Partial Replacement of Cement with GGBS in Self Compacting Concrete for Sustainable Construction

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Abstract

*The concept of partial replacement of cement which is capable for sustainable development is characterized by application of industrial wastes to reduce consumption of natural resources and energy and pollution of the environment. A presently large amount of ground granulated blast furnace slag is a by-*product *of manufacturing of pig iron with an important impact on environment and humans. This research work describes the feasibility of using the GGBS in self compacting concrete production as partial replacement of cement. GGBS can be used as filler and helps to reduce the total voids content in self compacting concrete. Constant level of Fly ash is also used in all set of mix proportion to increase the powder content for achieve the Workability. The cement has been replaced by GGBS accordingly in the range of 0%, 25%, 30%, 35%, and 40% by weight of cement for M-30mix. After iterative trial mixes the water/cement ratio (w/c) was selected as 0.40. Self compacting Concrete mixtures produced, tested and compared in terms of compressive ,split tensile strength and flexural strength with the conventional concrete for 7,14,28 days. It is found that, 25% of GGBS can be replaced and strength obtained is comparable to the conventional concrete.*

KeyWords*: *Self compacting concrete, Compressive Strength, split tensile strength, Flexural strength, Fly ash, GGBS, Green concrete.

I. INTRODUCTION

Green concrete is very often also cheap to produce, because, for example, waste products are used as a partial substitute for cement, charges for the dumping of waste are avoided, energy utilization in production is inferior, and durability is superior. In India there is an extreme manufacture of fly ash as it is used in the production of electricity in nuclear power plants. Ground granulated blast furnace slag (GGBS) is obtained by quenching molten iron slag (a byproduct of iron and steel making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. By well judged use of available materials for concrete making and their proportioning, concrete mixes are produced to have the desired properties in the fresh and hardened states, as the situation demands. Waste can be used to fabricate new products or can be used as admixtures so that natural sources are used more effectiveness and the environment is sheltered from waste deposits. To avoid the toxic waste and reprocess the waste material, the present study is carried out. As the properties are as good as the cement, the Class F fly ash (coal fly ash) and Ground granulated blast furnace slag (GGBS) is used as fine partial replacement in the cement in Self compacting concrete.

II. MATERIALS INVESTIGATION

A. Cement

The Ordinary Portland cement of 53-grade was used in this study conforming to IS: 12269-1987 .The specific gravity of cement is 3.15. The initial and final setting times were found as 35 minutes and 178 minutes respectively. Standard consistency of cement was 31%.

B. Fine aggregates

The river sand is used as fine aggregate conforming to the requirements of IS: 383-1970. Having specific gravity of 2.62 and fineness modulus of 2.86 has been used as fine aggregate for this study.

C. Coarse Aggregate

Coarse aggregate obtained from local quarry units has been used for this study, conforming to IS: 383-1970 is used. Maximum size of aggregate used is 20mm with specific gravity of 2.707.

D. Fly Ash

Fly ash is a byproduct of the thermal power plants. Fly ash normally produced from burning anthracite or bituminous coal. Class F fly ash was used have a lower content of Cao and exhibit Pozzolonic properties. Specific gravity of fly ash is 2.2 as per Specific gravity Test, IS: 2386 Part III, 1963,(ASTM C 618) .

Table -1: Chemical Composition of Fly Ash

Content	Cao	Sio2	Al2o3	Fe2o3	Mgo
Fly ash	2	60	30	4.0	1.0

E. Ground Granulated Blast Furnace Slag (GGBS)

Ground Granulated Blast furnace Slag (GGBS), a co-product produced simultaneously with iron, molten blast furnace slag is cooled instantaneously by quenching in large volumes of cold water, known as granulation, to produce Granulated Blast furnace Slag.

Table -2: Chemical Composition of (GGBS)

Content	SiO_2	AL_2O_3	CaO	MgO	Fe_2O_3	SO_3	L.O.I
GGBS	40.0	13.5	39.2	3.6	1.8	0.2	0.0

Table -3: Physical properties of (GGBS)

Sl.No	Physical Properties	GGBS
1	Colour	White powder
2	Specific gravity	2.94
3	Specific surface(m^2/kg)	430
4	Bulk Density(kg/m^3)	1200

F. Water

The water used for experiments was potable water conforming as per IS: 456-2000.

