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A Study on Effect of Ground Granulated Blast Furnace Slag on Strength Characteristics of Gravel

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***Abstract*— The vehicle load transfer mechanism can be efficiently managed by the inter-connecting layers and their characteristics. Gravel soils in large quantity can be popularly used as Sub Base, Base-course materials in the construction of pavements. When the gravel soil possesses considerable amount of fines (silt and clay), they take moisture and deform under loading. To reduce the excess deformations of the gravel soils under saturation and to increase the strength and durability, stabilization is one of the techniques to be adopted and ground granulated blast furnace slag can be chosen as stabilizer. This project work aims to evaluate the effect of addition of 0%, 2%, 4%, 6%, 8% and 10%, ground granulated blast furnace slag in order to stabilize the gravel and to verify its suitability to be used as a construction material for road, embankment and structural fills. The overall testing program was conducted in two phases. In the first phase, the engineering properties of gravel were studied by conducting Atterberg limits, specific gravity test, proctor compaction test, California Bearing Ratio and unconfined compression tests were conducted. In the second phase gravel was mixed with 2%, 4%, 6%, 8% and 10%, of blast furnace slag as percentage of dry weight of gravel soil to know the optimum percentage of blast furnace slag. Finally, in this project the effects of addition of ground granulated blast furnace slag are investigated and are compared with that of the virgin gravel soil. The investigation showed that generally the engineering properties of gravel has improved with the addition of Ground Granulated Blast Furnace Slag (GGBS) and the optimum % is 8%.**

***Keywords*—CBR, Compaction, Gravel, Ground Granulated Blast Furnace Slag, UCS Tests.**

I. INTRODUCTION

Economic development of any country is controlled to a great extent by the highway and airport networks. This is becoming particularly apparent in the developing countries, where tremendous lengths of roads need to be constructed in order to facilitate the development of agriculture, commerce and industry. The cost of any road pavement project includes initial costs and subsequent maintenance costs. The initial costs include many items such as land, accommodation works, bridges and subways, drainage, pavement construction etc.

The type and the thickness of the pavement construction determine a large percentage of the initial cost of any road project. Therefore, the development and use of methods to decrease the cost of pavement construction is very beneficial. Good qualities of sub grade soils are preferable for durable road but not always available for highway construction. The highway engineer designing a road pavement may be faced by weak or unsuitable sub grade. In this case the following methods to overcome this problem can be considered. The introduction of randomly oriented fibres to a soil mass may also be considered similar to admixture stabilization. One of the primary advantages of randomly distributed fibers is the absence of potential planes of weakness that can develop parallel to oriented reinforcement Maher and Woods, (1990). Material used to make fibers for reinforcement may be derived from paper, metal, nylon, synthetic plastics and other materials having widely varied physical properties. The inclusion of discrete fibres increased both the cohesion and angle of internal friction of the specimens Gray and Maher, (1989). Mixing a predetermined amount of fiber at particular moisture content gives a mesh like configuration leading to a mechanical means for reinforcement of the soil matrix Natraj and McManis, (1997**)**. Rao and Dutta, 1997 reported that sand-waste plastic mixtures improve the bearing capacity of granular trench and consequently the bearing capacity ratios. Manjunath et al., (2012), were conduct experimental investigations on ground granulated blast furnace slag blending with Red soil along with small percentages of lime. Based on results, unconfined compressive strength of stabilized soil samples increases with increase in percentage of lime and UCS of stabilized soil samples decreases with increase in percentage of slag at 0 day and UCS stabilized soil samples increases with increase in days of curing. After addition of lime and slag, soil gains strength with time and Red soil + 30% slag +4 % lime is the best combination as it has highest UCC strength & red soil only has lowest UCC strength. Oormila and Preethi (2014), studied by using flyash and ground granulated blast furnace slag by evaluation of soil properties like unconfined compressive strength test and California bearing ratio test.

