Plasticity Characteristics of Ferrock Reinforced Expansive Soils

H.S.Prasanna, RuchaNerlikar, Shubhashree SR, Sowndarya KM, GazalaManzoor

Abstract: ***The rapid growth in urbanization and the major development of metropolitan cities is leading to a rapid shift of population from rural to urban regions. This is having a tremendous impact, leading to rapid growth of constructional activities. Further, due to lack of good sites available for construction, it is forcing the construction industries to use marginal lands and lands considered unsuitable for construction, such lands are largely made up of problematic soil (expansive soil). Expansive soils due to their swelling and shrinkage behavior make the construction difficult and need periodic maintenance which increases the overall life cycle cost of structure. And with nearly 657,452.6 km^2 area in India being covered with expansive soil, it is imperative to find a cost effective solution for improving engineering behavior as well as reducing cost of construction. It is observed that the engineering behavior of fine-grained soils mainly depends on the magnitude of clay minerals present in it i.e., kaolinite (least active clay mineral), montmorillonite (most active clay mineral) in different proportions. The soils which are having expansive behavior are predominantly enriched by montmorillonitic clay mineral. The plasticity characteristics of montmorillonitic soils like Liquid limit vary significantly. In order to understand physicochemical phenomena of expansive soils many researchers in the past have made several attempts to understand the engineering behavior in particular with plasticity characteristics. It is seldom observed that most of the studies related to expansive soils are region specific. Ferrock, a carbon negative material which is produced by recycling waste materials such as waste steel dust from steel industries and fly ash from thermal plants is used to treat expansive soil. No information is available in documented literature on use of a new and alternative material Ferrock in soil stabilization, invented by Dr. David Stone in 2017. In the present experimental research study a detailed study of index properties of plain expansive soil and soil stabilized with Ferrock have been carried out. An attempt has been made to study the plasticity behavior of three natural field expansive soils having a wide range of Liquid limit (55%-75%) with that of same soils treated with different proportions of Ferrock. It is also intended to stabilize the expansive soil having wide range of liquid limits varying from 55%-75% which exactly represent field conditions. Free swell ratio, free swell index and swell pressure tests were carried out to assess the swelling potential of Ferrock stabilized black cotton soil. The natural field soils were treated with varying proportions of Ferrock in order to determine a stable mix proportion. The degree of expansion of expansive soils were analyzed. Unique and very useful correlations were established between the percent fines and plasticity characteristics. A new plasticity chart was developed for the classification purpose. It is observed that by reinforcing the montmorollinitic soils with Ferrock the intensity of free swell ratio, Liquid limit can be reduced reasonably and thereby increasing the plastic limit and shrinkage limit which greatly influences the engineering behavior of soil. This innovative project is eco-friendly and provides an economical solution in overall development of infrastructural facilities by using industrial waste materials which otherwise reach landfill.***

Key words: expansive soil,Ferrock, Industrial waste, plasticity characteristics.

I. INTRODUCTION

Expansive soils are the most problematic soils which are prone to notable changes in voulume (swelling or shrinkage) associated withsignificant changes in moisture contents. These soils contain minerals such as smectite clays including montmorillonite and bentonite, which has the most shrink and swell capacity. Their liquid limit and Plastic limit are normally more than 40% and 20% respectively. When they absorb water, there is an increase in volume. Higher the absorption rate, higher will be the swelling. Expansive soil will also shrink when they dry out which places stress on structures. To overcome the problems caused by expansive soil, many innovative techniques and methods have been developed. In the present study inclusion of Ferrock (iron powder 60%, fly ash 20%, metakaolin 8%, lime 10% and oxalic acid 2%)in expansive soil is seen to be effective in decreasing the swelling potential and plasticity index of expansive soil. Related tests specifying to code of Indian Standards has been conducted for expansive soil stabilised with different proportions of Ferrock content (4% - 20%).
Following are the essential ingredients used in Ferrock which are varied in optimum percentage.

