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Study of Unconfined Compressive Strength of Residual Industrial Waste Products

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Abstract: India faces major environmental challenges associated with waste generation and inadequate waste collection, transport, treatment and disposal. Current systems in India cannot cope with the volumes of waste generated by an increasing urban population, and this impacts on the environment and public health. The challenges and barriers are significant, but so are the opportunities. Industrial sites where residuals and wastes, such as slags, ashes, dust, and sludges, have been dumped are essential parts of the environment and of the economic structure. The amount of waste produced, distributed, and deposited is constantly increasing. The wastes can contain hazardous components that pollute and endanger the environment, but they can also consist of valuable materials, which are a source of secondary raw materials. Disposal of this enormous amount of waste products as fly ash, blast furnace slag, lime etc faces problem of huge land requirement, transportation, and ash pond construction and maintenance, which can be reduced by utilizing residual waste products as a construction material for civil engineering structures. Industrial waste products as Fly ash becomes an attractive construction material because of its self hardening characteristics for which available free lime is responsible. The variation of its properties depends upon the nature of coal, fineness of pulverization, type of furnace and firing temperature. Currently, more than 50% of the concrete placed in the U.S. contains fly ash. Dosage rates vary depending on the type of fly ash and its reactivity level. Typically, Class F fly ash is used at dosages of 15% to 25% by mass of cementitious material and Class C fly ash at 15% to 40%. The use of iron blast furnace slag as a constituent of concrete, either as aggregate or as a cementing material, or both, is well known. Viscosity & flow characteristics of the Blast Furnace slag constitute two very important parameters for ensuring the smooth operation of the Blast Furnace producing pig iron. So assessment of the behavior of residual industrial waste products at different condition is required before its use as a construction material in Civil engineering structure.

Keywords: Blast Furnance Slag, FlyAsh, Lime, Unconfined Compressive Strength, Residual industrial waste products.

I. INTRODUCTION

1) *Slag:* Slag can be used in concrete to improve its mechanical, physical and chemical properties and it is the one of the waste products which could have a better future in construction industry as partial or full substitute for either cement or aggregate.

Chemical composition of BF slag can vary in the following range under indian condition:

CaO = 31-40%, SiO₂ = 29-38, Al₂O₃ = 14-22%, MgO = 7-11%, FeO = 0.1-1.9%,

MnO = 0.01-1.2, S = 1-1.9, Basicity (CaO/SiO₂) = 0.9-1.3%.

Types of Slag: Blast furnace slag and Steel slag.

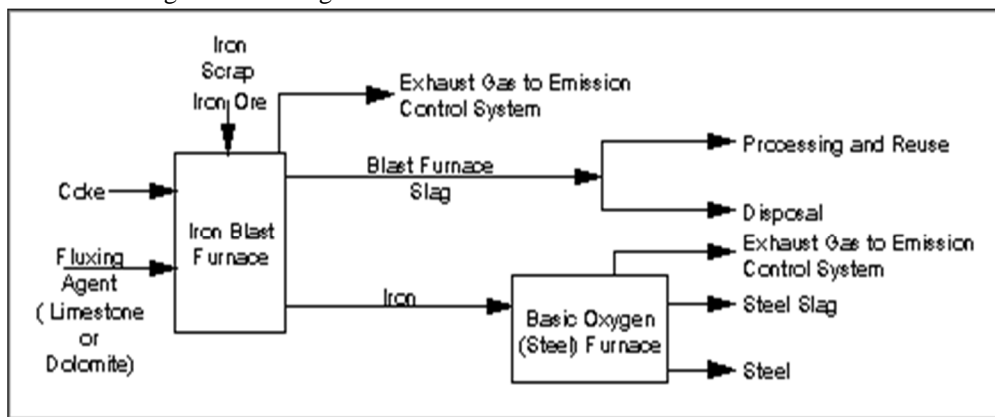


Fig: General schematic of blast furnace operation and blast furnace slag production.

