International Journal For Technological Research In Engineering
Volume 9, Issue 10, June-2022 *ISSN (Online): 2347 - 4718*

STUDY OF LIME STABILIZED SLAG FLY ASH MIXES AS A HIGHWAY MATERIAL

Khoob Lal Raikwar[1], Mohit Verma[2]
M.Tech Scholar[1], Assistant Professor[2]
Department of Civil Engineering, JEC Jabalpur

Abstract: This research aims to find out suitability to use industrial wastes rather than natural soil, aggregates, etc. in roads and highway construction after enhancing its strength, stability and durability. Stabilization method highlighted in this paper 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 strength parameters that are the unconfined com-pressive 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 in-creases 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.

I. INTRODUCTION

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.

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. 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.

Fly Ash, an industrial by-product from Thermal Power Plants (TPPs), with current annual generation of approximately 205 million tones. Cement and concrete industry accounts for half the fly ash utilization. The other areas are low lying area fill, roads and embankment, dike raising, brick manufacturing and safe disposal of fly ash in paint industry, agriculture, etc

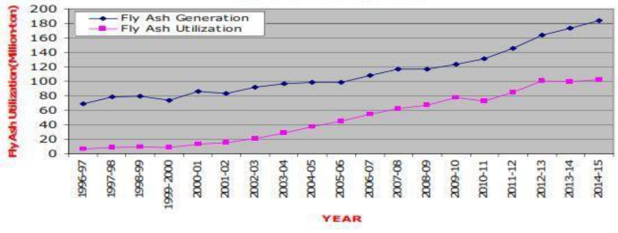

Figure 1.1 Generation and utilization on fly ash in India
(Source: Central Electricity Authority, New Delhi, 2015)

Despite the continuous efforts to increase the utilization rate, the government still does not achieve maximum utilization.

Considering the future aspect there will be certainly increase in the thermal power plant in the country, hence it is predicted that the fly ash generation will also increase and achieve the greatest level of utilization.

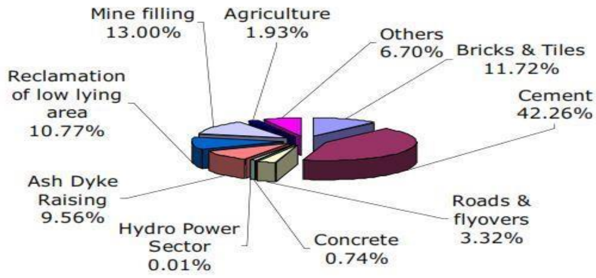

Figure 1.2 Modes of fly ash utilization
(Source: Central Electricity Authority, New Delhi, 2015)

Table 1.1 Economic Benefits of Fly ash
(Source: Central Electricity Authority, New Delhi, 2015)

Sl.No.	Utilization	Fly ash consumption(millions tones /year)	Savings per year(rupees in crores)
1	Cement	25	2500
2	Road embankment	15-20	100
3	Mine fills	15-20	150
4	Bricks	5	20
5	Agriculture	200	3000

Table 1.2 Plant wise capacity of iron and steel slag in India

(Source: Indian Minerals Yearbook, 2015)

Steel Plant	Capacity for granulation(„000 tpy)
Bhillai Steel Plant, Durg, Chattisgarh	2675
Bokara Steel Plant, Bokara, Jharkhand	7884
Rourkela Steel Plant, Rourkela, Odisha	600
Durgapur Steel Plant, Durgapur, West Bengal	566
IISCO Steel Plant, Burnpur, West Bengal	400
Visvesvarya Iron & Steel Plant, Bhadravati, Karnataka	400
Rastriya Ispat Nigam Ltd., Vishakhapatnam, Andhra Pradesh	440
IDCO Kalinga Iron Works Ltd., Barbil, Odisha	53
JSW Steel Ltd., Bellary, Karnataka	-
Tata Steel Ltd., Jamsedpur, Jharkhand	2100
Visa Steel Ltd., Kalinganagar, Odisha	175

II. OBJECTIVE

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

III. 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.

IV. MATERIAL USED

1. Fly Ash
The physical properties of fly ash were evaluated and presented in Table 3.1

Table 4.1 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

2. Blast Furnace Slag (BFS)

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

Table 4.2 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

3. 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.

V. METHODOLOGY

DETERMINATION OF INDEX PROPERTIES

Determination of Specific gravity

The specific gravity of fly ash and 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.