- Iron powder: It is the major content of Ferrock which holds almost 60%. It provides stiffness.
- Fly-ash: Optimum percentage of fly-ash is added, which provides strength and chemical resistance with durability. (28%)
- Powdered limestone: It is the least content of Ferrock which holds 12%.

In this study metakaolin is replaced by fly ash and oxalic acid is not used to for the purpose of economy.All the above mentioned properties of Ferrock makes an expansive soil rigid and strong by reducing liquid limit, when it is mixed in optimum ratio
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II. LITERATURE REVIEW

A number of research papers are available on use of industrial and agricultural waste for stabilization of black cotton (expansive) soils. Also many researchers have proposed use of iron ore tailings in the stabilization. Nevertheless no

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documented literature is available on use of this innovative and new blended material known as Ferrock for stabilization of such soils.

Ali and Koranne (2011) studied the behavior of stone dust and fly ash with Expansive soil and their effect on properties of soil. They showedtheremarkable improvement in the characteristics of Expansive soil and also the significant control in swelling nature if fly ashand stone dustare mixed in equal proportions.

Cokca (2001) showed the effect of Expansive Soil stabilized with Flyash in his study. Hisinvestigation established that the plasticity index, activity and swelling ratio of the expansive soil decreases with increase in percentage of stabilizer and the optimum content of fly ash was found to be 20% in decreasing the swell potential.

Jaganmohan Mishra(2014) in his study on the behavior of black cotton soil treated with limestone and granite dust inferred that incorporation of granite dust to the lime stabilized soil decreases the swelling potential of soil to a greater degree.

Ankit Singh Negi(2013) in his study of Soil Stabilization using Lime concluded that lime acts as an excellent stabilizing material and subsequent decrease in shrinkage and plasticity was observed.

This paper presents the effectivenessof the use of Ferrock in expansive soil. Laboratory tests are undertaken to evaluate the plasticity characteristics of expansive soil using Ferrock

III. MATERIALS AND METHODS

In the present experimental research study a detailed study of index properties of plain expansive soil and soil stabilised with Ferrock are carried out. Locally available natural field expansive soils from three different sources passing are 425micron sieve is used. The results of XRD analysis of the three soil samples are as follows,

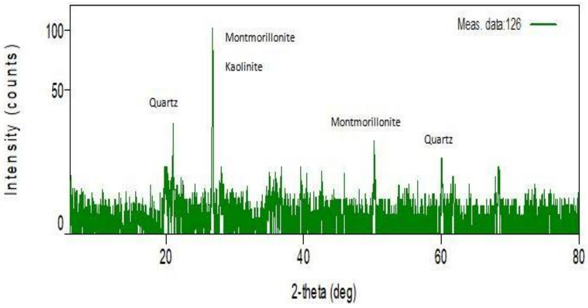

FIGURE I (SOIL 1)

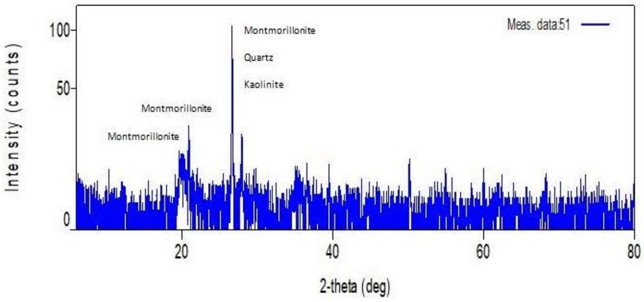

FIGURE II (SOIL 2)

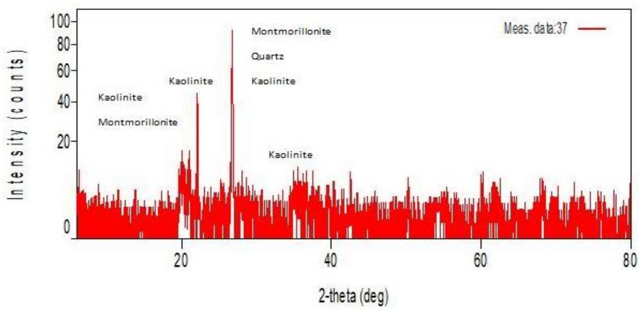

FIGURE III (SOIL 3)

From the XRD analysis it is observed that the principal clay dominance of three soilsis Montmorillonite.

