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STUDY ON PROPERTIES OF GLASS FIBER REINFORCED SELF COMPACTING CONCRETE (GFRSCC) USING FLY ASH

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***Abstract*—Self-compacting concrete (SCC) is a high performance concrete characterized by better workability, its ability to flow under is own weight, completely filing the formwork without any segregation or bleeding and consolidation without the need of vibration. It is more desirable to use in concreting as it can be used in more complex molds, in congested reinforcement and lean structures due to the high early strength gain , lower construction time and costs. Hence, the use of Self-Compacting Concrete (SCC) has a tremendous acceptance in the construction industry and hence requires extensive research. The objective of this paper presents the details on the experimental investigation of finding the effective use of Class C Fly Ash in Glass Fiber Reinforced Self-Compacting Concrete (SCC). Mixtures with the inclusion of Glass Fibers (GFs) and containing FA at replacement rates of 0%, 20%, 40%, 60% cement mass were prepared. Fresh Properties were determined by Slump Flow, T_{50} cm Slump Flow, V Funnel and L Box Apparatus and its corresponding hardened properties of Compression strength, Split tensile strength and Flexural Strength were determined. Results showed that the best properties of GFRSCC was obtained when FA was added at a replacement rate of 40% cement mass.**

***Index Terms*—SCC, GFRSCC, Fly Ash, Glass Fibers, Self-Compacting Concrete**

I. INTRODUCTION

The growing use of concrete in special architectural configurations and closely spaced reinforcing bars has made it necessary to produce concrete that ensures proper filling ability, good structural performance and adequate durability. Self- compacting concrete (SCC) is an innovative concrete that does not requires vibration for placing and compaction. It has the ability to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. Hence, the use of Self-Compacting Concrete (SCC) has a tremendous acceptance rate in the construction industry and hence requires extensive research.

Fly Ash, Silica Fume, Metakaoline, Blast Furnace Slag are some fine industrial wastes having pozzolanic properties and hence can be used in concrete. The ecological trend nowadays aims at limiting the use of natural raw materials in the field of building materials and increasing the use of alternative materials from these various industrial wastes (by-product), which have shown significant advantages in economic, energetic and environmental terms. One of such industrial wastes is fly ash which shows pozzolanic properties. The addition of Fly Ash results in sufficient viscosity consequently increasing workability, reducing bleeding, segregation and plastic shrinkage. It also increases the hardened concrete properties such as compressive, indirect tensile and flexural strengths.

This study focuses on the effective use of Fly Ash in improving the properties of SCC reinforced with Glass Fibers (GFs). The addition of glass fibers improves the ductility, post crack resistance, energy absorption capacity and bleeding resistance.

SCC requires the addition of Superplasticizers (SP) to achieve the desired workability and appropriate mix proportions. The addition of Glass Fibers to SCC slightly reduces its workability. Fly Ash aims to compensate this workability loss as it increases the viscosity of the mixtures as well as avoids the use of adding a Viscosity Modifying Admixture (VMA) to increase the viscosity of the fresh concrete.

In this study, FA was added at replacement rates of 0%, 20%, 40%, 60% cement mass. Slump Flow, $T_{50\,cm}$ Slump Flow, V-Funnel and L-Box tests were conducted on fresh concrete. In addition, compressive, flexural and tensile strengths of hardened concrete at ages 7 and 28 days were investigated.

II. MATERIALS AND METHODOLOGY

A. Materials

1. Cement: Ordinary Portland Cement (OPC) of 43 Grade was used in the present investigation. All tests were performed based on methods conforming to IS 4031. The cement characteristics conform to IS 8112:2013. Table 1 shows the physical characteristics of cement.

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TABLE 1. Physical Characteristics of Cement

Sl. no	Material Property	Results Obtained	Requirements as per IS 8112
1.	Fineness of Cement	4%	Max 10%
2.	Relative Density (SG)	3.316	2.99 – 3.15
3.	Normal Consistency	37%	
4.	Time to Set Initial Final	 59 min 361 min	 Minimum 30 min Maximum 600 min
5.	Strength of Compression 7 days 28 days	 35.07 MPa 47.7 MPa	 >33 >43

2. Fly Ash: Fly Ash of Class C was used for cement substitution. The Fly Ash used in this experiment was obtained from Raichur Thermal Power Station, Karnataka. The Relative Density(SG) of fly ash used was 2.17.