Determination of Grain Size Distribution

For determination of grain size distribution, sieve analysis was conducted for coarser particles as per IS: 2720 part (IV), 1975 and also hydrometer analysis was conducted for finer particles as per IS: 2720 part (IV). Coefficient of uniformity (Cu) and coefficient of curvature (Cc) for fly ash was found to be 7.755 and 1.939 respectively. The grain size distribution curve of fly ash is presented in Figure. 3.1. Similarly, for determination of grain size distribution of blast furnace slag, it was passed through test sieve 20 mm down. Sieve analysis was conducted for coarser particles as per IS: 2720 part (IV),1975. Coefficient of uniformity (Cu) and coefficient of curvature (Cc) for blast furnace slag was found to be 30.625 and 0.816 respectively. The grain size distribution curve of blast furnace slag is presented in Figure. 3.2. Combined graphs for various slag- fly ash mixes were plotted and presented in Figure. 3.3.

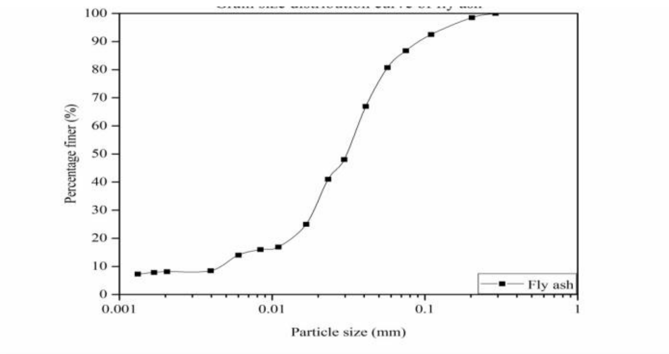

Figure 5.1 Grain Size Distribution Curve for Fly Ash

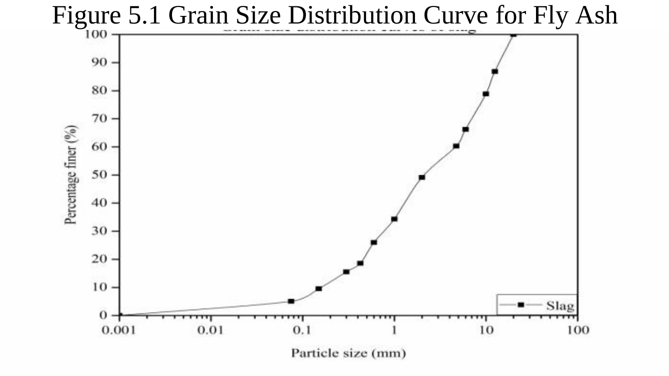

Figure 5.2 Grain Size Distribution Curve for Blast Furnace Slag

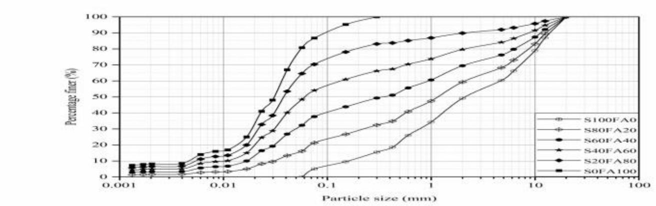

Figure 5.3 Grain Size Distribution Curve for Fly ash – Slag mixes

DETERMINATION OF ENGINEERING PROPERTIES

Compaction Characteristics

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 layer 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 3.3. The compaction graph of the various slag- fly ash mixes are shown in Figure.

Table 5.1 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

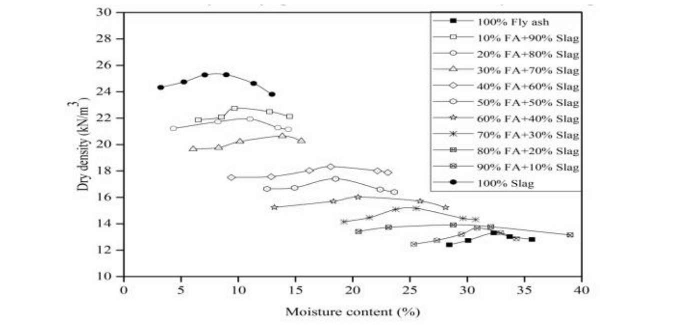

Figure 5.4 Compaction curves for fly ash- slag mixes

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 5.5 View of stabilized samples

Figure 5.6 Test set up for stabilized samples.

