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Effect of Iron Chloride on the Strength Behaviour of the Expansive Clay

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Abstract: From the fast few decades, several techniques were introduced inorder to modify the behaviour of expansive clays. The use of strong electrolytes like calcium chloride ($CaCl_2$), aluminum trichloride ($AlCl_3$) and iron chloride ($FeCl_3$) were extensively used in various civil engineering applications. Expansive soils possesses alternate shrinkage and swelling with the removal and addition of water from it. Iron chloride was effectively used to alter the swelling and shrinkage and also improve the engineering behaviour of expansive clays. Therefore, in the current work an effort is made for study the influence of iron chloride ($FeCl_3$) on the strength behaviour of the expansive soil. The outcomes from the laboratory investigation proved that the usage of iron chloride ($FeCl_3$) produce reduction in swelling and improvement in the strength. It was found that 1% $FeCl_3$ be the optimum for both the UCS and CBR. Hence, from the investigation it was showed that iron chloride is a valuable stabilizer to enhance the properties of black cotton soil and to create it apt for various applications of Civil Engineering.

Key words: Expansive clay, iron chloride, FSI, UCS, CBR.

I. INTRODUCTION

Expansive soils are existing at different parts around the world. The problematic behaviour of alternate shrinkage and swelling causes severe effects to the civil engineering structures constructed all around the world resulting heavy financial loss [1], [2], [3], [4]. Among the different available methods, chemical stabilization is one of the alternative solution to thwart the problems caused by expansive soils. Several researchers worked on chemical stabilization, [5], [6], [7], [8], [9], [10], [11], [12] revealed that electrolytes like Sodium chloride, potassium salt, calcium chloride, aluminium trichloride and iron chloride perhaps powerfully used in position of the traditionally used $Ca(OH)_2$, as of their prepared dissolvability in water and deliver of adequate cations for geared up cation substitute.

This paper presents the efficacy of iron chloride ($FeCl_3$) on the properties and on the strength behaviour of the selected expansive soil.

II. EXPERIMENTAL PROGRAM

Material Used:

Soil: The soil adopted in the experimental program was taken from the town of Bhimavaram, India. Detailed laboratory work was performed to characterize the expansive soil. The clay used in the current investigation was categorized as CH and basic properties of the expansive clay were given in Table 1. And the soil has high amount of expansion depends on its high FSI.

Iron chloride ($FeCl_3$): The ferric chloride used for the present study is of commercial grade and is purchased from the local market.

Tests conducted:

The laboratory tests for basic and engineering properties were organized in two distinct series. For the initial series, the experiments were conducted for the virgin soil. Whereas in the next series, the experiments were conducted on expansive soil-iron chloride mixes to study the influence of iron chloride on various properties of the selected soil.

Mix compositions:

Mix compositions of clay-iron chloride blends were considered for the improvement of soil properties based upon the previous literature as 0%, 0.25%, 0.5%, 0.75%, 1.00%, 1.25%, 1.50%. Index and engineering properties of the selected blended mix were assessed in the laboratory.

Table 1. Basic and Engineering properties of the selected parent soil

	Result value
Gravel (%)	0
Sand (%)	10
Silt (%)	18
Clay (%)	72
Specific gravity, G	2.67
Free swell index, FSI (%)	122
Moisture content, LL (%)	82
Moisture content, PL (%)	26
Plasticity index, PI (%)	56
I. S. Classification	CH
Optimum water content, OMC (%)	33.54

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Maximum dry density, MDD (kN/m^3)	13.20

III. RESULTS AND DISCUSSION

Free swell index (%):

F. S. I tests for both the virgin clay and clay-iron oxide blends were conducted according to IS: 2720 (part-40)-1977. Figure 1 and Table 2 demonstrates the influence of iron chloride on swelling of the selected expansive clay. From the laboratory results it can reveal that, when iron chloride content raised from zero% to 1.5%, it causes a reduction in free swell index of 122% to 52%. The values from Table 2 indicate that the highly swelling expansive soil perform low swelling with the addition of iron chloride. The reduction of FSI is mainly due to swelling particles of parent clay were substituted by non-swelling particles of ferric ions which causes reduction in swelling.

