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EXPERIMENTAL INVESTIGATION ON THE EFFECT OF PHYSICAL, CHEMICAL AND MECHANICAL PROPERTIES OF FLY ASH AND GROUND GRANULATED BLAST FURNACE SLAG(GGBS) ON CONCRETE

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ABSTRACT
This experiment study aimed to investigate the physical, chemical and mechanical properties of fly ash and blast furnace slag cement concrete. Specific gravity is determined by specific gravity bottle method for cement, fly ash and GGBS. Universal Testing Machine is used for compressive and flexural strength. Characteristics compared to the standard requirements. To determine the compressive strength of fly ash and GGBS, 18 number of cubes for each are tested at the age of 28 days of size (150mm x 150mm x 150mm), grade of concrete is M20, mix proportion is 1:1.5:3 and water-cement ratio is 0.5 and 0.4 for fly ash and GGBS respectively. Different percentages like 0%. 5%, 10%, 15%, 20%, 25% for fly ash and 0%, 10%, 20%, 30%, 40%, 50% for GGBS is tested. Compressive strength of fly ash obtained for 5% replacement of cement has shown significant improvement in various properties at the age of 28 days indicated by 13% increase in compressive strength and In GGBS, 40% replacements has shown significant improvement in various properties at the age of 28 days indicated by 85% increase in compressive strength. To determine the flexural strength a rectangular specimen is considered of size (150mm x 150mm x 500mm), and water-cement ratio is 0.4 and 0.5 for fly ash and GGBS respectively. Percentage replacements of cement by fly ash are 0%, 10%, 20%, 30% and for GGBS is 20%, 30%, 40%, 50%. Highest Flexural strength in fly ash is obtained for 20% replacement and strength is 5.43 N/mm2 and in GGBS 30% replacements have got highest flexural strength and the strength is 3.54 N/mm^2.

KEYWORDS: Fly ash, concrete mixture, construction material, Physical properties, Chemical properties, Mechanical Testing; Blast Furnace Slag(GGBS).

INTRODUCTION
In India, due to its activity creates a significant industrial waste (slag) and fly ash which creates a storage problem and pollution. For (countries with a lot of factories), the availability of this product is abundant raw material at low cost that must be used on a large scale public works. High strength of concrete can be made and including mixture or substitute to improve the properties of concrete.

Coal-ash management causes a serious (related to surrounding conditions or the health of the Earth) problem for India and demands a mission-mode approach. Research and development work have been done and still trying across the country towards confidence building and developing good technologies for disposal and utilization of fly ash in construction industries. This is very much in contrast with 80% or more fly ash used in developed countries for the manufacture of bricks, cellular concrete blocks, road construction, land fill application, ceramics, farming, insulating bricks, recovery of metals and cenospheres and dam constructions. It Consist mostly of silica, alumina and iron, fly ash is a "pozzolan" which is a substance containing aluminous and siliceous material that forms cement in the presence of water. When mixed with lime and water it forms a compound almost the same as Portland cement. The spherical shape of the particles reduces internal friction by that way increasing the concrete's consistency and ability to move around, permitting longer pumping distances. Improved workability means less water is needed, resulting in less segregation of mixture. Although fly ash cement itself is less dense than Portland cement, the produced concrete is denser and results in a smoother surface with sharp details.

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Fly ash has been successfully used as a mineral mixture in PCC for nearly 60 years. This is the largest single use of fly ash. It can also be used as a feed material for producing Portland cement and as a part of a Portland-pozzolan blended cement. It must be in a dry form when used as a mineral mixture. Fly ash quality must be monitored closely when the material is used in PCC. Fineness, loss on ignition, and chemical content are the most important characteristics of fly ash affecting its use in concrete. Fly ash used in concrete must also have well enough pozzolanic reactivity and must be of consistent quality.

Researchers have discovered that fly ash can substitute significant proportions of Portland cement, a key part in manufacturing concrete. Concrete is the world's most commonly used construction material, going past steel, wood and aluminum combined. Now, 5 to 7 percent of the world's GHG emissions have been attributed to cement and concrete production

To preserve the environment, natural resources, en- courage recycling, Construction and maintenance of road require huge amounts of aggregate, rather restrictive specification road that only certain categories of materials are commonly used.

Slag is a by-product collected during manufacturing of iron and steel. It is produced by action of different fluxes upon gangue materials within the iron ore during the process of iron making in blast furnace and steel manufacturing in steel melting shop. Mostly, the slag consists of calcium, magnesium, manganese and aluminum silicates in different combinations. The cooling process of slag is responsible mainly for generating different types of slag required for different end-use people. Although, the chemical composition of slag may remain unchanged, physical properties differ widely with the changing process of cooling.