The unconfined compressive test of the stabilized Samples after 0, 7 and 28 days of curing are tabulated in Table 3.4, 3.5, 3.6 respectively.

Table 5.2 Unconfined Compressive Strength (in kN/m2) of fly ash – blast furnace slag mixes 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

Table 5.3 Unconfined Compressive Strength (in kN/m2) of fly ash – blast furnace slag mixes stabilized with lime after 7 days of Curing\

% Fly Ash	% Slag	0 % Lime	2% Lime	4% Lime	8% Lime
100	0	47.74	399.63	551.60	720.45
80	20	58.26	500.94	562.92	810.69
60	40	67.10	551.60	602.32	855.73
40	60	79.26	607.95	698.02	962.59
20	80	94.71	962.59	1114.57	1283.45
0	100	15.23	112.56	157.60	264.57

Table 5.4Unconfined Compressive Strength (in kN/m2) of fly ash – blast furnace slag mixes stabilized with lime after 28 days of Curing

% Fly Ash	% Slag	0 % Lime	2% Lime	4% Lime	8% Lime
100	0	57.32	422.93	719.60	1378.78
80	20	64.12	516.366	780.12	1538.43
60	40	73.85	785.52	1148.20	1945.02
40	60	87.25	1131.59	1252.58	1835.13
20	80	105.26	1163.20	1404.91	2311.30
0	100	20.6	226.60	271.92	362.56

Determination of California Bearing Ratio

Table 5.5 California Bearing Ratio of Samples of fly ash – blast furnace slag mixes stabilized with lime for 0 days (Unsoaked Condition and Soaked Condition)

% Fly Ash	% Slag	Unsoaked CBR (%)	Soaked CBR (%)	Ratio(SOAKED /UNSOAKED
100	0	22.7	6	0.264
80	20	24.6	6.3	0.256
60	40	27.5	6.9	0.251
40	60	29.5	7.5	0.254
20	80	30.8	7.9	0.256
0	100	46	30.7	0.667

Table 5.6 California Bearing Ratio of Samples of fly ash – blast furnace slag mixes stabilized with lime (0%, 2%, 4% and 8% lime) after 28 days (Soaked condition) of Curing

% Fly Ash	% Slag	CBR value (%)		
		2% Lime	4% Lime	8% Lime
100	0	88.9	143.7	239.5
80	20	141.1	160.8	252.3
60	40	153.9	187.3	260.8
40	60	165.3	203.5	265.1
20	80	198.4	252.3	278.8
0	100	124.3	164.8	145.4

VI. RESULTS AND DISCUSSION

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 with lime.

