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ASSESSMENT OF LIME STABILIZED SLAG- FLY ASH MIXES AS A HIGHWAY MATERIAL

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ABSTRACT: The objective of the thesis is to use industrial wastes rather than natural soil, aggregates, etc. in roads and highway construction after enhancing its strength, stability and durability. Conventionally, soil, stone aggregates, sand, bitumen, cement etc. are used in construction of roads and highway. Characteristic materials being limited in nature and thereby need of alternate materials is necessary. Gigantic quantities of soil are utilized as a part of the development of street and parkway yet adequate quantity of soil of required quality is not available effectively. To meet this demand extensive deforestation is being done which cause deforestation, soil disintegration and loss of rich soil which hampers in the farming efficiency. Additionally, cost of procurement of suitable quality of material is increasing. Worried about this, the researchers are searching for option materials for thruway development, and modern waste item is one such class. Stabilization method highlighted in this thesis is mainly to enhance the inherent strength of wastes like fly ash and crushed blast furnace slag (CBFS). This will automatically reduce the use of natural soil in addition to mitigate the disposal problems of industrial solid wastes in a great way. Fly ash and blast furnace slag was collected from Rourkela steel plant (RSP). Tests were conducted by blending fly ash and blast furnace slag in different proportions. The compaction characteristics, strength properties and the bearing value of different mixes are determined.

I. INTRODUCTION

From the beginning of the industrial revolution the major issue in front of the industries is the disposal of the industrial waste. Industrial wastes are generally harmful to health and have environmental impact. Therefore, disposal of these wastes is a major issue in the current scenario. The solution to the above problem is to use these industrial waste to a maximum level for various purposes like road construction, highways and embankments. Moreover, by the use of these materials the environmental issues especially pollution can be reduced to a great extent.

In addition to aggregates and binder, tremendous amounts of soil are likewise required for development of roadway, highway and embankments Loss of valuable topsoil in this procedure renders the agricultural lands unfit for cultivation. Research and development studies ponders and fruitful field exhibit ventures have demonstrated that industrial waste like fly ash, iron and steel industry slags, rice husk, marble slurry dust, etc. can be used for roadway construction. While using such materials, the construction procedure would be broadly similar to construction of roads using conventional materials.

The fly ash used was collected from the Rourkela steel plant and blast furnace slag from the slag crusher unit of Rourkela steel plant. The geotechnical properties of fly ash and blast furnace slag were then evaluated by conducting various laboratory experiments. Specific gravity test was conducted for various fly ash- blast furnace slag mixes.

II. EXPERIMENTAL SETUP

INTRODUCTION

The major issue of thermal power plants is safe and economic disposal of fly ash. Hence, utilization of this fly ash in geotechnical constructions will reduce the burden of the thermal power plants. Thus the pavement to be constructed using fly ash should be assessed in terms of safety and stability. The industrial waste fly ash and blast furnace slag was collected from Rourkela steel plant. Specific gravity, grain size distribution, compaction characteristics was performed for various fly ash- slag mixes. Lime stabilized samples of slag- fly ash mixes were prepared at an increasing percentage of 0%, 2%, 4% and 8%.Unconfined compressive strength was performed for the lime stabilized fly ash- slag mixes after 0, 7 and 28 days of curing. Similarly, California bearing ratio test was conducted for soaked and unsoaked conditions after 0 and 28 days of curing. Details of the materials used, sample preparation and testing procedure adopted have been outlined in this chapter.

MATERIALS USED

Fly Ash

Source of Fly ash

Fly ash used in this study was collected from the Rourkela steel plant. Fly ash samples were dried at a temperature of around 105-110^{o}c. In order to separate the vegetative matter or some foreign matter, the fly ash was screened through 2 mm sieve and then mixed thoroughly to bring homogeneity.
Physical Properties of Fly ash The physical properties of fly ash were evaluated and presented in Table 3.1.