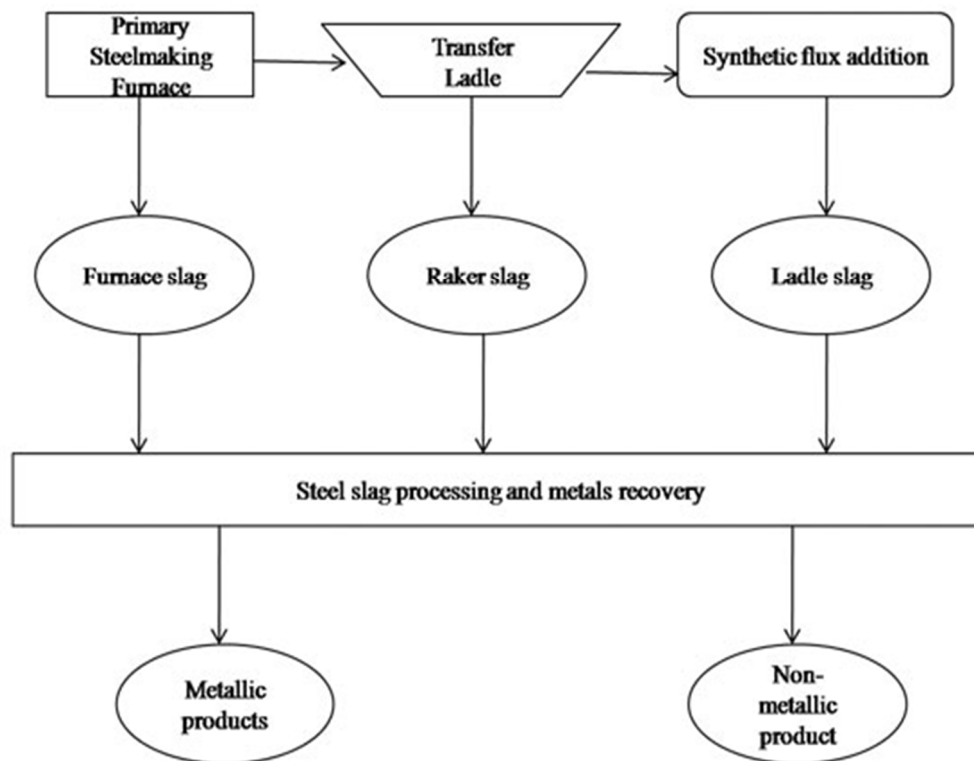


Figure 1: Flowchart of slag production in a modern steel plant

Fig: Flow chart of Slag production in a modern steel plant

2) *Fly Ash*: Fly ash is a byproduct from burning pulverized coal in electric power generating plants. During combustion, mineral impurities in the coal (clay, feldspar, quartz, and shale) fuse in suspension and float out of the combustion chamber with the exhaust gases. As the fused material rises, it cools and solidifies into spherical glassy particles called fly ash.

Types of fly ash are commonly used in concrete: Class C & Class F.

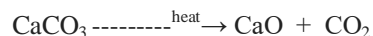
Class C are often high- calcium fly ashes with carbon content less than 2%; whereas,

Class F are generally low-calcium fly ashes with carbon contents less than 5% but sometimes as high as 10%.

In general, Class C ashes are produced from burning sub-bituminous or lignite coals and Class F ashes bituminous or anthracite coals. Fly ash has not been used in interior, steel-troweled slabs because of the inherent problems or challenges associated with fly ash variability and delayed concrete hardening.

3) *Lime*: is a calcium-containing inorganic material in which carbonates, oxides, and hydroxides predominate. In the strict sense of the term, lime is calcium oxide or calcium hydroxide. It is also the name of the natural mineral (native lime) CaO which occurs as a product of coal seam fires and in altered limestone xenoliths in volcanic ejecta. The word *lime* originates with its earliest use as building mortar and has the sense of *sticking or adhering*.