Depending upon the cooling process, three types of slag are there; namely, air-cooled slag, granulated slag and expanded slag. Air-cooled slag is produced by allowing the (hot) liquid slag to cool under atmospheric conditions in a pit. Under slow cooling conditions, escaping gases leave behind porous and low-density aggregates with special physical properties, making it good for many applications. When formed under controlled cooling, the slag tends to be hard and dense, making it especially good for use in road base and almost the same applications in construction. Granulated slag is produced by quenching the (hot) liquid slag by means of high-pressure water jets. Quenching prevents crystallization, this way resulting in granular, glassy aggregates. This slag is crushed, ground up (into little pieces) and screened for use in different applications, especially in cement production because of its pozzolanic characteristics.

METHODOLOGY

a) Specific gravity of cement, fly ash and GGBS is obtained by specific gravity bottle method, averages of three trials are considered.
b) Compressive strength of fly ash and GGBS for 28 days is obtained by using universal testing machine (UTM). Different percentages like 0%. 5%, 10%, 15%, 20%, 25% for fly ash and 0%, 10%, 20%, 30%, 40%, 50% for GGBS is tested to find out the compressive strength. Size of the cube will be (150 mm x 150mm x 150mm), mix proportion is 1:1.5:3. Compressive strength result will be average of three samples for each percentage. Water cement ratio is 0.5 for fly ash and 0.4 for GGBS First, take samples from the mixture which will be used for the slump test.
c) Flexural strength of Fly ash and GGBS have obtained by making rectangular specimen. Size of the rectangular specimen is (150mm x 150mm x500mm). Percentage replacements of cement by fly ash are 0%, 10%, 20%, 30% and for GGBS is 20%, 30%, 40%, 50%.

EXPERIMENT AND RESULTS

The physical and chemical properties of materials used in this study are listed in Table 1 and 2. The fly ash was characterized as a fine, powdery particle which has a high lime (CaO) content that helps act as a binder to hold the aggregates parts together. Slag is primarily made up of silica, alumina, calcium oxide, and glass (95%). Other elements like manganese, iron, and trace amounts of other elements make up about other 5% of slag. The exact concentrations

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of elements vary slightly depending on where and how the slag is produced. When cement reacts with water, it hydrates and calcium silicate hydrate (CSH) is produced, the main component to the cements strength, and calcium hydroxide Ca(OH)2. When GGBS is used in the mixture, it also reacts with water and produces CSH from its available supply of calcium oxide and silica. A pozzolanic reaction takes place which uses the excess SiO2 from the slag, Ca(OH)2 produced by the hydration of the Portland cement, and water to produces more of desirable CSH making slag a beneficial mineral admixture to the durability of concrete. Fly Ash and GGBS into the concrete increase the workability. The concrete mix was found to become strongly, cohesive compared to that of ordinary plain concrete. Segregation and bleeding was not observed. This may be due to the void filling action of the superfine nature of particles, which gives a high cohesion to the mix. Since industrial wastes are relatively lesser-known materials than cement, it is possible to have questions on their long-term effects on concrete. Doubts about effects of fly ash and GGBS on durability of concrete had initially inhibited their full use in structural concrete. However, experience over the years and continuous researches have actually revealed positive effects on durability. Corrosion of reinforcement, sulphate attack, heat of hydration and alkali aggregate reaction in concrete are the major issues for the durability. These are supported by well-documented case studies and performance records reported from foreign sources. Data and case studies on Indian experiences with indigenous materials have been presented earlier, hence only the salient trends are enumerated.

Table 1 Physical of Materials Used

S no	Material	Physical property
1	GGBS	Granulated blast furnace slag is a glassy granular material that varies, depending on the chemical composition and method of production
2	Fly ash	Whitish grey in colour, Powdery particles-fine particles, spherical in shape, either solid or hollow and mostly glassy in nature
3	Fine aggregate	Porous rock consisting grain of sand whose size is less than 4.75mm
4	Coarse aggregate	Small pebble of rock fragment whose size is greater than 4.75mm
5	Cement	It is a fine powder, Grayish in colour.