Table 3.1 Physical properties of Fly ash

Properties	Value
Colour	Light grey
Specific gravity, G	2.44
Maximum dry density (gm/cc)	1.36
OMC (%)	32.4
Shape	Rounded/sub-rounded
Uniformity coefficient, (Cu)	7.755
Coefficient of curvature, (Cc)	1.939
Plasticity Index	Non-plastic

Blast Furnace Slag (BFS)

Source of Blast furnace slag

The blast furnace slag was collected from the slag crusher unit of Rourkela steel plant. The finer portion of the crusher unit that is portion passing through the 20mm sieve was collected and is mixed thoroughly in order to bring homogeneity to the sample. The material was first sun dried followed by drying in a hot air oven at a temperature of 105-110^{o}C. The dried material is stored in containers for further use.

Physical Properties of Blast furnace slag

The physical properties of Blast furnace slag were determined and presented in Table 3.2.

Table 3.2 Physical properties of Blast furnace slag

Properties	Value
Colour	Brown
Specific gravity, G	3.10
Maximum dry density (gm/cc)	2.58
OMC (%)	8.96
Shape	Sub-rounded /Angular
Uniformity coefficient, (Cu)	30.625
Coefficient of curvature, (Cc)	0.816
Plasticity Index	Non-plastic

Lime

Source of Lime

Lime used in the study is a form of calcium hydroxide ($Ca(OH)_2$),95 % extra pure, was taken from the market and was kept in air tight bags.

III. TEST RESULTS AND DISCUSSIONS

INTRODUCTION

Fly ash as discussed above is a by- product of thermal power plant and similarly blast furnace slag is a co product in the process of iron production. In geotechnical constructions a proper understanding of the interaction of various slag- fly ash mixes with lime should be studied. Various laboratory test have been carried out according to Indian Standards such as specific gravity, sieve analysis, hydrometer analysis, heavy compaction test, unconfined compressive strength tests and California bearing ratio test with various slag – fly ash mixes stabilized either lime. The test result are presented and discussed in this chapter.

INDEX PROPERTIES

Specific Gravity

The specific gravity of fly ash and blast furnace slag was determined according to IS: 2720 (Part- III, Section –I/II) 1980. The specific gravity of fly ash and slag was found to be 2.44 and 3.10 respectively. The specific gravity of fly ash is found to be lower than that of the conventional earth material. Source of coal, degree of pulverization and firing temperature affects the specific gravity of fly ash. Moreover, transportation and deposition of fly ash may lead to mixing with other materials, which influences its specific gravity.

Grain Size Distribution

A particle size distribution curve gives us an idea about the type and the gradation of the soil. Gradation is used to classify soils for engineering and agricultural purposes. Grain size distribution also provides information whether it is well graded, poorly graded, uniformly graded, fine or coarse.The grain size distribution of fly ash shows that it contains mostly silt size particles with no plasticity. The coefficient of uniformity (Cu) was found out to be 7.755 and the coefficient of curvature (Cc) was found out to be 1.939. The grain size analysis indicates fly ash is well graded. Figure 3.2 shows the grain size distribution of fly ash.

The grain size analysis of blast furnace slag shows that the coefficient of uniformity (Cu) was found out to be 30.63 and the coefficient of curvature (Cc) was found out to be 0.816. The grain size analysis indicates the blast furnace slag is not a well graded one. It is a poorly graded material. Figure 3.1 shows the grain size distribution of blast furnace slag.

ENGINEERING PROPERTIES

Compaction Characteristics

The compaction characteristics of fly ash – blast furnace slag mixes have been investigated. The OMC and MDD of fly ash – blast furnace slag mixes have been evaluated and presented in Table 3.3. Relationship between dry density and moisture content of various fly ash – blast furnace slag mixes have been shown in Figure 3.4. It is seen that as the slag content increases the MDD increases and the water required to achieve this maximum dry density is reduced. The specific gravity of slag is more than that of fly ash, thus replacement of fly ash by same amount of slag will certainly increase the dry density of the compacted mix.

Variation of OMC and MDD with fly ash content

From the figure 4.1 and 4.2 it is seen that with increase in fly ash content, the optimum moisture content (OMC) increase. The increase in optimum moisture content can be explained by the fact that as fly ash is having more specific surface area, hence more fines are available which require more water for lubrication. Hence OMC of the slag- fly ash mixes increases. Further it is seen that with increase in fly ash content in the mixture the MDD value decreases. The reason behind it is that fly ash having low specific gravity may be responsible for this reduced dry density. The following graphs are plotted to show the variation of OMC and MDD with fly ash content.

