Experimental Investigation On Durability And Mechanical Properties Of Self Compacting Concrete Using Mineral Admixtures

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Abstract— *Self-Compacting Concrete (SSC) is a flowing concrete mixture that is capable to consolidate under its own weight. The highly fluid nature of SSC makes it suitable for placing in difficult conditions and in section with congested reinforcement. Use of SSC can also assist in minimize hearing related damage on the work site that is induce by vibration of concrete. In this paper experimental studies are carried out to know the fresh and hardened properties of Self Compacting Concrete (SSC) in which cement is replaced by Ground Granulated Blast Furnace Slag (GGBS) and Fly Ash (FA) in different proportions for M30 grade concrete. The proportions in which cement replaced are 20% of GGBS, 25% of GGBS, 20% of fly ash and 25% of fly ash with 1 % of Polypropylene fiber for all combinations. The main aim of this experimental study has been carried out to achieve target compressive strength, flexural strength and split tensile strength. Super plasticizer conplast SP430 used was maintaining workability with constant Water-cement ratio. This is done to determine the efficiency and optimum percentage of replacement at which maximum strength is achieved.*

Keywords—Self-Compacting Concrete, Granulated Blast Furnace Slag, Fly Ash, Super plasticizer Conplast SP430.

I. INTRODUCTION

Self-compacting concrete (SCC) is an inventive concrete that does not require vibration for placing and compaction. It is proficient to flow under its own weight, wholly filling formwork and achieving full compaction, even in the incident of congested reinforcement. The hardened concrete is dense, homogeneous and has the same engineering properties and durability as conservative vibrated concrete. The use of SCC will conduct to a more industrialized production, reduce the industrial costs of in situ cast concrete constructions pick up the quality, durability and consistency of concrete structures and remove some of the likely human error. Self-compacted existing (SCC) is one of the high performance concrete which had an massive increase in the construction industry in the recent years. Self-compacting concrete (SCC) first developed in Japan, represent one of the most important advances in concrete technology for decades. Use of Self-compacting concrete offers substantial benefits in enhancing construction efficiency, dropping overall cost, improving working surroundings and in sustainability.

The foremost generation of SCC used in the UK and Europe, such as the one developed in a large European investigate project, which investigated the practicability of with self-compacting concrete in both civil engineering and in building structures, contain a high amount of powder, as well as a high amount of super plasticizer (SP), to make sure adequate filling capacity and transitory abilities and separation resistance. Savings in labor costs might equalize the increased cost related to the use of more cement and SP, but the use of mineral admixtures, such as could raise the flexibility of the concrete, without any increase in the cost.

There is no ordinary method for SCC mix design, and many intellectual institutions as well as admixture, ready-mixed, precast and constricting companies have developed their own mix proportioning methods. As per EFNARC Guidelines for SCC mix design, Filling ability, Passing ability, and Segregation resistance are the primary parameters of concrete which fix the quality and strength of SCC. Slump flow, V-funnel, T5 minutes, L-Box and U-box are the basic tests to check condition of SCC.

ADVANTAGES

There are many advantages of using SCC particularly when the material cost is minimize which include

- ✓ Improved excellence of concrete and decrease of onsite repairs.
- ✓ Faster building times.
- ✓ Lower overall costs.
- ✓ Facilitation of opening of computerization into Concrete construction.
- ✓ Improvement of physical condition and safety is also achieved through exclusion of handling of vibrators.
- ✓ Substantial drop of environmental blast loading on and around a site.
- ✓ Potential for consumption of "dusts", which are Currently waste goods and which are costly to set out of.
- ✓ Better exterior finishes.
- ✓ Easier insertion

II. MATERIALS

*A. **Cement**: Ordinary Portland cement, 43 Grade conforming to IS: 12269 – 1987.*

TABLE 1: Properties of cement

S,No	Property	Test result
1	Specific gravity	3.16
2	Fineness modulus	3.6%
3	Consistency	32%
4	Initial setting time	30 min
5	Final setting time	10 hrs

*B. **Fine Aggregate**: Locally available river sand confined Grading zone II of IS: 383-1970.*

TABLE 2: Properties of fine aggregate

S,No	Property	Test result
1	Specific gravity	2.8
2	Water absorption	1.5%
2	Fineness modulus	2.8
3	Bulk density	1843.09kg/m^3

*C. **Coarse Aggregate**: Locally available crushed blue granite stones conforming to graded aggregate of nominal size 12.5 mm as per IS: 383 – 1970.*

TABLE 3: Properties of coarse aggregate

S,No	Property	Test result
1	Specific gravity	2.77
2	Impact test	15%
2	Fineness modulus	6.75
3	Bulk density	1673.46 kg/m^3

*D. **Mineral Admixture***

FLY ASH:

Fly ash is a another pozzolanic material it has been shown to be an effective addition for SCC providing increased cohesion and reduced sensitivity to changes in water content. However, high levels of fly ash may produce a paste fraction which is so cohesive that it can be resistant to flow. Two classes of fly ash are defined by ASTM C618: Class F fly ash and Class C fly ash. The chief difference between these classes is the amount of calcium, silica, alumina, and iron content in the ash. The chemical properties of the fly ash are largely influenced by the chemical content of the coal burned.

