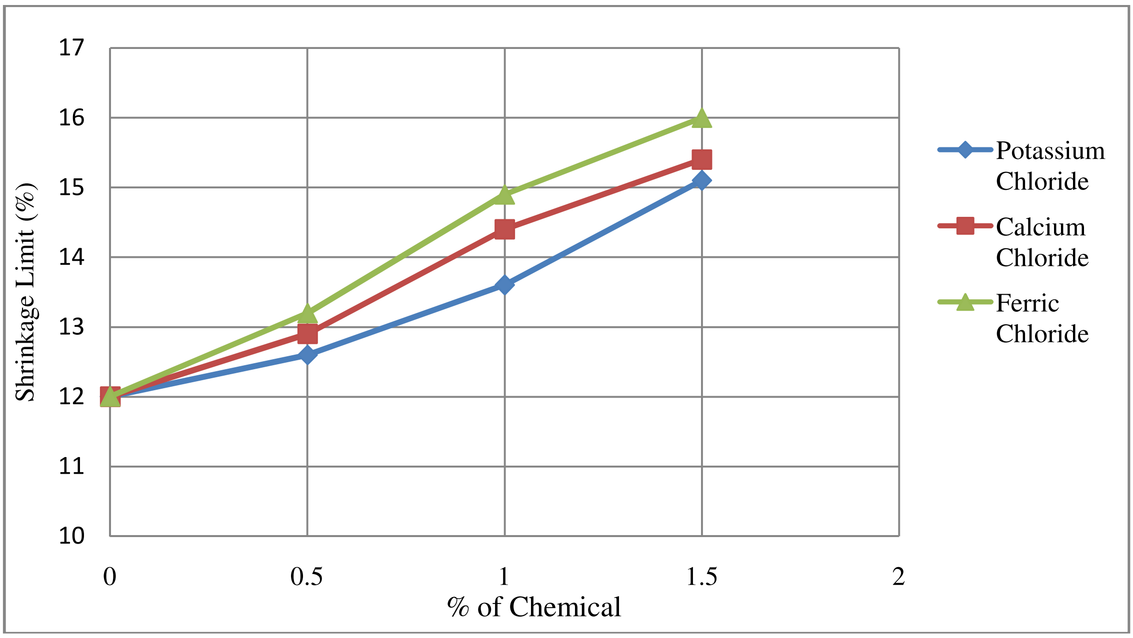

Fig.4: Variation of shrinkage limit with addition of percentage Chemical

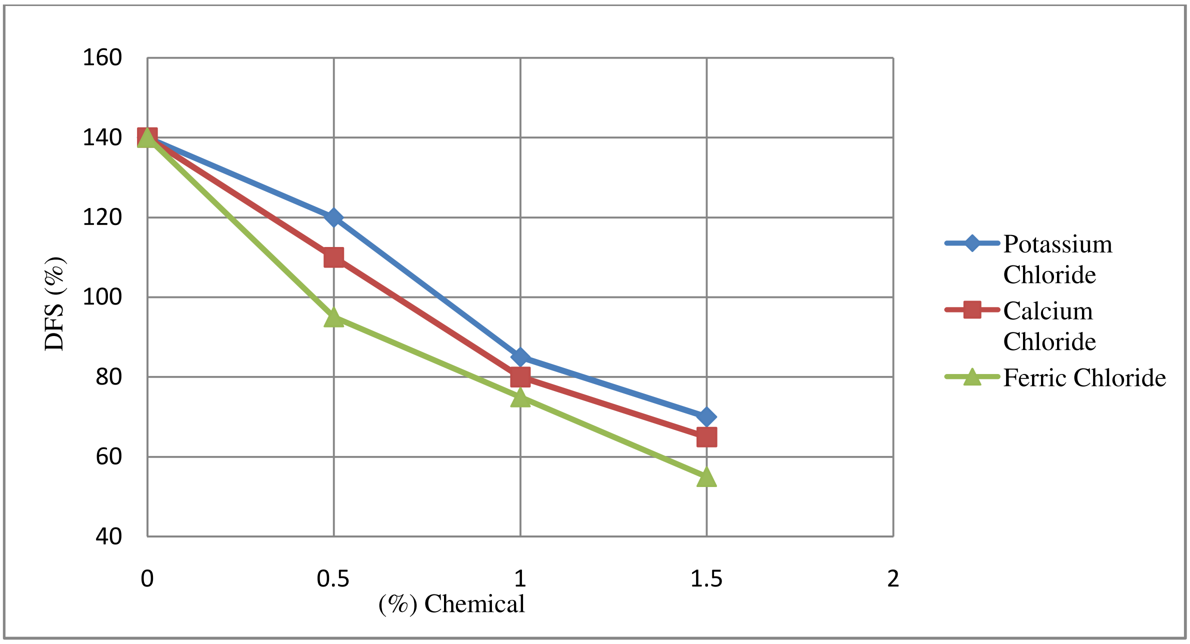

Fig. 5 Variation of DFS with addition of percentage Chemical

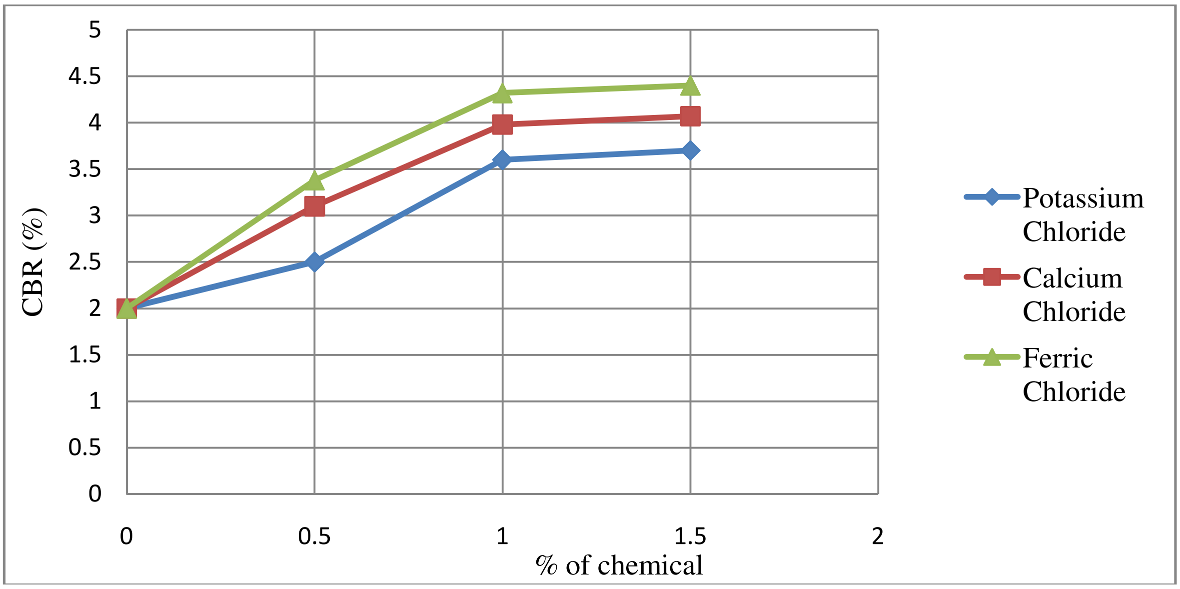

Fig.6: Variation of CBR of stabilized expansive bed with percentage of Chemical

3.4. Effect of Additives on Shear Strength Properties

The unconfined compressive strength of the remoulded samples prepared at MDD and optimum moisture content with addition of 0.5%, 1% and 1.5 % of chemicals, KCl, $CaCl_2$ & $FeCl_3$, to the expansive soil are presented in the table 2. The prepared samples are tested after 1day, 7 days and 14 days. As expected, the unconfined compressive strength is increasing with time may be due chemical reaction. It is observed that the unconfined compressive strength of the stabilized expansive soil is increasing with increase in percentage of chemical added to the soil. The unconfined compressive strength of stabilized expansive clay is increased by 133%, 171% & 230% when treated with 1% chemical, of KCl, $CaCl_2$ and $FeCl_3$ respectively. The increase in the strength with addition of chemicals may be attributed to the cation exchange of KCl, $CaCl_2$ & $FeCl_3$ between mineral layers and due to the formation of silicate gel. The reduction in strength beyond 1% each of KCl, $CaCl_2$ & $FeCl_3$ may be due to the absorption of more moisture at higher KCl, $CaCl_2$ & $FeCl_3$.