Limestone is extracted from quarries or mines. Part of the extracted stone, selected according to its chemical composition and optical granulometry, is calcinated at about 1,000 °C (1,830 °F) in different types of lime kilns to produce quicklime according to the reaction:



Before use, quicklime is hydrated, that is combined with water, called slaking, so hydrated lime is also known as slaked lime, and is produced according to the reaction:



The result of the reaction –calcium hydroxide- is a strong base and corrodes the mucous membranes. This is further accentuated by the heat generated in connection with slaking.

The following diagram illustrates the processes:

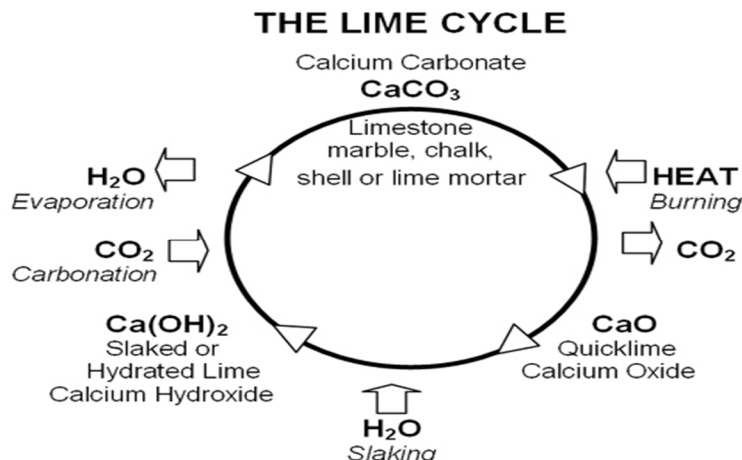


Fig: Flow diagram of Lime

II. LITERATURE REVIEW

Elsayed investigated experimentally in his study the effects of mineral admixtures on water permeability and compressive strength of concretes containing silica fume (SF) and fly ash (FA). The results were compared to the control concrete, ordinary Portland cement concrete without admixtures. The optimum cement replacement by FA and SF in this experiment was 10%.

Venu Malagavelli et al. studied on high performance concrete with BFS and robo sand and concluded that the percentage increase of compressive strength of concrete is 11.06 and 17.6% at the age of 7 and 28 days by replacing 50% of cement with BFS and 25% of sand with ROBO sand. Luo et al. experimentally studied the chloride diffusion coefficient and the chloride binding capacity of Portland cement or blended cement made of Portland cement and 70 % BFS replacement with or without 5 % sulphate. They found that (i) chloride diffusion coefficient decreased; (ii) chloride ion binding capacity improved in samples of blended cement.

Clear concluded that higher the proportion of BFS, the slower the early age strength development.

Jakka et al. have studied that densities of compacted ash is lower than natural soil due to their low value of specific gravity and inraparticle voids. Singh and Panda performed shear strength tests on freshly compacted fly ash specimens at various water contents and concluded that most of the shear strength is due to internal friction.

Bell indicates that with Increase in liquid limit and plasticity index lime has increased the plasticity of the soils treated with. This is suggested due to the action of hydroxyl ions modifying the water affinity of the soil particles. Besides, increase in lime content, beyond a certain limit, is found to have reduced the strength.

III. EXPERIMENTAL WORK

A. Material Used For Test

- 1) Fly ash & BFS:** Fly ash was Collected from the captive power plant (CPP-II) and BFS from the dump pad of Rourkela steel plant (RSP).The sample was screened through 2mm sieve to separate out the foreign and vegetative matters. The collected samples were mixed thoroughly to get the homogeneity and oven dried at the temperature of 105-110 degree. Then the Fly ash samples were stored in airtight container for subsequent use.
- 2) Lime:** Lime (Calcium Oxide CaO) used in this study was first sieved through 150 micron sieve and stored in airtight container for subsequent use.

