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STRENGTH OF HIGH PERFORMANCE CONCRETE WITH GGBS

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Abstract:

High Performance concrete (HPC) has received increased attention in the development of infrastructure Viz., Buildings, Industrial Structures, Hydraulic Structures, Bridges and Highways etc. leading to utilization of large quantity of concrete. This represents a comprehensive coverage of High Performance concrete developments in civil engineering field. It highlights the High Performance concrete features and requirements over conventional concrete. Furthermore, recent trends with regard to High Performance Concrete development in this area are explored. This paper also includes effect of Mineral and Chemical Admixtures used to improve performance of concrete.

KEY WORDS: Cement, GGBS, Super plasticizer, Compressive strength

1-INTRODUCTION

1.1 General

Conventional ordinary Portland cement concrete which is designed on the basis of compressive strength does not meet many functional requirements as it is found deficit in aggressive environments, time of construction, energy absorption capacity, repair and retro fitting jobs, etc. so, there is a need to design High Performance concrete with GGBS contribute most efficiently to the various properties.

1.2 High Performance Concrete

High Performance Concrete is used for concrete mixture which possesses high workability, high strength, highmodulus of elasticity, high density, high dimensional stability, low permeability and resistance to chemical attack. It is therefore, logical to describe by the more widely embracing term "High Performance Concrete"(HPC). Cement of 53grade isdesirable for design of High strength concretes. Concrete materials most high-performance concretes produced today contain mineral admixtures in addition to Portland cement to help achieve the compressive strength or durability performance. These materials include fly ash, silica fume and **ground-granulated blast furnace** slag used separately or in combination. At the same time, chemical admixtures such as high-range water-reducers are needed to ensure that the concrete is easy to transport, place and finish. For high-strength concretes, a combination of mineral and chemical admixtures is nearly always essential to ensure achievement of the required strength.

Most of the high-performance concretes have a high cementitious content and a water-cementitious material ratio of 0.40 or less. However, the proportions of the individual constituents vary depending on local preferences and local materials. Mix proportions developed in one part of the country do not necessarily work in a different location. Many trial batches are usually necessary before a successful mix is developed. High-performance concretes are also more sensitive to changes in constituent material properties than conventional concretes. Variations in the chemical and physical properties of the cementitious materials and chemical admixtures need to be carefully monitored. Substitutions of alternate materials can result in changes in the performance characteristics that may not be acceptable for high-performance concrete. This means that a greater degree of quality control is required for the successful production of high-performance concrete.

1.3 Ground Granulated BlastFurnace Slag

Ground Granulated Blast Furnace Slag (GGBS) is abyproduct of the steel industry. Blast furnace slag is defined as "the non-metallic product consisting essentially of calcium silicates and other bases that is developed in a molten condition simultaneously with iron in a blast furnace". Iron ore, coke and limestone are fed into the furnace, and the resulting molten slag floats above the molten iron at a temperature of about 1500°C to 1600°C. The molten slag has a composition of 30% to 40% silicon-dioxide (SiO2) and approximately 40% CaO, Which is close to the chemical composition of Portland cement. After the molten iron is tapped off, the remaining molten slag, which mainly consists of siliceous and aluminous residues, is then rapidly water-quenched, resulting in the formation of glassy granulate. This glassy granulate is dried and ground to the required size which is known as ground granulated blast furnace slag (GGBS). The production of GGBS requires little additional energy compared with the energy required for the production of Portland cement.

1.3.1 Chemical Composition

Slag is primarily made up of silica, alumina, calcium oxide, and magnesia (95%). Other elements like manganese, iron, sulfur, and trace amounts of other elements make up about other 5% of slag. The exact concentrations of elements vary slightly depending on where and how the slag is produced. When cement reacts with water, it hydrates and produces calcium silicate hydrate (CSH), the main component to the cements strength, and calcium hydroxide $Ca(OH)_2$. When GGBFS is added to the mixture, it also reacts with water and produces C-S-H from its available supply of calcium oxide and silica. A pozzolanic reaction also takes place which uses the excess SiO_2 from the slag source, $Ca(OH)_2$ produced by the hydration of the portland cement, and water to produces more of the desirable C-S-H making slag a beneficial mineral admixture to the durability of concrete.

1.3.2 GGBS Effects on Compressive Strength

GGBS has a positive effect on compressive strength of concrete after 28 days. In the first 7 days the compressive strength is generally slightly lower than pure 100% Portland cement mixtures. In the 7 to 14 day range, the compressive strength is about equal to the strength of concrete without slag. The real gain in strength is noticed after the 28 day mark especially when above M-60 Grade with GGBS is used. The long term strength of slag cement depends on many factors such as the amount of slag and Portland cement, and water to cement ratio.

2-EXPERIMENTALINVESTIGATION

2.1 Initial Test

2.1.1 Cement: 53grade ordinary Portland cement is used. (Birla-super)Specification Confirming to IS12269:1987 is given in **Table 2.1.1** below.

