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A LABORATORY STUDY ON THE PERFORMANCE OF EXPANSIVE SOIL SUBGRADE TREATED WITH SEASHELL POWDER AND FERRIC CHLORIDE

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Abstract*—Black cotton soils are one among the problematic soils that has a high potential of shrinking and swelling due to change of moisture content. The volume changes due to the shrink-swell behaviour of the soil cause excessive total and differential movements of overlying structures and embankments in addition to load induced settlement of the soil. Population growth leading to rapid urbanization requires various types of civil engineering infrastructures and facility services. The growing metropolitan cities need more number of good lands for both construction activities and road development. The present study deals with the influence of sea shell powder and ferric chloride in stabilizing these problematic soils

Keywords— Black cotton soil, Sea shell powder, Ferric Chloride, OMC, MDD, CBR

I. INTRODUCTION

In India large tracts are covered by expansive soils also 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 in India. These soils are mostly found in areas such as Gujarat, Madhya Pradesh, Maharashtra, Tamil Nadu, Andhra Pradesh and Karnataka. The soil swells in rainy season and develops cracks on drying. This behavior of the soil is attributed to the presence of minerals such as montmorillonite, illite and Kaolinite etc. Such unstable conditions also include the heaving of expansive clays and collapse of silty sands, sandy silts and clayey sands from alteration of natural water content. 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 the 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. Several researches have been made to improve the strength of the expansive soils. Kate J.M (2005), Dr. Koteswara Rao. D et al (2011), Timani K.L, Patel R.M (2015), Prof. R.D.Babu et al. (2015) and several others have conducted experimental studies to improve the properties of the expansive soils using different admixtures and the tests yielded better results. 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.

II.OBJECTIVES OF STUDY

- The objectives of the present laboratory investigation are to determine the properties of the expansive soil and Sea shell powder.
- To evaluate the performance of expansive soil when treated with Sea Shell Powder as an admixture and Ferric Chloride as additive.

III. MATERIALS USED

Black Cotton (BC) Soils: - The soil used in this study is black cotton soil, obtained from Amalapuram East Godavari District Andhra Pradesh at a depth of 1.5m from ground level. The Index an Engineering properties of the black cotton soil are determined as per IS code of practice.

The geotechnical properties of the air dried BC soil, the liquid limit, plastic limit, specific gravity, differential free swell, Compaction, CBR as per IS Codes of practice were determined and the results were tabulated as follows.

Table1. Geotechnical properties of the untreated BC soil

S. No.	Property		BC Soil
1	Liquid limit %		62.06
2	Plastic Limit %		25.13
3	Plasticity Index %		39.90
4	Soil Classification	Gravel%	5
		Sand%	12
		Silt%	24
		Clay%	59
5	Specific Gravity		2.26
6	D.F.S %		100
7	OMC%		27.40
8	MDD g/cc		1.450
9	Cohesion kg/cm^2		0.55
10	CBR		1.49

Sea Shell Powder (SSP): - The sea shells were collected from local seafood vendor in Visakhapatnam. The shells were cleaned, dried, burnt at brick furnace, crushed into small pieces using Los Angeles machine, then grounded with a blender, and sieved using 150 micron sieve to produce seashell powder. The shells were burnt at high temperature of $500^{O}C$ for 3 days. The sea shell powder mainly consists of 1.60% SiO_2 and 51.56% CaO. The quantity of SSP was varied from 0% to 15% by dry weight of soil. The chemical composition of the Sea Shell powder were shown in table 2.

Table2. Chemical composition of ground sea shells

S. No.	Oxide	Percentage (%)
1	SiO_2	1.60
2	Al_2O_3	0.92
3	CaO	51.56
4	MgO	1.43
5	Na_2O	0.08
6	K_2O	0.06
7	H_2O	0.31
8	LOI	41.84

Courtesy to Monita Oliviaa, Annisa Arifandita Mifshella, Lita
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Chloride: - Laboratory grade Ferric Chloride consisting of 96% Ferric Chloride ($FeCl_3$) was used in this work. The amount of Ferric Chloride used was between 0.5 to 2.5 % by dry weight of the soil.

IV.LABORATORY INVESTIGATION

The laboratory studies were carried out on the samples of Expansive soil, Expansive soil+ Sea Shell powder, expansive soil, seashell powder and ferric chloride mixes.

Liquid limit Liquid limit test was conducted on Expansive soil, Expansive soil+10% Sea Shell powder, expansive soil+10% seashell powder and 1.5% ferric chloride mixes using Casagrande's liquid limit apparatus as per the procedures laid down in IS: 2720 part 4 (1970).

Plastic limit Plastic limit test was conducted on soil, Expansive soil+10% Sea Shell powder, expansive soil+10% seashell powder and 1.5% ferric chloride as per the specifications laid down in IS: 2720 part 4 (1970).