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The soil sample was collected from Palur, Tamil Nadu and addition to that, different percentages of flyash (5, 10%, 15% and 20%) and GGBS (15%, 20%, 25%) was added to find the variation in its original strength. Based on these results CBR test was performed with the optimum flyash, optimum GGBS and combination of optimum flyash with varying GGBS percentages (15%, 20%, and 25%). From these results, it was found that optimum GGBS (20%) gives the maximum increment in the CBR value compared with all the other combinations. Nanda et al., (2016), were studied unconfined strength including compaction characteristics of Lithomargic soil stabilized with GGBS and lime with % of slag added to the soil, as % of dry soil mass, varied from 10 to 50%. Based on results, strength of Lithomargic soil and GGBS mixtures increases with increase in GGBS percentage and curing. 30% of GGBS is found to be optimum, which gives the strength of 336.35kPA after 90 days of curing and addition of 4% of lime to optimum GGBS soil mixture predominantly increases the strength. In this investigation, different laboratory experiments like Atterberg limits, Compaction, unsoaked, soaked CBR and Unconfined compressive strength tests were conducted by varying percentages of GGBS as 2%, 4%, 6%, 8% and 10% blended with gravel with a view to determine optimum percentage of GGBS. From test results, it is found that there is an improvement in geotechnical properties.

II. Materials Used

Details of various materials used during the laboratory study are presented in the following section**.**

A. Gravel

Gravel is composed of unconsolidated rock fragments that have a general particle size range and include size classes from granule- to boulder-sized fragments. Gravel is an important commercial product, with a number of applications. Many roadways are surfaced with gravel, especially in rural areas where there is little traffic. The gravel soil collected from Rajahmundry, East Godavari District in Andhra Pradesh.

Fig.1 Gravel

B. Ground Granulated Blast Furnace Slag

Slag is the by-product of iron and steel manufacturing Industries which can be broadly categorized into blast furnace slag and steel making slag. Slag is a derivative of the iron-making method. When it is quenching with water and rapidly chilled, it forms a smooth granulated material of sand-like consistency. While its high calcium silicate content, it become tremendous cementations properties. Quenching (i.e. sudden cooling with water or air) of hot slag may result into formation of vitrified slag. The ground granulated blast slag (GGBS) is a result of use of water during quenching process. The GGBS used in this project work is collected from Steel Plant, Visakhapatnam.

Fig. 2. Ground Granulated Blast Furnace Slag (GGBS)

III. Laboratory Experimentation

Various tests were carried out in the laboratory for finding the index and other important properties of the gravel used during the study.

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Specific gravity, Compaction, CBR and UCS tests were conducted by using different percentages of GGBS mixed with Gravel materials for finding optimum percentage of lime. The overall testing program is conducted black cotton soil mixed with different GGBS, i.e. 2%, 4%, 6%,8% and 10% by weight was used for preparing samples mixed in powdered form.

A. Specific Gravity

Specific gravity was determined by using the soil fraction passing 4.75 mm IS sieve by using a density bottle of 50 ml capacity. The test was conducted in accordance with IS:2720 (part - III).

B. Index Properties

Standard procedures recommended in the respective I.S. Codes of practice [IS:2720 (Part-5)-1985; IS:2720 (Part-6)-1972], were followed while finding the Index properties viz. Liquid Limit and Plastic Limit of the samples tried in this investigation.

C. Compaction Properties

Optimum moisture content and maximum dry density of gravel and with different percentages of GGBS mixes were determined according to I.S heavy compaction test IS: 2720 (Part VIII).

D. California Bearing Ratio (CBR) Tests

Different samples were prepared for CBR test using Gravel material mixing with different percentages of GGBS with a view to determine optimum percentages. The CBR tests were conducted in the laboratory for all the samples as per IS Code (IS: 2720 (Part-16)-1979) under unsoaked condition.

E. Unconfined Compressive Strength Test

Unconfined compressive strength is one of the most widely referenced properties of stabilized soils. Unconfined compressive test at OMC is conducted as per IS: 2720 (part - X)-1991.

IV. Results And Discussions

The results of the laboratory experimentation carried-out with and without Ground Granulated Blast Furnace Slag blended with different percentages in gravel obtained from various tests were presented below.

A. Laboratory Test Results on Gravel

The effects of adding GGBS to the gravel soil on Atterberg limits, and Specific Gravity, Compaction Characteristics (O.M.C, M.D.D), California Bearing Ratio, unconfined compression test, direct shear test are discussed in the following sections.