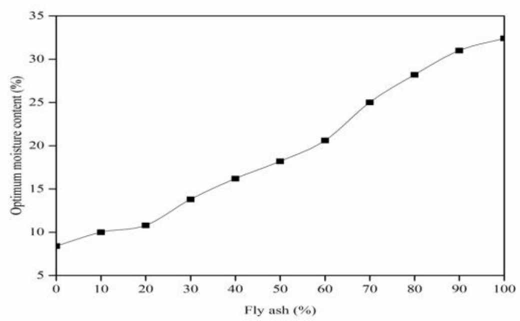

Figure Variation of OMC with fly ash content

Variation of MDD with fly ash content:

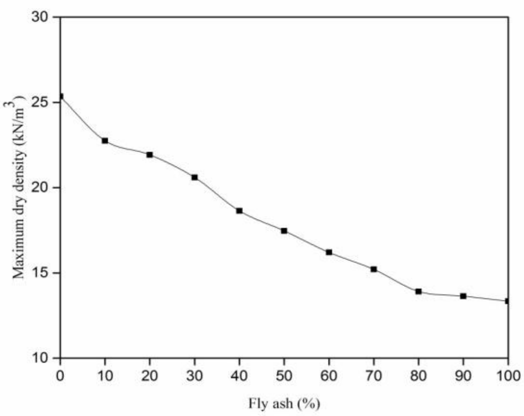

Figure Variation of MDD with fly ash content

Variation of OMC and MDD with BFS content:

From the Figure 4.3 and 4.4 it is seen that with increase in slag content, the optimum moisture content (OMC) decreases. The decrease in moisture content can be explained by the fact that as slag is having lower specific surface area, hence quite few fines are there, which require less water for lubrication. Hence OMC of the slag- fly ash mixes decreases whereas the MDD value is found to be increased with increase in slag content. The reason behind it is that slag having high specific gravity may be responsible for this increase in MDD value of the mix. The following graphs are plotted to show the variation of OMC and MDD with slag content.

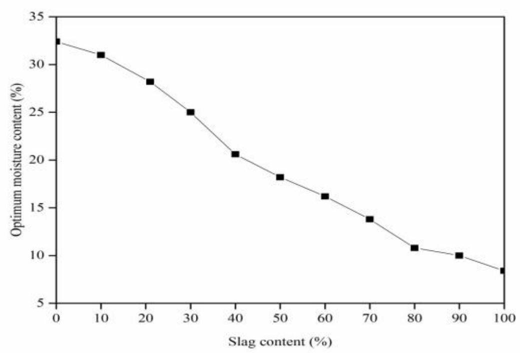

Figure Variation of OMC with Slag content

Variation of MDD with BFS content:

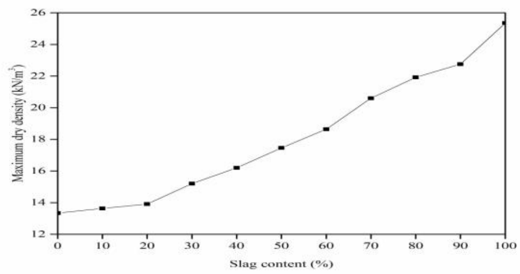

Figure Variation of MDD with slag content

Unconfined Compressive Strength

Effect of Lime

With increase in lime content, the unconfined compressive strength values increases. At 0 days, the maximum UCS value comes to be 235.38 kN/m^2 at 8 % lime content for 80% slag of the slag – fly ash mixes. Similarly, at 7 and 28 days, the maximum UCS value comes to be 1283.45 kN/m^2 and 2311.30 kN/m^2 at 8 % lime content for 80% slag of the slag – fly ash mixes. The strength of fly ash- slag mixes did not significantly increase on the very first day of testing. Considerable increase in strength was noticed on 7 and 28 days of curing, which can be attributed to the fact that as the percentage of slag increases, both material added sufficient lime and silica for the pozolanic reaction and thereby attending considerable strength. The mixture containing 80% slag of the slag – fly ash mixes showed higher strength after 28 days of curing as compared to other mixes. This may be due to formation of compact structure with coarse grain slag particles acting as skeleton whereas fly ash particles act as void filler in the skeletal structure. A too high percentage of slag leaves behind a porous structure which might have reduced the strength whereas at higher fly ash content the grain to grain contact between the coarse slag particles gets lost thereby reducing the mechanical strength. Further it is noticed that with increase in curing period the strength increases continuously. The formation of cementitious compounds like calcium silicate hydrate (CSH) depends mainly on curing period, hence higher strength is obtained at 28 days of curing. Following graphs are plotted to show the Variation of UCS value with lime content.

