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Experimental Study of Partial Replacement of Cement by Pozzolanic Materials

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Abstract: Pozzolanic materials such as ground granulated blast furnace slag i.e. GGBS, Solid waste ash, iron husk, silica fumes, iron slag etc are the most common industrial by-products generated. Some of these waste material shows similar properties/elements as that of cement. So these waste materials can be used in concrete as a partial replacement of cement. So, in this study, the attempt to partially replace the cement by GGBS and solid waste ash is carried out. Here, the cement is partially replaced by different percentage of GGBS (10%, 15%, 20% and 25%) and same for solid waste ash (4%, 6%, 8% and 10%) and the concrete mixes were made along with the control mix concrete. Workability test, compressive strength test etc. are performed on the specimen. From the results, it is observed that the workability of the concrete gets affected due to replacement by GGBS and solid waste ash. The compressive strength of GGBS concrete increases till 20% replacement whereas the compressive strength of solid waste ash concrete increase till 4% replacement. Further that it shows decrease in value. It is concluded that the optimum percentage for partial replacement of cement for GGBS is 20% and for solid waste ash is 4%.

Keywords: Cement, ground granulated blast furnace slag (GGBS), solid waste ash, partial replacement.

I. INTRODUCTION

Concrete is a composite material which consists of sand, aggregate, cement and water. It is used as a binding material. In India, the annual production of cement is about 380 million tones. India has the 2nd highest production all over the world. Cement manufacturing causes reduction in quantity of the non-renewable resources such as limestone. Also the Production Factory releases dust, noises, greenhouse gases especially carbon dioxide that contaminates the environment and responsible for climate change. So utilizing other alternative material whose production consumes lesser natural resources, economic and has lesser harm to the nature. Medical and industrial waste produced from different source is also causing great threat to the environment. Waste materials such as GGBS, Iron husk ash, Silica fumes, Iron slag, biomedical waste ash etc. Some of this waste material shows similar properties/elements as that of cement. So these waste materials can be used in concrete as a partial replacement of cement. It is the easy way to reduce the waste and also to protect environment

The cement sector is one of the largest source that causes the pollution and harms the environment. The cement industries emits various gases such as sulphur dioxide, nitrogen oxide and carbon monoxide in excess amount. These gases are hazardous in nature, they have harmful impact on environment as well as on human health. Nitrogen oxide (NO_x) causes ground level ozone, acid rain, global warming, and lung diseases. Sulphur dioxide (SO_2) also causes acid deposition, asthmatics, cardiovascular disease etc. Carbon monoxide (CO) is responsible for global warming, formation of smog etc. That is the reason why it is necessary to find a replacement for the cement.

GGBS (Ground Granulated Blast-furnace Slag) is a cementitious material which is a by-product from the blast-furnaces used to make iron. Blast-furnaces operate at temperatures of about 1,500°C and are fed with a carefully controlled mixture of iron ore, coke and limestone. GGBS does not emits environmental hazards. The use of GGBS as replacement of cement may reduce its demand, which will reduce the emission of carbon dioxide into the atmosphere. Solid waste ash is formed due to incineration of municipal solid waste and biomedical waste. Now a days Incineration is one of the most commonly used method for decomposition of waste. In this process the waste is burnt in a large container and the ash is deposited at the bottom. From different studies, it is seen that this solid waste ash contains similar elements and properties like cement. So it is also used as the partial replacement of the cement in concrete. Utilizing these waste products in construction work can minimize the environmental contamination. In this study we have worked on finding optimum percentage of replacement of cement by solid waste ash and GGBS.

II. MATERIALS AND ITS PROPERTIES

The primary raw materials used in this study were ordinary Portland cement, ground granulated blast furnace slag (GGBS), and incinerated solid waste ash, sand, and coarse aggregate in order to know the mechanical properties and the most effective result of various tests on concrete.