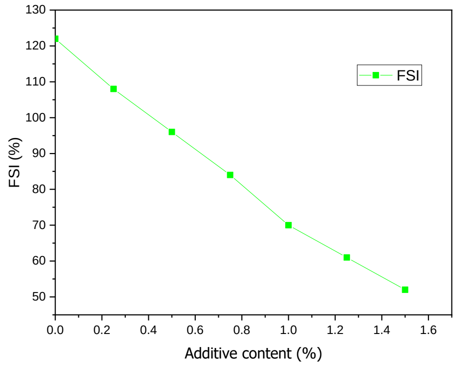

Fig 1. Effect of iron oxide on FSI of expansive clay

Table 2. Influence of iron oxide on basic properties of the selected expansive clay

Iron chloride content (%)	W_L(%)	W_P(%)	I_P(%)	FSI (%)
0	82	26.000	56.000	122
0.25	76	27	49.000	108
0.5	69	27.75	41.250	96
0.75	61	28.5	32.500	84
1	56	29.6	26.400	70
1.25	54	30	24.000	61
1.5	52	30.75	21.250	52

Index properties:

Consistency limits for both the untreated expansive soil and clay-iron oxide blends were determined according to IS: 2720 (part-5) -1985. Figure 2 and Table 2 describes the influence of iron oxide on Atterberg limits (W_L, W_P and I_P). W_L and I_P reduces from 82% to 52% and 56% to 21% respectively when iron oxide content raised from zero to 1.5%. Liquid limit was decreased with the raise in % of iron oxide, while plastic limit was raises with the gain in percentage of iron oxide, resulting decrease in the plasticity index. The reduction in plasticity is mainly due to the exchange of cations by high valency of ferric ions which enhance the electrolyte concentration.

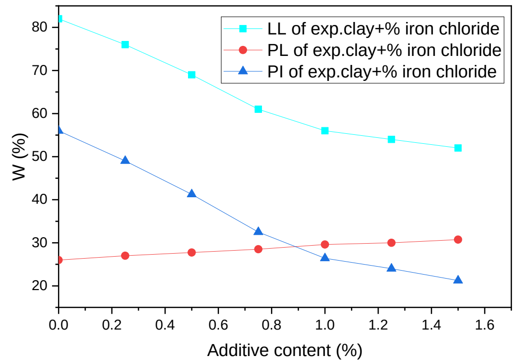

Fig 2. Effect of iron oxide on LL, PL, PI of the expansive clay

Compaction characteristics:

The compaction tests for all the mixes were done based on IS: 2720 (part-8) -1983. Figure 3 and 4 presents the effect of iron chloride content on virgin clay. From the outcome, it was found that OMC raises with the addition of small amounts of iron chloride and then it decreases with the increase of additive up to 1%, later on it increases with increase in the additive content. Similar behaviour is shown in the MDD values also. This indicate that 1% content is the optimum percentage for the clay-iron chloride. This implies that smaller amount of water needed to get the optimum percentage.

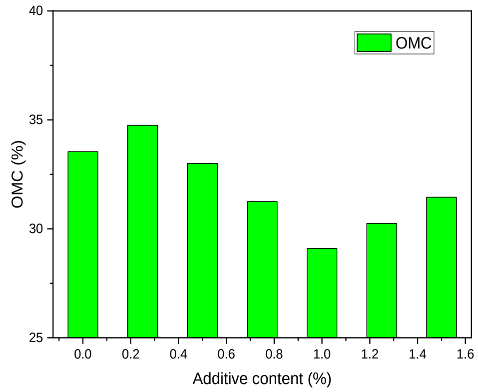

Fig 3. Effect of iron oxide on OMC of the expansive clay

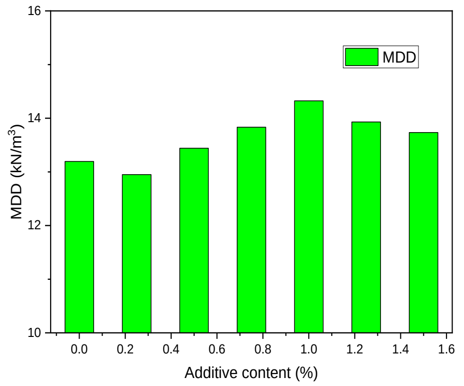

Fig 4. Effect of iron oxide on MDD of the expansive clay

Unconfined compressive strength (UCS):

The UCS tests were done in laboratory according to IS: 2720 (part-10)-1991. This test is very useful for estimate the strength behaviour for the clayey soils. The UCS test is conducted for both the parent soil and for the blended material. Figure 5 and Table 3 shows the influence of additive on the expansive clay for different curing periods. From the results it can be shown that the peak stress increased for entire curing times with raise in the additive content up to 1%. However, peak stress is decreased reasonably when iron chloride content increased from 1.00% to 1.5%, representing that 1% is the optimum content of iron chloride. Figure 6 shows the influence of curing time on expansive clay mixed with different percentage of iron chloride. The peak stress increases from 105 kPa to 715 kPa resulting an improvement of 580% at 28 days curing for the optimum 1% clay-iron chloride mix. This is mainly due to the formation of cementitious products resulting from the cation exchange capacity.