3. Fine Aggregates: M-Sand conforming to Zone-2 of IS 383-1970 was used in this experiment. The Physical characteristics and grading analysis of FAs is shown in Table 2 and 3 respectively.

TABLE 2. Physical Characteristics of Fine Aggregates

Sl. no	Material Property	Results Obtained	Requirements as per IS 383-1970
1.	Relative Density(SG)	2.537	Max 2.75
2.	Mass Density 1)Dense State 2)Loose State	(kg/m^3) 2403.72 1711.33	
3.	Water absorption	1.6%	Max 2%
4.	Packing Factor	1.404	

TABLE 3. Grading analysis of Fine Aggregates

Sl. no	Material Property	Cumulative % passing of Fine aggregate	Specification for Zone-2 as per IS 383-1970
1.	10mm	100	-
2.	4.75mm	100	90-100
3.	2.36mm	100	75-100
4.	1.18mm	89.95	55-90
5.	600 microns	53.48	35-59
6.	300 microns	31.5	8-30
7.	150 microns	0	0-10
8.	pan	0	0

3. Coarse Aggregates: Graded aggregate of nominal size 12.5mm conforming to IS 383-1970 was used in this experiment. The Physical characteristics and grading analysis of FAs is shown in Table 4 and 5 respectively.

TABLE 4. Physical Characteristics of Coarse Aggregates

Sl. no	Material Property	Results Obtained	Requirements as per IS 383-1970
1.	Relative Density(SG)	2.64	Max 2.85
2.	Mass Density 1)Dense State 2)Loose State	(kg/m^3) 2197.12 1793.57	
3.	Water absorption	0.2%	Max 0.6%
4.	Packing Factor	1.225	

TABLE 5. Grading analysis of Coarse Aggregates

Sl. no	Material Property	Cumulative % passing of Fine aggregate	Specification for Zone-2 as per IS 383-1970
1.	12.5 mm	100	90-100
2.	10 mm	83.63	40-85
3.	4.75 mm	8.5	0-10
4.	pan	7.87	-

4. Glass Fibers: Anti-Crak HP 67/36 Macro Glass Fiber was used in the experiment. The length of the glass filament was 36mm and its aspect ratio – 1:67. The diameter of the filament is 19µm. The fiber is alkali resistant in nature to avoid reaction with the alkaline nature of the cement.

5. Superplasticizer: Fosroc Conplast SP430 high range super-plasticizing admixture was used as the chemical admixture for SCC mixes to provide the necessary workability. The admixture complies with IS:1903-1999 and BS 5057.

B. Methodology

Mix Design: Mix design methods for SCC differ considerably from the regular conventional concrete design. There are various methods of designing SCC. There is no standard method for SCC mix design and many academic institutions, academic, ready-mix, pre-cast and contracting companies have developed their own mix proportioning methods. The mix design was done for M40 grade concrete. The mix design methods used here are based on the following methods:

- EFNARC 2005 Specification for SCC – Guidelines
- "A Simple mix design method for Self-Compacting Concrete" by Nan Su, Kung-Chung Hsu, His-Wen Chu

TABLE 6. Trial Design Mixes

Design Strength	*Trial Mix ID*	*Cement (kg/m³)*	*CA (kg/m³)*	*FA (kg/m³)*	*Water/Cement ratio*	*Water (lit/m³)*	*Fly Ash Replacement*	*Fly Ash (kg/m³)*	*GF(0.1%) (kg/m³)*	*SP(1.5%) (lit/m³)*
M40	TM0	285.71	1098.56	1201.35	0.5	140.71	0%	0	5	4.3
M40	TM1	228.54	1098.56	1201.35	0.5	140.71	20%	57.14	5	4.3
M40	TM2	171.43	1098.56	1201.35	0.5	140.71	40%	114.28	5	4.3
M40	TM3	114.28	1098.56	1201.35	0.5	140.71	60%	171.43	5	4.3

Trial Mixes: The trial mixes were designed with varying the proportions of fly ash added to the SCC mix ranging from 0% to 60% at 20% intervals keeping the percentage of Glass Fibers constant at 0.1% of total volume of mix. The quantity of glass fibers and superplasticizer that should be added were set from previous studies.

