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Effective Utilization of Fly Ash and Supplementary Cementitious Materials in Construction Industry

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ABSTRACT: The best way to dispose any waste material (fly ash) is to use it as one or the other forms like construction material. In developed countries electrostatic precipitators collects fly ash, which leads to greater fineness. Hence it shows good pozzolonic activity. So it can be used as part replacement of cement. The effective utilization of fly ash in any field is possible only when a study of physical, chemical and mineralogical properties of the particular fly ash available is done. The properties will vary from plant to plant and with in a plant the source of collection. It was decided to use the fly ash of Raichur thermal power station in Karnataka in the present work.

The concrete mix was prepared using IS 10262:2009. Compressive strength studies were planned to correlate the effect of the different characteristics of supplementary cementitious materials for various mix proportion for different replacement levels. Raichur fly ash (Class F) and Ground granulated blast furnace slag (GGBS) are used as part replacement of cement at various levels. Supplementary cementitious materials are replaced for various levels from 10 to 70 % for constant workability of 100 mm slump and by varying superplasticiser dosage. Drability of concrete is monitored against resistance to acid attack for various concentrations.

KEYWORDS: Supplementary Cementitious Materials, Ternary binders, Fly ash, GGBS, Compressive strength, slump, Durability.

INTRODUCTION

Long-term performance of structures has become vital to the economies of all nations. Concrete has been the major instrument for providing stable and reliable infrastructure since the days of the Greek and roman civilization. At the turn of the 20th century, concrete compressive strength was in the range of 13.8 Mpa, by the 1960s it was in the range of 27.6-41.4 MPa. Deterioration, long term poor performance, and inadequate resistance to hostile environment ,coupled with greater demands for more sophisticated architectural form, led to the accelerated research into the microstructure of cements and concretes and more elaborate codes and standards. As a result, new materials and composites have been developed and improved cements evolved. Today concrete structures with a compressive strength exceeding 138 Mpa are being built world over. In research laboratories, concrete strengths of even as high as 800 Mpa are being produced.

CHARACTARIZATION OF MATERIALS

Characterization is the art of determining the distinctive characteristics of the materials used. It is a salient activity undertaken to completely understand the related properties the materials with reference to particular application. The basic properties of the base materials directly influence the properties of the final product. Studies have been carried out to investigate the basic properties of different materials used in this investigation. This comprised of study of physical, chemical, mineralogical and morphological characteristics.

FINE AGGREGATE

Natural locally available river sand having fineness modulus (FM) of 3.40 was used as fine aggregate which was washed and made silt free. Then it was graded through different sieves according to IS: 383-1970 as shown in the **Table 1** and **Fig 1** shows the sieve analysis of fine aggregate sand. The standard sand (100 percent) passed through 2-mm IS sieve and (100 percent) retained on 90 micron IS sieve was mixed in the following proportion. Particle size greater than 1mm-33.33%, Particle size smaller than 1mm and greater than 500µ -33.33%, Particle size below 500µ-33.33%.

Sieve No	Mass retained (W) grams	% Retained "p"	% Passing (100-p)	Cumulative (%) retained
4.75	29.0	2.9	97	2.90
2.36	48.5	4.85	95.15	7.75
1.00	205.0	20.50	79.50	28.25
600 µ	171.0	17.10	82.90	45.35
300 µ	215.0	21.50	78.50	66.85
150 µ	223.0	22.30	77.70	89.15
pan	111.0	11.10	88.90	100.25
				∑F=340.25

