Evaluating the Influence of Chemical Additives on Swelling Characteristic of Expansive Soils

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Abstract: Swelling and shrinkage characteristic is of vital importance when a structure is to be designed on problematic soil. Swelling phenomena is considered as one of the most serious challenge because of the potential danger of unpredictable upward movements of structures founded on such soils. For this purpose it is essential to reduce the swelling of expansive soils. In this research work, effort has been made to check the effect of chemical additives on expansive soil. The chemical used are, (i) potassium chloride (KCl) (ii) magnesium chloride ($MgCl_2$) (iii) ferric chloride ($FeCl_3$).The main objective of present research work is to study and evaluate the swelling characteristics of expansive soil treated with various chemicals in different proportions of 0.5%, 1%, 1.5% and 2% of dry weight of soil respectively and comparing its result with raw soil. These chemical additives have the readily soluble capacity in water, which results in supply of adequate number of cations for ion-exchange reaction A methodical process, involving experimentation on Atterberg limits (liquid limit, plastic limit, shrinkage limit), compaction characteristics, swelling characteristics (free swell index ,swelling pressure)were conducted by adding Potassium Chloride, magnesium Chloride and Ferric Chloride to the expansive soil.

Index Terms - Expansive soil, Chemical additives, Swelling characteristics

I. INTRODUCTION

Expansive soil is one of the problematic soils that has high potential for Shrinking or swelling due to change of moisture content. These soils have the tendency to increase in volume when water content is increase and decrease in volume when water is removed. These soils covers about 20% of the total area of India. The problem that causes expansive soils is that deformations are significantly greater. There deformation cannot be predicted movement of soil because it is usually in an uneven manner & is of such magnitude which causes extensive damage to 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 identified in a project. 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 ash etc. are also used to alter the characteristics of the expansive soils. Chemical modification by adding lime and lime-pozzolanic mixes has been practiced for the last two decades. However, due to low solubility (about 1.2 g/lit @200°c) of lime and mixing problems involved. In this work it is attempted to study the effect of chemical additives like KCl, $MgCl_2$ and $FeCl_3$ on the swelling properties of expansive soil. The readily soluble capacity in water, which results in supply of adequate number of cations for ion exchange reaction, is the principal merit of using these chemical additives as compared with the conventional additives.

II. MATERIALS

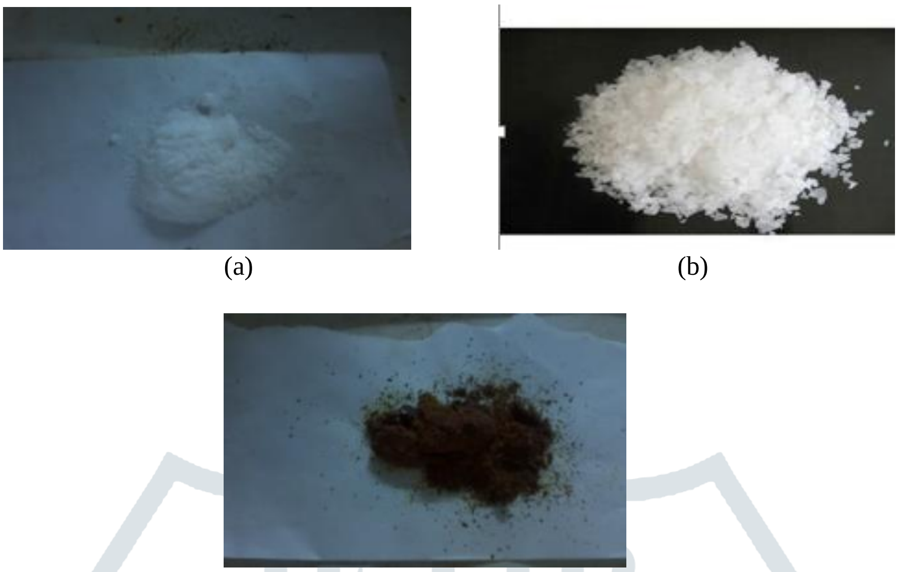
2.1 Expansive soil

Soil used in the experiments has been collected from Adhelaigam, a village near to Bhavnagar city situated in the Bhavnagar district of the Saurashatra region of Gujarat state of India. The soil was a taken from a depth of 2m from Ground Level. The obtained soil was air dried and pulverised manually.