Table 1:
Physical Properties of Gravel soil

Property	Value
Grain Size Distribution	
Gravel size	**51.62**
Sand size	**9.82**
Silt & Clay size	**38.56**
Atterberg limits	
Liquid limit (%)	**45.86**
Plastic limit (%)	**17.98**
Plasticity index (%)	**27.88**
Compaction Properties	
OMC (%)	**9.2**
MDD (g/cc)	**2.11**
Specific Gravity (G)	**2.56**
IS Classification	GC
CBR value	
Un soaked	**11.2**
Soaked	**5.2**
Shear Strength Parameters	
Cohesion (C) (kg/cm²)	**0.5**
Angle of Internal Friction (ø)	**30**

B. Effect of GGBS on Atterberg Limits

The variation of liquid limit values with different percentages of GGBS added to the gravel is presented in the Fig 3. It is observed that the decrease in the liquid limit by increasing the GGBS % added, liquid limit reduced from 45.86 to 31.2, is significant up to 8% and beyond addition shows a nominal decrease. Fig.4 shows the variation of plasticity limit with the addition of GGBS to gravel. From the results, plastic limit increases from 18 to 19.46 up to 8% GGBS and further addition not shows much improvement. The reduction in plasticity indexes are observed with increasing the GGBS added to the gravel.

C. Effect of GGBS on Specific Gravity Test

Gravel blended with different % of GGBS, the specific gravity of varies from 2.56 to 2.62 up to the addition of 8% GGBS and becomes constant due to further addition as shown in the fig.5.

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D. Effect of GGBS on Compaction Properties

The variation of Compaction Properties with different percentages of GGBS added to the gravel are presented in the figs.6 and 7. It is observed that maximum dry density increases from 1.19g/cc to 2.254 g/cc and beyond the addition it decreases as shown in the fig.6 whereas optimum moisture content continuously increases as shown in the fig.7.

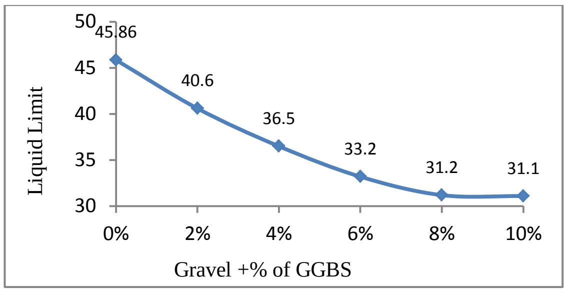

Fig.3. Variation of Liquid Limit with Addition of Percentage GGBS to the Gravel

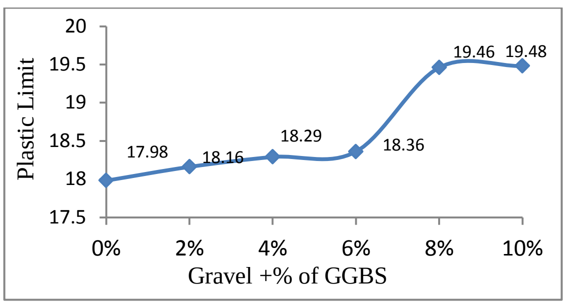

Fig. 4. Variation of Plastic Limit with Addition of Percentage GGBS to Gravel

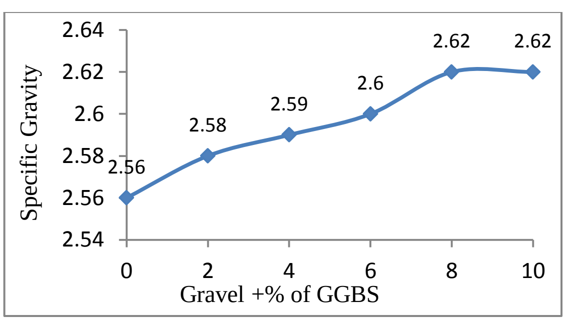

Fig.5 Variation of Specific Gravity with Different Percentage GGBS Mixed in Gravel