A. Cement

Cement is a binding material which is used to bind sand and aggregates to make concrete and allowed to dry, it is the most adaptable construction material. In this study the OPC 53 grade cement is used.
This is the chemical composition of cement

CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	Alkalies	SO_3
60.67	18.91	4.51	4.94	0.87	0.12	2.5

B. Ground Granulated Blast furnace Slag (GGBS)

Ground Granulated Blast furnace Slag (GGBS) is a cementitious substance specifically used in the production of concrete. It is a by-product of iron & steel making blast furnaces. Chemical and physical test results are given in Table 1

C. Fine Aggregate

According to IS: 2386-1(1963), high-quality river sand were used. Here zone II sand is used i.e. it passes 4.75mm IS Sieve and retained on 75microns IS Sieve.

D. Course Aggregate

Crushed granite obtained from machine crusher is used as aggregate. The aggregate which passes 20mm IS Sieve and retained on 4.75 IS Sieve is used. The details of physical properties of aggregate are shown in Table 2.

E. Solid Waste Incinerated ash (SWIA)

Solid waste incinerated ash is the by-product that is produced during the disposal process of the municipal Solid waste by Incineration. In this study the ash used is obtain from municipal solid waste disposal plant, bhandewadi.
Chemical composition of this ash is shown below,

OXIDES	COMPOSITION
Calcium oxide	10.98
Magnesium oxide	2.28
Sodium oxide	0.25
Potassium oxide	0.38
Silica	56.66
Alumina	17.43
Iron oxide	1.22

Table 1 GGBS test results

Test	Results obtained	Standard
Chemical test	% by mass	
Insoluble Residue	0.39	3.0 Max
Magnesia (MgO)	9.80	17.0 Max
Sulphur trioxide (SO_2)	0.47	3.0 Max
Total Loss on Ignition	0.98	1.0 Max
Ferric Oxide	0.48	
Silicon Oxide ($Si0_2$)	35.66	
Alumina Oxide (Al_2O_3)	16.3	
Calcium Oxide (CaO)	34.32	
Sulphide Sulphur (S)	0.55	2.0 Max
Physical test		
Fineness (M^2/Kg)	380	Min 320
Residue		
90 micron	1.20	
45 micron	12.60	
Specific gravity	2.91	

Table 2
Physical properties of coarse and fine aggregates:

Physical properties	Fine aggregate	Course aggregate
Specific gravity	2.6	3.13
Bulk density	1.61	1.5
Fineness modulus	2.76	3.48
Water adsorption	1.0%	0.6%

III. TEST RESULTS AND DISCUSSIONS

The following section discuss the results of the test like workability i.e. slump, density and compressive strength of concrete. The tests are performed on different proportion i.e.100% cement concrete and 10%, 15%, 20% and 25% cement replaced with GGBS concrete, as well as 4%, 6%, 8%, and 10% cement replaced with solid waste incinerated ash.

A. *Workability Test*

Fresh concrete has a characteristic known as workability, which is measured by the amount of practical internal work needed to completely compact the concrete without getting segregate in the final product. Here, slump values with different proportions of GGBS and Ash replacing cement in M25 grade concrete are shown in the table 3 and 4 respectively.

Table 3: slump value with various proportion of GGBS

TYPE OF CONCRETE	SLUMP VALUE
Control mix	72 mm
10%	77 mm
15%	79 mm
20%	84 mm
25%	85 mm

Table 4: slump value of various proportion of Ash

TYPE OF CONCRETE	SLUMP VALUE
Control mix	72 mm
4%	69 mm
6%	65 mm
8%	57 mm
10%	50 mm

From the above results, it is noted that the slump values for concrete with GGBS are more than that of the control mix concrete. The workability of concrete shows the increment in the value as the percentage of GGBS is increased (Table 3). The curve plotted indicates linier gain in the workability. The workability is keep on increasing till the 25% GGBS replacement.
Whereas, from the table 4, it is noted that workability of concrete decreased with the increase in the replacement level of the solid waste ash. The reason could be the light weight of ash than cement. It occupies more volume than the cement on the basis of equal weight which results in more requirement of water for lubrication due to which workability decreases.