Fig 1: Expansive soil

2.2 Chemical admixtures

Chloride Compound Chemicals chosen in the present study are potassium chloride (KCl), Magnesium Chloride ($MgCl_2$) and Ferric Chloride ($FeCl_3$). These chemicals are easily soluble in water and uniform mixing can be easily achieved. These chemicals are added to the expansive soil samples in varying percentages of 0.5%, 1.0%, 1.5%, 2.0% of dry weight of soil. The concentration of each chloride additives was obtained by dissolving in distilled water to obtain the specific concentration for each type of salt in ppm and then mixed with soil.



(a) (b)

(c)

Fig 2: Chemical admixtures (a) KCl (b) $MgCl_2$ (c) $FeCl_3$

III. METHODOLOGY

Laboratory experimentation is carried out as per the procedures given in the Indian Standard Codes. Grain size distribution as per IS 2720(part 4)-1965, Index properties IS 2720 (part 5)-1985, Free Swell Index as per IS 2720(Part XL)–197, Max Dry Density & Optimum Moisture Content as per IS 2720(Part 7&8)-1983, Swell Pressure Testing as per IS 2720(Part XLI)-1977.

3.1 Free Swell Index

The determination of free swell index of soil helps to identify the potential of a soil to swell. In this method 10 grams of oven-dried soil sample passing through 425 Micron sieve is poured in two graduated cylinders of 100 ml capacity. One cylinder shall then be filled with kerosene oil and the other with distilled writer up to the 100 ml mark. After removal of entrapped air by stirring with glass rod, the soils in both the cylinders shall be allowed to settle. Sufficient time (not less than 24 hours) shall be allowed for the soil sample to attain equilibrium state of volume.

Free Swell Index = $[(V_d – V_k)/V_k]$ x 100

Where, V_d and V_k are the final volumes of soil sample in water and kerosene.

3.2 Swelling Pressure

Swelling Pressure is the pressure at which the expansive soil exerts if the soil is not allowed to swell or the volume change of the soil is arrested. In this method the sample was prepared at OMC and $\gamma_{d\ (max)}$ consistency. The soil specimen is kept in between two porous stones saturated in boiling water providing a filter paper between the soil specimen and porous stone. The brass perforated plate is positioned centrally on the top of porous stone. Soil sample is always kept submerged in water, so that clay sample will be saturated through both ways The difference between the final and initial dial reading of the proving ring gives total load in terms of division which when multiplied by the calibration factor gives the total load. This value when divided by the cross-section area of soil specimen gives the swell pressure.

Fig 3: Setup for measuring swelling pressure in the constant volume method

IV. RESULTS AND DISCUSSION

4.1 Index and Engineering property of raw soil:

Table 1: Properties of untreated expansive soil

Sr. No	Properties of the soil	Value
1	Specific gravity	2.51
2	Color of soil	Black
3	Grain size distribution	
	Clay Silt	53% 47%
4	IS classification of soil	CH
5	Atterberg's Limits	
	a) Liquid Limit b) Plastic Limit c) Shrinkage limit d) Plasticity Index	80.00% 35.55% 10% 44.45%
6	Free Swell Index(FSI)	90%
7	Compaction Characteristics	
	Optimum Moisture Content Maximum Dry Density (kN/m^3)	28% 14.6
8	Swelling Pressure	65 kPa

4.2 Effect of additives on free swell index

The variation of Free swell index of treated expansive soil with addition of different percentages of chemicals is shown in the Fig.2. It is observed that the Free swell index is decreasing with increasing percentage of chemical added to the expansive soil. Percentage decrement observed in free swell index were 10%, 19%, 34% and 40% for 0.5%, 1%, 1.5% and 2% KCl addition to virgin soil. Percentage decrement observed in free swell index were 10%, 25%, 38% and 46% for 0.5%, 1%, 1.5% and 2% $MgCl_2$ addition to virgin soil. Percentage decrement observed in free swell index were 14%, 30%, 42% and 52% for 0.5%, 1%, 1.5% and 2% $FeCl_3$ addition to virgin soil. The reduction in free swell index is attributed to the fact that the double layer thickness is suppressed by cation exchange with potassium, magnesium and ferric ions and with increased electrolyte concentration.

