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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 Bokaro steel plant (BSP). 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. From the compaction tests the optimum moisture content and the maximum dry density are determined for respective mixes. The strength parameters that are the unconfined compressive strength and CBR value for different mixes compacted to their respective MDD at OMC are evaluated. Further these mixes are blended with lime varying as 0%, 2%, 4%, and 8% and the UCS values are determined after a curing period of 0, 7 and 28 days. Similarly, the soaked CBR values of lime stabilized mixes at 0%, 2%, 4%, and 8% are determined after a curing period of 0 and 28 days. The effect of lime, curing period, fly ash and slag content with the unconfined compressive strength values and California bearing ratio values were studied. From the experimental study, it was observed that with addition of blast furnace slag to fly ash- slag mixes, the MDD increases and thereby decreases its OMC value linearly. It was also observed that the UCS value of the fly ash- slag mixes increases with the addition of slag up to slag content of 80% and there after the same decreases with further increases in slag content. The mix with 80% slag shows higher value as compared to 100% slag in the mix. Similar trend was observed for the CBR value for the fly ash- slag mixes, and it was seen that with increase with the slag content the CBR values also increases. However, for 100% slag the CBR shows a lesser value. Higher UCS and CBR values were reported at 8% lime content having a curing period of 28 days. The objective of the present study is to access the suitability of lime stabilized fly ash- blast furnace slag mixes as a highway construction material. So it is concluded that appropriate blending of fly ash with slag gives a better strength compared to individual materials. Further the desired strength required for different component of road can be achieved by stabilizing the mix with appropriate amount of lime.**

***Index Terms*— Slag. Fly Ash, Industrial Waste, Natural Oil, Highway Materials.**

I. INTRODUCTION

Conventionally road pavements are constructed using soil, aggregates and binder. Aggregates form major portion of the total volume of pavement structure and is the primary mineral material used in road construction. Large volumes of aggregates are consumed by the road building programmed and similar quantities are used in maintenance works. It is estimated that construction of one cubic meter of Water Bound Macadam (WBM) involves use of about 1 .2 to 1 .4 cubic meter of aggregates, and laying of bituminous pavements involve even higher quantities. The aggregate extraction from natural rocks results into a lot of noise, dust, impacting vibrations, hazards, etc. Such ecological effects are creating worry in many parts of the nation. Unplanned exploitation of natural rock mass may sometimes lead to landslides of weak and steep hill slopes.

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 Bokaro steel plant and blast furnace slag from the slag crusher unit of Bokaro 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.

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.

II. LITERATURE REVIEW

Fly ash is a byproduct generated from the thermal power plants. The main issue with fly ash is its disposal which possesses huge economic loss to the power plants. Thus, a special consideration is required for the utilization of fly ash in highway, embankment constructions as a replacement to conventional natural materials. Blast furnace slag is formed as a co product in the process of iron production. The utilization of blast furnace slag in geotechnical constructions needs a study. Lime is produced by calcination of limestone in a lime kiln at temperatures above 1000°C

Fernandez et al. (2004) conducted a microscopic study on a set of fly ash samples which are activated by an alkali and thermally cured. The morphology of fly ash particles was studied that can be applied to physical life situation. The fly ash was thoroughly mixed with alkaline activators and the paste was allowed to solidify by curing. The results show that with time the degree of reaction is increasing continuously.

Lav et al. (2005) studied on the utilization of class F fly ash as a base material in road pavements. In this work only aggregate, fly ash and cement were used as the main motive is to use the waste material. In this study, cement content was varied (2%, 4%, 8%, 10%) to prepare samples. The test results obtained from the tests were then incorporated into pavement study.

Ghosh and Subbarao (2006) investigated the suitability of lime/gypsum stabilized fly ash as a roadway material. In this study unconfined compressive strength, bearing ratio, tensile strength and slake durability test were conducted. The effect of lime content, gypsum content and curing period on the above characteristics was highlighted. From this study, it can be said that stabilized class F fly ash has a potential for providing a strong road base.

Bera et al. (2008) carried out unconfined compressive strength test on both unreinforced fly ash and reinforced fly ash with jute geotextiles. The effect of degree of saturation, size of the sample, number of jute geotextile layers and age of the sample on UCS has been investigated.