TABLE 4: Composition of fly ash

S no	Characteristics	Results
1	SiO_2 +Al_2O_3 +Fe_2O_3	95.95
2	SiO_2	59.71
3	MgO	1.06
4	SO_3	---
5	Na_2O	0.63
6	Loss of ignition	0.71
7	Moisture	0.32
8	Calcium oxide as CaO	0.5

GROUND GRANULATED BLAST-FURNACE SLAG (GGBS):

Ground granulated blast furnace slag (GGBS) is a by-product from the blast-furnaces used to make iron. These operate at a temperature of about 1,500 degrees centigrade and are fed with a carefully controlled mixture of iron-ore, coke and limestone. The iron ore is reduced to iron and the remaining materials form a slag that floats on top of the iron. This slag is periodically tapped off as a molten liquid and if it is to be used for the manufacture of GGBS it has to be rapidly quenched in large volumes of water. The quenching, optimizes the cementitious properties and produces granules similar to a coarse sand. This 'granulated' slag is then dried and ground to a fine powder. The physical & chemical properties as shown below table 5&6.

TABLE 5: Physical properties of GGBS

S,No	Property	Test result
1	Specific gravity	2.91
2	Fineness modulus	3.85%
3	Particle size	≥45 microns
4	Surface area	350 to 450 m^2/kg
5	Relative density	2.92 tonnes /m^3

TABLE 6: Chemical properties of GGBS

S.no	Oxide composition	GGBS
1	Cao	37.34%
2	Al2o3	14.42 %
3	Fe2o3	1.11%
4	Sio2	37.73 %
5	MgO	8.71 %
6	MnO	0.02 %
7	Glass	92 %
8	Loss of Ignition	1.41%

E. **SUPER PLASTICIZER:** Conplast sp430 used as a super Plasticizer. Use of this super plasticizer speeds up construction, increases workability and cohesion and aids pumping by reducing line friction and dry packing. Low porosity results in substantially improved water penetration resistance.

Table 7: Properties of Conplast SP430

S.No	Property	Test result
1	Specific gravity	1.220 to 1.225
2	Chloride content	Nil
3	Air entrainment	1% additional air is entrained

III. MIX PROPORTION

For the present work SCC of grade M30 is adopted. The mix design of SCC is obtained as per standard procedure as out lined in IS: 10262-2009 was followed. Details of mix proportions obtained are given in **Table 8** for SCC, cement is replaced by 20% of GGBS, 25% of GGBS, 20% of fly ash and 25% of fly ash with 1 % of Polypropylene fiber for all combinations. These four mix are compared with the Normal SCC (100% cement) Super plasticizer is used to maintain the workability with constant Water/Binder ratio as obtained from the mix design. Typical detailed calculation of mix design as per standard procedure as out lined in IS: 10262-2009.

Table 8: Mix Proportion

Water	Cement	Fine aggregate	Coarse aggregate
177	**503**	**890**	**858**
0.35	**1**	**1.76**	**1.70**

Combinations of mixes

Concrete label	Explanations
SCC	nominal mix
SCC01	Nominal mix + 1% fiber
SCC02	Nominal mix + 1% fiber + 20% GGBS
SCC03	Nominal mix + 1% fiber + 25% GGBS
SCC04	Nominal mix + 1% fiber + 20% Fly Ash
SCC05	Nominal mix + 1% fiber + 25% Fly Ash

IV. EXPERIMENTAL WORKS

Experimental programs are carried out and the results are presented in this paper to study the fresh and hardened properties of SSC concrete.

TEST ON FRESH CONCRETE

The filling ability and stability of self-compacting concrete in the fresh state can be defined by four key characteristics. Each characteristic can be addressed by one or more test methods which are mentioned below. TABLE 10 gives the acceptance criteria.