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Ferrock is a material which is a mixture of various materials like Iron powder, Fly ash, Powdered Limestone(all passing 425 micron sieve). Iron powder was procured from JSW group, Bellary. Fly Ash and Limestone are purchased from locally available commercial source. The natural field expansive soils are mixed with different proportions of Ferrock.

Table.I Mix Proportions of Ferrock

Materials	Proportions (% by weight)
Iron Powder	60
Fly Ash	28
Limestone	12

Laboratory tests for Liquid Limit, Plastic Limit and Srinkage Limit, FSR and Specific Gravity for all mix proportions are carried out as per IS specifications.

1. Free Swell Ratio: IS 2720:1977 (Part 40)
2. Atterberg Limits :IS 2720:1985 (Part 5)
3. Specific Gravity : IS 2720:1980 (Part 3)
4. Grain Size Analysis : IS 2720 :1985 (Part 4)

Table.II Physical Propertites of Soils

Properties	SOIL 1	SOIL 2	SOIL 3
Specific Gravity	2.68	2.56	2.5
Free Swell Ratio	2.1	2.2	1.8
Liquid Limit(%) **a. Cone penetration method**			
Using distilled water	64.5	75.7	55.5
Using Kerosene	33.76	39	31.29
b. Casagrande method			
Liquid Limit	65.23	74.65	54.99
Plastic Limit	30.72	38.52	26.77
Grain Size Distribution			
Sand	27.2	10	33.89
Silt	32.39	28.44	27.51
Clay	40.41	61.56	38.6
Activity	85.39	58.69	73.11

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IV. TEST RESULTS AND DISCUSSIONS

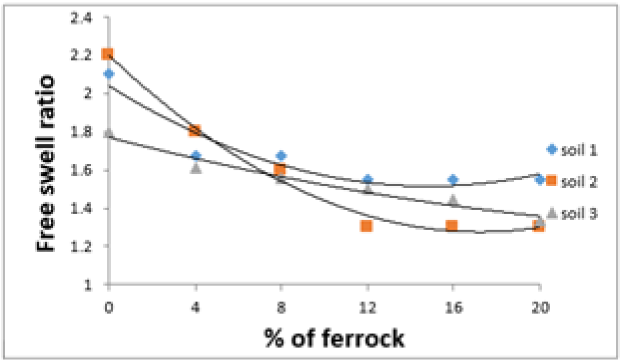

Fig 1 Correlation of free swell ration with different percentage of ferrock replacement by weight

Table.III Correlation and Regression values for Free Swell Ratio vs % of Ferrock for different expansive soils

Soil	Regression equation	R^2	R
soil 1	y = 0.002x² - 0.071x + 2.040	0.89	0.95
soil 2	y= 0.005x2 - 0.132x + 2.039	0.76	0.88
soil 3	y = 0.000x² - 0.029x + 1.770	0.96	0.98

