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Stabilization of Black Cotton Soil by Using Steel Slag Powder

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Abstract - *In India Black cotton soil is one of the major soil deposits which become highly problematic because of its property of higher degree of swelling and shrinkage. The improvement of the base materials, i.e., soil stabilization, is an integral part of the construction activity. Weak soils are generally stabilized utilizing cement or lime in addition to the mechanical effort. Since cement and lime are relatively costly, the use of other "cheap" materials such as electric arc furnace steel slag powder is used to stabilize the black cotton soil. The experimental investigation and studies was carried out to the improvement in geotechnical properties of an expansive soil and stabilized with industrial waste steel slag Powder. The aim of this study is to improve the engineering properties of expansive soil using steel slag powder and utilization of industrial waste. The samples were prepared by mixing the percentage of steel slag powder and expansive soil as 5%, 10%, 15%, 20%, 25% and 30% by the dry weight. The various experimental test results indicate significant increase in strength at 30% steel slag powder content. Standard proctor test, unconfined compressive strength, liquid limit and plastic limit tests are performed to analysis compressive strength, Maximum dry density (MDD) and optimum moisture content (OMC) of soil mixture.*

Key Words: Black Cotton Soil, Expansive Soil, Industrial Waste, steel slag powder, EAFS, Stabilization etc.

1. INTRODUCTION

An expansive soil is a soil which undergoes swelling and shrinkage on addition and removal of water content. Black cotton soil must be stabilized before used as foundation or construction material. Clay soil often possess poor strength characteristic and pose serious construction problem causing large differential settlement to the structure constructed over them. Since black cotton soil exhibit high swelling and shrinkage when exposed to change in moisture content and hence found to be most troublesome from engineering considerations. This behavior is due to presence of a mineral montmorillonite. Sometimes, it is not possible to avoid clayey soil in such sites because of non-availability of alternative locations having good load bearing capacity. The stabilization of clayey soil in such location is required by using various admixtures so that the strength of subgrade characteristic of soil can be improved. Stabilization can be achieved by using either by pozzolanic material or chemicals. The fly ash, rice husk ash (RHA), saw dust ash etc. Thus this work focused on investigating the effect of steel slag powder on some geotechnical properties of an expansive soil which are relevant for evaluating the performance of subgrade soil.

Waste materials are universally described as by-products of Commercial, industrial, building and demolition activities that do not have any long-lasting value. Due to the recent implementation of tougher environmental guideline around the world, recycling and reuse of waste materials has become very critical. Steel has been known as the one of the world's most recyclable materials. Annually, more than 1400 million tonnes of steel is manufactured worldwide (Brooks et al., 2011). The steelmaking process produces an industrial byproduct termed as slag powder. Electric arc furnace slag (EAFS) is a by-product of smelting iron ore to separate the metal fraction from impurities. It can be considered to be a mixture of metal oxides and silicon dioxide. However, slag can contain metal sulfides and metal atoms in the elemental form. While slag is generally used as a waste removal mechanism in metal smelting, it can also serve other purposes, such as soil stabilizer, assisting in the temperature control of the smelting; and also minimizing any re-oxidation of the final liquid metal product before the molten metal is removed from the furnace and used to make solid metal. It can be used as stabilizer for concrete and mortar [Fredericci et al., 2000].

1. Soil:

The locally available soil collected from Harsul-Pisadevi area Dist. Aurangabad and the soil was collected from a depth of 1.5 meter from the ground surface.

2. Steel Slag Powder:

It is a complex, fine-grained, high-density material containing high amounts of zinc and iron, and significant amounts of calcium, manganese, magnesium, lead and chromium [De Sauza et al., 2010].

Steel slag powder was taken from steel industry at Jalna (Vijaylaxmi Steels Group). The steel slag powder from the steel industry added in variable proportion by weight (5%, 10%, 15%, 20%, 25% and 30%) to the soil samples.

1.1 *Objective of the study*

Soil is an important construction material vastly used in every type of construction. All types of structures are constructed on foundation which is ultimately rested on soil. Remember, foundation does not carry the load it simply transfer the load to the soil. Entire load is to be taken up by soil only. If the soil is not capable of bearing the load, there will be no use of heavily designed, heavily reinforced foundation.

Black cotton soil is an expensive soil which undergoes swelling and shrinkage on addition and removal of water content. It may cause danger to any structure constructed on

such type of soil. Such soil must be stabilized before used as foundation or construction material. The study area in the present work consists of black cotton soil, so efforts have been made to improve the geotechnical properties of soil in cost effective way. So the main objective is to stabilize the soil and improve its geotechnical properties in order to make use of the soil in the study area for construction purpose.