Test Specimens: The Test Specimens consisted of cubes of 150mm x 150mm, cylinder of 100mm diameter and 200mm depth and Beams of 150 x 150 x 700 mm was used. 3 Trials for each trial mix was taken for each of the molds.

Testing of Specimens:

- *Fresh Properties:* The following tests were conducted on fresh mixes of SCC to access its workability properties.
    - Slump Flow Test
    - $T_{50\ cm}$ Time
    - V- Funnel
    - L-Box
- *Hardened Properties:* The following tests were conducted on 7 days & 28 days cured specimens.
    - Compressive Strength test
    - Split tensile strength test
    - Flexural strength test

In order to reduce the influence of workability loss on tests results of concrete samples, properties of fresh concrete were determined within 20 minutes of adding water. All the tests were performed in accordance with the European Guidelines for Self-Compacting Concrete (EFNARC) standards. The strength tests were performed conforming to IS 516 : 1959.

III. RESULTS AND DISCUSSION

Properties of Fresh Concrete:

The results for the slump flow tests are given in Table 7. The results represent the maximum spread (final diameter of the slump flow) and T_{50} cm which represent the time required for the concrete flow to fill a 50 cm diameter circle. EFNARC recommends that concrete mixtures should have a slump flow diameters of 55 cm to 75 cm to be considered a self-compacting mixture. Slump flow that exceeds a 75 cm diameter may cause concrete to segregate, whereas that with less than a 55 cm diameter may indicate concrete with flow rates that are insufficient for passing through an overcrowded reinforcement. The $T_{50\ cm}$ time is expected to be between 2 to 5s in case of SCC. The results showed that the workability of the concrete increased with the increase in the addition of FA in the concrete mixture. All mixtures showed optimum slump flow value and $T_{50\ cm}$ times. This increase in workability and filling ability of GFRSCC can be attributed to the addition of Fly Ash. The small size and essentially spherical size of Fly Ash particles may have increased the workability of the SCC mixes by providing a lubricating behavior for the various components of the concrete mix.

In addition to the slump flow test and slump flow $T_{50\ cm}$ time, the V-funnel test was conducted to estimate the filling ability of GFRSCC. The EFNARC Guidelines recommends that the flow time in V-funnel test should be between 8 to 12 s. Similar to slump flow tests, this test showed an increase in the workability of GFRSCC with the increase in the percentage of Fly Ash replaced. The V-funnel time remained almost same showing negligible improvements in time(s). Similarly, L-Box test was conducted to estimate the passing ability of the SCC. This test estimates the flow of concrete when the concrete is subjected to reinforcement. The Test results showed satisfactory results in terms of passing ability. They showed negligible improvement in the passing ability with the increase in the addition of Fly Ash. The H2/H1 ratio should be greater than 0.80 to be considered as SCC as per EFNARC Guidelines. All the mixes showed satisfactory results in terms of Passing ability. Table 8 shows the results of V-funnel and L-box tests.

TABLE 7. Results of Slump Flow Tests

Sl. no	*Trial Mix*	*Slump Flow (cm)*	*$T_{50\ cm}$ (s)*
1.	TM0	632	6.9
2.	TM1	645	6.7
3.	TM2	652	6.5
4.	TM3	659	6.2

TABLE 8. Results of V-Funnel and L-Box Tests

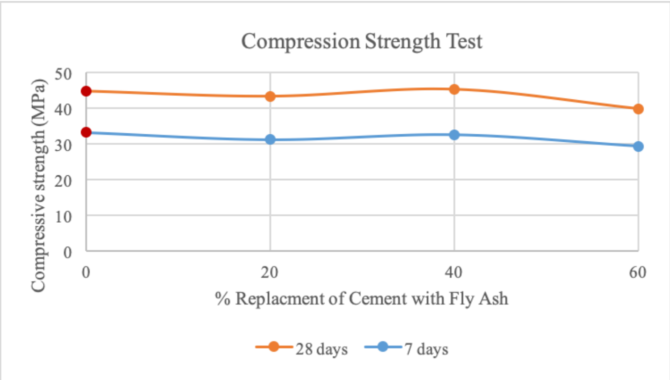
Sl. no	*Trial Mix*	*V-Funnel (s)*	*L-Box ratio (H_2/H_1)*
1.	TM0	12	0.82
2.	TM1	12	0.83
3.	TM2	11	0.83
4.	TM3	11	0.84

