Influence of GGBS Slag on the Erosion Rate and Strength of Dispersive Clay

Thasleema NU[1], Seemon S.[2]

[1]Post Graduate Student of Civil Engineering, IES College of Engineering, Kerala, India
[2]Assistant Professor, Dept. of Civil Engineering, IES College of Engineering, Kerala, India

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Abstract - *Clayey soils with dispersive characteristics are vulnerable to erosive failure when exposed to water, are challenging for geotechnical engineers in the construction of earth structures. This type of clay contains high percentage of exchangeable sodium ions. Dispersive clay particles can be detached by water entering cracks or openings and this enables them to go into suspension. Dispersion of a sodic soil occurs when wetted, and the clay particles are forced apart then they transported by water through the opening of the pores. This may result in heavy soil mass loss and lead to severe structural failure. As a result of their greater susceptibility to erosion, soils with dispersive characteristics are capable of initiating erosion failure with the fluctuation of the groundwater table below the pavement surface. The dispersive property of such soil can be reduced by chemical stabilization. Various stabilizers used for reducing the erosion rate and increasing the strength of dispersive soils are fly ash, lime, alum, cement, pozzolan and slag etc. In the present study, the effect of various proportions of GGBS slag (20%, 25% and 30%) at different curing period (0, 7 and 14 days) on the rate of erosion, compressive strength, and compaction are discussed. The erosion rate was evaluated using the crumb test while the compressive strength was evaluated using the unconfined compressive strength (UCS) test. The optimum content of GGBS found to be 25% based on the results of the unconfined compressive strength tests. The UCS test results showed an increase of 96% from its original state by the addition of 25% of slag at a curing period of 14 days. The UCC strength increases with increase in the curing period. It was found that GGBS slag is very effective for reducing the rate of erosion and increasing the strength of dispersive soil.*

Key Words: Dispersive Clay, GGBS Slag, Erosion, Crumb Test, UCC Test

1. INTRODUCTION

Clayey soils which are vulnerable to erosive failure exist in nature. These soils are referred to as dispersive soils. Dispersive soils lose inter-particle forces, when exposed to water, that means when the dispersive soil immersed in relatively pure and still water, it will deflocculates causing the clay particles to go into suspension. They are prevalent in many areas around the world and the presence of these soils has always posed a serious problem on potential construction sites. The use of dispersive soils in hydraulic and other engineering structures such as roadway embankments can also lead to serious failures if the problem is not properly identified and addressed appropriately. Although the causes and consequences of dispersion are well understood, one of the main problems is the inability to positively identify such soils and thereby to reduce the potential for failure of many engineering structures.

It is important to understand the nature of these soils and to be able to identify them so they can be treated or avoided. Structures such as embankments, channels, and other areas are susceptible to severe erosion when such soils are used for construction. The erodibility of clayey soil due to the flow of rainwater is a critical factor in the long-term performance of earth structures. Dispersion of a sodic soil occurs when it is wetted, and the clay particles are forced apart. Thus, dispersive soils erode under small seepage velocity leading to problems of stability of earth and earth retaining structures. Soil dispersity is mainly due to the presence of exchangeable of sodium present in the structure. The attractive forces are less than the repulsive forces under saturated conditions, and this will help the particle to segregate and to move in suspension Many identification methods have been proposed but none has been completely successful. The primary test methods that are currently used for the identification of dispersive soils are the Pinhole Test; the SCS Double Hydrometer test; the crumb test etc.

In the past several researchers have investigated the reduction of dispersive characteristics by mechanical treatment and chemical. Chemical treatment is more suitable for dispersive embankment materials at the foundation interface. In the present study GGBS slag was used as stabilizer for the reduction of dispersive properties and for increasing the strength of dispersive clay.

2. OBJECTIVES

The project aims at achieving the following objectives:

- To determine the dispersive property of dispersive clay
- To evaluate the effect of GGBS slag on dispersive clay
- To find the UCC strength of dispersive clay

3. MATERIALS

The materials used in the study are as follows.

3.1 Sodium Bentonite

Sodium bentonite was used as dispersive clay. Soil dispersity is mainly due to the presence of exchangeable of sodium present in the structure. Fig. 1 shows the sodium bentonite used in this study.

Fig -1: Sodium bentonite

The attractive forces are less than the repulsive forces under saturated conditions, and this will help the particle to segregate and to move in suspension. Sodium bentonite was collected from Perumbavoor, Ernakulam. It contains montmorillonite and sodium as the predominant clay mineral.