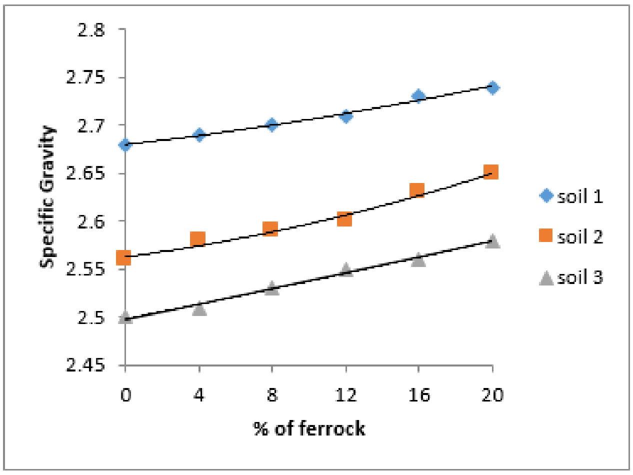

Fig 2 Correlation of Specific Gravity with different percentage of Ferrock

Table.IV Correlation and Regression values for Specific Gravity vs % of Ferrock for different expansive soils

soil	Regression equation	R^2	R
soil 1	y = 4E-05x² + 0.002x + 2.68	0.99	0.99
soil 2	y = 9E-05x2 + 0.002x + 2.562	0.98	0.99
soil 3	= 1E-05x2 + 0.003x + 2.498	0.99	0.99

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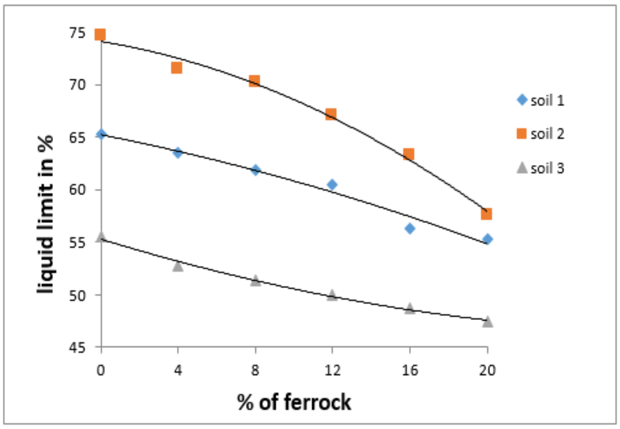

Fig 3 Correlation of Liquid Limit with different percentages of Ferrock replacement by weight

Table.V Correlation and Regression values for Free Swell Ratio vs % of Ferrock for different expansive soils

Soil	Regression equation	R^2	R
soil 1	y= -0.007x2 - 0.363x + 65.23	0.97	0.98
soil 2	y = -0.025x2 - 0.300x + 74.10	0.99	0.99
soil 3	y = 0.008x^2 - 0.562x + 55.28	0.99	0.99

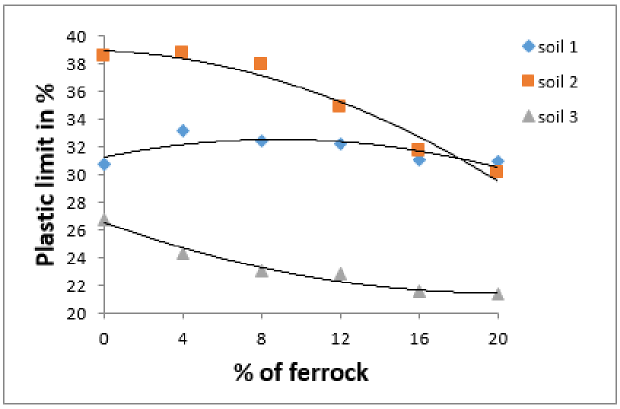

Fig 4 Correlation of Plastic Limit with different percentages of Ferrock replacement by weight

Table.VI Correlation and Regression values for Free Swell Ratio vs % of Ferrock for different expansive soils

Soil	Regression equation	R^2	R
soil 1	y= -0.016x2 + 0.288x + 31.26	0.61	0.78
soil 2	y = -0.020x^2 - 0.063x + 38.93	0.96	0.98
soil 3	y= 0.012x2 - 0.507x + 26.53	0.97	0.99