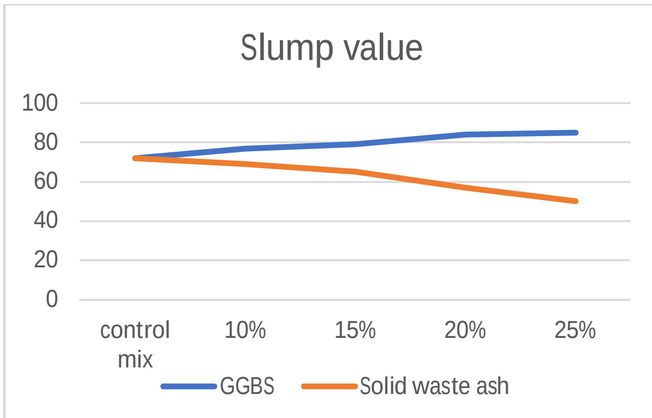

Fig:1 Workability of concrete with GGBS and ASH

The Fig.1 is the graphical representation of the workability of the concrete containing GGBS as well as concrete containing solid waste ash. It clearly shows the increase in the workability on addition of the GGBS whereas on addition of the solid waste ash in concrete reduces the workability of the concrete.

B. Compression Test

The maximum amount of compressive stress that a given solid material can sustain under a slow-moving load before failing is known as its compressive strength. In this study the compression test was performed on the 7, 14 and 28 days of curing. The results were taken as the average of the 3 specimen reading at each of the 3 days. Table.5 represents the test results of concrete with different replacements of GGBS. It shows that the 7 day aged concrete cube gives strength approximately 65% of target strength whereas on 28 day aging, the 99% target strength is achieved. The control mix concrete has the target strength of 31.6N/mm2. By comparing with this, it is seen that the compressive strength is increasing as we increase the percentage of GGBS replacement with cement in concrete. The strength increases up to 35.4 N/mm2 on 20% replacement after that it shows decrease in the strength on 25% replacement of GGBS. From this it is conclude that up to 20% of cement can be replaced by GGBS without any compromise in the strength.
Whereas the test results of concrete with different replacements of solid waste ash with cement is recorded in table.6. It shows that the control mix concrete has strength of 29.31 N/mm2 at 28 days age i.e. target strength. On replacement of 4% of Ash, there is increase in the strength. It increased to 32.19 N/mm2. Further on increasing the percentage of ash, it shows decrease in the strength constantly. On 6%, 8% and 10% replacement, the recorded strength are 29.82, 29.65 and 28.77 N/mm2 respectively. From this test results it is clear that increasing the amount of solid waste reduces the strength of the concrete.
In this study, it is found that the reason behind the increase in strength of GGBS and ash concrete is due to the micro filler effect of both pozzolanic materials which is also conclude through SEM image. It is also possible that the increase in the strength is due to

presence of calcium and silica. Both calcium and silica from GGBS and ash caused the pozzolanic activity with water and hence the strength is increased.

Table.5: Compressive strength of GGBS concrete.

% replacement	7 Days		14 Days		28 Days	
	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2
CONTROL MIX	20.58	20.54	26.35	28.58	32.8	31.76
	20.47		28.11		31.5	
	20.13		28.93		30.98	
10% GGBS	21.51	20.34	23.63	28.17	28.48	31.3
	19.95		26.08		31.2	
	21.73		29.62		34.97	
15% GGBS	22.61	21.46	25.15	29.71	30.17	33.02
	20.01		31.27		36.93	
	21.98		29.01		31.86	
20% GGBS	21.29	23.03	33.07	31.91	36.97	35.46
	23.5		28.34		31.55	
	25.33		34.83		37.42	
25% GGBS	19.24	20.18	31.75	27.95	35.73	31.9
	20.96		27.39		21.55	
	21.59		26.05		34.5	

