An Experimental Study on Effect of Steel Slag And Cement on The Subgrade of The Pavement

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Abstract- *Expansive soils are containing the swelling minerals such as illite and montmorillonite, they may cause extreme damage to structures, especially when these soils are subjected to wetting and drying conditions. High expansion and reduction in shear strength and subgrade strength will take place due to the increase in water content of these soils. The by-product of steel slag increasing day to day with a huge quantities and it is a major problem to disposal it.*

In this work, the by-product of steel slag and binders(cement) are varying percentages of, 0, 5, 15, 20 & 30% and 0, 2%, 4%, 6% are added to the expansive soil to improve the strength of the subgrade of pavements by conducting the California Bearing Ratio and UCS

It was observed that the maximum strength attained at 20% of steel slag and 6% of cement of additives added to the expansive soils, beyond that there is a marginal variation.

Keywords- Expansive soils, steel slag, binders, CBR and UCS.

I. INTRODUCTION

Expansive soil is one among the problematic soils that has a high potential for shrinking or swelling due to change of moisture content. Expansive soils can be found on almost all the continents on the Earth. Destructive results caused by this type of soils have been reported in many countries. In India, large tracts are covered by expansive soils 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 of India. 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 identified in a 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 ash etc. are also used to alter the characteristics of the expansive soils.

II. REVIEW LITERATURE

Homland Security (2014) In wet seasons, these soils swell and become soft as they gain water, while in dry seasons they shrink and become hard as they lose water. This behaviour is expected to cause severe damage to structures that are built on such soils. According to Wyoming Office of the USA looses about $2.3 billion/year due to structural damage (including buildings, roads, pipelines, and others) as a result of the swelling behavior of the expansive soils.

Many studies were carried out to reduce the damage effect of expansive soils (in terms of swelling or strength reduction) on structures. These studies used additives or admixtures as stabilizers (such as lime, cement, fly ash, calcium chloride, olivewaste, and asphalt), geo-textiles, and compaction-moisture control among other methods.

Al-Malack et al. (2016) used fuel oil fly ash (FFA) to stabilize marl soil. In their conclusions, the authors indicated that the treated marl met the durability and strength requirements.

Sengoz (2016) et al, to be generated annually in Nigeria is disposed in an environment-unfriendly manner. Steel slag is generally categorized based on its raw materials and production process into basic oxygen furnace (BOF) slag and electric arc furnace (EAF) slag. Unlike blast furnace slag, BOF and EAF slags contain high unhydrated lime (CaO) that causes it to volumetrically expand and this limits its use as a construction material. Researchers found out that steel slag can be used for manufacturing blended cement used as aggregate in Portland cement concrete and asphalt concrete and as unbound granular materials for road bases and sub-bases.

III. BINDERS

Manikant Mandal and Dr, Mayajit Mazumdar (1995), a study was made on the effect of additives on lateritic soil stabilization with cement and lime. Particularly, the strength and fatigue behaviour, under repeated flexure, of stabilized latertic soil treated with additives, have not been studied in our country till now.

Arumugam and K. Muralidharan (1997), stabilizing the locally available soils and using them as subgrade materials generally reduce the cost of pavement construction. It was concluded that the mechanical stabilization saving in the construction cost of pavement upto 43% has been effected. Lime and cement stabilization saves the amount by 46.2% and 27.56% respectively.

T.Lopez-Lara, J.A. Zepeda-Garrido and V.M. Castario (1999) this paper includes the evaluation of the main index properties of the soil, along with a characterization of the materials through X-ray diffraction.

Abu siddique and Bipradasrajbongshi (2002), A study of Mechanical properties of a cement stabilized coastal soil for use in road construction, this paper present the soil cement stabilization with 1%, 3%, and 5% cement fulfill the requirements of road sub-base and base subjected to light traffic. Analyses using CIRCLY computer program were conducted to estimate the thickness of soil-cement for paved and unpaved rural road maximum width 2.5 m and subjected to anticipated design traffic loading of light cross country vehicle (LCCV), i.e, jeep.

Virender Kumar (2002). **Costas A.Anagno– stopoulos (2004)**, In this study, a laboratory test programme was carried out to find out the effect of inclusion of cement and acrylic resin on physical and engineering behaviour of a soft clay. A series of tests are conducted with the addition of 5% to 30% of cement contents and acrylic resin of 5%. It is concluded that the development of strength and stiffness for a short curing time (7 days) is delayed significantly because of A.R addition while for long curing time (28 days) the engineering parameters are increased considerably

IV. MATERIALS

Soil

The black cotton soil collected from '**muramalla**' village near Amalapuram, East Godavari District in India.