California bearing ratio Test The California bearing ratio tests were conducted on Expansive soil+10% Sea Shell powder, expansive soil+10% seashell powder and 1.5% ferric chloride mixtures as per IS 2720 part 16 (1979). The test was conducted under a constant strain rate of 1.25mm/min. The proving ring reading is noted for 50 divisions, and loading was continued until 3 (or) more readings are decreasing (or) constant. The test was conducted at Optimum moisture content. The samples were tested in soaked condition.

Differential Free Swell Test Differential Free Swell (DFS) is a parameter used for the identification of the expansive soil. For the determination of the differential free swell of a soil, 20g of dry soil passing through a 425µ size sieve is taken. One sample of 10g is poured into a 100c.c capacity graduated cylinder containing water, and the other sample of 10g is poured into a 100c.c capacity graduated cylinder containing kerosene oil. Both the cylinders are kept undisturbed in a laboratory. After 24 hours, the settled volumes of both the samples are measured.

Where DFS=$((V_d-V_k)/V_k)*100$
V_d=volume of settled soil in water
V_k=volume of settled soil in kerosene

Table 3: Differential Free Swell

S. No.	Degree of expansion	DFS
1	Low	< 20%
2	Moderate	20 - 35%
3	High	35 – 50%
4	Very High	>50%

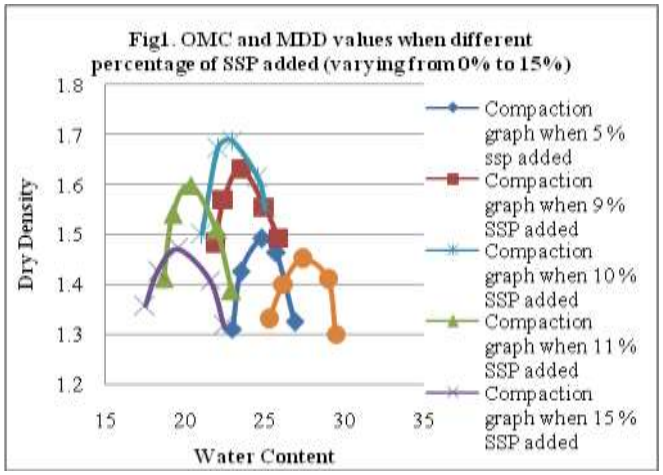
Compaction and CBR values of the treated BC soil

(i) Compaction

The BC soil was treated with different percentages of admixture i.e., the sea shell powder. SSP was replaced with the BC soil in different percentages varying from 5% to 15% to improve the properties of the soil. The compaction test values of the BC soil when treated with different percentages are presented in table 4 and figure 1.

Table4: Comparative results of the compaction test of the treated and untreated BC soil

Soil + varying % of SSP	MDD	OMC
100%soil+0%SSP	1.450	27.40
95%soil+5%SSP	1.491	24.82
91%soil+9%SSP	1.632	23.52
90%soil+10%SSP	1.689	22.96
89%soil+11%SSP	1.598	20.38
85%soil+15%SSP	1.471	19.57

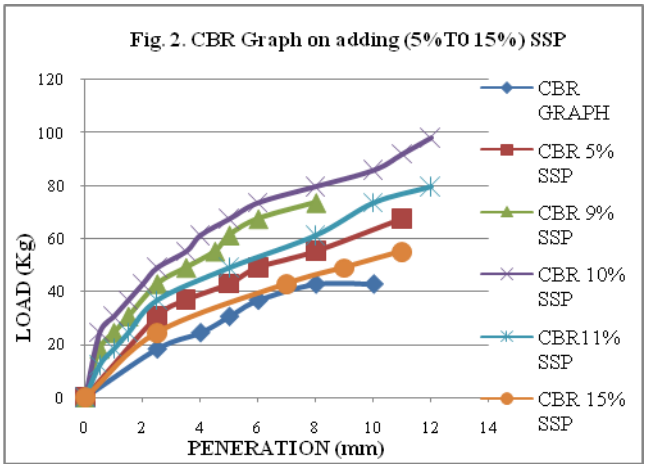


(ii) The CBR test was carried out as per the IS code 2720 part 16, 1987. CBR Test results when treated with different percentage of SSP are as follows:

Table5: CBR result of the soil upon treating with different percentages of SSP

S. No.	% REPLACEMENT	CBR VALUE
1	0	1.49
2	5	2.24
3	9	3.13
4	10	3.58
5	11	2.68
6	15	2.24

The CBR graphs of the soil when treated with different percentages of admixture and that of the untreated soil is shown in figure 2



It was observed from the compaction and CBR test results of the treated BC soil with different percentages of SSP, the compaction and the CBR values increased but did not achieve the desired results to be used in pavements as per IRC Codes of practise. Hence an additive ferric chloride was added to the optimum mix and again the tests were repeated. Ferric Chloride was added to the optimum percentage of SSP and soil mix in various dosages varying from 0.5% to 2% with an increment of 0.5% and the compaction and CBR results were carried out. The test results are as follows:

(a) Compaction test results:

Table6: Compaction test results of the optimum mix of soil upon adding different dosages of ferric chloride