TABLE 9: Characteristics for fresh concrete

Characteristics	Preferred test methods
Flow ability	Slump-flow Test
Viscosity (assessed by rate of flow)	V-funnel Test
Passing ability	L-box test
Segregation	Segregation resistance (Sieve) Test

TABLE 10: Acceptance criteria

Test	Property	Ranges of values
Slump-flow	Filling ability	2 – 5 sec
V-funnel	Viscosity	6-12 sec
L-box	Passing ability	0.8-1

TABLE 11: Result of fresh concrete

MIX-ID	SCC (CC)	SCC & 1% FIBER	GGBS20	GGBS25	FA20	FA25
Slump flow (650-800)mm	670	685	690	680	705	710
Slump flow(seconds)	4.5	3.9	3.6	4	2.6	2.8
V-funnel	10.8	9.9	9.2	10.1	9.1	8.3
L-box	0.9	0.91	0.90	0.92	0.94	0.96

TEST ON HARDENED CONCRETE

The concrete is tested for the hardened properties like compressive strength, split tensile and flexural strengths each for 7 days, 14 days and 28 days. All tests were performed in accordance with the provision of IS: 516-1959 and IS: 5816-1999. The test results are tested below.

TABLE 12: compressive strength (in MPa) test results

Mix-ID	SCC (CC)	SCC & 1% FIBER	GGBS20	GGBS25	FA20	FA25
7-days	20.99	21.6	24.1	24.74	21.9	23.9
28- days	32.3	33.11	36.44	38.22	33.45	32.8

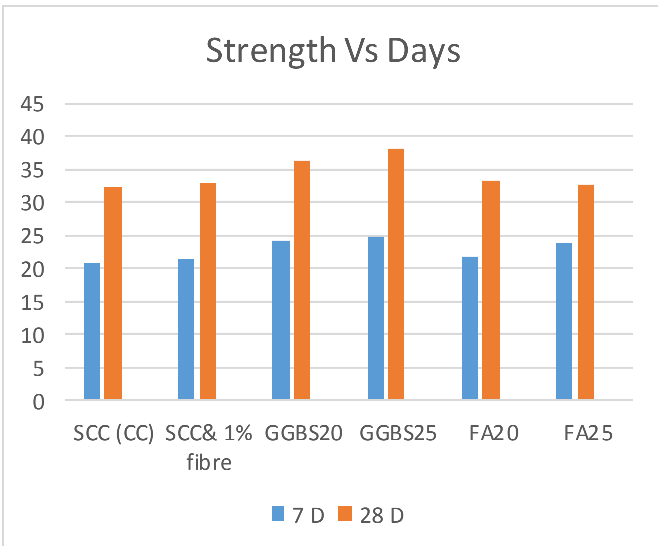

Figure 1: Average Compressive Strength for 7 and 28 Days

Fig 1 Strength Test For Cube

Table 13: split tensile strength (in MPa) test results

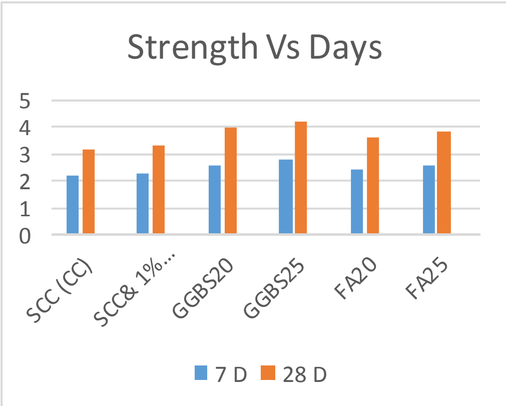

Figure 2: Average Split Strength for 7 and 28 Days

Fig 2 Strength Test For Cylinder

Table 14: Flexural strength (in MPa) test results

Mix-ID	SCC (CC)	SCC & 1% FIBER	GGBS20	GGBS25	FA20	FA25
28-days	5.2	6.2	6.3	6.75	6.27	6.45

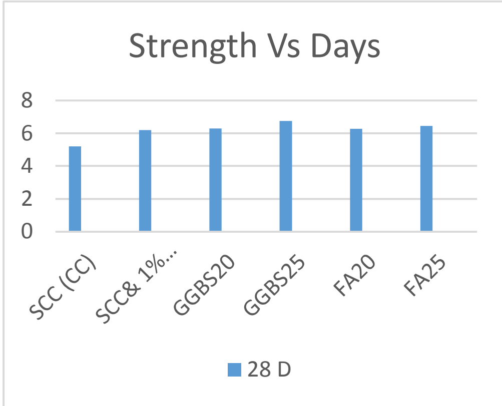

Figure 3: Flexural strength for 28 days

Mix-ID	SCC (CC)	SCC & 1% FIBER	GGBS20	GGBS25	FA20	FA25
7-days	2.19	2.26	2.62	2.84	2.43	2.55
28-days	3.18	3.32	4	4.2	3.6	3.82

TEST ON DURABILITY PROPERTIES

The durability study for SCC after 28 Days and 56 Days curing was done by conducting some of tests such as water absorption, sorpitivity, impact resistant test and sulphate attack and acid attack tests. Table 15, 16,17,18,19 shows the values of different SCC mixes. When cement is replaced by GGBS, a lower percentage super plasticizer is required to maintain the same filling ability.

