

Influence of Ferric Chloride on Strength and Deformation Characteristics of Expansive Soil Sub Grades In Konaseema Region

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ABSTRACT: Expansive soils pose problems to civil engineers in general and to geotechnical engineers in particular. They cause damage to structures founded in them because of their potential to react to changes in moisture regime. They undergo severe volume changes corresponding to changes in moisture content. Because of their potential to undergo volumetric changes, civil engineering structures such as foundations, retaining walls, pavements, airports, sidewalks, canal beds and linings are damaged. They swell or increase in their volume when they imbibe water and shrink or reduce in their volume on evaporation of water. Because of their alternate swelling and shrinkage, they result in detrimental cracking of lightly loaded structures. Various innovative practices have been devised to counteract the volume change problem and to safeguard the structures. Various remedial measures like soil replacement, moisture control, pre-wetting, lime stabilization have been practiced with varying degrees of success. However, these techniques suffer from certain limitations with respect to their adaptability, like longer time periods required for pre-wetting the highly plastic clays, difficulty in constructing the ideal moisture barriers, pulverization and mixing problems in case of lime stabilization and high cost for hauling suitable refill material for soil replacement etc.

In this present work, an attempt is made to study the strength and deformation behaviour characteristics of chemically stabilized expansive soil sub-grades using model tanks simulating field conditions in laboratory.

KEYWORDS: Expansive Soils, Ferric Chloride-Stabilization, Cyclic plate load tests, Strength and Deformation Studies.

I. INTRODUCTION

Expansive soil deposits occur in the arid and semi-arid regions of the world and are problematic to the engineering structures because of their tendency to heave during the wet season and shrink during dry season. Different damages in the form of cracking, undulation, differential settlements, etc are experienced by the roads, buildings, irrigation canals, water and sewer lines, etc. The loss due to extensive damage to highways founded on expansive soil sub grades is estimated to be in billions of dollars all over the world (Jones & Holtz 1973; Steinberg, 1992). Degree of expansion of these soils mainly depends on presence of active clay minerals in these soils. Of those mineral groups, Montmorillonite is more active and is responsible for expansiveness of these soils due to high affinity for water. In KONASEEMA region, expansive soils with abnormal swelling (i.e., having DFS around 180) are more predominant and extensive damages to structures and pavements laid over were also more predominant. An attempt is made to study the strength and deformation behaviour characteristics of chemically stabilized expansive soil sub-grades using model tanks simulating field conditions in laboratory. A better understanding of these characteristics will enhance the usage of ferric chloride in geotechnical works and thereby making clays suitable for foundation purpose. Cyclic plate bearing load tests were conducted on the model sub grade tanks to compare the strength and deformation characteristics of treated and untreated sub grades. They swell or increase in their volume when they imbibe water and shrink or reduce in their volume on evaporation of water.

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II. LITERATURE REVIEW

Katti et al (1966) made an attempt to stabilize the in-situ soil using Potassium Hydroxide (KOH) solution and they revealed that it is possible to alter the properties of black cotton soils in place by treating them with aqueous solution of KOH. Slate and Johnson (1958) published the bibliography on stabilization of soil and calcium chloride giving its wide use in highways. Leonards (1962), Hausmann (1990), Shepard et al (1991) has stated that CaCl_2 enjoyed its wide use as dust palliative and frost control of subgrade soil. Muhanned Qahtan Waheed,(2012) stated that increase in max dry density and the corresponding reduction in Optimum Moisture Content values were observed with the addition of varying percentages of Magnesium Chloride (MgCl_2) and Sodium Chloride (NaCl) chemicals. Chemical modification by adding lime has been practiced for the last two decades. However, due to low solubility (about 1.2g/lit @20°C) of lime and mixing problems involved, use of chemicals like KCl and CaCl_2 were tried by various researchers. Further, a group of researchers reported that CaCl_2 could be an effective alternative to conventional lime treatment due to its ready dissolvability to supply adequate calcium ions for Exchange reactions, (G.V.R.PrasadaRaju, 2001; Sivanna, G.S. et al.1976, Sivapullaiah, P.V. et al.1994). 5% FeCl_3 solution to treat the caustic soda contaminated ground of an industrial building in Bangalore [Sivanna,G.S. et al. (1976)]. Several test track studies (Patel and Quershi, 1979; Reddy et al, 1981; Sivaguru et al, 1986; Rolt et al, 1987; Deshpande et al, 1990; James and Pandey, 1990; CRRI, 1991; Gichaga, 1991; Gupta et al, 1992; Seeds et al, 1999) have been carried out in many countries to characterize the pavement materials and to assess the effectiveness of remedial techniques developed.