Table 1 Sieve analysis Results of Fine Aggregates

Fineness Modulus of sand= ∑ F⁄100=340.25⁄100=3.4

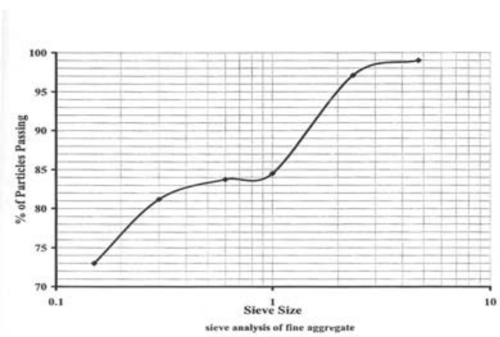

Figure 1: Sieve analysis of fine aggregate

COARSE AGGREGATE

Crushed stone derived from granite with a maximum nominal size of 10 mm was used as the coarse aggregate. The coarse aggregates had a specific gravity of 2.70 and dry rodded density of 1900 Kg/m^3.

FLY ASH

The fly ash used in this investigation was procured from RTPS, Raichur , Karnataka. The ash is characterized to assess the physical and chemical characteristics. The specific gravity of the fly ash was found to be 2.4. The reactivity of ashes was obtained from Lime reactivity test as per IS1727-1967. The lime reactivity of the ash was 7.47 MPa. It can be seen that the fly ash confirms to requirement of grade –F fly ash as per 3812-1981 IS code.

GROUND GRANULATED BLASTFURNACE SLAG (GGBS)

The physical and chemical properties of GGBS are verified . It contains more calcium oxide (CaO) compared to fly ash. Since it contains aluminum oxide and silica oxide, it is suitable for making high strength concrete with part replacement of fly ash and cement. Also it can be effectively utilized in making of the geopolymers.

CEMENT

The cement used in this investigation is 53 grade as per **IS:8112[170]**. The properties of cement are checked . The initial and final setting time of OPC was 120 minutes and 250 minutes respectively. The particle size of the cement was analysed using laser beam particle size analyses. It is noticed that more than 80% of the particles are less than 80 micron size.

EXPERIMENTAL PROGRAMME

Laboratory investigations is planned to achieve a high strength concrete of 45 MPa by part replacement of supplementary cementitious materials like Fly ash (Class F)and GGBS by varying percentage with cement. And to estimate the optimum percentage of ternary combination of supplementary cementitious materials. Investigations are carried out to achieve high strength and durable concrete by minimizing the quantity of cement.

MIX PROPORTION OF CONCRETE

To begin with, **IS method 10262:2009** was used to proportion the concrete mix. Control concrete was proportioned using OPC alone as binder for the target strength of 45 MPa at the age of 28 days and a minimum slump of 100 mm. Superplasticiser (GLENIUM B233 & SKX 715) was used to get the required slump. Final mix proportions were arrived based on trial castings. **Table 2** below shows mix proportion of control concrete and **Table 3,4** shows the various trial mix proportions. Concrete cubes of size 100 mm side were cast using both the concrete mixes. The step by step procedure of the method used in shown below. The cubes were cured in water till the age of 28 days or till the date of testing for compression whichever was earlier. They were tested for compression at 3,7,14,28,56 and 90 days to Compare the compressive strength of both at different ages.

Table 2 Mix proportion arrived from design mix.

Cement in kg/m^3	Fine aggregate in kg/m^3	Coarse aggregate in kg/m^3	Water in kg/m^3
534	889	889	160

RESULTS AND DISCUSSION

As discussed in the previous paragraph , the minimum binder used in concrete is 50 % in all concrete mixes. The actual mix proportions used for various series of concrete are indicated in the **Tables 3,** and **Table 4.**

Table-3 Mix proportion with combination of GGBS and Fly ash.

Mix ID	Cement kg/m^3	Fly ash kg/m^3	GGBS kg/m^3	SP dosage in %
NR	534	--	--	0.90
GA	240	267	26.7	1.70
GB	213	267	53.4	1.70
GC	160	267	106.8	1.60
GD	106.8	267	160.2	1.65
GE	160.2	320.4	53.4	1.65

Table-4 Mix proportion with combination of GGBS and Fly ash.