3.2 GGBS Slag

Ground-granulated blast-furnace slag (shown in fig. 2) was used as a stabilizer for reducing the dispersity of sodium bentonite. They are mainly obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. Ground -granulated blast furnace is highly cementitious and high in CSH which is a strength enhancing compound which increases the strength, durability.

Fig -2: GGBS slag

4. METHODOLGY

Materials were collected and tested. The variation of stabilized on stabilized soil were 20%, 25%, 30% by dry total weight of soil sample respectively. The experimental studies are required in order to know the effect of addition of slag on index, engineering and dispersive properties of the soils. In the present study, investigations are made according to standard procedure as per IS- 2720 and ASTM-D4647-06 (Crumb Test). Slag was added to the soil in dry condition, mixed thoroughly to get uniform mixture. Then the samples were prepared and tested. The tests conducted on soil samples before and after addition of slag powder were the sieve analysis, Atterberg limit, specific gravity, standard compaction test, unconfined compression test and crumb test.

The crumb test is the simplest and easiest of the physical tests and indicates the tendency of the particles to deflocculates in solution. It is similar to the traditional puddle clay soaking test in which a hand rolled ball of clay is immersed in water for 48 hours. A few crumbs of soil 6-10mm in diameter are placed in a large volume of distilled water or sodium hydroxide solution and observing the reaction as the crumb begins to hydrate. The test is primarily a visual assessment of the behavior of the soil in solution. After a certain time, the soil and solution in the beaker are observed and the soil is classified according to the quantity of colloids in suspension. Four grades can be noted, ranging from no reaction to strong reaction.

5. RESULTS AND DISCUSSIONS

For determining the type of clay and its properties, these tests were conducted and results of the tests are tabulated. Table 1 shows the properties of sodium bentonite.

Table -1: Properties of Sodium Bentonite

Properties	Values
Soil nature	Highly dispersive
Coefficient of uniformity	1.53
Coefficient of curvature	3.33
Specific gravity	2.22
Liquid limit (%)	190
Plastic limit (%)	52.6
Plasticity Index (%)	137.4
Soil classification	CH
Optimum moisture content (%)	46
Maximum dry density (g/cc)	1.16
Unconfined compressive strength (kN/m^2)	64.22

5.1 Influence of GGBS Slag on Compaction Characteristics

Compaction tests were carried out on the clay with and without the additives. The maximum dry density and OMC of the soil in its natural form were 1.16 g/cm3 and 46% respectively. Slag were added in to the clay in varying percentage of 20%, 25% and 30% by dry weight of the soil. Addition of 25% slag on clay results an 3% increase of dry density. Table 2 shows the maximum dry density and optimum moisture content values of untreated clay and clay with various percentages of GGBS Slag.

Table -2: Compaction Characteristics

Specifications	OMC (%)	MDD(g/cc)
Untreated Clay	46	1.16
Clay+20% Slag	44	1.18
Clay+25% Slag	40.9	1.19
Clay+30% Slag	42.5	1.16

By the addition of slag, the maximum dry density increased from a value of 1.16g/cm3 in its natural form to 1.19g/cm3 then reduced to a value of 1.16g/cm3. Addition of 25% slag on clay results an 3% increase of dry density. Chart 1 shows the compaction curves plotted between dry density and water content on addition of slag at 20, 25 and 30 percentages.

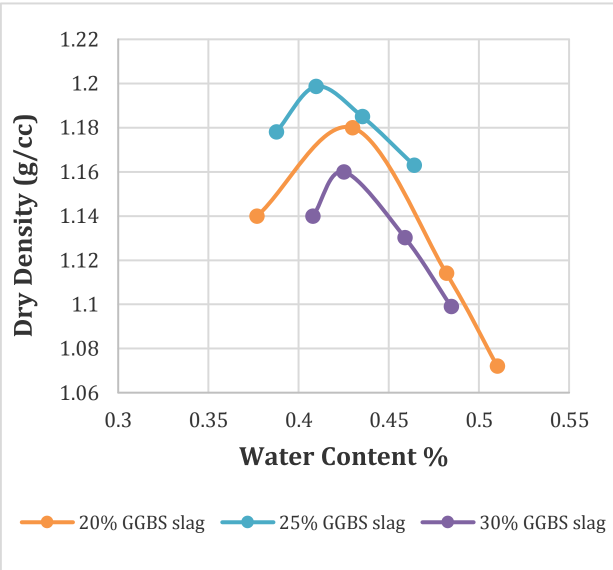

Chart-1: Compaction curves obtained by slag addition

From the above figure it can see that maximum dry density increases and OMC decreases on increase of slag content (20% and 25% plastic on clay) and then maximum dry density decreases on further addition of clay (30% of slag on clay) and OMC increases.