TABLE 15: Water Absorption Test Results

S.NO	Combination	Dry weight	Wet weight	Percentage of water absorption
1	SCC(CC)	8.954	9.133	2.01
2	SCC&1% fiber	8.816	9.044	2.59
3	GGBS 20	8.649	8.820	1.98
4	GGBS 25	8.677	8.757	0.93
5	FA 20	8.448	8.605	1.87
6	FA 25	8.452	8.540	1.05

Table 16: Impact Resistant Test Results

Type of concrete	First crack	Failure	Impact energy J or N-m	
			First crack	Failure
SCC(CC)	78	80	1586.24	1626.92
SCC &1%FIBER	84	87	1708.66	1769.27
GGBS 20	89	92	1809.94	1870.95
GGBS 25	113	117	2068.45	2088.32
FA 20	94	97	1911.63	1972.64
FA 25	102	110	2022.56	2043.27

TABLE 17: Sorpitivity Test Results

Type of Concrete	Dry weight in grams (W_1)	Wet weight in grams (W_2)	Sorptivity value in 10^{-5} $mm/min^{0.5}$
SCC(CC)	1334.2	1335	2.92
SCC&1%FIBER	1321	1322.5	3.65
GGBS 20	1403.4	1404.1	2.55
GGBS 25	1408.7	1409.2	1.82
FA 20	1410.3	1411.5	1.76
FA 25	1412.6	1413.7	1.63

TABLE 18: Acid attack Test Results

TYPE OF CONCRETE	WEIGHT OF SPECIMEN BEFORE ACID IMMERSION (kg)	WEIGHT OF SPECIMEN AFTER ACID IMMERSION (kg)		%loss in Mass for 28 days	%loss in Mass for 56 days
		28th day	56th day		
SCC(CC)	8.15	7.82	7.71	4.04	5.39
SCC&1% FIBER	8.26	7.86	7.41	4.84	10.29
GGBS 20	8.32	8.01	7.87	3.72	5.40
GGBS 25	8.46	8.16	8.01	3.54	5.31
FA 20	8.29	7.97	7.84	3.86	5.42
FA 25	8.37	8.05	7.92	3.82	5.37

TABLE 18: sulphate attack Test Results

MIX ID	WEIGHT OF SPECIMEN BEFORE SULPHATE IMMERSION (kg)	WEIGHT OF SPECIMEN AFTER SULPHATE IMMERSION (kg)		%loss in Mass for 28 days	%loss in Mass for 56 days
		28th day	56th day		
SCC(CC)	8.26	7.86	7.76	4.84	6.05
SCC&1% FIBER	8.37	7.97	7.87	4.77	5.97
GGBS 20	8.41	8.02	7.91	4.63	5.94
GGBS 25	8.47	8.07	7.97	4.72	5.90
FA 20	8.39	7.99	7.89	4.76	5.95
FA 25	8.42	8.03	7.92	4.63	5.93

VI. CONCLUSION

The following conclusions are drawn for feasibility study conducted on reinforced self compacting concrete with alccofine as partial replacement of cement includes,

The conclusion based on the limited observations from the present investigation on study of compressive, split tensile and flexural strength of the concrete made using alccofine as partial replacement of cement with steel fiber (1%) and constant dosage of super plasticizer (1.5%). The replacement level of alccofine ranging from 10%, 20% and 30% yields higher compressive strength than the conventional concrete mix. Beyond that there is a decrease in the compressive strength of concrete by replacing 40% of alccofine.

- The present investigation has shown that it is possible to achieve self compaction with different percentage of alccofine by the results of slump flow, J - ring, L - box, U – box and V - funnel. The fiber inclusion reduced the fluidity, but presence of alccofine enhance the flow properties.
- Although results obtained from all of the mixes satisfy the lower suggested by EFNARC, all mixes had good flow ability and possessed self-compaction characteristics.
- The addition of steel fiber increases the compressive strength, split tensile strength and flexural strength that is shows the results of SCC01 compared to the nominal concrete mix.
- Compressive strength, split tensile strength and flexural strength variation for the replacement of cement to a level of 30% alccofine indicate as an optimum replacement level. The observed maximum strength in compression, tension and flexural was 48.1MPa, 4.11MPa and 8.12MPa respectively at 28 days.
- The addition of alccofine in SCC improves microstructure of concrete that also helpful to enhance all mechanical properties of concrete.

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