III. EXPERIMENTAL PROCEDURE

SCC mixes with different replacements of mineral admixture were prepared and examined to quantify the properties of SCC. The replacement of GGBS was carried out at levels of 25%, 30%, 35% and 40% of cement content. After iterative trial mixes the water/cement ratio (w/c) was selected as 0.40.Some design guidelines have been prepared from the acceptable test methods. Many different test methods have been developed in attempts to characterize the properties of Self Compacting Concrete. So far, no single method or combination of methods has achieved universal approval and most of them have their adherents.

Table -4: Details of Mix Proportions of Concrete

MATERIALS kg/m^3	GGBS CONTENT				
	0%	25%	30%	40%	50%
	M1	M2	M3	M4	M5
Cement	420	315	294	273	250
GGBS	0	105	126	147	168
Fly Ash	105	105	105	105	105
Coarse Aggregate(12.5 mm)	1012	1012	1012	1012	1012
Fine aggregate	815	815	815	815	815
Crushed stone sand(CSS)	360	360	360	360	360
Water	210	210	210	210	210

Table -5: SCC- Acceptance Criteria for Fresh Properties

Sl.No	Property	Range	Property
1	Slump Flow Diameter	500-700 mm	Filling ability
2	T_{50cm}	2-5 sec	Filling ability
3	V-funnel	8-12 sec	Passing ability
4	V-funnel-T5min	11-15sec	Segregation resistance
5	L-Box H2/H1	≥ 0.8	Passing ability

Table -6: Test results on Fresh SCC Mixes

% of Replacement	% of GGBS				
	0%	25%	30%	35%	40 %
Slump Flow(mm)	635	670	675	635	610
U box (mm)	27	17	19	24	26
V funnel (sec)	10	7	8	10	11
L box	0.8 6	0.9	0.87	0.83	0.8 2

Table -7: Compressive Strength on 7, 14 and 28 Days

Mix Designation	Compressive strength in N/mm²		
	7 Days	14 Days	28 Days
Mix-1 Control mix	26.95	30.22	40.37
Mix-2 25% of GGBS	32.1	39.94	47.56
Mix-3 30% of GGBS	31.53	36.96	45.22
Mix-4 35% of GGBS	29.2	34.12	44.29
Mix-5 40% of GGBS	29.6	32.14	43.26

Chart -1: Compressive Strength on 7, 14 and 28 Days

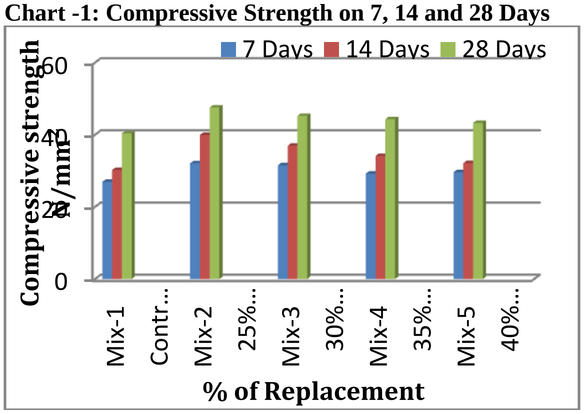

Table -8: Split Tensile Strength on 3, 7 and 28 days

Mix Designation	Split Tensile Strength in N/mm²	
	14 Days	28 Days
Mix-1 Control mix	2.27	4.05
Mix-2 25% of GGBS	3.74	5.55
Mix-3 30% of GGBS	3.70	5.48
Mix-4 35% of GGBS	3.46	5.38
Mix-5 40% of GGBS	2.78	5.01