G.V.R Prasada Raju et al., (2011) has conducted field studies on expansive soil subgrades treated with KCl, CaCl_2 and FeCl_3 . It was observed that FeCl_3 –treated test track showed the best performance. V. R. Bharambe ,G. K. Patil (2013) observed that CBR value of B.C. Soil increased to by 155% for Combination of fly ash and ferric chloride can stabilize black cotton soil. In view of the limitations of lime stabilization and recent trends to utilize electrolytes, it was found that FeCl_3 was quite effective in minimizing swelling of expansive soils.

III. MATERIALS

The study is carried out on expansive soils, which are collected from of East Godavari district along with Ferric chloride, which is being used as chemical additive along with road building materials like granular sub base and wet mix macadam.

3.1 Expansive Black Cotton soil:

Soil used in the experiments has been collected from a two different rural areas in Konaseema region. i.e., one from Kottapeta village and other from Moolapalem villages of Konaseema region. The soil is classified as highly compressible clay, CH, as per IS: 1498 (1970). The disturbed soil samples collected from above locations were air dried and pulverized thoroughly prior to laboratory testing. An initial screening is done and soil is made free from grass and weeds. Thus, prepared soils are bagged and used in laboratory for determination of properties and for laying pavements in laboratory models. The grain size distribution and the physical properties of soil are reported in Table 1.

TABLE: 1 Properties of expansive soils

S.No	Property	Kottapeta Soil	Mulapalem Soil
1	Grain size distribution		
	Sand (%)	4	2
	Silt (%)	20	18
	Clay (%)	76	80
2	Atterberg limits		
	Liquid limit (%)	80	92
	Plastic limit (%)	37	41

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	Plasticity index (%)	43	51
	Shrinkage limit (%)	12	15
3	Compaction properties		
	Optimum Moisture Content, O.M.C. (%)	26.2	30.2
	Maximum Dry Density, M.D.D (g/cc)	1.38	1.48
4	Specific Gravity (G)	2.42	2.68
5	IS Classification	CH	CH
6	Soaked C.B.R (%)	2	2
7	Differential free swell (%)	125	180
8	Permeability(cm/sec)	1.47×10^{-6}	1.89×10^{-6}
9	Shear Strength Parameters		
	Cohesion (C) (Kg/cm ²)	0.53	0.56
	Angle of internal friction (ϕ)	2°	1°

3.2 Ferric chloride:

Ferric chloride is an orange to brown-black solid. Ferric chloride is completely soluble in water. Ferric chloride is non-combustible. Ferric chloride is corrosive to aluminium and most metals when it is wet. Pick up and remove spilled solid before adding water. From earlier studies it was found that FeCl_3 was quite effective in minimizing swelling of expansive soils. So FeCl_3 – ferric chloride was adopted for study at optimum content of 1% to volume of soil. TABLE-2 clearly depicts the improvement in index properties and other parameters of kottapeta and mulapalem soils after treatment with 1% ferric chloride. On comparing untreated results (i.e., shown in table-1) with treated results (i.e., shown in table-2) clearly depicts the improvement in strengthening and shear parameters.

Table:2 Properties of soil after treatment with 1% ferric chloride

S.No	Property	Kottapeta Soil(treated with 1% FeCl_3)	Mulapalem Soil(treated with 1% FeCl_3)
1	Atterberg limits		
	Liquid limit (%)	54	70
	Plastic limit (%)	39	44
	Plasticity index (%)	14	26
	Shrinkage limit (%)	14.2	17.1
2	Soaked C.B.R (%)	5.25	5
3	Differential free swell (%)	78	90
4	Shear Strength Parameters		
	Cohesion (C) (Kg/cm ²)	1.46	1.36
	Angle of internal friction(Φ)	3°	5°

3.3 Granular Sub Base (G.S.B) Mix:

Granular sub base is a mixture of crushed aggregate of size varying from 0 to 12.5mm and water at optimum moisture content are used to form a layer of required thickness. The purpose of this layer is to act as drainage in pavement.

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3.4 Wet Mix Macadam (WMM):

This is used in base course, which acts as strength course in pavement. It is an aggregate mixture of varying sizes from 0 to 40mm, mixed in pug mill at OMC, paved over sub base, and compacted to 98%.

