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EXPERIMENTAL STUDY ON STEEL FIBRE REINFORCED HIGH STRENGTH SELF-COMPACTING CONCRETE

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Abstract – *In this experimental study the effect of GGBS and fly ash on steel fibre reinforced high strength self compacting concrete specimen produced by dramix steel fibers were investigated. The main objective is to obtain Steel Fibre Reinforced High Strength Self Compacting Concrete (SFRHSSCC) which flows under its own weight and homogeneity while completely filling any formwork and passing around congested reinforcement. The Self Compacting High Strength Concrete was produced by using fly ash, GGBS and steel fibers and Polycarboxylate-ether base super plasticizer. Dramix steel fibers were used in the experiments and volume fractions of steel fiber were 0.5%,1%,1.5% and 2.0 %. Replacement of GGBS and fly ash into the concrete were 15%,30%, 45% and 60% by weight of cement content. Apart from that combined replacement of GGBS and fly ash of varying percentages of 7.5%, 15%, 22.5% and 30% each were studied. Water/cement ratio was0.40. Compressive strength, Split tensile and Flexural strength test were carried out on hardened concrete specimens. In general, significant improvement in strengths is observed with the inclusion of GGBS, Fly Ash and steel fibres in the plain concrete up to certain limit.*

Key Words: Fly Ash, GGBS, Steel Fibre Reinforced High Strength Self compacting concrete (SFRHSSCC), Steel Fibres, Strength Parameters

1. INTRODUCTION

Around the world the construction material that is widely used is concrete. Due to technological advancements concrete properties have been undergoing changes. To improve the properties of concrete several types of concrete are developed. Self compacting concrete (SCC) is one of them. It is not at all a new concrete but it is somewhat complex and developing technology.

SCC is a new addition to the construction industry. SCC offers a number of advantages such as filling ability, passing ability and segregation resistance.SCC is widely used were congested reinforcements is required and normal vibration is not possible.
The main objective of this research is to produce of Steel Fiber Reinforced High Strength Self Compacting Concrete (SFRHSSCC).But the literature indicates that some studies are available on plain SCC but sufficient literature is not available.

2. Materials used:

Cement: Ordinary Portland Cement of 53 Grade conforming to IS: 12269-1987 was used in the investigation. The specific gravity of cement was 3.14.

Coarse Aggregate: Crushed stone coarse aggregate with a maximum size of 20 mm from a local source having the specific gravity of 2.71 conforming to IS: 383-1970 was used.

Fine Aggregate: Locally available river sand passing through 4.75 mm IS sieve conforming to grading zone-II of IS: 383-1970
was used. The specific gravity of fine aggregate was 2.64

Fly Ash : Class F fly ash is obtained from Raichur Thermal Power Station, District Raichur, Karnataka state, India. The fly ash properties are tabulated below. The physical properties and chemical composition of fly ash are shown in table1and table 2 respectively.

Table 1: Physical properties of Fly Ash

Serial number	Physical properties	Test results
1.	Colour	Grey
2.	Specific gravity	2.23
3.	Lime reactivity – after 28 days, average compressive strength of mixture 'A'	4.8 MPa

Table 2: Chemical properties of Fly Ash

Serial number	Constituents	Percent by weight
1.	Loss on ignition	4.15
2.	Silica (SiO_2)	58.66
3.	Iron Oxide (Fe_2O_3)	3.33
4.	Alumina (Al_2O_3)	28.30
5.	Calcium oxide (CaO)	2.12
6.	Magnesium Oxide (MgO)	0.35
7.	Total Sulphur (SO_3)	0.06
8.	Insoluble residue	-
9.	Alkalis a) Sodium Oxide (Na_2O)	0.56
	b) Potassium Oxide (K_2O)	1.28

Ground Granulated Blast Furnace Slag (GGBFS): Ground Granulated Blast furnace Slag (GGBS).It is a byproduct obtained from steel production. GGBFS is non metallic powder which has chemical composition of aluminates and silicates of calcium and other base. GGBFS is a mineral additive that may be used as an admixture in concrete, as its quality is good and consistent

The chemical composition and physical properties of GGBFS are tabulated in the table 3 &4