Mix ID	Cement kg/m^3	Fly ash kg/m^3	GGBS kg/m^3	SP dosage in %
GF	106.8	320.4	106.8	1.65
GH	53.4	320.4	160.2	1.90
GI	106.8	373.8	53.4	2.0
GJ	53.4	373.8	106.8	2.0

WORKABILITY OF GGBS CONCRETE (G SERIES)

In this investigation , concrete cubes was prepared using fly content of 50, 60 and 70 % at w/c ratio of 0.4. The balance of the binder was adjusted using OPC and GGBS, super plasticizer is varied to maintain a constant slump of 100mm . The water content and slump were maintained at 160 kg/m^3 and 100 mm respectively. It is observed that the variation of dosage of SP is marginal for different percentages of fly ash.

Table 5 Super plasticizer dosage GGBS (G series)

Mix ID	Cement %	Fly ash %	GGBS %	SP dosage
GA	45	50	5	1.7
GB	40	50	10	1.7
GC	30	50	20	1.6
GD	20	50	30	1.65
GE	30	60	10	1.65
GF	30	60	20	1.65
GG	10	60	30	1.9
GH	20	70	10	2
GI	10	70	20	2
GJ	Nil	70	30	2

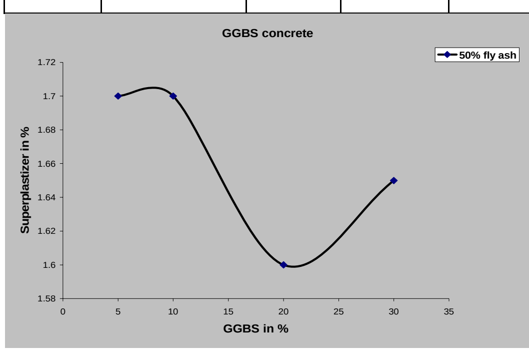

Figure 2 Super plasticizer dosage GGBS concrete at 50 % fly ash.

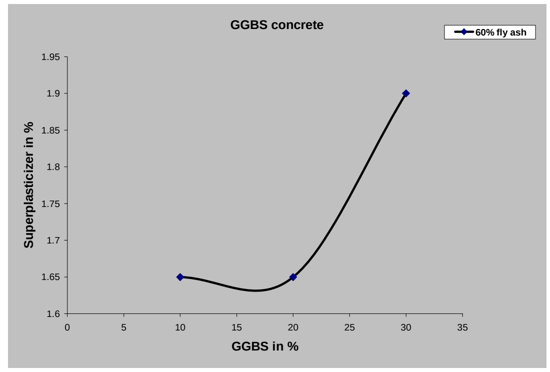

Figure 3 Super plasticizer dosage for GGBS concrete at by 60 % fly ash.

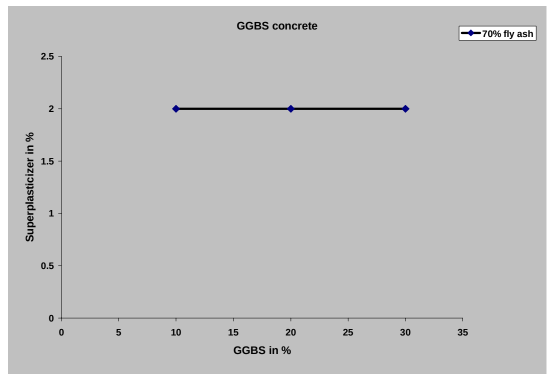

Figure 4 Super plasticizer dosage for GGBS concrete at 70 % fly ash

Similarly in case of GGBS concrete **(G series)** the dosage of super plasticizer is monitored, here the replacement level of fly ash was 50% and GGBS was replaced from 10 to 30%. The super plasticizer dosage is decreased as the percentage of GGBS increases and @ 30% replacement of GGBS the dosage of super plasticizer is marginally increased **(Figure 2)**. In the next trial the replacement level of fly ash was 60% and the GGBS is replaced from 10 to 30%, here the super plasticizer dosage increases as the percentage of GGBS increases **(Figure 3).** At 70% replacement level of fly ash and 10 to 30% replacement level of GGBS the superplasticiser dosage was constant **(Figure 4).**