IV. LABORATORY INVESTIGATION

4.1 CALIFORNIA BEARING RATIO (CBR) TESTS

Different percentages of ferric chloride is mixed with expansive soils and compacted at OMC to attain MDD of soil. Soaked CBR tests, after a curing period of 7 days, are conducted in the laboratory as per IS specification. It has been found from the laboratory results that expansive soils with 1% ferric chloride are quite effective in increasing CBR of soil.

4.2 MODEL FLEXIBLE PAVEMENT SYSTEMS (MFPS)

In this investigation, four model flexible pavements are prepared in the laboratory by using 60cm diameter mild steel tank with and without treated and untreated sub grade materials. Expansive soil collected from two areas as mentioned earlier are used as a sub grade material, GSB Mix and WMM are laid uniformly as sub base course and base course respectively. Mild steel tanks were fabricated having perforated inner wall and the gap between inner and outer walls are filled with sand up to sub grade level in order to develop field conditions of water intrusion into sub grade beneath the pavements as shown in plate. In this study four model flexible pavements are prepared in laboratory by using those mild steel tanks with treated and untreated soil sub grades. Expansive soils are mixed with water corresponding to OMC, and spread in the model tanks as sub grade layers, of 5cm compacted thickness, to a total thickness of 20cm as shown in figure 1,2,3.. Each layer is compacted, manually with the help of a rammer to get the required density. Further, the treatment for the stretch was done using the optimum percentage of additive obtained from the laboratory. A 10mm thick compacted granular sub base in two layers was laid over the prepared sub grade and then two layers of WMM as base course of total compacted thickness 10mm is laid on the sub base (as in table 3) for the construction of model flexible pavement system. Figures give a clear understanding and visual understanding of sequential operations of laying model pavements adopted /developed in laboratory.

TABLE 3 DETAILS OF THE MODEL FLEXIBLE PAVEMENTS

Model system	Subgrades(20cm thick)	Sub base(10cm thick)	Base course(10cm thick)
1	Expansive soil (kottapeta)	Granular Sub Base (GSB)	Wet Mix Macadam(WMM)
2	Expansive soil (kottapeta)+ 1% ferric chloride	Granular Sub Base (GSB)	Wet Mix Macadam(WMM)
3	Expansive soil (moolapalem)	Granular Sub Base (GSB)	Wet Mix Macadam(WMM)
4	Expansive soil (moolapalem)+ 1% ferric chloride	Granular Sub Base (GSB)	Wet Mix Macadam(WMM)

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Figure 1

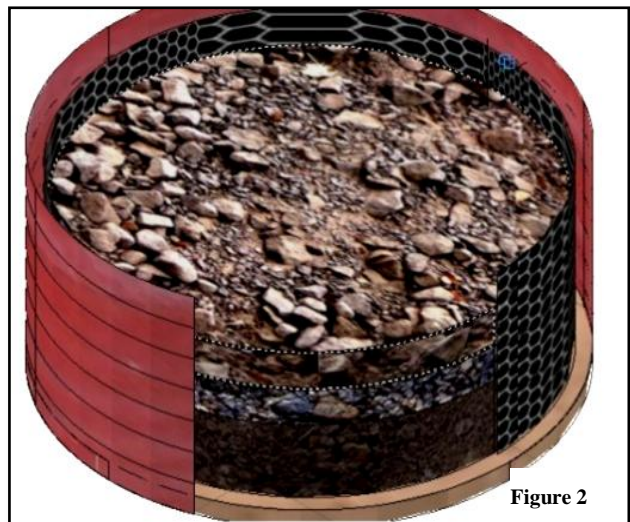


Figure 2

Fig: 1 Heave measurement setup in model pavement system tanks
Fig: 2 Sectional 3d view of model pavement system laid in laboratory