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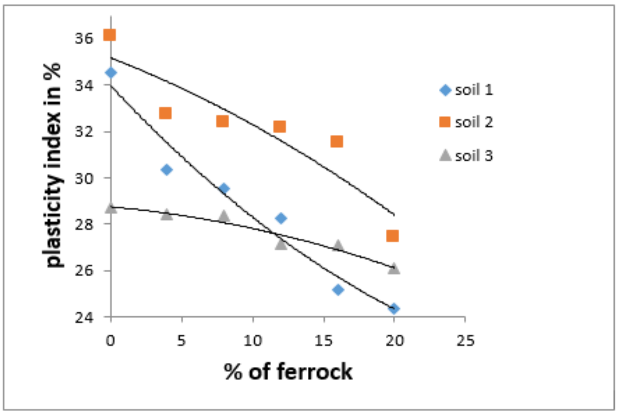

Fig 5 Correlation of Plasticity Index with different percentages of Ferrock

Table.VII Correlation and Regression values for Plasticity Index vs % of Ferrock for different expansive soils

soil	Regression equation	R^2	R
soil 1	$y = 0.0008x^2 - 0.0296x + 2.0894$	.90	.94
soil 2	$y = 0.0003x^2 - 0.004x + 1.9018$	.90	.94
soil 3	$y = 0.0008x^2 - 0.0296x + 2.0894$	.90	.94

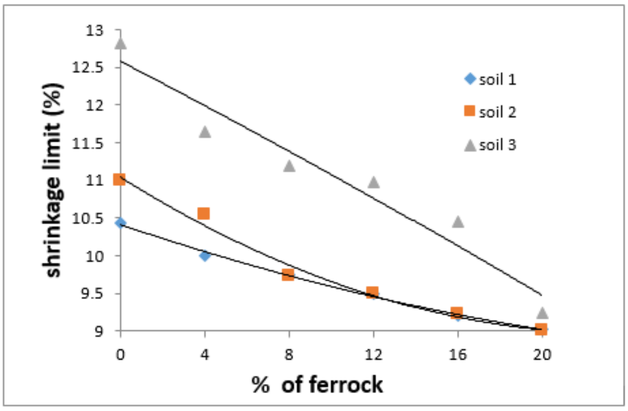

Fig 6 Correlation of Shrinkage Limit with different percentage of ferrock replacement by weight

Table.VIII Correlation and Regression values for Shrinkage Limit vs % of Ferrock for different expansive soils

soil	Regression equation	R^2	R
soil 1	$y = 0.008x^2 - 0.652x + 33.97$	0.96	0.98
soil 2	Y= = -0.005x2 - 0.237x + 35.17	0.83	0.91
soil 3	$y = -0.003x^2 - 0.055x + 28.75$	0.94	0.97

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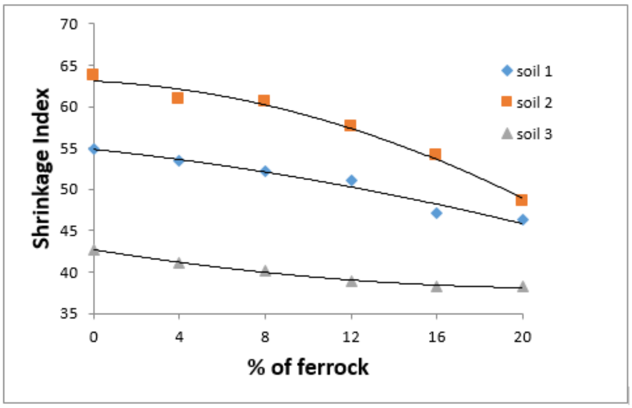

Fig 7 Correlation of Shrinkage Index with different percentages of Ferrock replacement by weight

Table.IX Correlation and Regression values for Shrinkage Index vs % of Ferrock for different expansive soils

Soil	Regression equation	R^2	R
soil 1	$y = -0.0005x^2 - 0.1445x + 12.579$	.94	.96
soil 2	$y = 0.0037x^2 - 0.175x + 11.042$	.98	.99
soil 3	$y = 0.0012x^2 - 0.0942x + 10.41$	.99	.99