Table no: shows the properties of soil

No	Property	Value
1	**Grain size distribution**	
	Sand (%)	2
	Silt (%)	20
	Clay (%)	78
2	**Atterberg limits**	
	Liquid limit (%)	82
	Plastic limit (%)	40
	Plasticity index (%)	42
	Shrinkage limit (%)	12
3	**Compaction properties**	
	Optimum Moisture Content, O.M.C. (%)	24.89
	Maximum Dry Density, M.D.D (g/cc)	1.38
4	Specific Gravity (G)	2.69
5	IS Classification	CH
6	Soaked C.B.R (%)	2.2
7	Differential free swell (%)	128
8	Permeability (cm/sec)	1.729×10^{-7}
9	**Shear Strength Parameters**	
	Cohesion (C) (Kg/cm²)	0.46
	Angle of internal friction (ø)	2°

Steel Slag:

Steel slag is used for this study. The quantity of the this was varied from 0 to 30% by dry weight of soil.

The steel slag aggregates (SSA) were obtained from the Vishakhapatnam Steel plant. The aggregates that passed 1.0 inch sieve were used in this study. The specific gravity of the fine and coarse portions of the aggregates were 3.1 respectively. The chemical tests showed that the aggregates were free of Cadmium (Cd) and Copper (Cu) elements.

Gravel size (%) = 88 Sand size (%) = 12.0 9

Silt size (%) = 67.10 Clay size (%) = 23.5

Classification (USCS):CH–MH = GP

Fig. shows the sample of steel slag

Table Properties of steel slag

S.NO	PROPERTY	VALUE
1.	Specific gravity	**FA** 3.2
2.	Liquid limit (%)	**Non plastic**
3.	Plastic limit (%)	**Non plastic**
4.	Plasticity index (%)	**Non plastic**

Binders:

Ordinary Portland cement was used for this study. The quantity of the cement was varied from 0 to 8% by dry weight of soil.

shows the sample of Cement

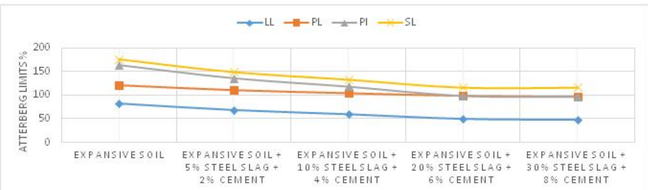
V. DISCUSSIONS ON TEST RESULT

Laboratory Test Results on Soil Stabilization

The effect of adding different proportions of steel slag and cement to the expansive soil on Atterberg limits, DFS and Strength Properties are discussed in the following sections.

Table: Effect of Steel Slag and Cement on Index Properties of Expansive soil

Particular	Index properties of soil			
	W_L (%)	W_P (%)	I_P (%)	W_S (%)
Expansive Soil	82	40	42	12
Expansive Soil + 5% Steel slag + 2% Cement	68	43	25	13
Expansive Soil + 10% Steel slag + 4% Cement	59	45	14	15
Expansive Soil + 20% Steel slag + 6% Cement	49	49	00	18
Expansive Soil + 30% Steel slag + 8% Cement	47	49	00	20



Graph: Shows the variation of Atterberg limits with the expansive soil

Effect of Additives on Atterberg limits

The variation of liquid limit values with different percentages of steel slag and cement added to the expansive soil is presented in the graph. It is observed that the decrease in the liquid limit is significant upto20% SS and 6% Cement added to the expansive soil, beyond that, there is a nominal decrease.

Maximum decrease in liquid limit for stabilized expansive clay is observed at 20% SS and 6% Nominal increase in plastic limit of stabilized expansive clay is observed with increase the percentage of the additives.

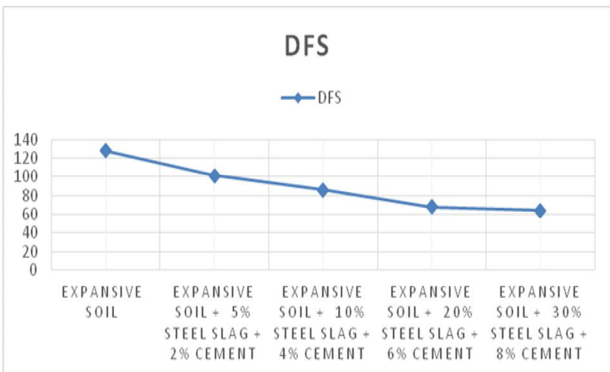
Graph shows the variation of plasticity index with the addition of steel slag and cement to expansive soil. The increase in the plastic limit and the decrease in the liquid limit cause a net reduction in the plasticity index.