COMPRESSION STRENGTH CHARECTERISTICS OF GGBS CONCRETE

Compression testing is carried out on the cube for the different age as given in the **Table 6** and **Table 7**

Table 6 Compressive strength of various mix

Compressive strength in MPa				
Mix ID / Age in Days	**NR**	**GA**	**GB**	**GC**
3	18.7	6.67	3.33	2.67
7	53.5	13.83	15.33	13.5
14	62	16.67	20	22
28	63.3	28	27	23.83
56	70.7	31.17	34.67	31
90	72.7	--	--	--

Table 7 Compressive strength of various mix

Compressive strength in MPa				
Mix ID / Age in Days	**GD**	**GE**	**GF**	**GG**
3	2.33	1.167	0	0
7	11.83	12	8.33	5.67
14	13.5	13.33	11.83	8.5
28	13.83	17.17	17.83	10.5
56	19.17	24.67	22.67	13.5
90	--	--	--	--

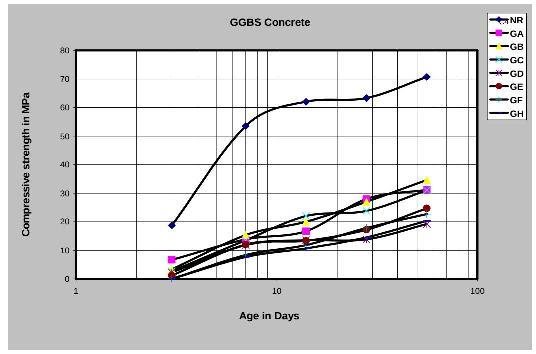

Figure 5 compressive strength of GGBS concrete

Figure 5 indicates the strength development with age for control concrete and GGBS concrete, there is increase in strength with age in all the cases, the strength of GGBS concrete (G series) is less when Compared with the control concrete even at the age of 90 days. Thus the difference in strength of GGBS concrete and control concrete is high Compared with control concrete.

Table 8 Compressive strength of GGBS concrete for 50% fly ash as constant.

Mix ID	Cement %	Fly ash %	GGBS %
GA	45	50	5
GB	40	50	10
GC	30	50	20
GD	20	50	30

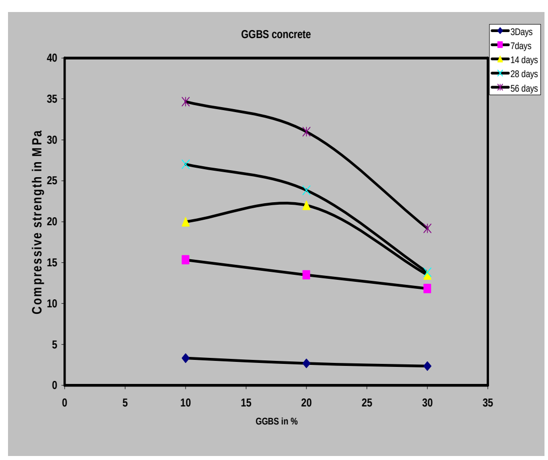

Figure 6 compressive strength of GGBS concrete by keeping 50% fly ash as constant

Table 9 Compressive strength of GGBS concrete for 60% fly ash as constant

Mix ID	Cement %	Fly ash %	GGBS %
GE	30	60	10
GF	30	60	20
GG	10	60	30

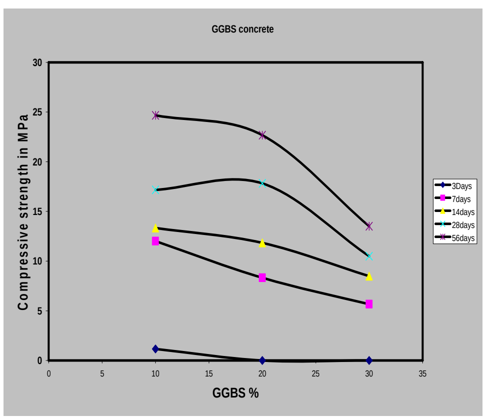

Figure 7 compressive strength of GGBS concrete by keeping 60% fly ash as constant