2. Experimental Test

The designations for soil and mix soil are detailed in Table 3.5. The soils are modified by the use of steel slag powder. The soil is modified by the use of steel slag powder in the range of 0-30%. Table-1 shows details of the soil mix and the symbols used for them.

Table -1: soil mix and the symbols used

Symbol	Proportion Soil + Steel Slag Powder
SSSP0	100:00:00
SSSP1	95:05:00
SSSP2	90:10:00
SSSP3	85:15:00
SSSP4	80:20:00
SSSP5	75:25:00
SSSP6	70:30:00

The term soil stabilization means the improvement of the stability or loading power of a poor soil through the use of controlled compaction; dosage and addition of suitable additives or stabilizers.

The stabilization of the soil deals with mechanical and chemical methods so that the stabilized soil fulfills its purpose. The stabilization process involves essentially the excavation of the in situ soil, the treatment of the in situ soil and the compaction of the treated soil.

The ground is the basic material for road construction. When expansive soil that has poor engineering properties is found, a civil engineer has the following options

1) To find a new site for the construction
2) To replace the poor soil
3) Redesign the structure
4) Improvement of the engineering properties of locally available soil area

In developing countries such as India, where industrial growth is very high and waste disposal is a problem, the use of waste to improve the technical properties of the expansive soil will be an ecological and economical solution.

In the laboratory tests are conducted on soil samples and industrial waste steel slag powder. The various tests conducted are as given below.

1. Consistency limits
2. Standard Proctor test,
3. Direct Shear test,
4. Unconfined Compressive strength test
5. Laboratory Soaked CBR test and

The observations, results and discussion based on the experimental work

Consistency limits

The Atterbergs limits are a basic measure of the critical water contents of a fine-grained soil: its shrinkage limit, plastic limit, and liquid limit. The effect of addition of steel slag powder in varying proportion with soil has been determined and the variation in consistency limits for various proportions are presented in Table-2 and chart-1.

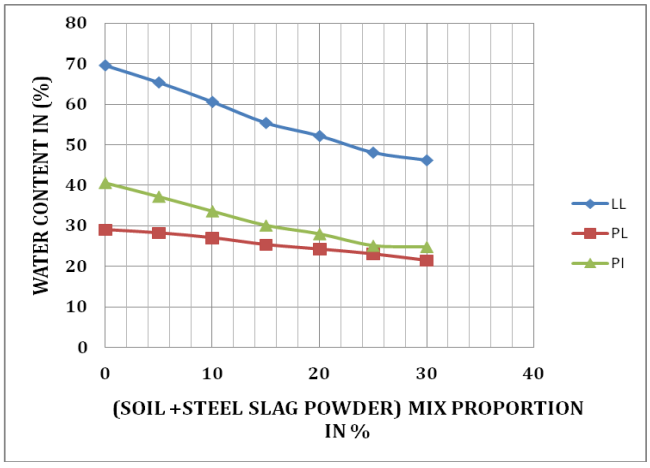
From the Table-2, it is found that as the percentage of steel slag powder increases the Liquid Limit of mix is reduced. As the percentage of steel slag powder is increased up to 30% the liquid limit of soil mix proportion is reduced by 33.62%.

Table -2: Consistency limits

Sr. No.	Property	Soil + Steel Slag Powder						
		SS SP_0	SS SP_1	SS SP_2	SS SP_3	SS SP_4	SS SP_5	SS SP_6
	Proportion Soil : Steel Slag Powder	100 :00	95 :05	90 :10	85 :15	80 :20	75 :25	70 :30
1	Atterberg's Limits :(%)							
	Liquid Limit	69.6	65.4	60.6	55.4	52.2	48.1	46.2
	Plastic Limit	29	28.2	27	25.3	24.2	23	21.4
	Plasticity Index	40.6	37.2	33.6	30.1	28	25.1	24.8

Expansive soil has been modified by the addition of steel slag powder in the range of 0-30%. The liquid limit, plastic limit and plasticity index of Soil, without modification is found to be 69.60%, 29% and 40.60% respectively. After modification with 5%, 10%, 15%, 20%, 25% to 30% of Soil mix the liquid limit is found to be reduced by 6.03%, 12.93%, 20.40%, 25%, 30.89% and 33.62% respectively.

The probable reason for reducing the liquid limit of modified soil may be the use of non-plastic material as steel slag powder.