B. Sample Preparation And Experimental Program

Initially standard proctor test was performed to get the OMC and MDD of fly ash and also specific gravity test was performed for both fly ash and BFS. The OMC and MDD of fly ash were found out to be 40.1% and 1.08 gm/cm³ respectively. The specific gravity of fly ash and BFS were found out to be 2.51 and 2.78 respectively. Standard proctor test was performed for samples mixed with different percentage composition of fly ash and BFS at an interval of 10% to find out OMC and MDD. Stabilized samples were prepared mixing fly ash and BFS with different percentage at an interval of 10% and with stabilizing agent lime with increasing percentage as 0%, 2%, 4%, 6%, and 8%. The samples were then subjected to unconfined compressive test after 7, 14, 28 and 60 days of curing.

C. Determination Of Engineering Properties

- 1) **Specific Gravity:** Specific gravity is one of the important physical properties needed for the use of coal ashes for geotechnical and other applications. In general, the specific gravity of coal ashes lies around 2.0 but can vary to a large extent (1.6 to 3.1). The variation of specific gravity of the coal ash is the result of a combination of many factors such as gradation, particle shape and chemical composition. The reason for a low specific gravity could either be due to the presence of large number of hollow cenospheres from which the entrapped micro bubbles of air cannot be removed, or the variation in the chemical composition, in particular iron content, or both .The specific gravity of Fly ash was determined according to IS: 2720 (Part-III) -1980 guidelines by Le-Chartelier method with kerosene oil. The average specific gravity value of flyash found to be 2.55 to be lower than that of the conventional earth material.
- 2) **Grain Size:** The particle size of Fly ash ranges from fine sand to silt size as shown in Fig. The percentage of Fly ash passing through 75 μ sieve was found to be 86.62%. The coefficient of uniformity (Cu) and coefficient of curvature (Cc) for Fly ash were found to be 5.88 & 1.55 respectively, indicating uniform gradation of samples. The grain size distribution mostly depends on degree of pulverization of coal and firing temperature in boiler units. The presence of foreign materials in fly ash also influences its grain size distribution. In ash pond the original particles undergoes flocculation and conglomeration resulting in an increase in particle size.
- 3) **Determination Of UCS:** The Unconfined compressive strength test is one of the common tests used to study the strength characteristics of soil and stabilized soil. To get Immediate UCS strength, UCS tests on fly ash and BFS with lime stabilized fly ash & BFS specimens compacted to their corresponding MDD at OMC with compactive effort varying as 118.6, 355.6, 593, 2483, kJ/m³ were performed according to IS: 2720 (Part X)-1991. For this test cylindrical specimens were prepared corresponding to their MDD at OMC in the metallic split mould with dimension 50mm (dia.) \times 100mm (high). These specimens were tested in a compression testing machine with strain rate of 1.25% per minute till failure of the sample.

To determined the effect of curing period on strength property all samples were coated with wax and cured in a humidity camber at an average temperature of 33° C for a period of 3,7,28 and 90 days before testing.



Fig : Lime stabilized fly ash & BFS coated with Wax



Fig : UCS test on wax coated Lime treated fly ash & BFS

The unconfined compressive strengths of specimens were determined from stress versus strain curves plots and the unconfined strength and corresponding failure strain at different compactive energy after 0,7,28,90 Days of curing is given in Table & graphs:

Table: Unconfined compressive strength of samples of different composition Fly ash, BFS with Lime after 7days

FLYASH %	BFS %	LIME2%	LIME 4%	LIME 6%	LIME 8%
100	0	288.2	302.01	390.25	432.23
75	25	420.23	562.2	642.23	715.2
50	50	455.02	1296.7	1326.42	1381.2
25	75	820.23	2564.2	2621.23	27.26
0	100	1010.23	2956.23	3021.23	3247.23

