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Stabilization of black cotton soil by using ground granulated blast furnace slag and steel slag

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Abstract: Soil stabilization is one of the modification techniques used to improve the index property and engineering properties of soil and has become the major practice in construction engineering which enables the effective utilization of industrial wastes as a stabilizer. Due to rapid increase in population, land is getting scarce hence it is necessary to strengthen weak or problematic soil enough to withstand all types of loads. This process of improving an on-site (in-situ) soil's engineering properties is also referred to as "soil modification" or "soil stabilization". This technique becomes more popular because of its easy availability and adaptability. Construction of structures over weak or soft soils possesses difficulties like differential settlements, poor strength and high compressibility. In many situations, a soil in natural state does not have adequate geotechnical properties to be used as road service layers, foundation layers and as a construction material. Expansive soils are poor in strength and they will result in poor pavement support and ultimately affects the pavement performance and its life period. Economy in construction needs the efficient way of waste utilization. Hence this paper aims to investigate the use of some industrial wastes such as ground granulated blast furnace slag and steel slag to stabilize the weak sub grade soil. The present work describes a study carried out to check the improvements in the properties of Expansive soil with the replacement of GGBS and Steel slag. An experimental investigation is carried out to study the influence of mineral admixture in unmodified soil with respect to the strength characteristics. This study includes the ground granulated blast furnace slag and steel slag in different mix proportions. In this comparative study laboratory tests such as Atterberg's limit, Compaction test and UCC test were carried out for both modified and unmodified clayey Soil.
Keywords: Compressive strength, tensile strength, flexural strength of steel fiber, M-sand.

I. Introduction

Soil stabilization is the process of improving the engineering properties of weak soil and thus making it more stable. Black cotton soil possesses great threat for the construction of the buildings due its less characteristics shear strength and high swelling characteristics. In order to control this behavior, the cohesive soils have to be suitably treated with chemicals or any other available materials which can alter its engineering behavior. The Black cotton soil used in the study is collected from Coimbatore near Ganapathy area.

II. Materials Used

1. Black cotton soil

Black cotton soil possesses great threat for the construction of the buildings due its less characteristics shear strength and high swelling characteristics. In order to control this behavior, the cohesive soils have to be suitably treated with chemicals or any other available materials which can alter its engineering behavior. The Black cotton soil used in the study is collected from Coimbatore near Ganapathy area. Laboratory tests were carried out to find the index and engineering properties of unmodified soil. Based on the test results, from the IS classification the obtained soil sample is designated as clay of intermediate plasticity.

2. Ground Granulated Blast furnace Slag (GGBS)

The Blast furnace slag is produced as a by-product during the manufacture of iron in a blast furnace. Molten blast furnace slag has a temperature of 1300-1600^{o}C and is chilled very rapidly to prevent crystallization. The granulated material thus produced is known as granulated blast furnace slag. Blast furnace slag has a glassy, disordered, crystalline structure which can be seen by microscopic examination which is responsible for producing a cementing effect. The GGBS used in this study was collected from Tirupur, Tamilnadu, India.

3. Steel slag

Steel industry is producing substantial amount of waste with fairly good engineering characteristics. The steel waste obtained during the manufacturing process and from the moulds during forging process is used for the stabilization of soil. The skinny metal pieces alter the gradation of soil resulting in improvement in the density and strength of the stabilized material. Steel slag, a by-product of steel making, is produced during the separation of the molten steel from impurities in steel- making furnaces. The slag occurs as a molten liquid melt and is a complex solution of silicates and oxides that solidifies upon cooling. The steel slag used in this study is collected from Madhampalayam, Coimbtore, Tamilnadu, India.

III. Methods of Testing

The laboratory tests carried out on the natural soil include Sieve analysis, Atterberg limits, Specific gravity, Standard Proctor test, and Unconfined Compressive strength test.

1. Unconfined compressive strength test (UCC).

The shearing strength is commonly investigated by means of compression tests in which an axial load is applied to the specimen and increased until failure occurs. The unconfined compressive strength is the load per unit area at which and unconfined cylindrical specimen of soil will fail in a simple compression test. If the unit axial compression force per unit area has not reached a maximum value up to 20 percent axial strain, unconfined compressive strength shall be considered the value obtained at 20 percent axial strength. This test was conducted as per IS 2720 (Part10): 1973.

2. Standard proctor test.

Compaction is the process of densification of soil by reducing air voids. The degree of compaction of a given soil is measured in terms of its dry density. The dry density is maximum at the optimum water content. A curve is drawn between the water content and the dry density to obtain the maximum dry density and the optimum water content. Atstart as water content increases dry density also increases but after optimum moisture content value (OMC), dry density decreases with increases in water content.

3. Atterberg limits test.

3.1 Liquid limit: The boundary between the liquid and the plastic states. The water content at which the soil has such small shear strength that it flows to close a groove of standard width when jarred in a specified manner.

3.2 Plastic limit: The boundary between the plastic and semi-solid states. The water content at which the soil begins to crumble when rolled into threads of specified size.

IV. Test Result and Discussion

Admixture Influence factor (AIF) is fixed by conducting individual UCC test for GGBS and steel slag with black cotton soil to find optimum content. The maximum strength of UCC test of the mixture is obtained at 18% of GGBS and 11% of Steel slag. Hence, we fixed the above percentages of GGBS and Steel slag as the optimum percentage for the taken black cotton soil. The tests were done with 12 samples at 14%, 18% of GGBS and 9%, 11% of Steel slag for 0,7,14 days to show the considerable increase in the UCC value. As the UCC values of the sample gets decreased with percentages of GGBS and Steel slag more than the optimum content. Hence the values more than optimum values are not considered.