Table 2 Chemical Properties of Materials

S no	Constituents	Percentage contents		
		Cement clinker	GGBS	Fly ash
1	Cao	60-66	30-45	1.0-2.0
2	Sio_2	17-24	30-39	35-59
3	Al_2o_3	3-7	15-24	10-29
4	Fe_2o_3	0.5-0.6	0.5-2.1	4-9
5	Mgo	0.1-4.0	4.0-16.0	.2-4.9
6	Mno_2	-	1.0-5.1	-
7	Glass	-	85-97	20-29

MECHANICAL PROPERTIES OF PLAIN CONCRETE, FLY ASH CEMENT CONCRETE AND GGBS

Specific Gravity

The comparative specific gravity of cement, fly ash and GGBS is listed in Table 3, 4 and 5. Figure 1 shows that the specific gravity of fly ash is less than cement and GGBS. Specific gravity of GGBS is a closer to specific gravity of cement.

Table 3 Specific Gravity of Cement

S no	Description	Trial 1	Trial 2	Trial 3
1	Weight of empty bottle, W_1 gm	69.7	69.7	69.7
2	Weight of bottle+ water, W_2 gm	192	190	193
3	Weight of bottle+ kerosene, W_3 gm	171	173	172
4	Weight of bottle+ cement+ kerosene, W_4 gm	215	216.5	217.2
5	Wt of cement, W_5 gm	25	25	25

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6	Sp. gravity of kerosene, $S=(W_3-W_1)/(W_2-W_1)$	0.83	0.83	0.84
7	Sp. Gravity of cement, $S=W_5 (W_3-W_1)/((W_5+W_3-W_4)(W_2-W_1))$	3.14	3.14	3.15
8	Average specific gravity of cement	3.15		

Table 4 Specific Gravity of Fly Ash

S no	Description	Trial 1	Trial 2	Trial 3
1	Weight of bottle (W_1)	106	96.5	116
2	Weight of bottle + fly ash(W_2)	155	145.5	176.5
3	Weight of bottle+water+flyash(W_3)	379	312	389.5
4	Weight of bottle +Water(W_4)	352	293.5	364.2
5	Specific Gravity (G)	2.11	2.09	2.10
6	Average specific gravity of fly ash	2.1		

Table 5 Specific Gravity of GGBS

S no	Description	Trial 1	Trial 2	Trial 3
1	Weight of empty bottle, W_1 gm	69.8	69.8	69.8
2	Weight of bottle+ water, W_2 gm	191	190.5	192
3	Weight of bottle+ kerosene, W_3 gm	168	167.5	172
4	Weight of bottle+GGBS + kerosene, W_4 gm	208	209.5	209
5	Weight of GGBS, W_5 gm	55.3	56.2	57
6	Sp. gravity of kerosene, $S=(W_3-W_1)/(W_2-W_1)$	0.8	0.82	0.825
7	Sp.Gravity of GGBS, $S=W_5 (W_3-W_1)/((W_5+W_3-W_4)(W_2-W_1))$	2.95	2.7	2.8
8	Average specific gravity of GGBS	2.92		

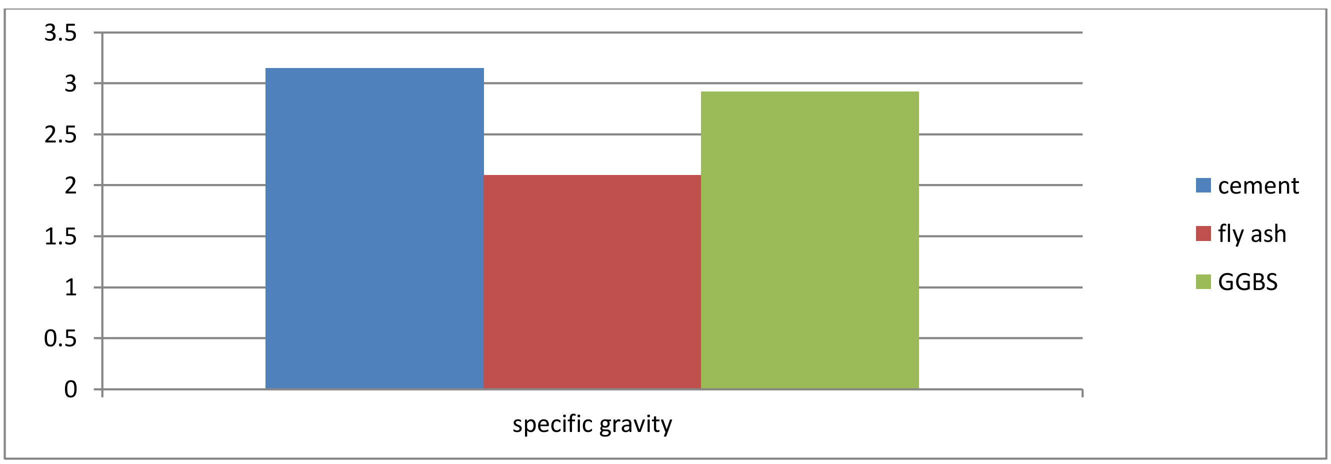

Figure 1 Comparative Specific Gravity Test Results of Plain Cement and Fly Ash Cement Concrete and GGBS

COMPRESSIVE STRENGTH

Compressive strength diagram is shown in figure 2 . Fly ash continues to combine with the lime in cement, increasing compressive strength. It helps the concrete mixture to achieve its maximum strength faster, where as in GGBS, 40% replacement shows high compressive strength.