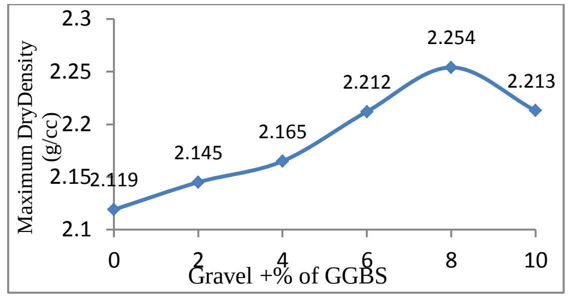

Fig.6 Variation of MDD with Addition of Percentage GGBS to Gravel

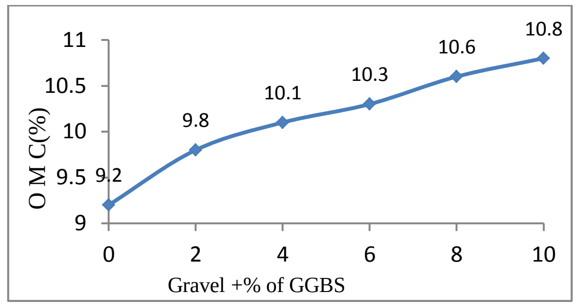

Fig.7 Variation of OMC with addition of percentage GGBS to Gravel

E. Effect of GGBS on California Bearing Ratio Test

From the fig. 8 shows the variation of unsoaked and soaked CBR of gravel blended with different percentages of GGBS. It is can be seen that the CBR is increasing with increasing percentage of GGBS added to the Gravel and maximum values of unsoaked and soaked CBR values are 22.3 and 17.32 obtained at 8%.

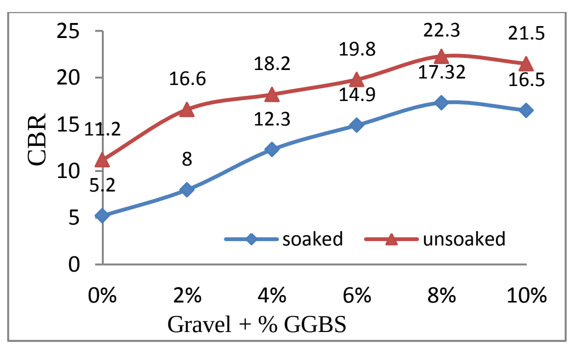

Fig.8 Effect of Different % of GGBS on Unsoaked and Soaked CBR Mixed in Gravel

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F. Effect of GGBS on Unconfined Compressive Strength

The unconfined compressive strength specimens were at MDD and Optimum Moisture Content with addition of 2%, 4%, 6%, 8% and 10 % of GGBS to the Gravel are presented in the fig.9. The prepared samples are tested at different curing period's i.e. 1day, 7 days and 14 days respectively. It is observed that the maximum unconfined compressive strength of the soil is increasing with increase in percentage of GGBS and curing period obtained at 8% GGBS mixed in gravel.

G. Unconfined Compressive Strength of Gravel

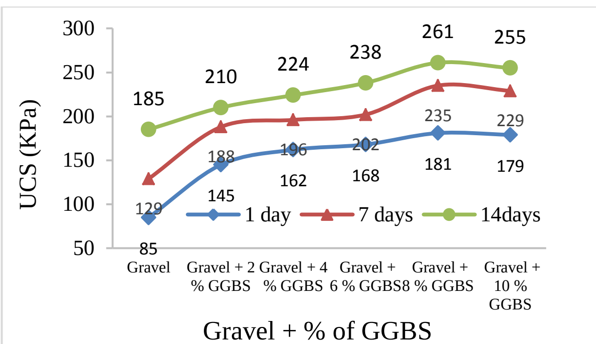

Fig.9. Variation of Unconfined Compressive Strength with Different % of GGBS blending in Gravel at Different Curing Periods

V. CONCLUSIONS

The following conclusions are drawn based on the laboratory experimentation carried out in this investigation.

- ❖ The variation of Liquid Limit values decreases from 45.86 to 31.2, Plastic Limit increases from 17.98 to 19.46, cause a net reduction in the plasticity index Up to 8% of GGBS added to gravel and beyond 10% there is a nominal decrease.
- ❖ Specific Gravity with the addition of GGBS to gravel soil increases from 2.56 to 2.62 up to 8% of GGBS added to the Soil, beyond 10% there is a nominal decrease.
- ❖ Maximum Dry Density increases from 2.119 to 2.254 and Optimum Moisture Content also increases from 9.2 to 10.6 up to the addition of 8% GGBS and beyond decreases.
- ❖ The unsoaked and soaked CBR values are increasing from 11.2 and 5.2 to 22.3 and 17.32 respectively up to the addition of 8% GGBS and beyond decreases.
- ❖ Unconfined Compressive Strength goes on increasing due to the addition of GGBS up to 8% and beyond it decreases and also with respect to curing 30% and45% increase in strength for 7 days and 14 days curing at 8% GGBS.

From the above experimental results the optimum percentage of Ground Granulated Blast Furnace Slag (GGBS) is 8%.

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