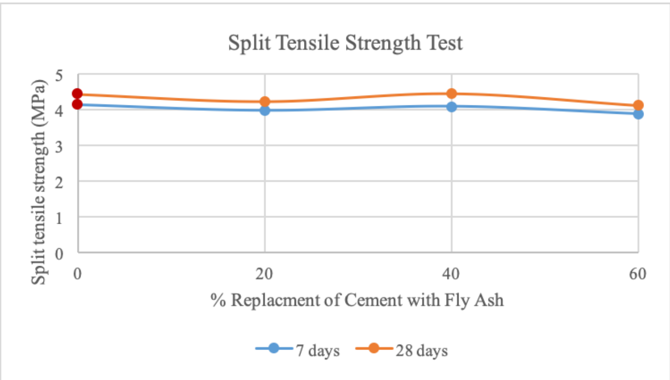
TABLE 9. Results of Properties of Hardened Concrete

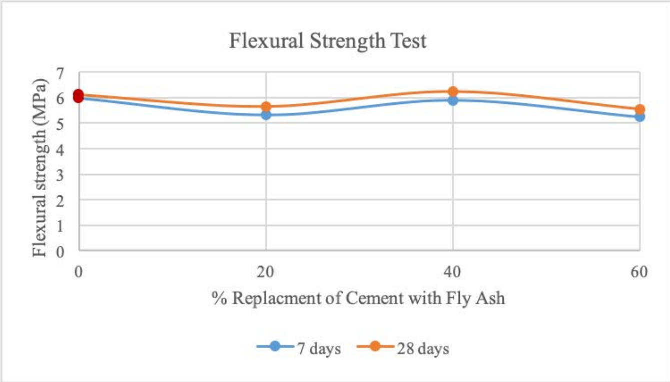
Sl. no	Trial Mix	*Compression Strength Test (MPa)*		*Split Tensile Strength Test (MPa)*		*Flexural Strength Test (MPa)*	
		7 days	*28 days*	*7days*	*28 days*	*7days*	*28 days*
1.	TM0	33.21	44.72	4.13	4.43	5.97	6.1
2.	TM1	31.21	43.31	3.98	4.23	5.32	5.64
3.	TM2	32.62	45.24	4.09	4.45	5.89	6.23
4.	TM3	29.42	39.89	3.89	4.12	5.24	5.54

Properties of Hardened Concrete:

Table 9 shows the results of the various tests done to the hardened specimens of various mixes. The results showed that compressive strength increased at 40% replacement rate when compared to GFRSCC without fly ash. The 20% and 60% replacement rates showed a decline in compressive strength due to addition of Fly Ash. Similarly, Flexural strength and Split Tensile showed similar results with 40% replacement rate of Fly Ash showed optimum strengths when compared to GFRSCC without Fly Ash. The 60% replacement rate showed greater decrease in the strengths maybe due to the late reactivity, strength development of Fly Ash. The below figures shows a representation of the variation of strengths with different replacement rates.







IV. CONCLUSION

The following conclusions were drawn from the results of this study:

1. The addition of FA positively affected the properties of fresh concrete and hardened concrete at all intervals of replacements.
2. The addition of FA increased the workability properties of GFRSCC with the increase in replacement levels when compared to GFRSCC without Fly Ash.
3. However, optimum strengths for hardened concrete samples were found at replacement rates of 40% with Fly Ash. Compressive strength achieved 45.24 MPa when FA was added at replacement rates of 40%.
4. The improvements of strength of GFRSCC with 40% Fly Ash over GFRSCC without Fly Ash is negligible. However, the workability of fresh concrete of GFRSCC with 40% replacement Fly Ash increased by 11% than GFRSCC without Fly Ash.
5. The increase in workability and strength provides a reason to use and replace Cement with Fly Ash in SCC. The increase in workability also compensates for the workability loss due to the addition of Fly Ash. Also, the use of Fly Ash reduces the overall economics of concrete construction.

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