Table 6 Compressive strength of fly ash concrete (three sample average)

Size of cube= 150 mm x150 mm x150 mm
Number of days= 28 days, Grade of concrete= M20, Mix proportion= 1:1.5:3, water cement ratio=0.5

% fly ash	Trial 1	Trial 2	Trial 3	Average compressive strength(N/mm^2)

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0	22.2	21.36	20.96	21.5
5	23.33	24.65	24.86	24.28
10	18.92	20.01	18.94	19.29
15	20.96	19.85	19.82	20.21
20	18.56	20.23	18.9	19.23
25	17.56	19.27	20.02	18.95

Table 7 Compressive Strength of GGBS concrete (four sample average)

Size of cube= 150 mm x150 mm x150 mm
Number of days= 28 days, Grade of concrete= M20, Mix proportion= 1:1.5:3, water cement ratio=0.4

% GGBS	Trial 1	Trial 2	Trial 3	Average Compressive strength(N/mm2)
0	22.2	21.36	20.96	21.5
10	27.22	28.36	29.38	28.32
20	33.26	32.12	30.95	32.11
30	34.2	35.95	34.85	35.0
40	39.77	38.21	39.26	39.08
50	37.25	36.23	37.89	37.1

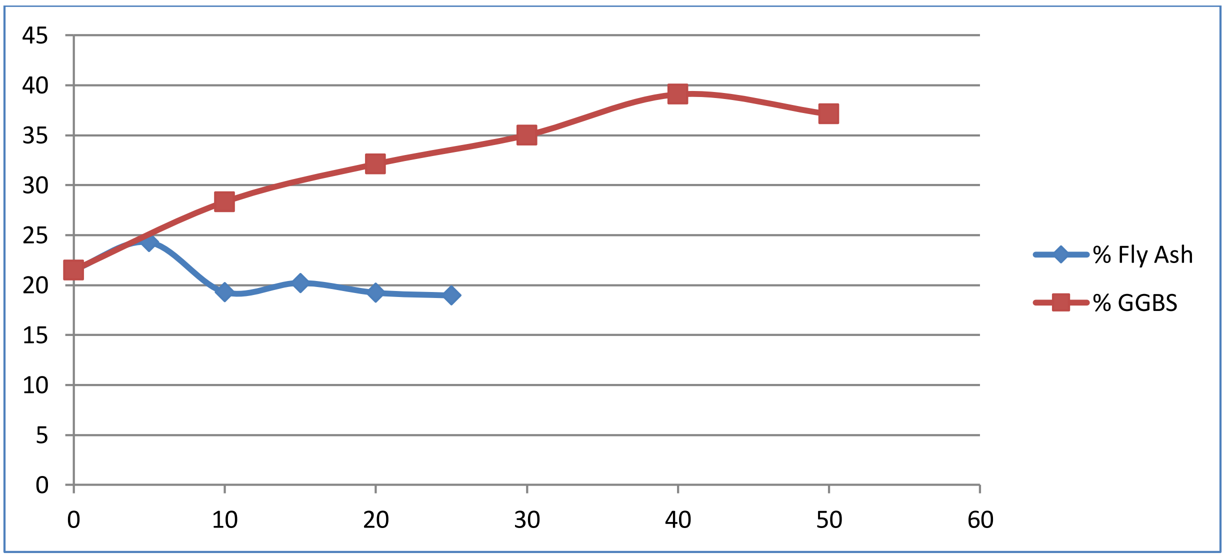

Figure 2. Compressive strength test result of Fly Ash Concrete and GGBS concrete

FLEXURAL STRENGTH

Flexural strength diagram is shown in figure 4 and figure 5. Concrete with 0% replacement of cement i.e, plain concrete shows flexural strength of 4.98 N/mm2.With the 20% replacement of fly ash , it show maximum flexural strength where as in GGBS 30% replacement shows maximum strength compare to others.