Table 3: Chemical composition in percentages of GGBFS

Serial number	Constituents	Percent by weight
1.	SiO_2	34.30
2.	Fe_2O_3	0.50
3.	Al_2O_3	22.15
4.	CaO	34.40
5.	SO_3	1.75
6.	MgO	8.54
7.	K_2O	0.36
8.	Loss of Ignition	0.16

Table 4: Physical properties of GGBFS

Serial number	Physical properties	Test results
1.	Physical form	Off white colour
2.	Specific surface area	400-600 m^2/Kg
3.	Specific gravity	2.75
4.	Bulk density (Loose)	1000-1100 Kg/m^3
5.	Bulk density	1200-1300 Kg/m^3

Steel Fibres: The main variables used in the study are dramix steel fibres. The steel fibres were obtained from Stewols India Pvt Ltd Nagpur. The properties of dramix steel fibres are mentioned in the table 5

Table 5: Properties of Dramix Steel Fibres

Properties	Specifications
Type of steel Fibre	Dramix
Length of Fibre	60
Diameter of Fibre	0.75
Aspect Ratio	80
Tensile Strength	1225 Mpa
Appearance	Bright Glued
Applications	Composite slab reinforcements

Super plasticizer: Polycarboxylatether base Muraplast FK 30 super plasticizer obtained from MC-Bauchemie (India) Pvt. Ltd. was used. It conforms to IS: 9103-1999.

Water: Fresh portable water which is free from concentration of acid and organic substances is used for mixing the concrete and curing.

3. Mixture Proportion and Specimen Preparation

The experimental investigation was carried out to study the properties of high strength concrete of M40 grade which was design by modified Nansu method. . The Self Compacting High Strength Concrete was produced by using fly ash, GGBS and steel fibers and Polycarboxylate-ether base super plasticizer. Dramix steel fibers were used in the experiments and volume fractions of steel fiber were 0.5%,1%,1.5% and 2.0 %. Replacement of GGBS and fly ash into the concrete were 15%, 30%, 45% and 60% by weight of cement content. Apart from that combined replacement of GGBS and fly ash of varying percentages of 7.5%, 15%, 22.5% and 30% each were also studied.

Mix design is carried out by using IS Code, IS 456-2000, & IS 10262-2009.Apart from that for SCC Design EFNARC guidelines are followed and Modified Nansu Method was also used. The mix proportion obtained for CVC was 1:1.44:2.6 for a W/c= 0.4 and for SCC was 1:1.36:1.52 for W/B=0.34

Table 6: Mix proportioning of CCM40, CCSCC and cement replaced by fly ash

Materials	Conventional M40	Conventional SCC	Fly Ash			
			M1	M2	M3	M4
Percentage	--	0%	15%	30%	45%	60%
Cement (kg/m^3)	450	560	476	392	308	224
Fly Ash (kg/m^3)	--	0	84	168	252	336
GGBFS (kg/m^3)	--	0	0	0	0	0
Coarse Aggregate (kg/m^3)	1169.85	763.4	763.4	763.4	763.4	763.4
Fine Aggregate (kg/m^3)	648.3	850.3	850.3	850.3	850.3	850.3
W/B Ratio	0.4	0.34	0.34	0.34	0.34	0.34
Super plasticizers (kg/m^3)	--	8.4	8.4	8.4	8.4	8.4
Water (kg/m^3)	180	187.6	187.6	187.6	187.6	187.6

Table 7: Mix proportioning of CCM40, CCSCC and cement replaced by Ground granulated blast furnace slag (GGBFS)

Materials	Conventional M40	Conventional SCC	GGBFS			
			M5	M6	M7	M8
Percentage	--	0%	15%	30%	45%	60%
Cement (kg/m³)	450	560	476	392	308	224
Fly Ash (kg/m³)	--	0	0	0	0	0
GGBFS (kg/m³)	--	0	84	168	252	336
Coarse Aggregate (kg/m³)	1169.85	763.4	763.4	763.4	763.4	763.4
Fine Aggregate (kg/m³)	648.3	850.3	850.3	850.3	850.3	850.3
W/B Ratio	0.4	0.34	0.34	0.34	0.34	0.34
Super plasticizers (kg/m³)	--	8.4	8.4	8.4	8.4	8.4
Water (kg/m³)	180	187.6	187.6	187.6	187.6	187.6