Table I. Unconfined Compressive Strength

Test	**Mixes**			
GGBS	**14%**		**18%**	
Steel slag	**9%**	**11%**	**9%**	**11%**
UCC test @ 0thday (n/mm^2)	0.0655	0.0857	0.065	0.069
UCC test @ 7thday (n/mm^2)	0.460	0.279	0.342	0.211

UCC test @ 14th day (n/mm^2)	0.762	0.629	0.816	0.304

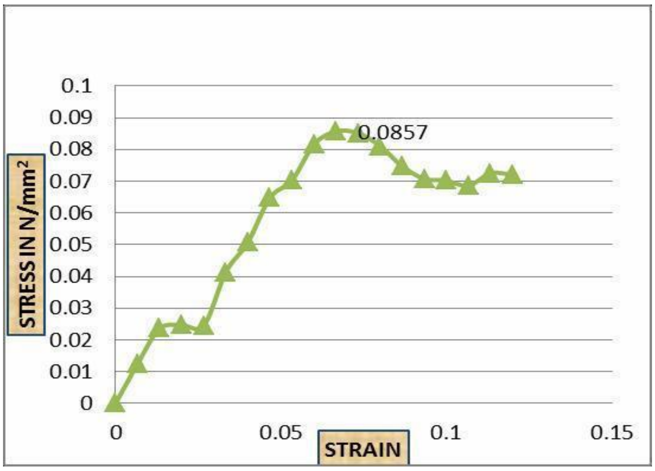

Fig. 1. **UCC** strength for GGBS 14%+steel slag 11%

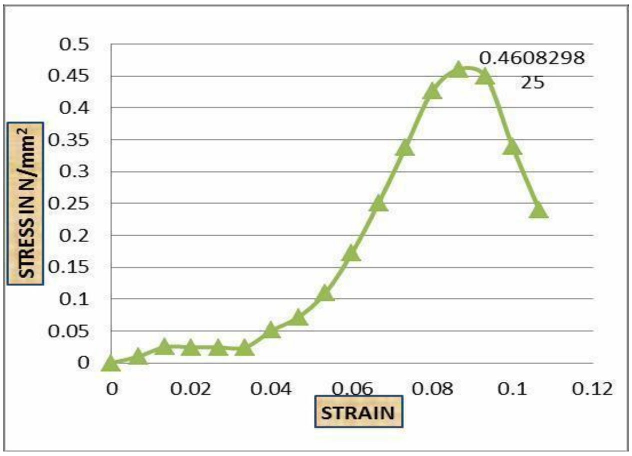

Fig. 2. **UCC** strength for GGBS 14%+steel slag 9%

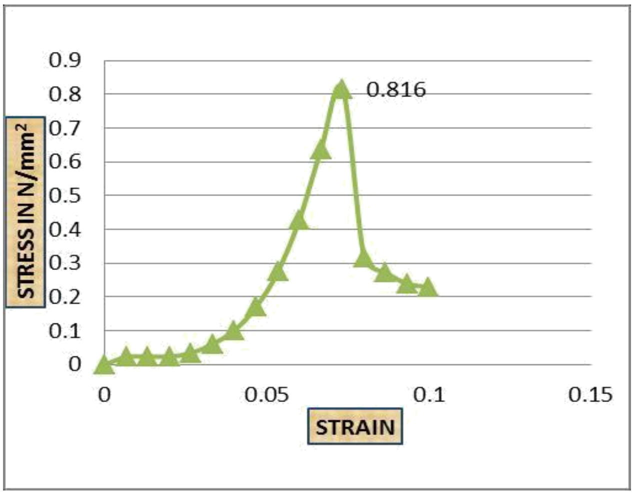

Fig. 3. **UCC** strength for GGBS 18%+steel slag 9%

V. Conclusion

Soil stabilization using slag is found to be an effective means for enhancing the engineering performance of Black Cotton soil. Following are the observations while using ground granulated blast furnace slag and steel slag as a stabilizer in black cotton soil.

5.1 The primary benefits of using these additives for soil stabilization are
5.1.1 Cost Saving: Slag is typically cheaper than cement and lime.
5.1.2 Availability: Slag sources are easily available across the country from nearby steel plant industries.

5.2 The industrial wastes can be used economically and eco- friendly.

5.3 Use of slag as an admixture for improving engineering properties of the soil is an economical solution for strengthening poor soil.

5.4 It is observed that with increase of slag, more stability of soil is achieved as compared with lime or GGBS.
5.4.1 Liquid limit of the unmodified soil (60%) has been reduced to 46% for replacement of 9% Steel slag and 18% GGBS.
5.4.2 Plasticity index of the unmodified soil (40%) has been reduced to 24.6% for replacement of 9% Steel slag and 18% GGBS.
5.4.3 Optimum Moisture Content of the unmodified soil (22%) has been increased to 26% for replacement of 9% Steel slag and 18% GGBS.
5.4.4 Maximum dry density of the unmodified soil has been increased by 9.9% for replacement of 9% Steel slag and 18% GGBS.

5.5 UCC strength of ordinary Black Cotton Soil was found to be 47kN/m2, which is partially replaced with 18% of GGBS and 9% of steel slag and then the UCC strength increased to 816.1kN/m2 on 14th day.

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