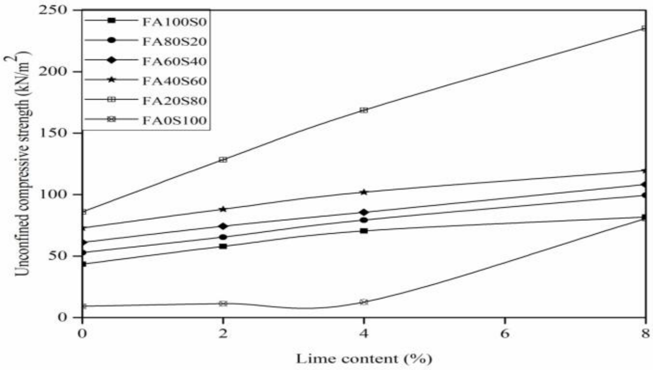

Figure Variation of UCS with Lime Content at 0 Days

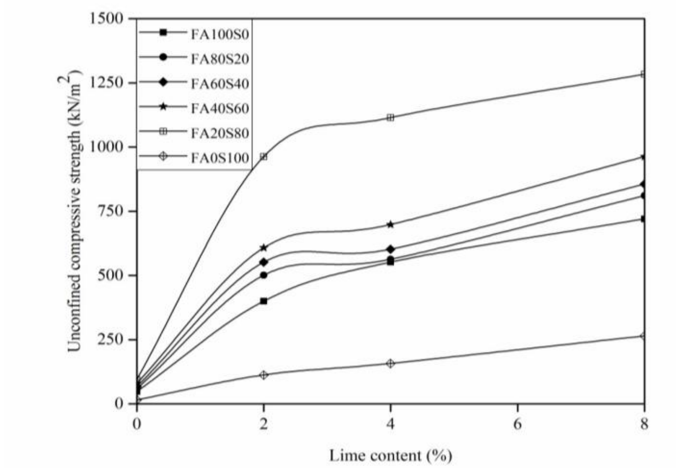

Figure Variation of UCS with Lime Content at 7 Days

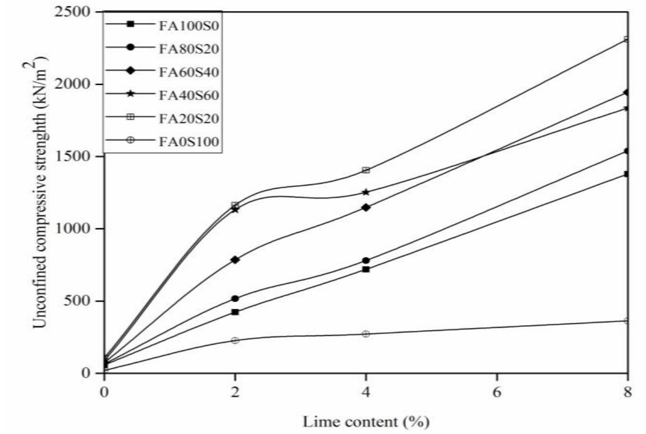

Figure Variation of UCS with Lime Content at 28 Days

Effect of curing period

The strength of stabilized fly ash –slag mixes increases with curing time. At 0% lime, maximum UCS values are around 105.26 kN/m^2 at 28 days of curing for 80% slag of the slag- fly ash mixes. Similarly, at 2%, 4%, 8% lime, maximum UCS values is around 1163.20 kN/m^2 ,1404.91 kN/m^2 and 2311.30 kN/m^2 at 28 days of curing for 80% slag of the slag- fly ash mixes. Slag contains appreciable amount of unreacted lime, however this latent hydration property of the slag is to be activated by an alkali. So extra amount of lime is used to activate the slag and initiates the pozzolanic reaction. As cementitious reactions are slow in slag, stabilizing agent is required. In the presence of lime, the reaction is accelerated, forming cementitious compounds like CSHs providing strength. The CSH gel is responsible for binding the materials in the slag – fly ash mixes together and increasing strength of the mixture. A similar trend was observed with addition of 4 and 8% lime. The quantity of gel formation increased with increase in lime content and hence particles are more effectively bound. Following graphs are plotted to show the variation of UCS value with curing period.