It is observed that, the reduction in plasticity indexes are 100% respectively for 20% SS and 6% added to the expansive soil. The reduction in plasticity index with steel slag and cement treatment could be attributed to the depressed double layer thickness due to cation exchanges steel slag and binding property

The variation of shrinkage limit with the percentage of steel slag and cement added to the expansive soil is presented in the graph.4. With increase in percentage of steel slag and cement added to the expansive soil the shrinkage limit is increasing. With 20% ss & 6% binder additives addition, the shrinkage limit of stabilized expansive clay is increased from 0% to 50%.

Table Effect of Steel Slag and Cement on DFS of Expansive Soil

Particular	DFS
Expansive Soil	128
Expansive Soil + 5% Steel Slag + 2% Cement	101
Expansive Soil + 10% Steel Slag + 4% Cement	86
Expansive Soil + 20% Steel Slag + 6% Cement	68
Expansive Soil + 30% Steel Slag + 8% Cement	64



Graph: Shows the variation of DFS with the expansive soil

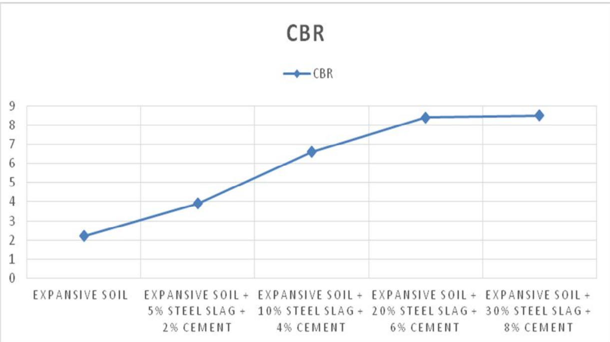
Effect of Additives on DFS

The variation of DFS of stabilized expansive clay with addition of different percentages of steel slag and cement is shown in the graph.5. It is observed that the DFS is decreasing with increasing percentage of additives added to the expansive soil. Significant decrease in D.F.S. is recorded in stabilized expansive clay with addition of 20%SS and 6% Cement.

The reductions in the DFS of stabilized expansive clay with addition of 20% SS and 6% Cement 1% chemical are 46.87% respectively compared with the expansive soil. The reduction in DFS values could be supported by the fact that the double layer thickness is suppressed by cation exchange.

Table: Effect of Steel Slag and Cement on CBR of Expansive Soil

Particular	CBR
Expansive Soil	2.2
Expansive Soil + 5% Steel Slag + 2% Cement	3.9
Expansive Soil + 10% Steel Slag + 4% Cement	6.6
Expansive Soil + 20% Steel Slag + 6% Cement	8.4
Expansive Soil + 30% Steel Slag + 8% Cement	8.5



Graph:Shows the variation of CBR with the expansive soil

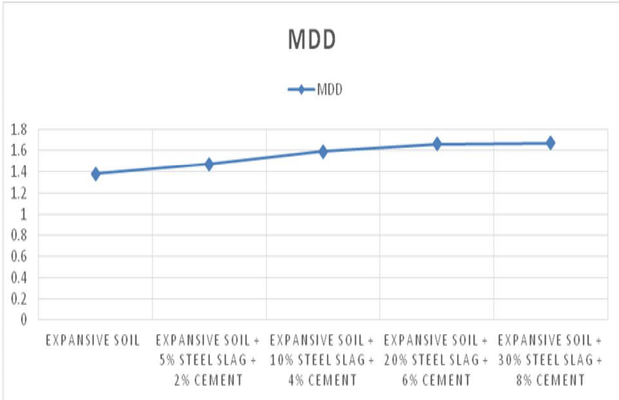
Effect of Additives on CBR

Graph 6. shows the variation of CBR of stabilized expansive soil with addition of different percentages of steel slag and cement. It is can be seen that the CBR is increasing with increasing percentage of steel slag and cement added to the expansive soil. Significant increase in CBR is recorded in stabilized expansive clay with addition of additives upto 20% SS and 6% Cement, beyond this percentage the increase in CBR is marginal. The increase in CBR values of stabilized expansive clay with addition of additives are 286.36% respectively compared with the expansive soil.