The undrained shear strength parameters of the remoulded samples prepared at MDD and optimum moisture content with addition of 0.5%, 1% and 1.5 % of chemicals, KCl, $CaCl_2$ & $FeCl_3$, to the expansive soil are presented in the table 3. The prepared samples are tested after 1day, 7 days and 14 days. Significant change in undrained cohesion and marginal change in angle of internal friction is observed with addition of chemicals to the expansive clay. The increase in the shear strength parameters with addition of chemicals may be attributed to the cation exchange of chemicals. The shear strength parameters are increases upto 1 % chemical addition of above three chemicals, beyond this percentage there is a considerable decrease is observed may be due to the absorbtion of more moisture at higher chemical content.

Table: 2 Variation of Undrained compressive strength of stabilized expansive clay

Chemical added to the soil	**Percentage of Chemical added to the soil**	**Unconfined Compressive Strength (KPa)**		
		1 day	7 days	14days
Without chemical	--	92	--	--
KCl	0.5	130	175	188
	1.0	170	185	215
	1.5	125	160	180
$CaCl_2$	0.5	135	200	215
	1.0	175	215	250
	1.5	128	184	207
$FeCl_3$	0.5	140	245	256
	1.0	181	270	304
	1.5	132	223	248

Table: 3 Variation of Shear strength parameters with the addition of chemicals to the expansive clay

Chemical added to the soil	**Percentage of Chemical added to the soil**	**Unconfined Compressive Strength (KPa)**					
		1 day		**7 days**		**14days**	
		Cohesion, C_u (kg/cm^2)	**Angle of internal friction, ϕ, (Deg.)**	**Cohesion, C_u (kg/cm^2)**	**Angle of internal friction, ϕ, (Deg.)**	**Cohesion, C_u (kg/cm^2)**	**Angle of internal friction, ϕ, (Deg.)**
Without chemical	--	0.56	2^0	--	--	--	--
KCl	0.5	0.61	7^0	1.11	5^0	1.28	7^0
	1.0	0.72	5^0	1.23	4^0	1.32	4^0
	1.5	0.65	6^0	1.15	4^0	1.26	4^0
$CaCl_2$	0.5	0.70	7^0	1.21	5^0	1.30	4^0
	1.0	0.78	6^0	1.32	5^0	1.38	3^0
	1.5	0.77	6^0	1.27	4^0	1.34	3^0
$FeCl_3$	0.5	0.89	6^0	1.26	4^0	1.33	3^0
	1.0	0.96	4^0	1.35	3^0	1.46	3^0
	1.5	0.93	3^0	1.30	4^0	1.38	3^0

In this section the results of various tests carried out in the laboratory are discussed. Conclusions will be discussed in the next section.

IV. CONCLUSIONS

The following conclusions can be drawn from the laboratory study carried out in this investigation.
It is observed that the liquid limit values are decreased by 57 %, 63% and 70% respectively for 1% of KCl, $CaCl_2$ and $FeCl_3$ chemicals added to the expansive clay. Marginal increase in plastic limits is observed with addition of chemical to the expansive clay. Decrease in plasticity index is recorded with addition of chemical to the expansive soil. The shrinkage limit is increasing with 1.5 % chemical addition; it is observed that the shrinkage limit of stabilized expansive clay is increased from 12% to 15.1%, 15.4% and 16% respectively for KCl, $CaCl_2$ and $FeCl_3$.
The DFS values are decreased by 40%, 43% and 47% for 1% of KCl, $CaCl_2$ and $FeCl_3$ treatments respectively.
The CBR values are also increased by 80%, 103% and 116% respectively for 1% of KCl, $CaCl_2$ and $FeCl_3$ treatment.
It is observed that the Significant change in undrained cohesion and marginal change in angle of internal friction is observed with addition of chemicals to the expansive clay.
The UCS values are increased by 133%, 171% and 230% respectively for 1% of KCl, $CaCl_2$ and $FeCl_3$ treatments for a curing period of 14 day

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