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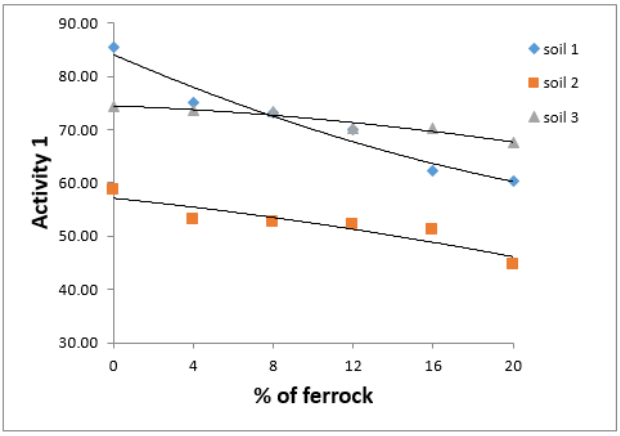

Fig 8 Correlation of Activity 1 with different percentages of Ferrock replacement by weight

Table.X Correlation and Regression values for Activity 1 vs % of Ferrock for different expansive soils

Soil	Regression equation	R^2	R
soil 1	$y = -0.009x^2 - 0.2697x + 54.819$	.96	.98
soil 2	$y = -0.0292x^2 - 0.1255x + 63.064$	.98	.99
soil 3	$y = 0.0094x^2 - 0.4183x + 42.707$	.99	.99

In the figure 1 it can be noted that the FSR of the expansive soils is dropping with increase in percentage of Ferrock, with soil 2 having the maximum effect at 20%. The specific gravity (figure 2) is seen to be increasing with inclusionof Ferrock content for all the three soils, as the iron powder is heavy in nature. A notable drop in liquid limit (figure 3), Plastic limit (figure 4) and plasticity index (figure 5) is observed with probable increase in amount of Ferrock. Also the shrinkage limit (figure 6) along

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with the shrinkage index (figure 7) is observed to be decreasing. The activity of the soils (figure 8) is seen to be abating with increase in Ferrock percentage

CONCLUSION

- The FSR of the soil 1 and soil 3 is dropping by 26% whereas for soil 2 it is decreasing by 40% at 20% of Ferrock replacement, also the activity of soils is brought down to the maximum of 29%, 24% and 10% for soil 1, soil 2 and soil 3 respectively.
- The Plasicity index and liquid limit can be brought down to the required extent just by increasing the % of Ferrock. However in the present study maximum drop in plasticity index is at 20% of Ferrock replacement for all the soils.
- As decrease in the shrinkage limit is observed with increase in percentage of Ferrock, it can be clearly stated that the Ferrock upgrades the index propertiesand packing phenomena of soil.

REFERENCES

[1] Ali M S and Koranne S S (2011), "Performance Analysis of Expansive Soil Treated With Granite dust and Fly ash", EJGE, Vol. 16, Bund. I, pp. 973-982.

[2] Cokca E (2001), "Use of class C fly ashes for the stabilization- of an expansive soil", Journal of Geotechnical and Geoenvironmental Engineering, Vol. 127, pp. 568-573.

[3] Jagmohan Mishra, R K Yadav1 and A K Singhai (2014) EFFECT OF GRANITE DUST ON INDEX PROPERTIES OF LIME STABILIZED BLACK COTTON SOIL, International Journal of Research and Science and Technology ISSN 2319-5991 www.ijerst.com Vol. 3, No. 1, February 2014 © 2014 IJERST.

[4] Ankit Singh Negi1 , Mohammed Faizan2 , Devashish Pandey Siddharth3 , Rehanjot singh4 SOIL STABILIZATION USING LIME, ISSN: 2319-8753, International Journal of Innovative Research in Science, Engineering and Technology Vol. 2, Issue 2, February 2013.

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