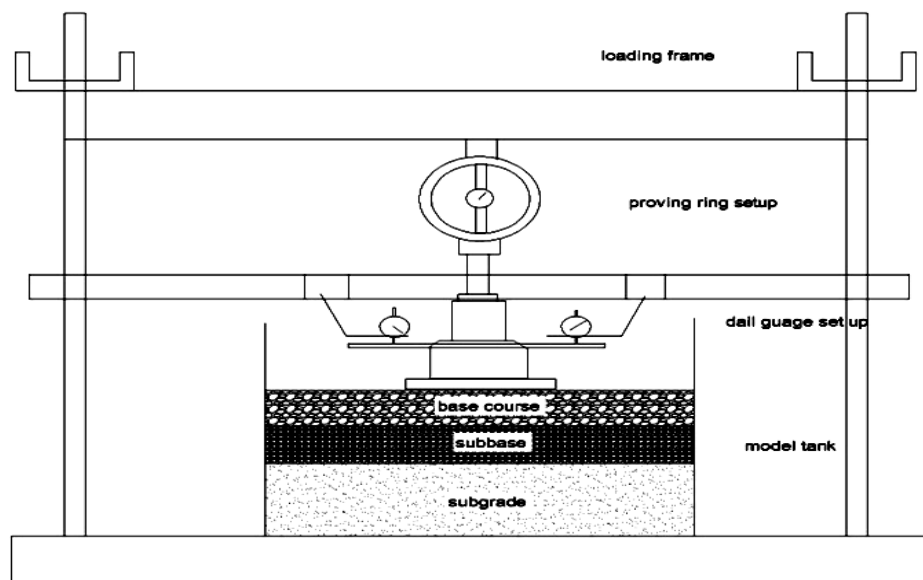


Fig:3 section of plate load test setup.

V. EXPERIMENTAL RESULTS

5.1 Results of Experimental Studies:

In the laboratory studies heave measurements and plate load tests were conducted on four different combinations of model pavement systems with two different sub grade materials (i.e., Expansive soil collected from Kottapeta and Moolapalem villages.)

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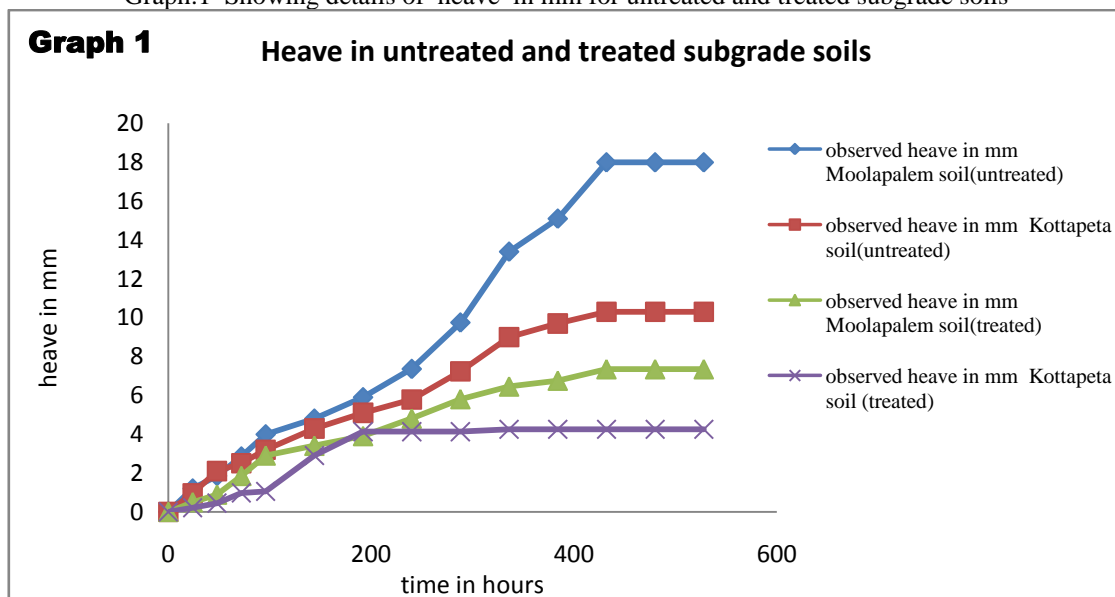
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Heave studies: The in-situ heave measurements were taken for different time intervals for all the alternatives of model flexible pavements in laboratory using dial gauges. The heave vs. time graphs for different model pavements are represented in graphs below.(i.e., in **graph 1**) Amount of heave has reduced considerably by more than 45% when compared to that of untreated subgrade soil.

Cyclic Plate Load Test Results: Cyclic plate load tests are carried on all the MODEL PAVEMENT SYSTEMS laid in fabricated mild steel tanks with four Expansive soil sub grade alternatives (Treated and untreated expansive soils collected from both Kottapeta and Moolapalem). All the tests are carried after complete arrival of fully saturated condition of subgrade for different tyre Pressures. The cyclic Pressure-deformation curve for the MODEL PAVEMENT SYSTEMS on expansive soil Subgrade with four combinations are plotted and presented in graphs. The total and elastic deformation values obtained for different pavement systems on different sub grades are deduced from the cyclic Pressure-deformation curves and are shown below(i.e., in **graphs 2,3**).