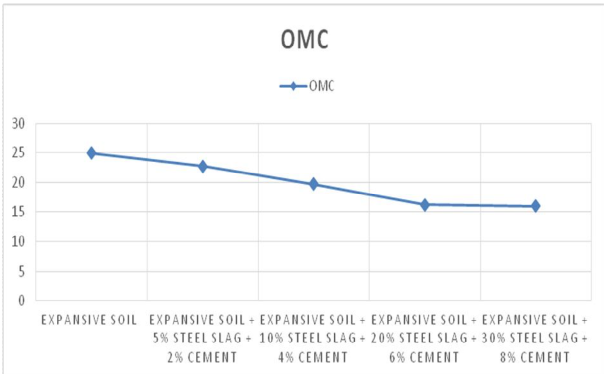
The increase in the strength with addition of additives may be attributed to the cation exchange of steel slag and cement and soil between mineral layers and due to the formation of silicate gel. The reduction in improvement in CBR beyond 20%SS and 6% Cement, may be due to the absorption of more moisture at higher chemical content.

Table: Effect of Steel Slag and Cement on Maximum Dry Density and Optimum Moisture Content of Expansive Soil

Particular	MDD(g/cc)	OMC (%)
Expansive Soil	1.38	24.89
Expansive Soil + 5% Steel Slag + 2% Cement	1.47	22.66
Expansive Soil + 10% Steel Slag + 4% Cement	1.59	19.66
Expansive Soil + 20% Steel Slag + 6% Cement	1.66	16.22
Expansive Soil + 30% Steel Slag + 8% Cement	1.67	15.99



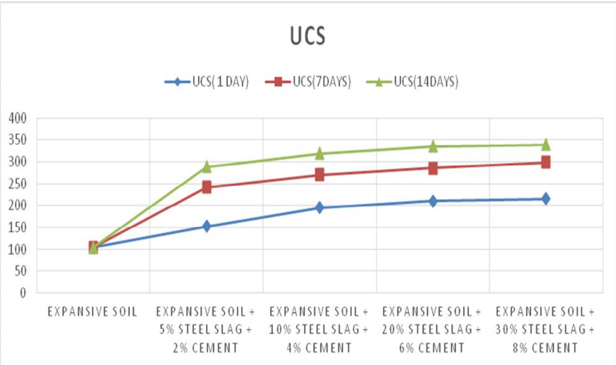
Graph: Shows the variation of MDD with the expansive soil



Graph:Shows the variation of OMC with the expansive soil

Table: Variation of Undrained compressive strength of stabilized expansive clay

Particular	Unconfined Compressive Strength (KPa)		
	1 day	7 days	14days
Expansive Soil	105	105	105
Expansive Soil + 5% Steel Slag + 2% Cement	152	241	288
Expansive Soil + 10% Steel Slag + 4% Cement	195	270	318
Expansive Soil + 20% Steel Slag + 6% Cement	210	285	335
Expansive Soil + 30% Steel Slag + 8% Cement	215	298	339



Graph: Shows the variation of UCS with the expansive soil

Effect of Additives on Shear Strength Properties

The unconfined compressive strength of the remoulded samples prepared at MDD and optimum moisture content with addition of steel slag and cement to the expansive soil are presented in the table 4.6. The prepared samples are tested after 1day, 7 days and 14 days. As expected, the unconfined compressive strength is increasing with time may be due chemical reaction. It is observed that the unconfined compressive strength of the stabilized expansive soil is increasing with increase in percentage of additives added to the soil.

The unconfined compressive strength of stabilized expansive clay is increased by 219% & 51.16% when treated with 20% SS and 6% Cement respectively. The increase in the strength with addition of steel slag and cement may be attributed to the cation exchange between mineral layers and due to the formation of silicate gel. The reduction in strength beyond 20%SS and 6% Cement, may be due to the absorption of more moisture at higher steel slag and cement.

The **optimum percentage** of different additives observed during the laboratory experimentation are summarized and presented in the following Table.

Optimum percentage of different additives

Additives	Optimum percentage
Expansive Soil +Steel Slag +Cement	20%SS + 6%C

VI. CONCLUSIONS

The following conclusions can be drawn from the laboratory study carried out in this investigation.

- It is observed that the liquid limit values are decreased by 40.24% respectively for 20% SS and 6% Cement added to the expansive clay.
- Marginal increase in plastic limits is observed with addition of additives to the expansive soil.
- Decrease in plasticity index is recorded with addition of additives to the expansive soil.
- The shrinkage limit is increasing with 20% Steel Slag and 6% Cement addition; it is observed that the shrinkage limit of stabilized expansive soil is increased from 0% to 50%
- The D.F.S values are decreased by 20% SS and 6% Cement treatments respectively.
- The CBR values are also increased by 286.36% respectively for 20% SS and 6% treatment
- The UCS values are increased by 219% respectively for 20% SS and 6% treatments for a curing period of 14 days.