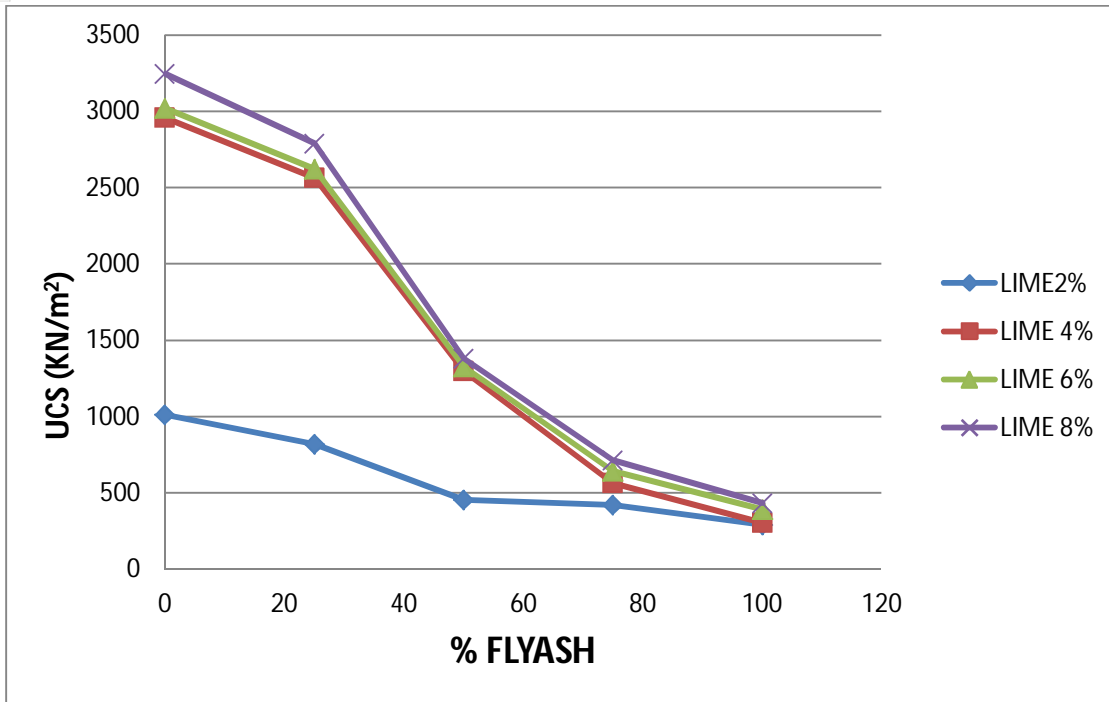


Table :Unconfined compressive strength of samples of different composition Fly ash, BFS with Lime after 14days

FLYASH %	BFS %	LIME2%	LIME 4%	LIME 6%	LIME 8%
100	0	312.2	375.23	519.21	722.54
75	25	430.25	620.13	812.56	1144.23
50	50	498.22	1590.36	1759.23	2275.54
25	75	860.45	3222.21	3546.54	4657.4
0	100	1110.2	3670.2	4110.5	5487.54