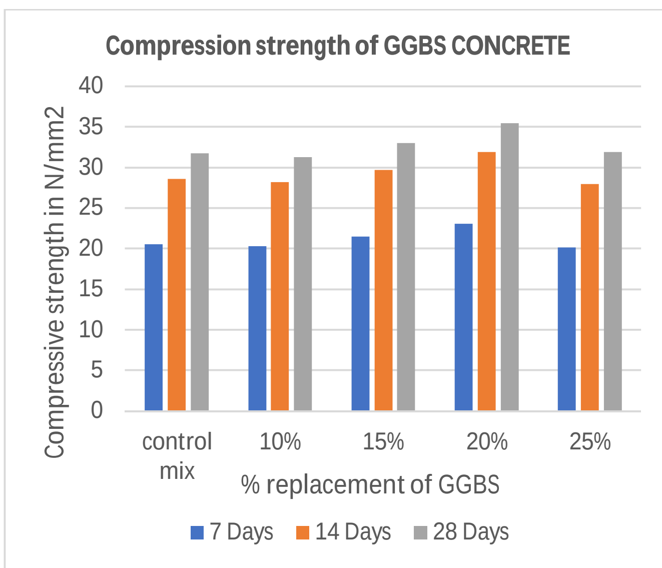

Fig.2 Compressive strength of GGBS concrete after 7, 14 and 28 days curing

IV. CONCLUSION

From this study, it is conclude that,

1) The workability of concrete gets affected when the cement in concrete is partially replaced by the GGBS and solid waste ash.
2) Workability decreases when solid waste ash is used in concrete while workability of GGBS concrete increases on increasing the percentage of GGBS. Thus the super plasticizer is used to increase the workability.
3) The cement can be partially replaced by GGBS in concrete up to 20% of it quantity without compromising with the compressive strength.

The compressive strength of GGBS concrete is Increased by 11.67% as compared to the control mix concrete.

Table.6: Compressive strength of solid waste

% replacement	7 days		14 days		28 days	
	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2
CONTROL MIX	19.25	19.00	26.65	26.44	29.62	29.31
	17.93		25.62		28.47	
	19.83		27.05		30.06	
4 %	21.35	20.91	29.57	28.96	32.86	32.19
	20.46		28.34		31.49	
	20.94		28.99		32.22	
6 %	19.54	19.38	27.06	26.83	30.07	29.82
	19.2		26.58		29.54	
	19.4		26.87		29.86	
8 %	19.63	19.27	27.18	26.68	30.21	29.65
	19.21		26.60		29.56	
	18.97		26.27		29.19	
10 %	18.68	18.27	25.86	25.89	28.74	28.77
	17.6		26.17		29.08	
	18.53		19.23		23.18	

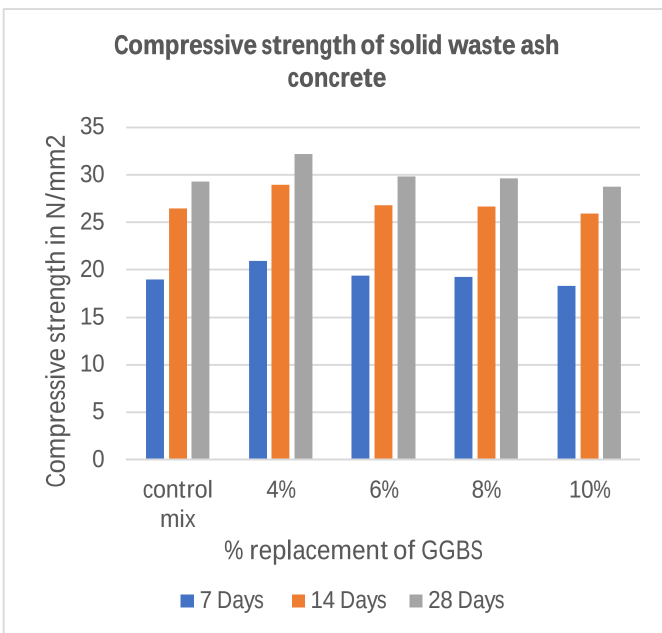

Fig.3 Compressive strength of solid waste ash concrete after 7, 14 and 28 days curing

4) The concrete can be made by using Solid waste ash up to 4% of its replacement with cement without compromising the compressive strength.