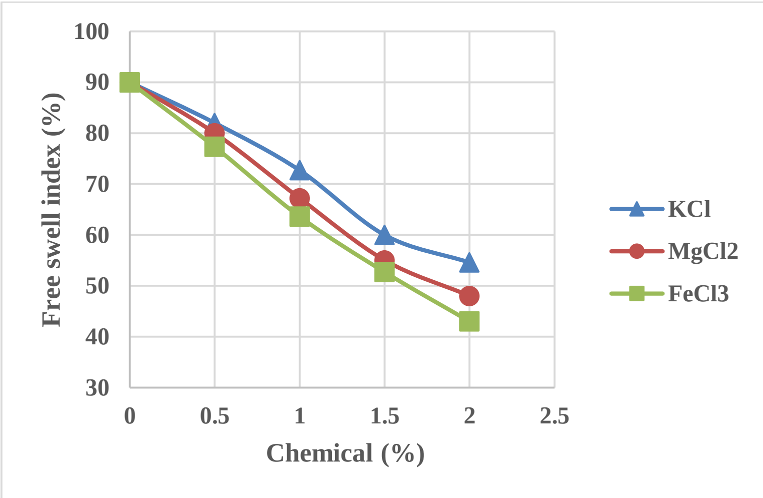


Fig 4: Variation of free swell index for different chemicals blending in expansive soil

4.3 Effect of additives on compaction characteristics

The variation of optimum moisture content (OMC) and maximum dry density (MDD) of treated expansive soil with addition of different percentages of chemicals is shown in the Fig.3 & 4. It is observed that the OMC is decreasing and MDD is increasing with increasing percentage of chemical added to the expansive soil. Percentage decrement observed in OMC were 4%, 11%, 18% and 22% for 0.5%, 1%, 1.5% and 2% KCl addition to virgin soil. Percentage decrement observed in OMC were 11%, 21%, 25% and 32% for 0.5%, 1%, 1.5% and 2% $MgCl_2$ addition to virgin soil. Percentage decrement observed in OMC were 18%, 25%, 28% and 35% for 0.5%, 1%, 1.5% and 2% $FeCl_3$ addition to virgin soil. Maximum dry density value of soil increases from 14.6kN/m^3 to 15kN/m^3 for soil treated with 2% of $FeCl_3$. This decrease in OMC was backed to chemical reaction and ion change mechanism which dissipated and absorbed the water during the chemical action.

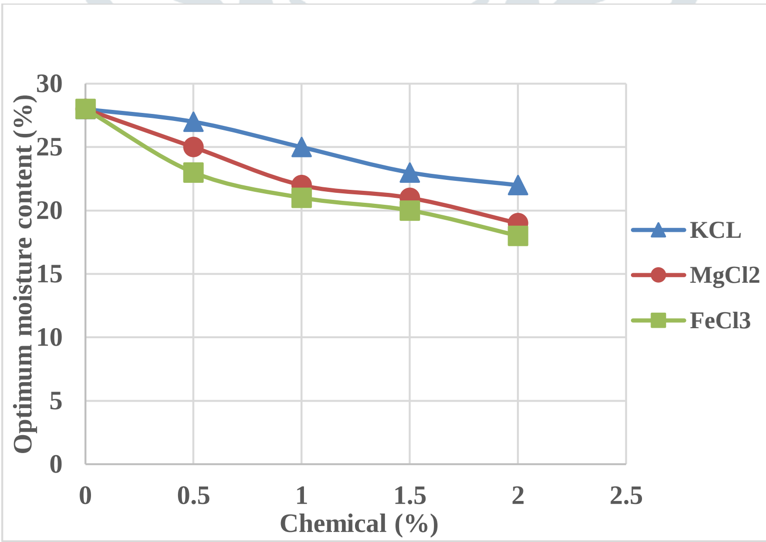


Fig 5: Variation of optimum moisture content for different chemicals blending in expansive soil