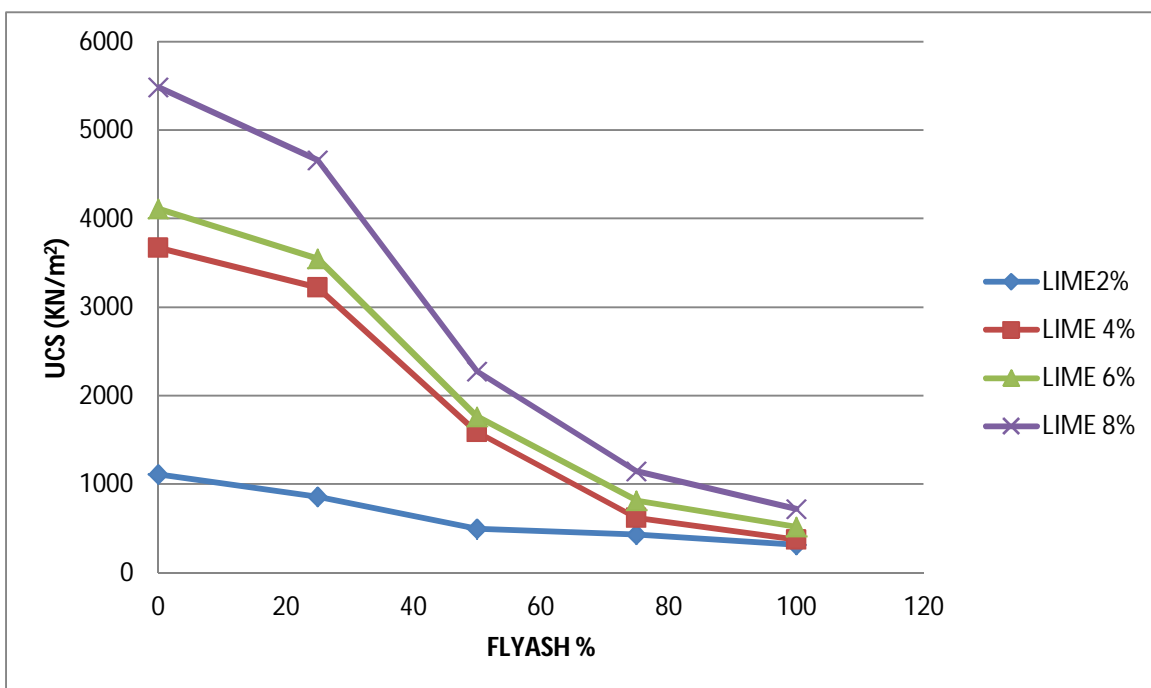
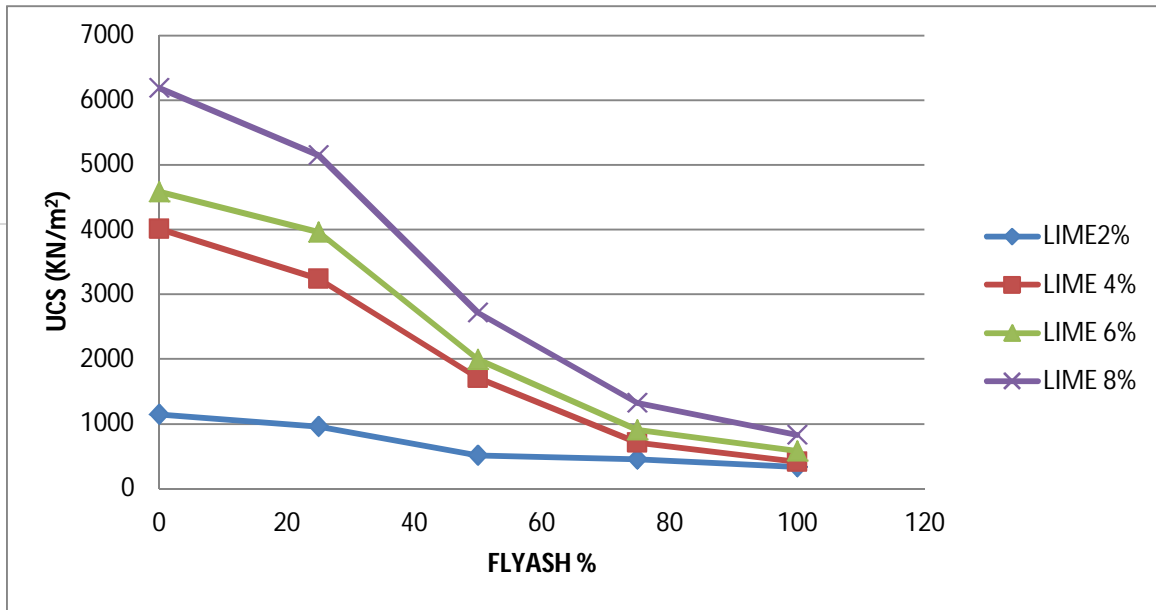