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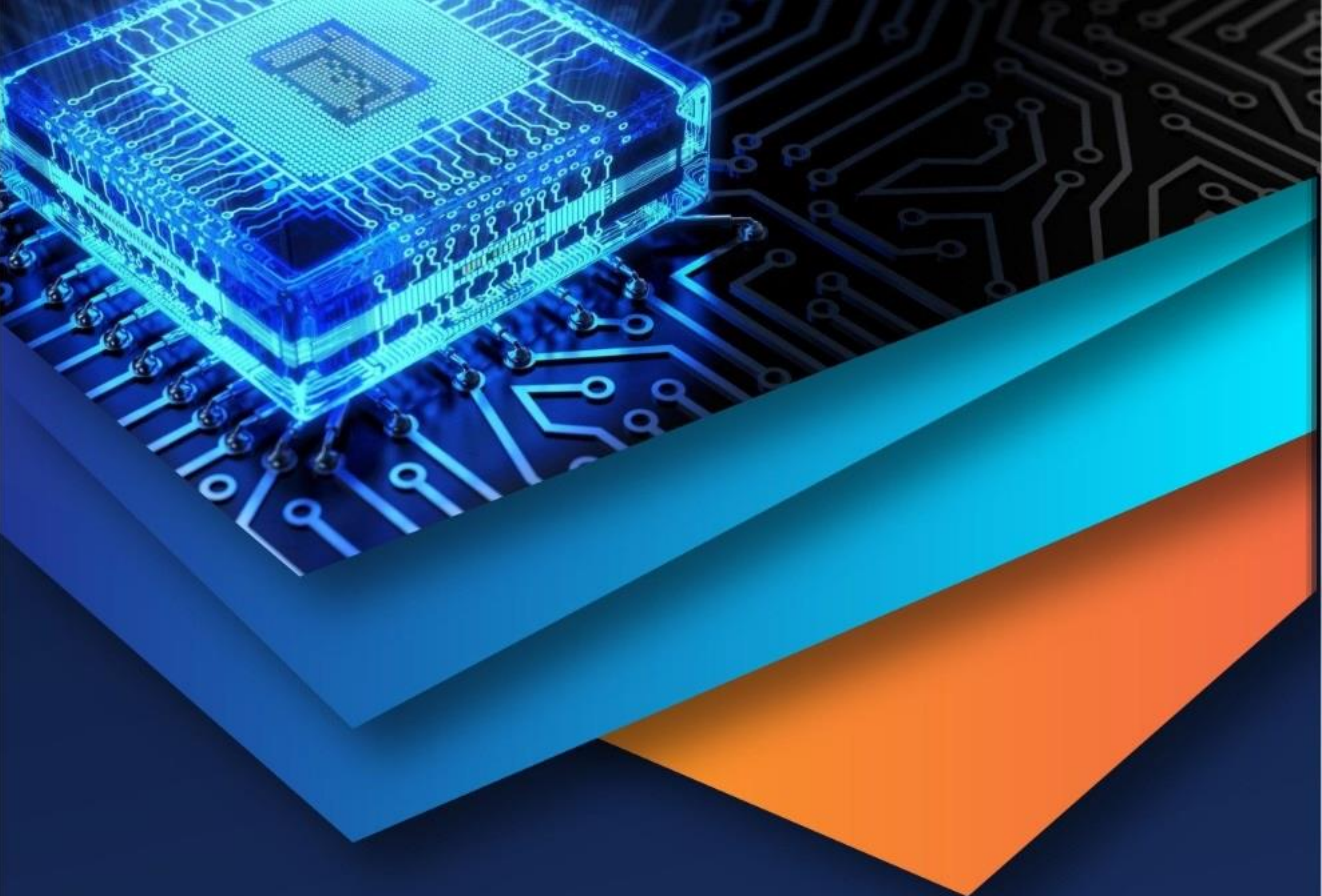

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