Nassarr et al. (2013) studied the effect of high volume fly ash on pavement construction. From the study it was found that the fly ash in pavement can be used as partial replacement for cement due to enhanced durability characteristic.

Pal and Rajak (2015) investigated the CBR values of soil mixed with fly ash and lime in different percentages. Soil was mixed with lime at 5%, 8%, 10% and 12% and with fly ash at 10%, 20%, 30% and 40% to enhance its CBR values. The optimum moisture content increases and dry density decreases with increase in fly ash and lime percentage due to the variation in clay and silt size particle. Addition of fly ash and lime enhanced the Unsoaked CBR value of the soil.

Wild et al. (1998) focused on the use of granulated ground blast furnace slag for highway and other different foundation layers by evaluating the beneficial effect on strength by substituting GGBS for lime in lime-stabilized clay soils, particularly in the presence of gypsum. The result shows that there is improvement in strength by the addition of lime with GGBS and the content of lime and slag is to be maintained for required bearing capacity and strength.

Behiry (2012) evaluated the effect of quality of steel slag on mechanical properties of mixes with crushed limestone aggregates, which was used as sub base material. The results show that by increasing the steel slag percentage to the limestone in the blended mix increases the mechanical properties such as maximum dry density, California Bearing Ratio and resilient modulus. The best density and strength for the layer with the least construction costs obtained at a blended mix of 70% steel slag percentage to 30% limestone.

Bhattacharyya (2012) made a study on use of Blast Furnace Slag in sub base/base layer of pavement. Test was conducted for suitability of slag in pavement layers. Various field studies of BFS layers after laying and after compaction were made analyzed. From the analysis it was obtained that cumulative % retained decreases. It was concluded that the material was very useful alternative of stone material in GSB layer.

Sinha et al. (2013) focused on the geotechnical characteristics of slag design. The stability analysis of embankment, sub-grade and sub base layers and suitability of slag in bituminous layers were highlighted. In this study the utilization of slag in different layer of roads was carried out. From the study it was observed that slag can be used for embankment construction and for sub grade, but not suitable for bituminous layers.

Yadu and Tripathi (2013) focused on the effectiveness of granulated blast furnace slag in improving the engineering behavior of soft soil(CI-MI). Different proportions of GBS such as 3%,6%,9% and 12%was combined with the soil and CBR as well as UCS test was conducted and it was obtained that 9% GBS is optimum for improving strength.

Puertas et al. (2000) carried out a study on activation of fly ash / slag pastes with NaOH solution. The effect of curing temperature, activator concentration and fly ash slag ratios were studied. From the study it was observed that with increase in slag content, the compressive strength also increases. Moreover, the curing temperature has a positive trend at initial days, and at longer days the effect is reversed. It was observed that at a curing temperature of 25°C the strength attained was higher.

Singh and Ramaswamy (2005) conducted a study to assess the suitability of cement stabilized fly ash- granulated blast furnace slag (GBFS) mixes for its use as embankment, base and sub- base courses of highway pavement. The compaction characteristics, unconfined compressive strength and CBR value of the stabilized fly ash- GBFS mixes were evaluated. In the study cement content was varied from 0 to 8 percent at 2 % interval, whereas slag content was varied from 0 to 10, 20, 30 and 40 % respectively. From the compaction test it was studied that the mixes show an increase in MDD. Moreover, the UCS and CBR values of compacted mixes depend, to a large extent, on the cement content.

A. PROBLEM STATEMENT

The motive of the thesis is to utilize the industrial wastes like slag and fly ash instead of natural soil and aggregates for the highway construction after stabilizing the slag- fly ash mixes with lime.

B. OBJECTIVE OF THE WORK

Accessing the suitability of lime stabilized fly ash- blast furnace slag mixes as a highway construction material.

C. SCOPE OF THE WORK

- Characterization of raw materials.
- Study on the compaction characteristics of the slag- fly ash mixes.
- Determination of unconfined compressive strength of the slag- fly ash mixes stabilized with various percentage of lime and cured for 0, 7, 28 days.
- Determination of California Bearing Ratio test of the lime stabilized slag- fly ash mixes for Soaked and Unsoaked Condition at 0 and 28 days of curing.
- Accessing the suitability of above stabilized mixtures for different components of pavement.