5.2 Influence of GGBS Slag on Unconfined Compressive Strength Characteristics

The unconfined compressive strength of the natural and treated clay at their optimum moisture content and maximum dry density increases with increases in the percentage of slag content up to an optimum percentage and then decreased by the further addition of slag in to the clay. Also, the unconfined compressive strength of clay with slag content at different percentages increases with increases in the curing period. Unconfined compressive strength and cohesion value of the clay on treating with slag without curing is given in the table 3.

Table -3: UCC Values of Clay Containing Slag Without Curing

Specifications	q_u (kN/m²)	C_u (kN/m²)
Untreated Clay	64.22	32.11
Clay+20% Slag	81.57	40.7
Clay+25% Slag	111.1	55.6
Clay+30% Slag	99.9	49.9

Unconfined compressive increases with increase the addition of slag without curing up to an optimum percentage, that means 25% slag addition. Further addition of slag (30%) results a decrease in strength of clay. The stress strain relationship of clay with different percentage of slag without curing is shown in chart 2.

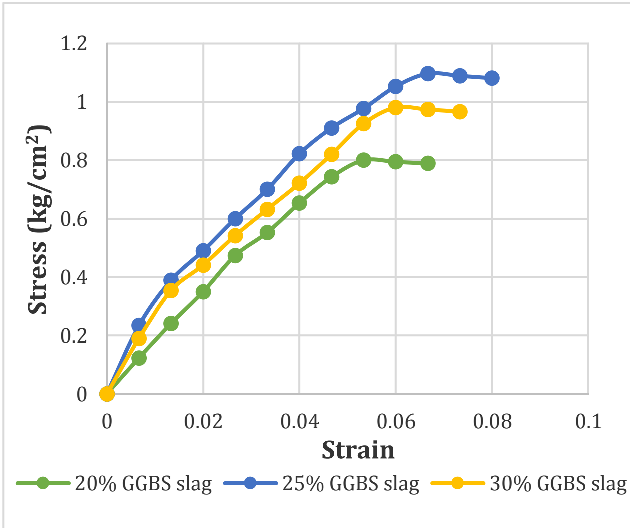

Chart -2: Stress strain curve for clay with various percentage of slag

Addition of 20%, 25% and 30% slag on clay show an increase of 21.27%, 42.2% and 35.7% UCC strength. The highest UCC strength was obtained by the addition of 25% slag. Results of Unconfined compression test after 7 days curing of clay containing slag is shown in table 4

Table -4: UCC Values of Clay with Slag After 7 Days Curing

Specifications	q_u (kN/m²)	C_u (kN/m²)
Clay+20% Slag	656.44	328.2
Clay+25% Slag	1385.5	586.3
Clay+30% Slag	1172.2	656.4

Unconfined compressive strength increased with increase in the addition of slag after 7 days of curing up to an optimum percentage, that means 25% slag addition. Further addition of slag (30%) results a decrease in strength of clay.

The stress strain relationship of clay with different percentage of slag after 7 days of curing is shown in chart 3.

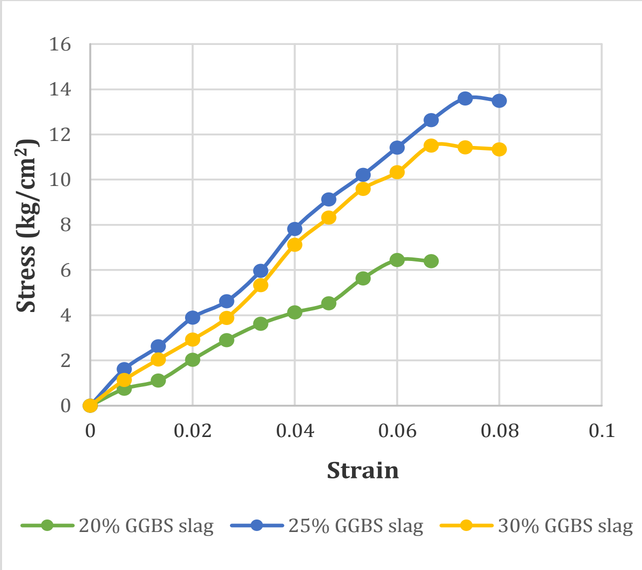

Chart -3: Variation of UCS value for the clay with slag after 7 days of curing

Addition of 20%, 25% and 30% slag on clay show an increase of 90.2%, 95.3% and 94.22% UCC strength after 7 days of curing. The highest UCC strength was obtained by the addition of 25% slag. Table 5 shows the results of unconfined compression test after 14 days curing of clay containing slag.