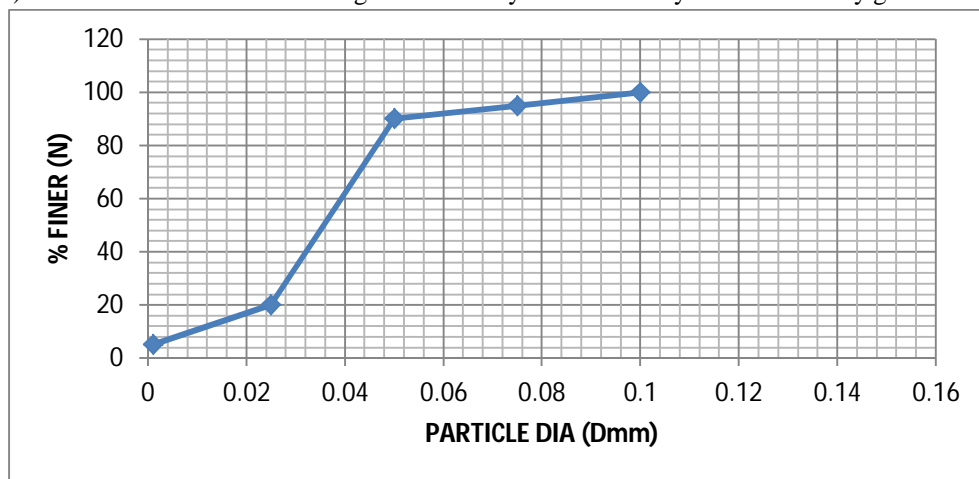
Table :Unconfined compressive strength of samples of different composition Fly ash, BFS with Lime after 28days

FLYASH %	BFS %	LIME2%	LIME 4%	LIME 6%	LIME 8%
100	0	332.2	412.34	582.5	826.54
75	25	455.21	710.54	905.14	1322.24
50	50	507.2	1712.5	1991.8	2718.25
25	75	955.8	3238.6	3962.5	5145.8
0	100	1141.5	4012.5	4590.0	6185.2



IV. ANALYSIS OF RESULT

- 1) *Grain Size Analysis:* A particle size distribution curve gives us an idea about the type and the gradation of the soil. Grain size distribution indicates if a material is well graded, poorly graded, uniformly graded, fine or coarse.
- 2) *Fly Ash:* The grain size analysis shows that it contains particles mostly of silt size with no plasticity. The percentage of clay and silt content is 89% and that of fine sand is 11%. The coefficient of uniformity (Cu) was found out to be 3.16 and the coefficient of curvature (Cc) was found out to be 1.04. The grain size analysis indicates fly ash is uniformly graded.



- 3) *Blast furnace slag (BFS):* The grain size analysis shows the percentage of clay and silt content is 0.023%, that of fine sand is 3.723%, medium sand is 13.013%, coarse sand is 17.96% and fine gravel is 63.45%. The coefficient of uniformity (Cu) was found out to be 5.9 and the coefficient of curvature (Cc) was found out to be 1.66. The grain size analysis indicates BFS is well graded.

V. CONCLUSION

- A. The unconfined compressive strength of stabilized samples increases with increase in percentage of lime and RBI grade 81. The rate of increase is more in case of lime.
- B. The unconfined compressive strength of stabilized samples increases with increase in days of curing.
- C. The unconfined compressive strength of stabilized samples is more for lime than grade after 7, 14, 28 and 60 days of curing.
- D. The unconfined compressive strength of stabilized samples increases with increase in blast furnace slag (BFS) percentage i.e. 90% BFS + 10% fly ash has highest strength and 100% fly ash has lowest strength.

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