Table 8: Mix proportioning of CCM40, CCSCC and cement replaced by Combination of Fly Ash and GGBFS

Materials	Conventional M40	Conventional SCC	Mix ID			
			M9	M10	M11	M12
Cement replacement %	--	0%	15%	30%	45%	60%
Fly ash and GGBFS content (%)	--	--	7.5 & 7.5%	15 & 15%	22.5& 22.5%	30& 30%
Cement (kg/m³)	450	560	476	392	308	224
FA and GGBFS (kg/m³)	--	--	84	168	252	336
Fly Ash (kg/m³)	--	0	42	84	126	168
GGBFS (kg/m³)	--	0	42	84	126	168
Coarse Aggregate (kg/m³)	1169.85	763.4	763.4	763.4	763.4	763.4
Fine Aggregate (kg/m³)	648.3	850.3	850.3	850.3	850.3	850.3
W/B Ratio	0.4	0.34	0.34	0.34	0.34	0.34
Super plasticizers (kg/m³)	--	8.4	8.4	8.4	8.4	8.4
Water (kg/m³)	180	187.6	187.6	187.6	187.6	187.6

4. RESULTS AND DISCUSSIONS

Fresh Properties of SCC

Table: 9 Test Results for SCC

MIX ID	SLUMP FLOW (mm)	T500 (sec)	LBOX TEST	V FUNNEL TEST (sec)	T 5 MIN (SEC)
CCSCC	684	4.6	0.9	10.4	13.1
M1	699	3.5	0.92	9.3	12.1
M2	700	3.3	0.94	8.6	10.7
M3	705	3.2	0.95	8.4	10.4
M4	706	3.1	0.96	8.3	10.3
M5	707	3.3	0.98	8.1	10.1
M6	710	3.4	0.99	8.6	10.0
M7	690	4.1	0.91	10	12.4
M8	705	3.3	0.95	8.3	10.4
M9	707	3.4	0.96	8.1	10.3
M10	709	3.5	0.98	8.0	10.1
M11	688	4.2	0.93	10.2	12.6
M12	710	3.6	0.99	8.2	10.4

Hardened Properties of SCC

Compressive Strength Test

Cube specimens of size 150x150x150mm were casted and cured and were test in a compressive testing machine at 7 and 28 days.

Table 10: Compressive Strength Test Results

MIX ID	Average Compressive strength in N/mm²	
	7 days	28 days
CCM40	31.75	43.54
CCSCC	33.20	44.22
M1	31.02	42.25
M2	32.44	43.25
M3	29.18	41.35
M4	32.45	43.50
M5	33.45	44.75
M6	34.42	46.20
M7	37.40	47.87
M8	32.43	44.20
M9	34.45	45.30
M10	36.80	47.10
M11	38.20	49.26
M12	34.25	46.20

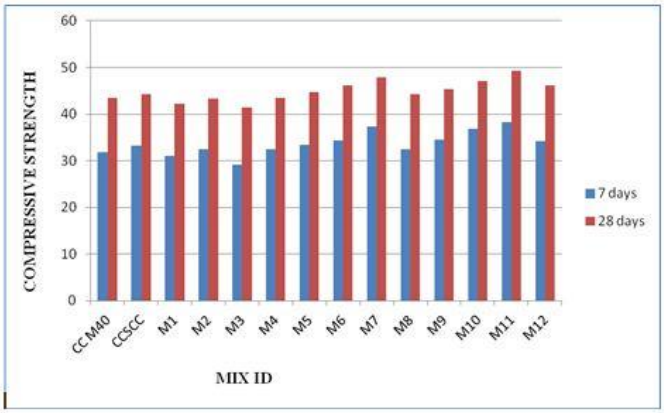

Chart 1: Compressive Strength Test Results

Split Tensile Strength Test: This test was conducted on a cylindrical specimen of dimension 150x300mm. Curing of specimens was done in an open tank and they were tested at 7 and 28 days.