Table -5: UCC Values of Clay with Varying Slag Content After 14 Days of Curing

Specifications	q_u (kN/m²)	C_u (kN/m²)
Clay+20% Slag	1285.5	642.7
Clay+25% Slag	1616.8	808.4
Clay+30% Slag	1383.2	691.6

Unconfined compressive increases with increase the addition of slag after 14 days of curing up to an optimum percentage, that means 25% slag addition. Further addition of slag (30%) results a decrease in strength of clay. The stress strain relationship of clay with different percentage of slag after 14 days of curing is shown in chart 4.

Addition of 20%, 25% and 30% slag on clay show an increase of 95%, 96% and 95.35% UCC strength. The highest UCC strength was obtained by the addition of 25% slag. The Unconfined compressive strength of clay without slag was 64.22 kN/m2. UCS value was increased to 1285.5 and 1616.8 kN/m² on addition of 20 and 25% slag respectively. Then UCS value decreased to 1382.2 kN/m2 for 30% slag addition.

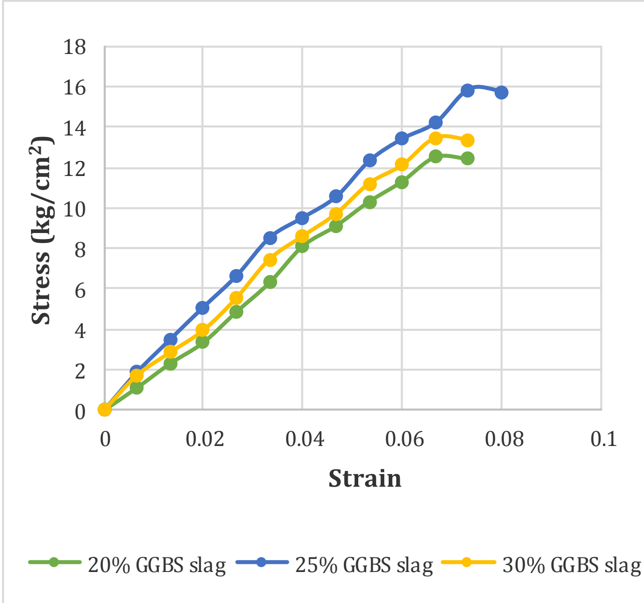

Chart -4: Variation of UCS value for the clay with slag after 14 days of curing

The maximum UCS value was obtained for the clay with 25% slag content at a curing period of 14 days. It was found that UCC strength increases with increase in the curing period.

5.3 Influence of GGBS Slag on Erosion Rate of Sodium Bentonite

Crumb test was conducted for the sodium bentonite with and without GGBS slag. GGBS slag was added in the clay at different percentages that means 20%, 25% and 30% content. The purpose of conducting crumb was to determine the dispersive properties of clay and for finding the effectiveness of GGBS slag on reducing erosion rate of such dispersive clays. Initially the clay was highly dispersive. That means the solution turned cloudy and a colloidal cloud covered most of the bottom of beaker. After the addition of 20% of slag the solution showed a moderate dispersive condition. That means there was an easy recognizable cloud of colloidal in suspension. Addition of 25% slag reduces the dispersivity from strong to slight condition. There was only a slight reaction and a very slight cloudiness observed in the water at the surface of the crumb even after 6 hour continues immersion in the water. A similar reduction in the dispersion was observed in the case of sample with 30% slag. That means the clay showed a non-dispersive nature by the addition of 25% and 30% slag. That means 25% and 30% slag content was the optimum percentage of slag on sodium bentonite. So, it was observed that the addition of slag in to the dispersive clay was highly effective for reducing the dispersivity.

6. CONCLUSIONS

The following conclusions are drawn based on this study:

- The selected soil sample was highly dispersive. The addition of slag caused a decrease in the dispersive characteristics of the soil.
- The optimum content of GGBS found to be 25% based on the results of the unconfined compressive strength tests.
- The unconfined compressive strength test results showed an increase of 96% from its original state by the addition of 25% of slag at a curing period of 14 days.
- It was observed that UCC strength increases with increase in the curing period
- It was found that GGBS slag is very effective for reducing the rate of erosion and increasing the strength of dispersive soil.

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