Table 8 Flexural Strength of fly ash concrete

Size of cube= 150 mm x150 mm x500 mm
Number of days= 28 days, Grade of concrete= M20, Mix proportion= 1:1.5:3, water cement ratio=0.4

% fly ash	Trial 1	Trial 2	Trial 3	Average flexural strength of beam(N/mm^2)
0	4.56	4.75	5.63	4.98

10	4.93	4.65	5.15	4.91
20	5.36	5.26	5.67	5.43
30	4.85	4.95	4.96	4.92

Table 9 Flexural Strength of GGBS concrete

Size of cube= 150 mm x150 mm x500 mm

Number of days= 28 days, Grade of concrete= M20, Mix proportion= 1:1.5:3, water cement ratio=0.5

% GGBS	Trial 1	Trial 2	Trial 3	Average flexural strength of beam(N/mm2)
20	3.36	3.12	3.51	3.33
30	3.65	3.45	3.52	3.54
40	3.29	3.39	3.34	3.34
50	3.27	3.31	3.32	3.3

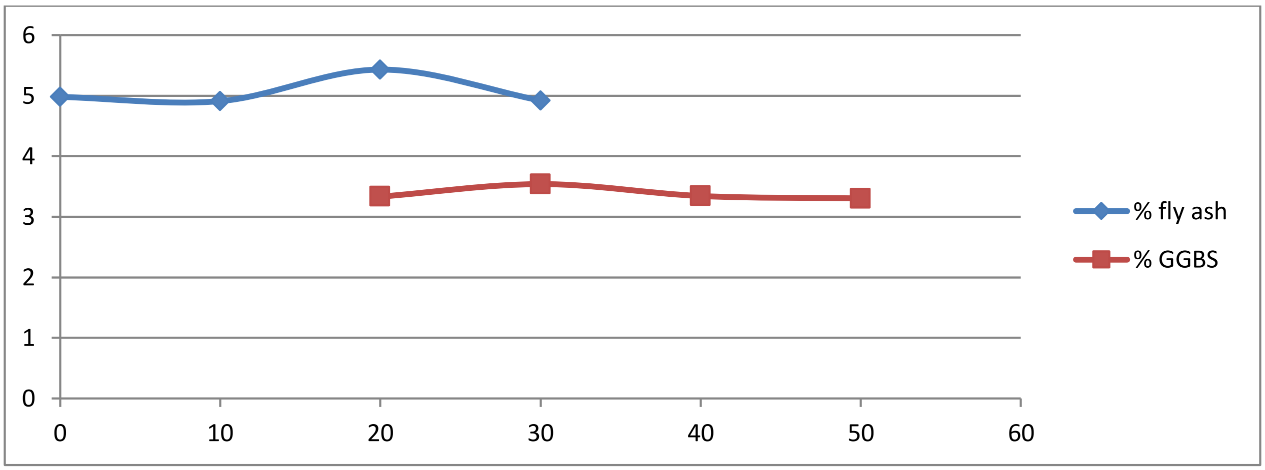

Figure 3 flexural strength test result of Fly Ash Concrete and GGBS Concrete

CONCLUSION

Based on the set of materials in a concrete mixture, there may be a Portland cement content that produces a moderate concrete strength. To obtain higher strengths one of the most practical methods is the use of fly ash and GGBS in the mixture. Fly ash and GGBS proportioned using the concepts suggested by this paper has been shown to give strengths significantly above those obtainable by a Portland cement concrete. This method of proportioning proposed in this paper allow us for the use of a wide range of fly ashes and GGBS, it has been found that it is not the quality of fly ash that is important but the variation of that quality about a mean. The advantage of the use of fly ash and GGBS in concrete is the flexibility that it allows with the selection of the mixture proportions. With the use fly ash, a wide range of possible mixtures can be investigated for any specification. For the required situation it is possible to choose either the lowest cost mixture, or the more durable. Fly ash have less unit weight which means the greater the percentage of fly ash in the paste the better lubricated the aggregates are and the better the concrete flow and it continues to combine with the lime in cement which increases compressive strength over time. It helps the concrete mixture achieve its maximum strength faster. It shows that the fly ash can be used effectively as material in concrete road pavement. The sub grade of the road infrastructures can consume the slag produced or stored with significant quantities. Slag is an insensitive material with water, quality which is suitable for the use of sub-grade. The insensitivity is due primarily to its cleanliness and its small percentage of tamis at lower than 80 µm. This slag has a very tight grain-size distribution, which decreases the aptitude for the compaction, and this will be necessary thus to carry out a correction with other material.

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