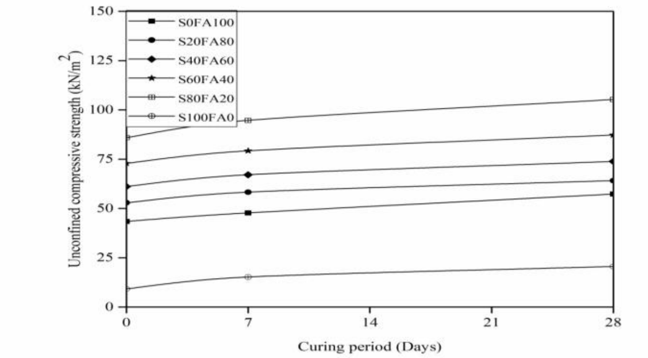

Figure Variation of UCS with curing period with 0 % Lime

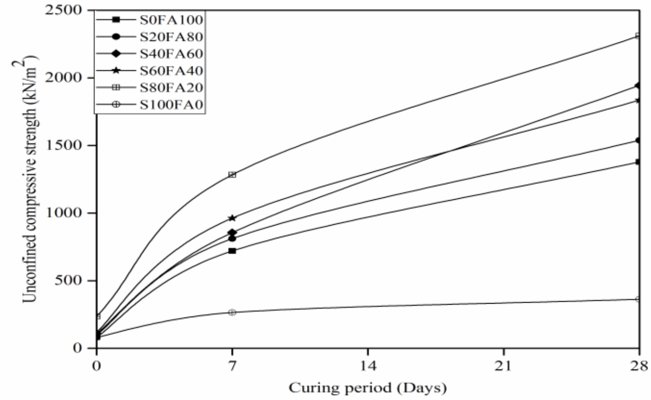

Figure 4.11 Variation of UCS with curing period with 8% Lime

Effect of fly ash/slag content

The maximum UCS value is obtained for 80% slag of the slag- fly ash mixes. The addition of slag to fly ash –slag mixes increases the strength of lime stabilized mixes which is maximum at 8 % lime. This increase in strength may be due to the fact that slag contains some percentage of unreacted calcium oxide, which reacts with silica and alumina producing hard masses. Moreover, the addition of slag to fly ash makes the mix well graded thus increasing the compacted density and hence mechanical strength of the compacted mixture also increases. The addition of slag to fly ash mixes accelerates pozzolanic reaction. Following graphs are plotted to show the variation of UCS value with fly ash content.