Table 11: Tensile Strength Test Results

MIX ID	Average Tensile strength in N/mm²	
	7 days	28 days
CCM40	3.70	4.54
CCSCC	3.24	4.22
M1	3.02	4.23
M2	3.40	4.25
M3	2.18	4.35
M4	3.20	4.50
M5	3.45	4.75
M6	3.50	4.80
M7	3.75	4.94
M8	3.43	4.20
M9	3.45	4.30
M10	3.80	4.40
M11	3.95	4.99
M12	3.25	4.20

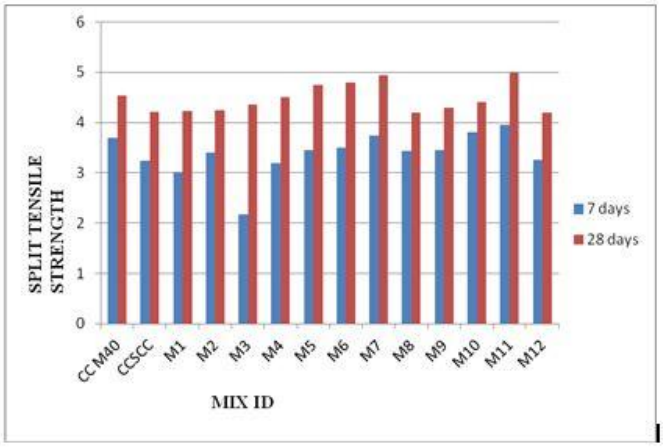

Chart 2: Split Tensile Strength Test Results

Flexural Strength Test: Prism specimen of size 100x100x500mm were casted and tested for 7 and 28 days strength

Table 12: Flexural Strength Test Results

MIX ID	Average Flexural strength in N/mm^2	
	7 days	28 days
CC M40	3.72	4.56
CCSCC	3.26	4.24
M1	3.04	4.25
M2	3.42	4.27
M3	2.20	4.37
M4	3.22	4.52
M5	3.48	4.78
M6	3.52	4.82
M7	3.78	4.95
M8	3.45	4.22
M9	3.47	4.32
M10	3.80	4.40
M11	3.98	5.00
M12	3.28	4.22

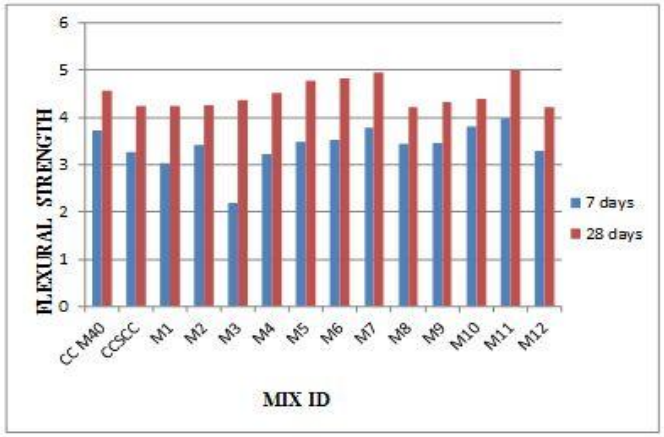

Chart 3: Flexural Strength Test Results

5. CONCLUSIONS

The following conclusions are drawn after replacing Cement with GGBS and Fly ash in varying percentages along with steel fibres to produce high strength Steel fibre reinforced self compacting concrete

1. Comparing varying percentage of fly ash used in the research, it was observed that maximum values of compressive strength, Tensile strength and Flexural strength was obtained for Mix M4 containing 60% Fly ash and 2% steel fibres

2. Similarly when the results of GGBS replacement were studied it was found that Mix M7 containing 45% GGBS and 2% steel fibres gives maximum values for compression, tensile and flexural strength.

3. Apart from this when the combined effect of GGBS and Fly ash was observed it was seen that Mix M11 containing 22.5% Fly ash and 22.5% GGBS and 1.5% steel fibres gives maximum values for all three strength test results

4. Hence it was concluded that both fly ash and GGBS can be used as an alternative for cement to a certain extent however GGBS was found to be more efficient compared to GGBS

5. When both fly ash and GGBS are easily available they can be used as a combined replacement for cement upto 45% along with steel fibres to produce high strength steel fibre reinforced SCC

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