III. EXPERIMENTAL PROGRAMME AND METHODOLOGY

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 Bokaro 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.

A. MATERIALS USED

1) Fly Ash

Fly ash used in this study was collected from the Bokaro steel plant. Fly ash samples were dried at a temperature of around 105-110oc. 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.

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

B. DETERMINATION OF ENGINEERING PROPERTIES

The compaction characteristics were found by using compaction tests as per IS: 2720(Part -8)-1983. For this test, slag- fly ash mixes was mixed properly with requisite amount of water and then the mix was compacted in proctor mould in five equivalent layers using rammer of 4.5 kg. The moisture content of the compacted mixture was determined as per IS: 2720 (Part-2) 1973.From the compaction characteristics, optimum moisture content (OMC) and maximum dry density (MDD) were determined. The test results are presented in Table 3.2. The compaction graph of the various slag- fly ash mixes are shown in Figure.

Table 3.2 Compaction characteristics of fly ash – blast furnace slag mixes

Sl.No.	% Fly Ash	% Slag	MDD(kN/m^3)	OMC
1	100	0	13.342	32.4
2	90	10	13.636	31
3	80	20	13.911	28.2
4	70	30	15.206	25
5	60	40	16.187	21.8
6	50	50	17.462	18.2
7	40	60	18.639	16.2
8	30	70	20.601	13.8
9	20	80	21.925	10.8
10	10	90	22.749	10
11	0	100	25.309	8.96

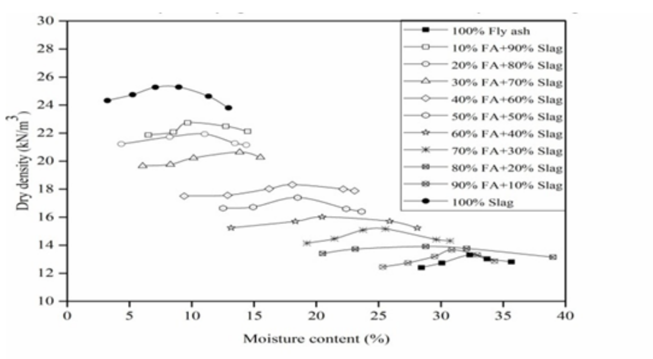

Figure 3.1` Compaction curves for fly ash- slag mixes

C. Determination of Unconfined Compressive Strength

Unconfined compressive strength tests on various lime stabilized slag- fly ash mixes were performed according to IS:2720 (Part -10),1991. For this test cylindrical specimens were prepared in a split mould with dimension 75 mm (dia.) x 150 mm (high). The stabilized samples were prepared for various slag- fly ash mixes corresponding to their maximum dry density (MDD) and optimum moisture content (OMC) with stabilizing with lime with enhancing percentage of 0%, 2%, 4%, 8%. For each composition two samples were prepared. The lime stabilized samples were kept for 7 and 28 days after coating with wax.

Figure 3.2 View of stabilized samples.

Figure 3.3 Test set up for stabilized samples.

The unconfined compressive test of the stabilized Samples after 0, days of curing are tabulated in Table 3.3.

Table 3.3 Unconfined Compressive Strength (in kN/m^2) of fly ash – blast furnace slagmixes stabilized with lime after 0 days of Curing

% Fly Ash	**% Slag**	**0% Lime**	**2% Lime**	**4% Lime**	**8% Lime**
100	0	43.40	57.90	70.49	81.81
80	20	52.87	65.45	79.29	99.43
60	40	61.10	74.26	85.58	108.24
40	60	72.89	88.10	101.95	119.57
20	80	85.89	128.39	168.67	235.38
0	100	9.23	11.33	12.59	80.53

IV. TEST RESULTS AND DISCUSSIONS

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 below..

A. INDEX PROPERTIES

1) 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.

2) 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.

B. ENGINEERING PROPERTIES

1) 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.

2) 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.