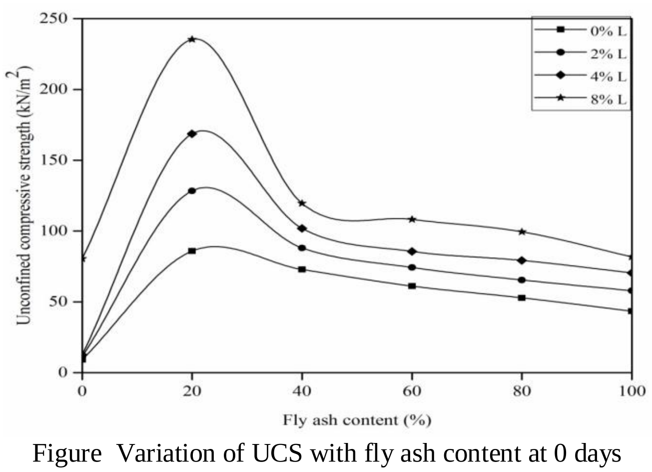

Figure Variation of UCS with fly ash content at 0 days

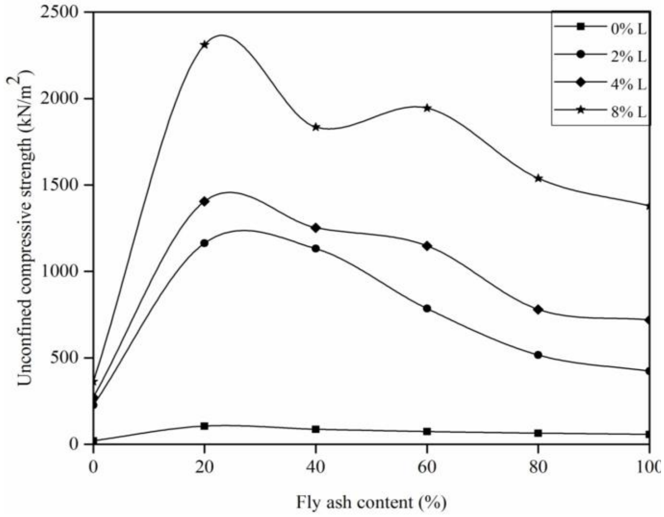

Figure Variation of UCS with fly ash content at 28 days

California Bearing Ratio

Effect of Lime

With increase in Lime content, the CBR values also increases, maximum CBR value was reported as 278.8 % at 8 % lime having 80% slag in the slag –fly ash mixes. However at maximum slag content the CBR value shows a lesser value. The increase in CBR value after addition of lime can be attributed to the fact that formation of various cementing agents due to pozzolanic reaction between reactive silica and alumina present in the slag and lime. Following graphs are plotted to show the variation of CBR value with Lime content.

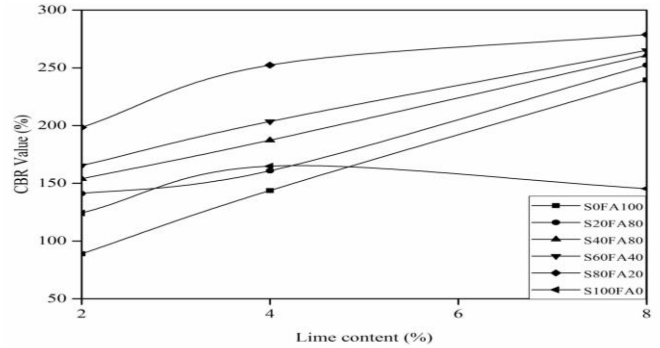

Figure Variation of CBR with Lime content at 28 days

Effect of Fly ash/slag content

With increase in slag content, the CBR value follows a increasing trend. The increase of CBR values can be attributed to increase in mechanical strength of fly ash –slag mixes. Moreover, the free calcium oxide present in slag helps in pozzolanic reaction which imparts higher strength. Hence, addition of slag to fly ash- slag mixes attains higher CBR values. However CBR values attain a higher value at 80% slag of the slag-fly ash mixes at 28 days of curing. The mechanical strength of the mixture largely depend on the amount of chemical added, specific surface area of the material, crushing strength of constituent particles, gradation of the mix and to some extent the particle shape. In this present investigation, a mixture containing (80% slag +20% Fly ash) gives the highest strength. This indicates that at this mixed proportion, the resulting void ratio is the minimum. Thus a more dense mass is formed which renders higher compressive strength. Following graphs are plotted to show the Variation of CBR value with fly ash content.