Table 10 Compressive strength of GGBS concrete for 70% fly ash as constant

Mix ID	Cement %	Fly ash %	GGBS %
GH	20	70	10
GI	10	70	20
GJ	00	70	30

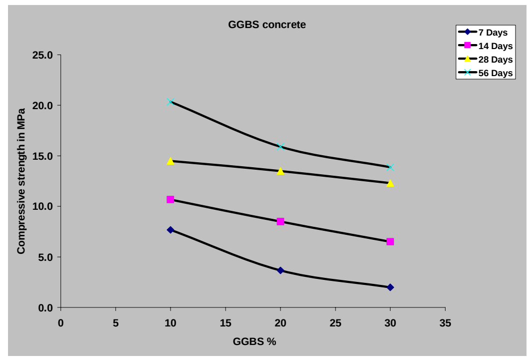

Figure 8 compressive strength of GGBS concrete by keeping 70% fly ash as constant

Figure 7-8 indicates the strength development of GGBS concrete for 50, 60,70% of fly ash, and the GGBS is replaced from 10-30%. It is noted that strength remain almost same at early age then at later age i.e. 28,56,90 days there is decrease in strength with the increase of GGBS content, the optimum quantity being 10%.

DURABILITY

WEIGHT LOSS IN CHLORIDE AND SULPHATE SOLUTION

Here samples are casted from SF series , G series and M series for durability test. Solution is prepared for 5% concentration of HCl and 5% concentration of $NaSo_4$. The test samples are immersed in the solution for age 7, 14, 21, 28, 45 days. Then the sample is verified for its loss of weight and loss strength at different age by comparing with the samples preserved out side the solution of same age. Strength loss and weight loss are given in the **Table11-12**

Table 11 Weight loss in HCl and $NaSo_4$ solution

Mix ID : G / Age in Days	HCl Solution	$NaSo_4$ solution
7 Days	**0.63**	0.23
14Days	**0.92**	0.42
21 Days	**1.21**	**0.61**
28 Days	**1.3**	**0.89**
45 Days	**1.76**	**1.21**

Table 12 Strength loss in HCl solution and $NaSo_4$ solution

Mix ID : G / Age in Days	HCl Solution	$NaSo_4$ solution
7 Days	**2.21**	**3.96**
14Days	**3.89**	**6.73**
21 Days	**6.52**	**8.71**

CONCLUSIONS

With the study on the strength development on various high volume fly ash concrete (with at least 50 % fly ash as binder) mixes, the following conclusions can be drawn.

1. High volume fly ash concrete can be developed using GGBS upto 70% of fly ash as binder.
2. It is possible to maintain a workability of minimum slump 100 mm using the available super plasticizer.
3. The decrease in strength compared to control concrete with OPC as sole binder is around 20%.
4. As the GGBS content increases the workability reduces at the same water containing and w/c.
5. With a combination of 70% fly ash 10 % of GGBS and remaining quantity of binder compressive strength of 15MPa can be achieved.
6. The cost of concrete may reduced upto 20% for high strength concrete, and about 45 % for lower strength concrete.

SCOPE FOR FURTHER STUDY

After the study on high volume fly ash concrete with other binders like GGBS and, it is felt that there is scope for future study.

1.All the combinations of binders and aggregates can be used to optimize the materials used.

2.Durability studies like permeability, sulfate resistance, acid resistance, impact etc can be made on high volume fly ash concrete to ascertain its use under different extreme conditions.

3.Bond strength of concrete with steel can be studied.

The strength of concrete can be studied at later age like 2-5 years.

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