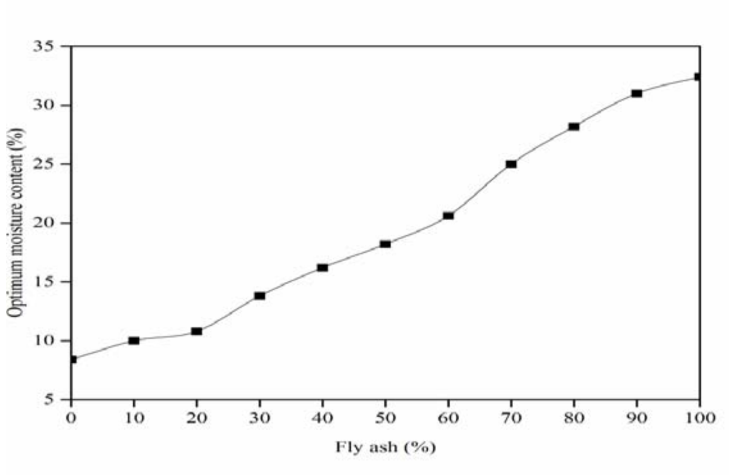

Figure 4.1 Variation of OMC with fly ash content

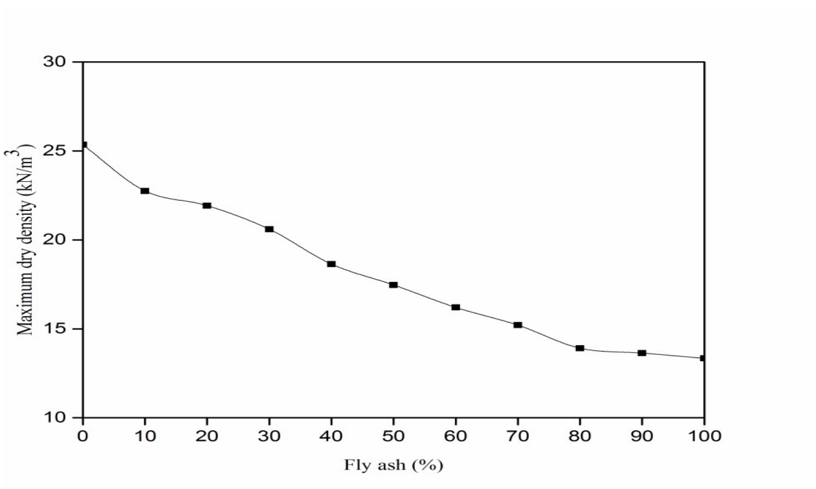

Figure 4.2 Variation of MDD with fly ash content

3) 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.