Dosage of Ferric Chloride to 90%soil+10%SSP	OMC (%)	MDD (g/cc)
0.5	23.8	1.696
1	24.2	1.723
1.5	24.8	1.780
2	24.5	1.746
2.5	23.9	1.700

(b) CBR test results

Table6: CBR test results of the soil and optimum percentage of SSP when different dosages of $FeCl_3$ was added

S. No.	Dosage of Ferric Chloride to 90%soil+10%SSP	CBR
1	0.5	5.37
2	1	6.27
3	1.5	7.61
4	2	7.17
5	2.5	5.82

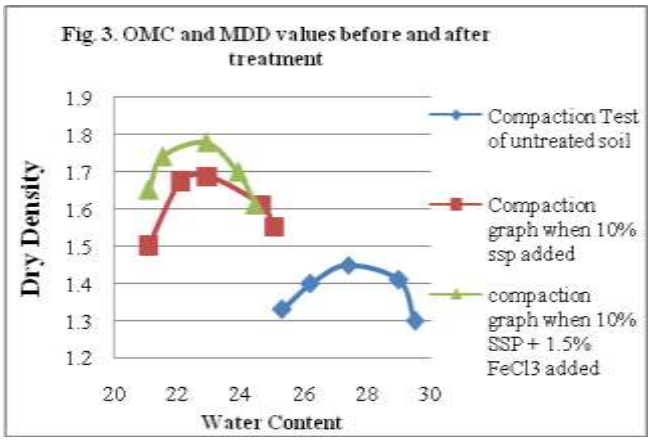
V.RESULTS AND DISCUSSION

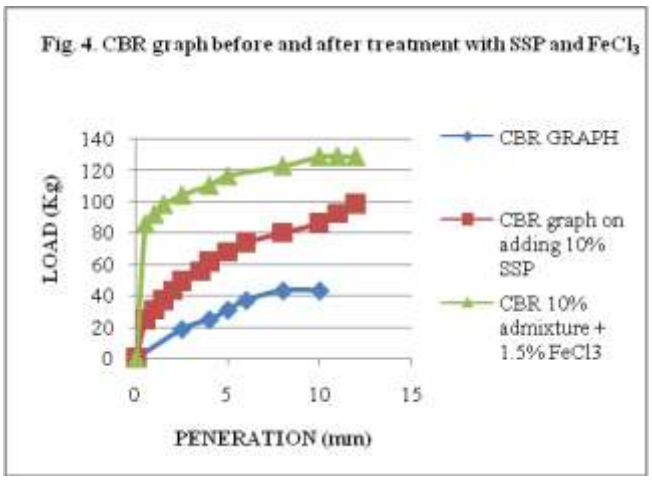
The test results of the soil before and after stabilization are compared. The test results of the soil before and after treating it with Seashell powder and Ferric Chloride are presented in table 7.

Table7: Comparative results of the soil before and after stabilization

Property	Untreated BC soil	BC soil + 10% of SSP	90% BC soil+10 % of SSP with optimum (1.5%) Ferric Chloride
LL (%)	62.06	32.7	19.10
PL (%)	25.13	20.67	10.23
PI (%)	36.9	12.03	8.86
MDD(g/cc)	1.45	1.68	1.78
OMC (%)	27.4	23.82	22.89
CBR	1.79	3.58	7.618

DFS (%)	100	20	0
G	2.56	2.61	2.78
Cohesion (kN/m^2)	105	55	23
Angle of shear resistance(ϕ)	5.5^o	17^o	23^o





VI.CONCLUSION

- It was observed from the laboratory test results that the liquid limit of the BC soil has been improved by 47.3% on the addition of 10% Sea shell powder when compared with the untreated BC soil and further upon adding 1.5% $FeCl_3$ the liquid limit increased by 41.59%.
- The plasticity index was improved by 67.39% on adding 10% SSP and further improved by 26.35% on adding 1.5 % $FeCl_3$
- OMC was improved by 13.06% on adding 10% SSP and further improved by 3.904% on adding 1.5% $FeCl_3$
- MDD increased by 15.86% on adding 10% SSP and further increased by 5.95% on adding 1.5% $FeCl_3$
- CBR value increased by 50% 10% SSP and further increased by 53.006% on adding 1.5% $FeCl_3$
- DFS was improved by 80% on adding 10% SSP and further on adding 1.5% $FeCl_3$ DFS improved by 100%
- Specific gravity of the soil increased by 1.95% on adding 10% SSP and further on adding 1.5% $FeCl_3$, it increased by 6.51%
- Cohesion improved by 47.6% on adding 90% SSP and further increased by 58.18% by adding 1.5% $FeCl_3$

Thus it was observed that the addition of 1.5% $FeCl_3$ dosage to the optimum mix of 90% soil and 10% SSP improved the properties of the soil. Hence, the addition of 10 percentage of Seashell powder and 1.5 percentage of Ferric Chloride improved the properties of the air dried Black Cotton soil to the desirable extent, making it useful for pavement subgrades as per IRC Codes of practise.

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