Chart -2: Split Tensile Strength on 3, 7 and 28 days

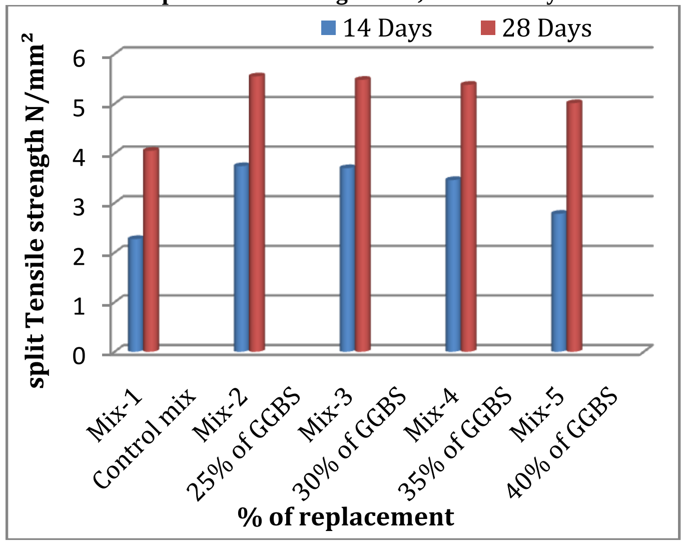

Table -9: Flexural Strength on 14 and 28 days

Mix Designation	Flexural Strength in N/mm²	
	14 Days	28 Days
Mix-1 Control mix	5.85	6.72
Mix-2 25% of GGBS	7.73	10.01
Mix-3 30% of GGBS	7.54	9.26
Mix-4 35% of GGBS	6.86	8.16
Mix-5 40% of GGBS	6.56	7.67

Chart-3: Flexural Strength in Prism on 14 and 28 days

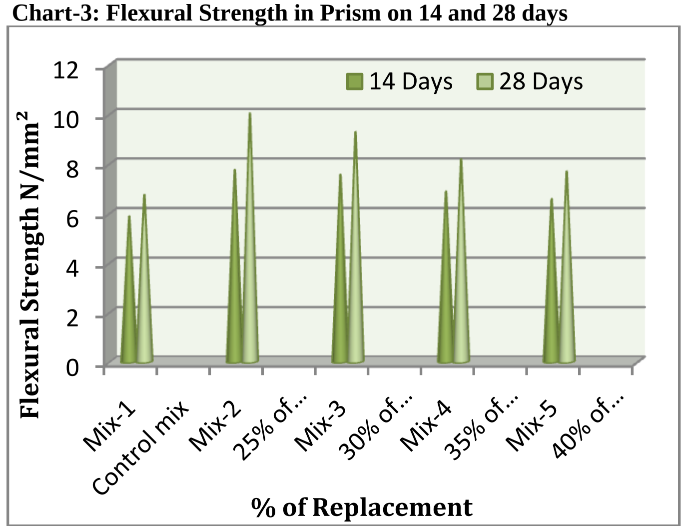

Table -10: Results of Rapid Chloride Penetration Test

Mix Identity	Average charge passed(coulombs)	Chloride irons permeability
M1	2150.46	Moderate
M 2	3536.1	Moderate
M3	3341.4	Moderate
M4	3104.4	Moderate
M5	2545.5	Moderate

IV. RESULTS AND DISCUSSION

When the percentage of GGBS replaced to cement with varying percentage from 25% to 40% the following results were drawn.

1. With 25% of GGBS the compressive strength at the end of 7,14 and 28 days 32.1, 39.94 and 47.56N/mm2 respectively.
2. The compressive strength at the end of 28 days decreases when the GGBS percentage is increased beyond 40%. However the compressive strength of M30 concrete at the end of 28 days for 40% replacement of GGBS is 43.26 N/mm2 as shown in Table -7.
3. The compressive strength showed a steep decrease when the GGBS percentage is increased as shown in Chart -1.
4. A similar increase in the split tensile strength was observed when the GGBS is increase 25% (5.55 N/mm2 at the end of 28 days).
5. The split tensile strength at the end of 28 days decreases when the GGBS percentage is increased beyond 40%. However the split tensile strength of M30 concrete at the end of 28 days for 40% replacement of GGBS is 5.01 N/mm2 as shown in Table -8.
6. The split tensile strength showed a steep decrease when the GGBS percentage is increased beyond 40% as shown in Chart -2.
7. A similar increase in the Flexural strength was observed when the GGBS is increase 25% (10.1N/mm2 at the end of 28 days).
8. The Flexural strength at the end of 28 days decreases when the GGBS percentage is increased beyond 40%. However the Flexural strength of M30 concrete at the end of 28 days for 40% replacement of GGBS is 7.67 N/mm2 as shown in Table -9.
9. The Flexural strength strength showed a steep decrease when the GGBS percentage is increased beyond 40% as shown in Chart -3.
10. Corrosion of reinforcing steel due to chloride ingress is one of the most common environmental attacks that lead to the deterioration of concrete structures. Rapid Chloride Penetration is moderate in all mixes as shown in Table -10.

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