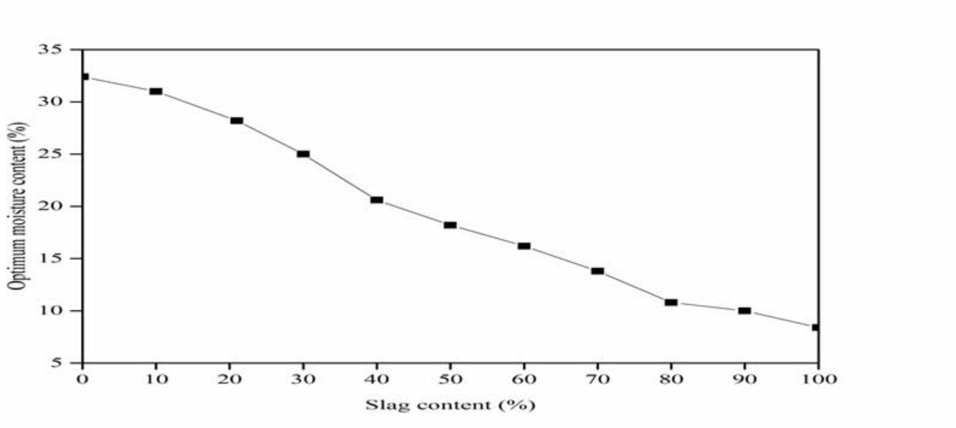

Figure 4.3 Variation of OMC with Slag content

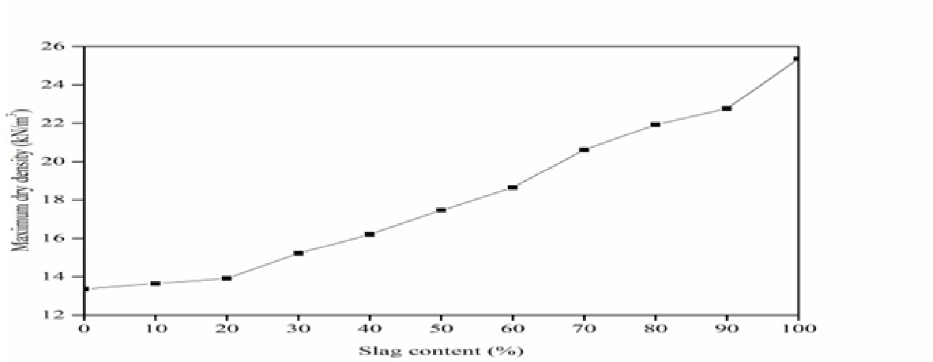

Figure 4.4 Variation of MDD with slag content

V. 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 cenospheres. 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.

REFERENCES

[1] Behiry, A. E. A. E. M. (2013). Evaluation of steel slag and crushed limestone mixtures as subbase material in flexible pavement. Ain Shams Engineering Journal, 4(1), 43-53.

[2] Bera, A. K., Chandra, S. N., Ghosh, A., & Ghosh, A. (2009). Unconfined compressive strength of fly ash reinforced with jute geotextiles. Geotextiles and Geomembranes, 27(5), 391-398.

[3] Bhattacharyya, A. K. (2012). Blast furnace slag in roadway-an essence from field and related discussions. Indian Highways, 40(1).

[4] Deb, P. S., Nath, P., & Sarker, P. K. (2014). The effects of ground granulated blast- furnace slag blending with fly ash and activator content on the workability and strength properties of geopolymer concrete cured at ambient temperature. Materials & Design (1980-2015), 62, 32-39.

[5] Fernández-Jiménez, A., Palomo, A., & Criado, M. (2005). Microstructure development of alkali-activated fly ash cement: a descriptive model. Cement and concrete research, 35(6), 1204-1209.

[6] Gao, X., Yu, Q. L., & Brouwers, H. J. H. (2015). Reaction kinetics, gel character and strength of ambient temperature cured alkali activated slag–fly ash blends. Construction and Building Materials, 80, 105-115.

[7] Ghosh, A., & Subbarao, C. (2006). Tensile strength bearing ratio and slake durability of class F fly ash stabilized with lime and gypsum. Journal of materials in civil engineering, 18(1), 18-27.

[8] IS: 2720(Part 2), 1973 Methods of Test for Soils, Determination of water content. Bureau of Indian standards, New Delhi, India.

[9] IS: 2720(Part 3/ Sec-1,2), 1980 Methods of Test for Soils, Determination of specific gravity of soil. Bureau of Indian standards, New Delhi, India.

[10] IS: 2720(Part 4), 1980 Methods of Test for Soils, Grain size analysis of soil. Bureau of Indian standards, New Delhi, India.

[11] IS: 2720(Part 8), 1980 Methods of Test for Soils, Determination of water content dry density relationship using heavy compaction test. Bureau of Indian standards, New Delhi, India.

[12] IS: 2720(Part 10), 1991 Methods of Test for Soils, Determination of unconfined compressive strength. Bureau of Indian standards, New Delhi, India.

[13] IS: 2720(Part 16), 1987 Methods of Test for Soils, Laboratory determination of CBR. Bureau of Indian standards, New Delhi, India.

[14] Lav, A. H., & Lav, M. A. (2000). Microstructural development of stabilized fly ash as pavement base material. Journal of Materials in Civil Engineering,12(2), 157-163.

[15] Lav, A. H., Lav, M. A., & Goktepe, A. B. (2006). Analysis and design of a stabilized fly ash as pavement base material. Fuel, 85(16), 2359-2370.

[16] Pandian, N. S., & Krishna, K. C. (2002). California bearing ratio behavior of cement- stabilized fly ash-soil mixes. Journal of testing and evaluation, 30(6), 1-5.

[17] Uerta- art ne -Ra re S. lonso S. que T. (000). l ali-activated fly ash/slag cements: strength behaviour and hydration products. Cement and Concrete Research, 30(10), 1625-1632.