Sl. No	properties	Obtained Values	Requirements as per IS: 12269-1987
1	Fineness	7.4%	Not more than 10%
2	Setting Time Initial Final	 165 min 380 min	Not less than 30 min Not more than 600 min
3	Compressive Strength 3 days 7 days 28 days	 39.5MPa 51 MPa 70 MPa	Not less than 27 N/mm^2 Not less than 37 N/mm^2 Not less than 53 N/mm^2
4	Standard Consistency	34%	-----
5	Specific Gravity	3.15	-----

2.1.2 Fine Aggregates

2.1.2.1 Specific Gravity Test and Water Absorptions: Specific gravity of fine aggregate is **2.6** and percentage of water absorption is **1%**

2.1.2.2 Fineness Modulus of Fine Aggregate:
Result: AS Per IS 383-1970 Table no 2, sand confirms **Zone- II**

2.1.3 Coarse Aggregates (CA)
2.1.3.1 Specific Gravity and Water Absorption:
Specific gravity of Coarse Aggregate = **2.7**and Percentage of water absorption is **0.5%**
2.1.3.2 Fineness Modulus of Coarse Aggregate:

Fineness Modulus of Coarse Aggregate = 1.84

2.1.4 Ground Granulated Blast Furnace Slag (GGBFS):

The properties as provided bythe manufacturer are given in below **Table 2.1.4**

Sl. no	Characteristics	Requirement as per BS:6699	Test Result
	Chemical Requirements		
1	Fineness(m^2/kg)	275 (Min)	392
2	Specific Gravity	--	2.91
3	45micron(Residue)(%)	--	6.20
4	Insoluble Residue (%)	1.5(Max)	0.40
5	Magnesia Content (%)	14.0(Max)	7.59
6	Sulphide Sulphar (%)	2.00(Max)	0.48
7	Sulphite Content (%)	2.50(Max)	0.38
8	Loss on Ignition (%)	3.00(Max)	0.35
9	Manganese Content (%)	2.00(Max)	0.13
10	Chloride Content (%)	0.10(Max)	0.010
11	Glass content(%)	67 Min	90
12	Moisture Content (%)	1.00 (Max)	0.12
13	Chemical Modulus		
A	CaO+MgO+SiO2	66.6(Min)	76.47
B	(CaO+MgO)/Sio2	>1.0	1.35
C	Cao/SiO2	<1.4	1.12

2.1.5 Admixture
Super plasticizer **MASTER GLENIUM SKY 8580** of M/s. BASF Construction Chemicals (I) Pvt. Ltd,confirming to IS: 9103: 1999 has been used. High Performance super plasticiser based on PCE(Poly-carboxylic ether) for concrete.
MasterGlenium SKY 8580 is an admixture of a new generation based on modified poly-carboxylic ether. The product has been primarily developed for applications in High Performance Concrete where the highest durability and performance is required.

Table2.1.5

Aspect	Reddish brown liquid
Relative density	1.11±0.01 at 25°C
PH	≥ 6 at 25°C
Chloride ion content	< 0.2%

3-MIX DESIGN BASED ON IS: 10262 - 2009

3.1Mix Design of M60 Grade Concrete (using Ordinary Portland Cement):

The mix proportions of M-60 concrete for 1m^3, along with GGBS are tabulated in the table below.**Mix Ratio**
Table: 3.1(A),

CONCRETE MIX	Cement	F.A	C.A	GGBS	Water	SP
Conventional Concrete(CC)	1	1.82	2.66	--	0.35	0.5 %
CC+10% GGBS	1	2.0	2.96	0.11	0.35	0.5 %
CC+20% GGBS	1	2.7	3.3	0.25	0.35	0.5 %
CC+30% GGBS	1	2.6	3.8	0.43	0.35	0.5 %
CC+40% GGBS	1	3.0	4.41	0.66	0.35	0.5 %
CC+50% GGBS	1	3.61	5.28	1	0.35	0.5 %

Table 3.1(B)

4-TEST PROCEDURE:

4.1 Compressive strength of concrete:

By this single test one can judge that whether Concreting has been done properly or not. For cube test two types of specimens either cubes of 15 cm X 15 cm X 15 cm or 10cm X 10 cm x 10 cm depending upon the size of aggregate are used. The concrete is poured in the mould and tampped properly so as not to have any voids. After 24 hours these moulds are removed and test specimens are put in water for curing. The top surface of these specimen should be made even and smooth. This is done by putting cement paste and spreading smoothly on whole area of specimen.

These specimens are tested by compression testing machine after 7 days, 14 days and 28 days curing. Load at the failure divided by area of specimen gives the compressive strength of concrete.