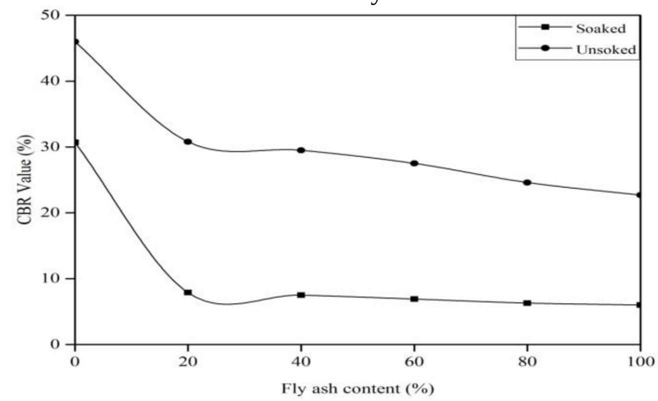

Figure Variation of CBR with fly ash content at 0 days

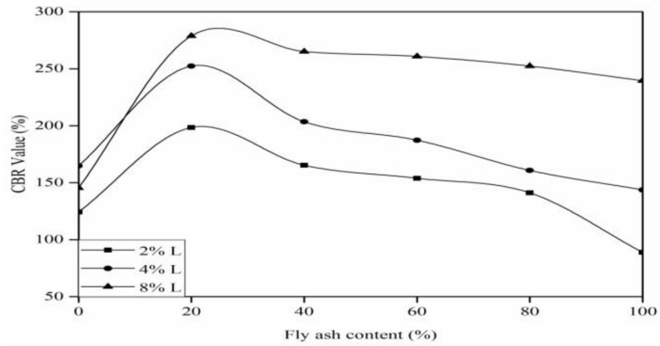

Figure Variation of CBR with fly ash content at 28 days

Evaluation of lime stabilized fly ash – slag mixes as a highway construction material

According to the IRC: 37- 1984 for cumulative traffic up to 2 million standard axle (MSA), the CBR value for sub-base course should be between 20-30 % , for base course it lies between 80-100% and for sub grade course , the CBR value should not be less than 25%. The CBR value of unstabilized fly ash – slag mixes ranges from 6 -30% , which will fail to satisfy the CBR requirement of different pavement layers. And the combination of fly ash and slag alone will also not be able to cope to the CBR requirement. Hence the CBR test of lime stabilized slag- fly ash mixes were conducted. It is seen that CBR value ranges from 6- 278.8% for fly ash- slag mixes stabilized with lime. But depending upon the traffic load and pavement layer, particular fly ash- slag mixes stabilized with lime is designed which can be successfully utilized in base and sub- base courses of highway pavement. The desired lime stabilized fly ash- slag mix will be a promising material in reducing the use of natural soil in addition to mitigate the disposal problems of industrial solid wastes in a greater way. Modified Proctor test was also performed for evaluating the optimum moisture content (OMC) and maximum dry density (MDD) of fly ash- slag mixes. Lime stabilized samples were obtained for slag- fly ash mixes by enhancing the lime percentage (0%, 2%, 4%, and 8%). These stabilized samples were then subjected to unconfined compressive strength test following 0, 7 and 28 days of curing and California bearing ratio test for soaked and unsoaked conditions following 0 and 28 days of curing.

IV. CONCLUSION

Experiments are carried out to investigate the geo-engineering properties of fly ash- slag mixes stabilized with lime. The geo engineering properties are investigated by the effect of lime on fly ash- slag mixes. Based on the experimental finding the major conclusions drawn from this study are as follows.

- Fly ash is mostly well graded material within its size range having specific gravity lower than that of slag. The low specific gravity of fly ash is because of the presence of enospheres.
- The addition of blast furnace slag to fly ash- slag mixes increases the MDD and decreases its OMC value linearly. This is due to the fact that fly ash having more surface area and more fines are present , which require more water for lubrication and thus OMC values keeps on increasing with the increase in fly ash content.
- The UCS value of the fly ash- slag mixes increases with the addition of slag. The mix with 80% slag shows higher value as compared to 100% slag. Moreover the UCS value is maximum for 8% lime in the fly ash - slag mixes subjected to 28 days of curing. This is due to fact that in the presence of lime, the reaction is accelerated forming CSH gel responsible for strength in the mixture.
- The maximum strength observed at 0 days curing is about 235.38 kN/m2 at a lime content of 8%. After 28 days of curing for the same slag – fly ash mix the maximum UCS value is around 10 times higher than 0 days curing and value is around 2311.30 kN/m2.
- The CBR value of the fly ash- slag mixes increase with the addition of slag. As that of UCS, similar pattern were observed for CBR values, with 80 % slag the CBR values reported were higher having lime content 8% subjected to 28 days of curing. The increase of CBR values can be attributed to increase in mechanical strength of fly ash –slag mixes.
- The desired lime stabilized fly ash- slag mix will be a promising material in reducing the use of natural soil in addition to mitigate the disposal problems of industrial solid wastes in a greater way and can be successfully utilized in base and sub- base courses of highway pavement.

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