VII. SCOPE FOR FURTHER WORK

- Advanced cyclic Tri axial tests may be conducted for further confirmation of test results.
- Conducting field test

REFERENCES

[1] Holtz, W.G. and Gibbs, H.J. (1956): "Eng. Properties of Expansive Clays", Transactions of ASCE, Vol. 121, pp. 641-647.
[2] Holtz, W.G. (1959): "Expansive Clays – Properties and Problems", First Annual Soil Mechanics Conf., Colorado School of Mines, Colorado, pp. 1-26.
[3] Low, P.F. (1959): "Physico-chemical properties of soils: ion exchange phenomena", Discussion paper by A.W. Taylor, Journal of the soil mechanics and foundation division, ASCE, Vol. 85, No. SM2, pp. 79-89.
[4] Mc Dowell, C. (1959): "Stabilization of Soils with Lime, Lime-flyash and other Lime reactive minerals", HRB, Bulletin No. 231.
[5] Taylor, A.W. (1959): "Physico Chemical Properties of Soils: Ion Exchange phenomena", Journal of Soil Mechanics and Foundations Division, ASCE, Vol. 85,

[6] Leonards, G.A. (1962): "Foundation Engineering", Mc-Graw Hill Book Co., New Delhi.

[7] Davidson, L.K., Demirel, T. and Handy, R.L (1965): "Soil Pulverization and Lime Migration in Soil-Lime stabilization", Highway Research Record-92, pp 103-126.

[8] Uppal, H.L. (1965): "Field Study on the Movement of Moisture in Black Cotton Soils under road pavements", Symposium on Moisture Equilibrium and Moisture changes in soils beneath covered areas, Butterworths, Australia, pp. 687-693.

[9] Williams, A.A.B. (1965): "The Deformation of Roads Resulting from Moisture changes in expansive soils in south Africa", a symposium on moisture equlibria and moisture changes in soils beneath covered areas, Butterworths, Australia, pp. 143-155.

[10] Katti, R.K., Kulkarni, K.R. and Radhakrishnan, N. (1966): "Research on Black Cotton Soils without and with Inorganic Additives", IRC, Road Research Bulletin, No. 10, pp. 1-97.

[11] Ring, W.E. (1966): "Shrink-Swell Potential of Soils Highways Research Record No. 119, National Academy of Sciences, National Research Council Publication No. 1360, Washington D.C.

[12] Yong, R.N. and Warkentin, B.P. (1966): "Introduction to Soil Behavior", GMC Millan Co., New York.

[13] Nordquist, E.C. and Bauman, R.D (1967): "Stabilization of expansive mancos shale", Proc. of 3rd Asian Regional Conf. on soil mechanics and foundation Eng., Vol.1, Israel.

[14] Ho, M.K (1968): "Swelling Characteristics of Expansive Clay with Access to Common Electrolytes", Proc. of the Southeast Asian Regional Conf. on soil Eng., Asian institute of Tech., Bangkok, pp. 159-167.

[15] Gokhale, Y.C. (1969): "Some Highway Eng. Problems in Black Cotton Soil Region", Proc. of the Symposium on characteristics of and construction techniques in black cotton Spil, pp, 209-212.

[16] Holtz, W.G. (1969): "Volume Change in Expansive Clay Soils and Control by lime Treatment", Proc. of 2nd Int. Research and Eng. Conf. on expansive clay soils, Texas A & M Press, Texas, pp. 157-174.

[17] Roy, S. and Char, A.N.R. (1969): "Eng. Characteristics of black cotton soils as related to their mineralogical composition", Proc. of symposium on characteristics of and construction techniques in black cotton soil., The college of military Eng, Poona, India, pp. 19-23.

[18] Ramannaiah, B.K., Sivananda, M and SatyaPriya, (1972): "Stabilization of Black Cotton Soil with lime and Rice-Husk-Ash", 13th Annual General Body Meeting of Indian Geotechnical Society.

[19] Chu. T.Y. AND Mou, C.H. (1973): "Volume Change Characteristics of expansive soils determined by controlled suction tests", Proc. of 3rd Int. Conf on expansive soils, Haifa, Israel, Vol 1, pp 177-185.

[20] Jones, D.E. and Holtz, W.G. (1973): "Expansive Soils – the Hidden Disaster", Civil Eng., Vol. 43, No. 8.