The materials were first dry mixed then mixed with water and super plasticizer thoroughly. Slump test was conducted to measure degree of workability. The test results are given in Table 4.1

TABLE 4.1

SL.NO	CONCRETE MIX	SLUMP VALUE in mm
1	CC	100
2	CC+10%GGBS	110
3	CC+20%GGBS	113
4	CC+30%GGBS	118
5	CC+40%GGBS	121
6	CC+50%GGBS	126

4.1.2Testing on Hardened Concrete

Casted specimens are tested by compression testing machine after 7 days, 14days and 28 days curing. Load

TYPE OF MIX	CEMENT in KGs	F A in KGs	C A in KGs	GGBS in KGs	SUPER Plasticizer (In litres)	WATER In Litres
CC	423	770	1127	-	2.115	161.35
CC+10% GGBS	381	769	1126	42	2.115	161.35
CC+20% GGBS	338	768	1124	85	2.115	161.35
CC+30% GGBS	296	767	1122	127	2.115	161.35
CC+40% GGBS	254	766	1121	169	2.115	161.35
CC+50% GGBS	212	765	1120	211	2.115	161.35

at the failure divided by area of specimen gives the compressive strength of concrete.

At each desired curing periods specimens were taken out of water and kept for surface drying. The cubes were tested in 200T capacity compressive testing machine to get the compressive strength of concrete

5-RESULTS AND CONCLUSION

5.1 Compressive Strength Results

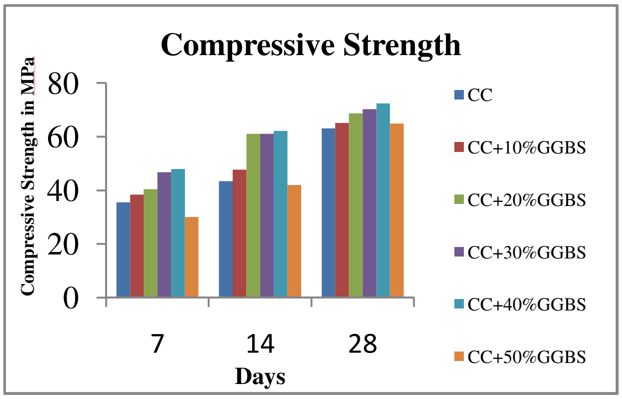
The type of concrete, age of concrete, and compressive strengths of the experiment is tabulated in thetable given below.

TABLE 5.1 Tabulation of Compressive Strength Results

Sl. No	Type of concrete	Age of concrete in days	Avg Compressive Strength (N/mm^2)
1	CC	7	35.47
		14	43.42
		28	63.11
2	CC+10%GGBS	7	38.4
		14	47.64
		28	65.11
3	CC+20%GGBS	7	39.07
		14	54.88
		28	68.71

4	CC+30%GGBS	7	46.71
		14	61.02
		28	70.27
5	CC+40%GGBS	7	47.96
		14	62.17
		28	72.31
6	CC+50%GGBS	7	30.10
		14	41.96
		28	64.84

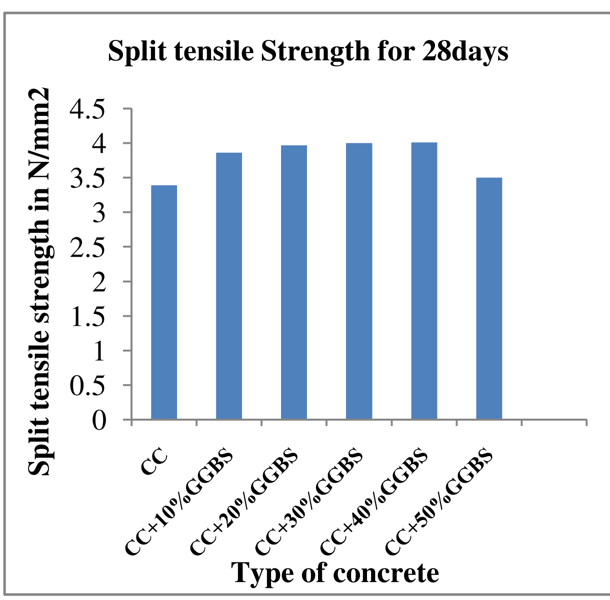
Fig 4.1.2Compressive strength testing of concrete



5.2:Split Tensile Strength of Cylinders

TABLE: 5.2 Tabulation of Split Tensile Strength Results

Concrete +GGBS	Split Tensile Strength @28days (MPa)
CONVENTIONAL CONCRETE(CC)	3.39
CC+10%GGBS	3.86
CC+20%GGBS	3.97
CC+30%GGBS	4.00
CC+40%GGBS	4.01
CC+50%GGBS	3.50



5.3 Conclusion

The experimental investigation deals with the study of compressive strength of GGBS under direct compression. A concrete mix of grade M_{60} was designed. A total of 56 cubes were casted under various mix namely CC, 10%GGBS, 20%GGBS, 30% GGBS, 40%GGBS and 50% GGBS are tested under direct compression. Based on the results so obtained the following conclusions are made.

- The optimum percentage of GGBS replacing cement is 40% for getting maximum compressive strength and obtainedmaximum compressive strength is 72.31N/mm^2.
- The maximum increase in compressive strength is about 12.72% as compared to that of conventional mix at the age of 28 days.
- Split tensile strength increases with the increase in percentage of GGBS and the maximum tensile strength obtained is 4.01N/mm^2 at 40% replacement of GGBS.
- The maximum increase in split tensile strength is about 15.46% as compared to that of conventional mix at the age of 28 days.

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