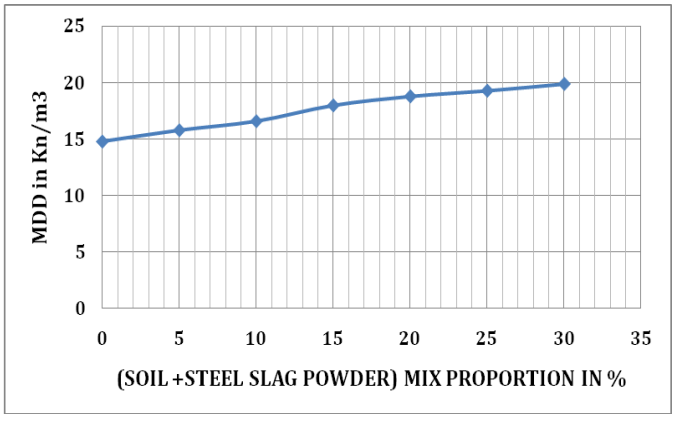
Graph -1: Effect of Addition of Steel slag powder on Atterbergs Limit for expansive Soil

From the Table 02 it is also found that the value of plastic limit decreases as increase in the percentage of steel slag powder. As the percentage of steel slag powder increased up to 30% the value of plastic limit is reduced by 26.20%. Similarly the value of plasticity index is also reduced by increase in percentage of steel slag powder with soil. As the steel slag powder with soil percentage is increased up to 30%, value of plasticity index is reduced by 38.91%.

The reduction in plasticity index is found due to use of non-plastic material Steel Slag Powder for modification.

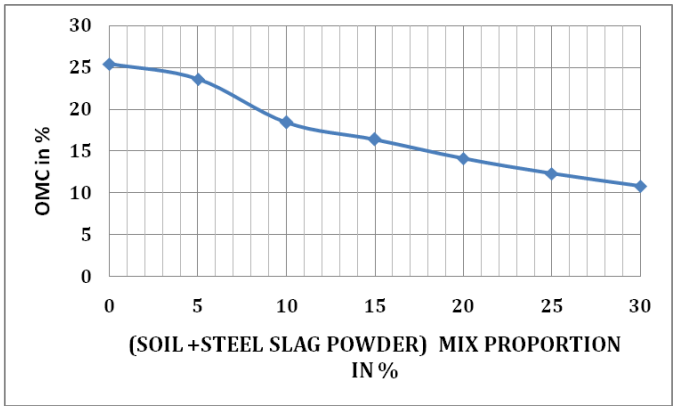
The result shows that on addition of Steel Slag Powder, as the percentage of Steel Slag Powder increases the liquid limit and plastic limit of the mix soil decreases. The above results indicate that the expansion characteristics are reduced on addition of Steel Slag Powder.

The Effect of Steel Slag Powder addition on Maximum Dry Density for soil



Graph -2: Effect of Addition of Steel slag powder on MDD

The dry density obtained by the compaction of soil at its optimum moisture content is called Maximum dry density. The maximum dry density of soil without modification is found to be 14.8 kN/m^3. After modification by 5%, 10%, 15%, 20%, 25% and 30% by steel slag powder, the maximum dry density is found to be increased for 30% mix proportion. The probable reason for increase in maximum dry density of soil by addition of steel slag powder in comparison with original soil may be proper rearrangement of modified soil mix and improved binding capacity.



Graph -3: Effect of Addition of Steel slag powder on OMC

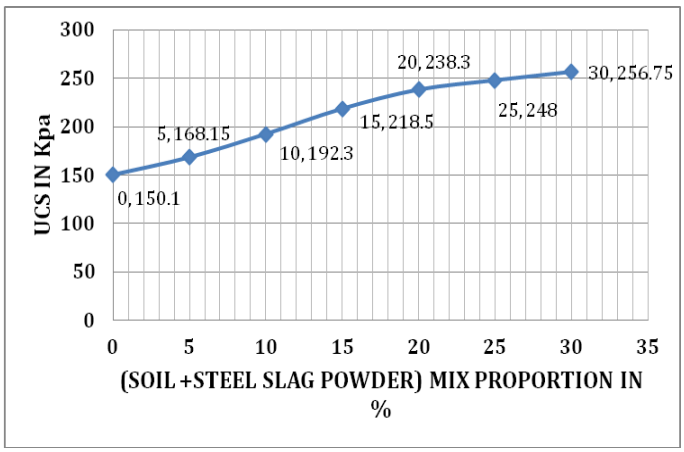
The Optimum moisture content of soil without modification is found to be 25.40%. After modification with 5%, 10%, 15%, 20%, 25% and 30% of Steel Slag Powder, the optimum moisture content is found to be reduced by 7.08%, 27.55%, 35.43%, 44.48%, 51.57% and 57.48% respectively. The probable reason for reduction in optimum moisture content of soil by addition of Steel Slag Powder in comparison with original soil may be proper rearrangement of soil particles of modified mix which may be reducing the voids.
The MDD of the steel slag powder stabilized soil increased with increase in steel slag powder content while the OMC reduced with increase in steel powder content. The results show that the steel powder content increased the compaction and strength of the soil while reducing the moisture content.