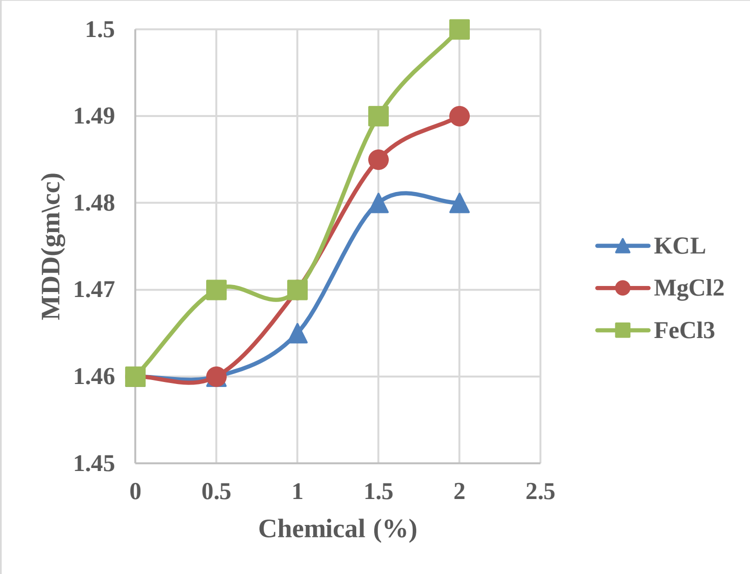


Fig 6: Variation of maximum dry density for different chemicals blending in expansive soil

4.4 Effect of additives on swelling pressure

The variation of swell pressure of treated expansive soil with addition of different percentages of chemicals is shown in the Fig.5. It is observed that the swell pressure is decreasing with increasing percentage of chemical added to the expansive soil. Percentage decrement observed were 10%, 23%, 34% and 42% for 0.5%, 1%, 1.5% and 2% KCl addition to virgin soil. Percentage decrement observed were 16%, 29%, 40% and 46% for 0.5%, 1%, 1.5% and 2% $MgCl_2$ addition to virgin soil. Percentage decrement observed were 16%, 29%, 40% and 46% for 0.5%, 1%, 1.5% and 2% $FeCl_3$ addition to virgin soil. This is due to that the additive KCl contains monovalent cation (K^+), $MgCl_2$ contains divalent cations (Mg^{+2}), $FeCl_3$ contains trivalent (Fe^{+3}). A base exchange occurs with the strong ions replacing the weaker ions (typical cation's replaceability is: Na^+\$K^+$\$Mg^{+2}$\$Ca^{+2}$\$Al^{+3}$\$Fe^{+3}$), which in turn results decrease in thickness of the diffuse double layer develops on the surface of clay particles. This alteration in electrical charge around a clay particle reduces the spacing between clay particles resulting creation of flocculated structure, which in turn reduces swell pressure of a soil.

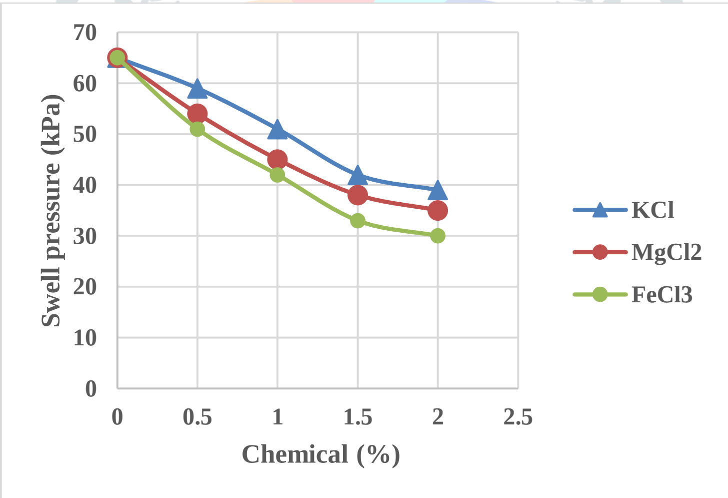


Fig 7: Variation of swelling pressure for different chemicals blending in expansive soil

V. CONCLUSION

This paper demonstrates the performance of chemical additives KCl, $MgCl_2$, $FeCl_3$ in reducing the swelling behavior of expansive soils. Results shows that all the chemical additives are effective in reducing swelling characteristics, among the three chemical additives FeCl3 exhibit better performance as comparing other two. It has been observed that both valence of cation and the atomic radius of additive significantly affect the swelling characteristics. Results show that with increase in valence of cations and decrease in atomic radius swelling characteristics decreased to a significant level. The percentage reduction in free swell index for the addition of 2% chemical is 40%, 46% and 52% respectively for KCl, $MgCl_2$ and $FeCl_3$. The percentage reduction in swelling pressure for the addition of 2% chemical is 42%, 46% and 54% respectively for KCl, $MgCl_2$ and $FeCl_3$.

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