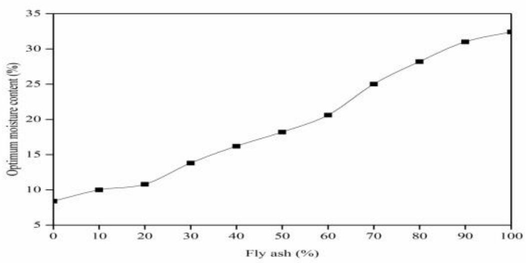

Figure 6.1 Variation of OMC with fly ash content

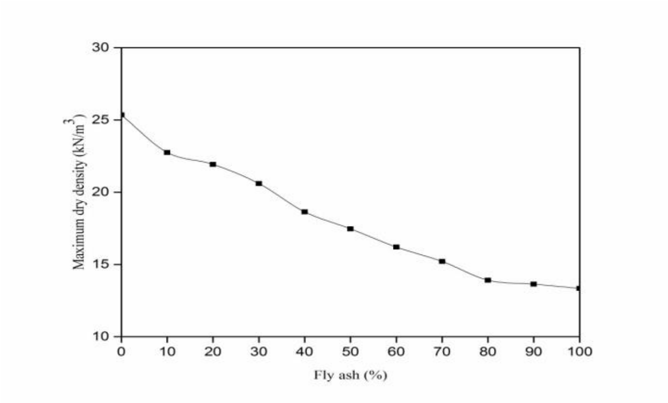

Figure 6.2 Variation of MDD with fly ash content

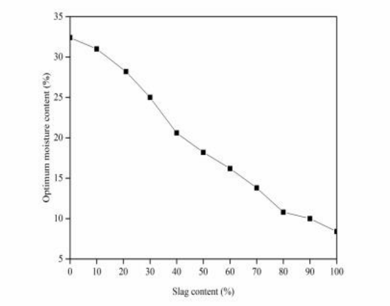

Figure 6.3 Variation of OMC with Slag content

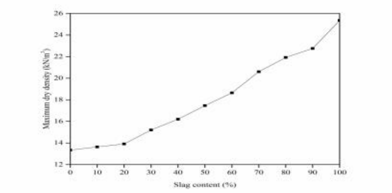

Figure 6.4 Variation of MDD with slag content

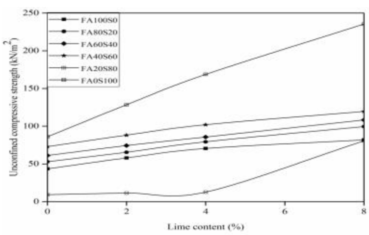

Figure 6.5 Variation of UCS with Lime Content at 0 Days

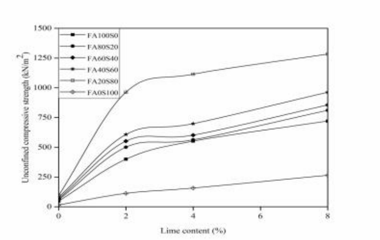

Figure 6.6 Variation of UCS with Lime Content at 7 Days

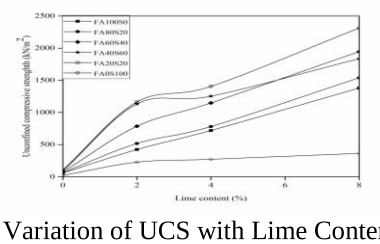

Figure 6.7 Variation of UCS with Lime Content at 28 Days

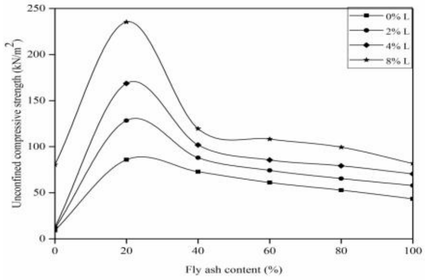

Figure 6.8 Variation of UCS with fly ash content at 0 days

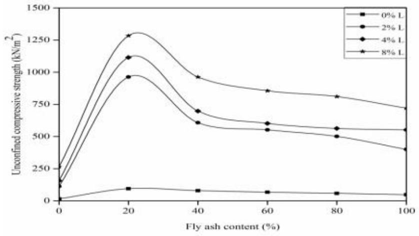

Figure 6.9 Variation of UCS with fly ash content at 7 days

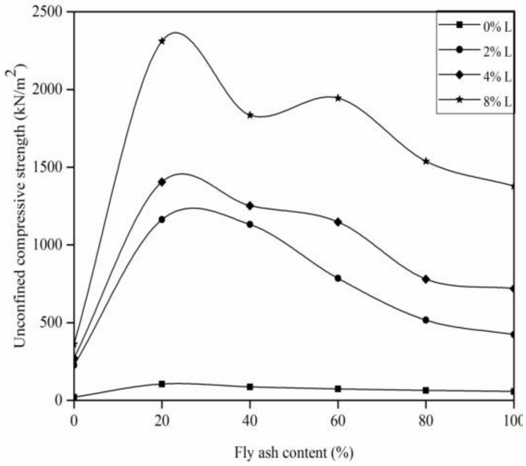

Figure 6.10 Variation of UCS with fly ash content at 28 days

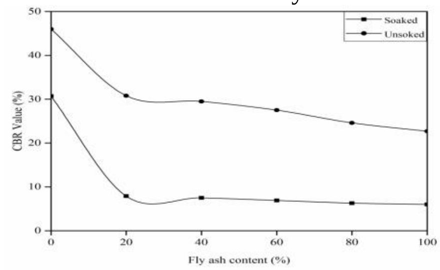

Figure 6.11 Variation of CBR with fly ash content at 0 days

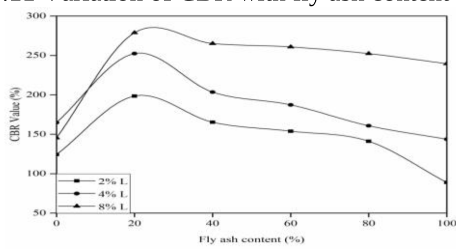

Figure 6.12 Variation of CBR with fly ash content at 28 days

VII. CONCLUSION

- 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 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

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