It was observed from the laboratory investigation of the cyclic plate load test results,(i.e., from **graphs 2,3**) the ultimate load carrying capacity of the model flexible pavement systems with ferric chloride treated expansive soil sub grades (for both Kottapeta and Moolapalem soils) have been increased from 750kPa to 1000kPa at FSC, when compared to that of the model flexible pavement systems with untreated expansive soil Subgrade.

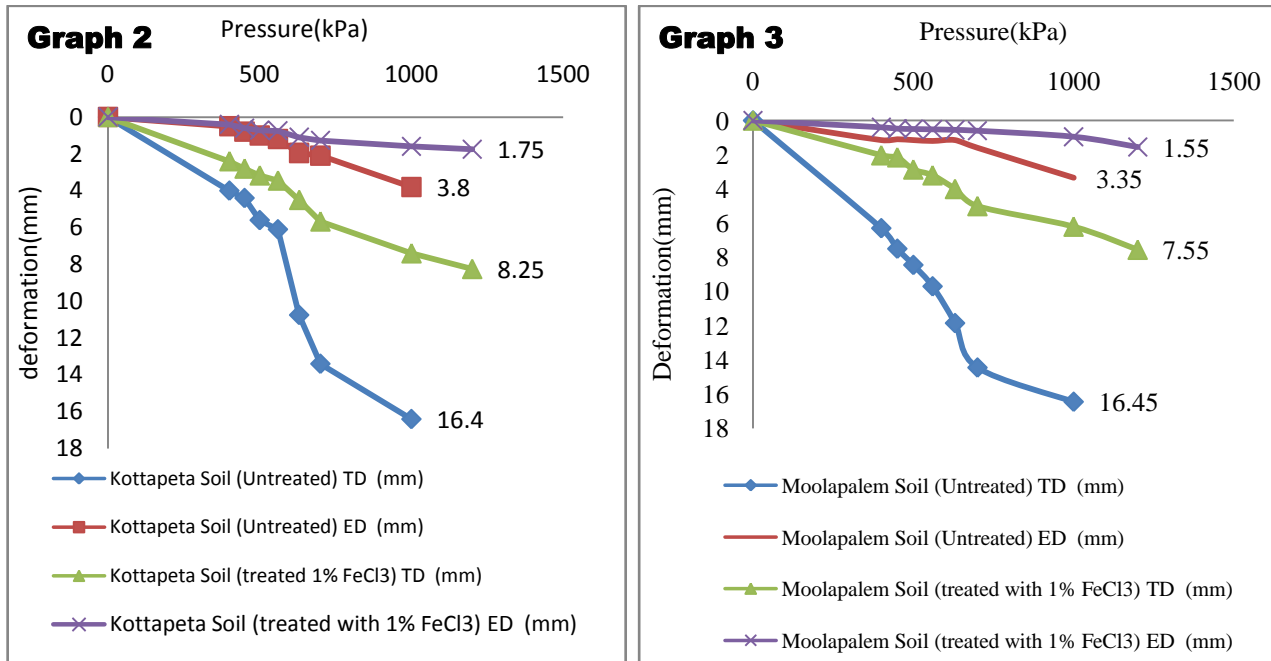
Graph:1 Showing details of heave in mm for untreated and treated subgrade soils



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Graph:2 Pressure vs. deformation(TD&ED) curves for untreated and treated expansive soil (Kottapeta)

Graph-3 Pressure vs deformation(TD&ED) curves for untreated and treated expansive soil (Moolapalem)

VI. CONCLUSION

- 1) The percentage change in amount of heave in laboratory Model Flexible Pavement Systems(MFPS) when the subgrade soils are treated with 1% Ferric chloride are reduced by 58.2% and 59.2% respectively. However, Change in Total and Elastic deformation values at ultimate load carrying capacity are around 49% and 55% respectively.
- 2) It was observed that, cyclic plate load test results on MFPS laid with soils of different regions in laboratory have shown more or less nearly same results. It clearly depicts the fact that soil ferric chloride is quite effective in arresting maximum amount of heave and improving strength characteristics of those soils.
- 3) Finally, by careful evaluation and application of the finding from laboratory model flexible pavement systems (MFPS), it is possible to predict performance of pavements in service and thus these are best tools, which provide meaningful input for development of design procedures for highway pavements in reality.

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