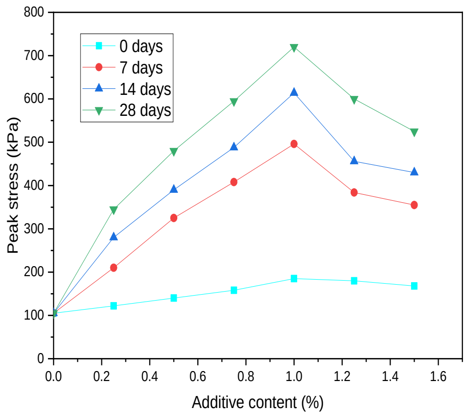

Fig 5. Effect of iron oxide on UCS of the expansive clay for different curing periods

California Bearing Ratio:

The CBR experiments were done at soaked condition in according to IS:2720 (part 16)- 1987. The soaking is done for 96 hours. This CBR method is widely used for the design of sub-base and base courses in the pavements. Figure 7 and Table 3 shows the influence of additive on selected soil. The CBR value increases from 1.5% to 6.9% , when the additive content increase from 0% to 1%. The steady reduction in CBR value after 1% is may be owing to excess iron chloride that was not activated in the reaction, and hence dropping the bond in the blends.

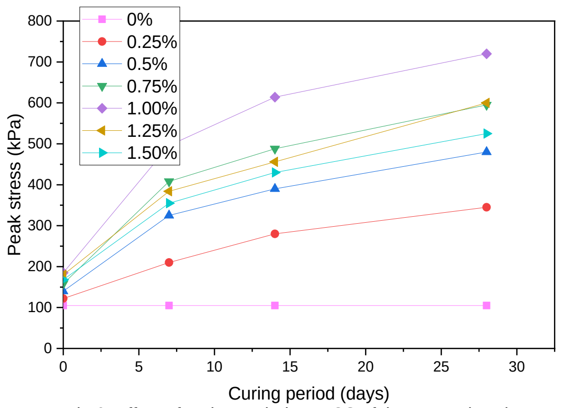

Fig 6. Effect of curing period on UCS of the expansive clay for different % of iron chloride

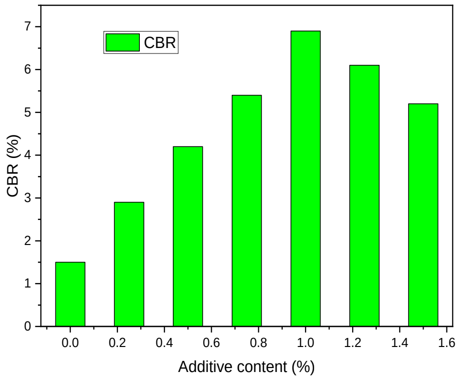

Fig 7. Effect of iron oxide on CBR of the expansive clay

Table 3. Influence of iron oxide on strength properties of the selected clay

Iron chloride content (%)	UCS (kPa) 0 week	1 week	2 weeks	4 weeks	CBR (%)
0	105	105	105	105	1.5
0.25	122	210	280	345	2.9
0.5	140	325	390	480	4.2
0.75	158	408	488	595	5.4
1	185	496	614	715	6.9
1.25	180	384	456	600	6.1
1.5	168	355	430	525	5.2

IV. CONCLUSIONS

The effectiveness of iron chloride on the expansive clay has been investigated from the present study. And it is a chemical treatment of iron oxide to modify the basic and strength properties of the selected expansive soil. So, from the present study following outcomes were made.

1. The W_L and I_P were decreases with raise in % of the additive content. FSI was also decreased with increasing additive content. Iron chloride was effectively used as a stabilizer to decrease the swelling property of the selected expansive soil.
2. Maximum dry density value increases with the addition of iron chloride content, the MDD value obtains maximum at 1% iron chloride content refers to optimum percentage of iron chloride.
3. The peak stress increases from 105 kPa to 715 kPa resulting an improvement of 580% at 28 days curing for the optimum 1% clay-iron chloride mix.
4. The CBR value increases from 1.5% to 6.9%, showing an improvement of 360% when iron chloride is added from 0% to 1%.
5. The basic principle behind this study was to decrease the swelling property of the selected soil through enhance the cation concentration and to replace the cations of the clay formation and to create additional firm clay structure.

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