Effect of Addition of Steel slag powder on UCS

The unconfined compressive strength test results for various combination of soil with fly ash and rice husk ash are presented in Table 03. The results in graphical form are also presented in Graph-4. Shear strength is the principal engineering property which controls the stability of soil mass under the load. It governs bearing capacity, stability of slope etc. The test is conducted in laboratory on unconfined compression machine as per IS: 2720 part 10-1973.

Table -3: Unconfined Compressive Strength

Sr. No.	Property	Soil + Steel Slag Powder						
		SS SP_0	SS SP_1	SS SP_2	SS SP_3	SS SP_4	SS S P_5	SS SP_6
	Proportion Soil : Steel slag powder	100: 00	95: 05	90: 10	85: 15	80: 20	75 : 25	70: 30
1	Unconfined compressive strength (kPa)	150	16 8.2	19 2.3	21 8.5	23 8.3	24 8	25 6.8



Graph -4: Effect of Addition of Steel slag powder on UCS

The percentage of Steel slag powder is increased the value of unconfined compressive strength is also increased. The percentage of steel slag powder is increased up to 30% the value of unconfined compressive strength is increased by 71.20%. The unconfined compressive strength of soil, without modification is found to be 150 kPa. After modification with 5%, 10%, 15%, 20%, 25% and 30% of steel slag powder, the value of unconfined compressive strength is increased by 12.13%, 28.20%, 45.66%, 58.86%, 65.33% and 71.2% respectively.

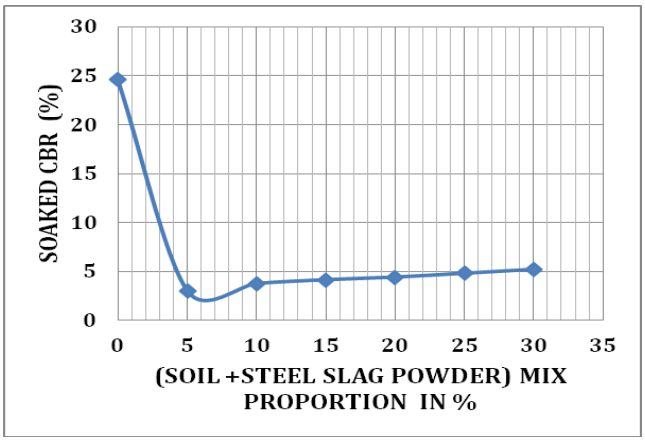
California bearing ratio test

The California Bearing Ratio test results for various combinations of soil + steel slag powder presented in Table 4. Same results in graphical forms are also presented in Graph -5.
It is found the percentage of mix proportion of soil, steel slag powder is increased the value of California bearing ratio after 5% addition is also increased.

Table -4: California Bearing Ratio

Sr. No.	Property	Soil + Steel Slag Powder						
		SS SP_0	SS SP_1	SS SP_2	SS SP_3	SS SP_4	SS SP_5	SS SP_6
	Proportion Soil : Soil +Steel Slag Powder	100 :00	95: 05	90: 10	85: 15	80: 20	75: 25	70: 30
1	California Bearing Ratio % (soaked)	24. 6	3.0 2	3.75	4.1 4	4.4	4.8	5.2

The Soaked CBR decreases with increase in steel slag powder up to 5%. The soaked CBR of the natural soil was greatly reduced by the steel slag powder thereby indicating a significant disintegration of the stabilized mixture in the presence of water.



Graph -5: Effect of Addition of Steel slag powder on CBR

The probable reason for increase in soaked California bearing ratio of soil by addition after 5% of steel slag powder in comparison with original soil may be increase in the density of modified soil mix.

3. CONCLUSIONS

By the addition of steel slag powder in an expansive soil may improve the bearing capacity of soil. Also by using industrial waste as an admixture it can reduce the cost of stabilization process and also due to the use of waste it does not affect the environment.

1. Thus we conclude that we increase the stability of an expansive soil using steel slag powder.

2. We can improve the shear strength of BC soil plasticity index.
3. The addition of 30% steel slag powder increased the Maximum Dry Density of expansive soil by about 34.45% and the optimum moisture content is found to be reduced by 57.48%.

4. By addition of 30% of steel slag powder in soil, the value of liquid limit, plastic limit and plasticity index of modified soil is reduced due to use of non-plastic material for modification.

5. From the practical consideration the modified soil mix (soil: steel slag powder) 70:30 percentage is recommended to be used for increasing expansive soil index properties.

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