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Experimental methods of investigation on glass fibre reinforced self-compaction concrete

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ABSTRACT

Self-Compacting Concrete (SCC) is skilled to flow using its own weight and entirely fill the formwork, in spite of reinforcements in place, without compaction, while maintaining homogeneity of the concrete. Usage of SCC will solve the compacting difficulty while casting and reduce manpower requirement. Adding fibres will enhance the tensile behaviour of concrete. SCC was added with moderately discrete, short and irregular glass fibers to produce Glass Fibre Reinforced Self Compacting Concrete (GFRSCC). The different lengths of fibres (1.2mm, 1.8mm and 2.4mm) were introduced in to the self-compacting mix with different percentages (0%, 0.25%, 0.5%, 0.75% and 1%). All SCC and GFRSCC mixes developed satisfy the requirements of self-compacting concrete specified by EFNARC. The maximum dosage of fibres which can be added without compromising the flow characteristics of the self-compacting concrete was found to be up to 1% addition of glass fiber. The main aim of this study is to examine the workability and mechanical properties of plain SCC and GFRSCC. The laboratory experimental investigation includes slump flow test, L-Box test, compressive strength test, splitting tensile strength test, and flexural strength test were carried out. It was observed that the quantity of super plasticizer required increased as fibre content increased. From the experimental study it was established that the maximum percentage increase in compressive strength with respect to the reference SCC mix is 13.5% and it is obtained from the mix containing 1% of S-glass fibres of length 2.4 mm (SCC 12).

KEY WORDS: SCC; GFRSCC; slump flow; glass fibre; super plasticizer.

1. INTRODUCTION

Production of durable cement concrete at the construction site is still a very big problem for the construction industry despite various technological advancements. For producing durable concrete proper compaction is necessary which helps to reduce the voids in the concrete. However it is not done in many of the construction sites leading to reduced quality of concrete. Compaction is done using vibration from power equipment which leads to highly undesirable noise, increased construction time and labour and sometimes injurious to workers. Hence to overcome all these difficulties Self-Compacting Concrete (SCC) was produced in Japan in the end of 1980s as a solution to achieve durable concrete structures independent of the quality of construction work.

SCC can be defined as a concrete which has high flowability when placed can fill entire formwork under its own weight even when reinforcements are closely spaced without any external compaction. SCC in its fresh state is characterised by high flowability and greater strength in its hardened state because of its compact matrix structure. SCC has many advantages that include quicker construction, easier insertion, better surface finishing, and decrease in noise levels and enhanced durability.

The term Fibre Reinforced Concrete (FRC) can be defined as concrete having randomly oriented and dispersed fibres. Fibres can be described as thin wire-like reinforcements which are made of either steel or polymers having high ductility. The fibres are produced in variety of sizes and shapes, stiff or flexible etc. Addition of fibres into concrete improves the ductility of the concrete by developing toughness, greater tensile strength, and resistance to impact, fatigue, blast loading and abrasion. Fibres are more importantly added to control the cracking, by the bridging of the fibres across the cracks, which delay the development of localized cracks.

The usage of glass fibres in SCC might bring both the advantages of both fibres and SCC. Glass Fibre Reinforced Self-Compacting Concrete (GFRSCC) gives the advantages of SCC in its fresh state and that of fibres in its hardened state. Because of the greater performance of SCC in its fresh state, addition of fibres will lead to a more uniform dispersion of fibres which is very critical for the performance of any fibre reinforced concrete. Even the density of SCC matrix due to higher amount of finer particles may improve the interface zone properties and as a result the fibre-matrix bond leading to better post-cracking toughness and energy absorption capacity. The objective of this experimental work is to find out the maximum dosage of fibres that can be added without compromising the flow characteristics of the self-compacting concrete and to study the effective utilization of glass fibre in self-compacting concrete by conducting the corresponding tests for the following properties like workability, Compressive strength and Split tensile strength.

2. MATERIALS AND METHODS

Coarse aggregate: Coarse aggregate shall satisfy the requirement of IS 383-1970. The nominal maximum size of coarse aggregate used in this study is 12mm.Table I. shows the different physical properties of coarse aggregate.

Table.1.Physical properties of coarse aggregate

Properties	Values
Specific gravity of C.A	2.71
Bulk Density in loose state	1346.7 kg/m³
Bulk Density in compacted state	1480.07 kg/m³
Crushing strength	19.93%
Impact strength	8.97%

Fine aggregates: Fine aggregates shall conform to the requirement of IS 383. The sand was washed and screened at site to remove deleterious materials and tested as per the procedure given in IS: 2386-1968 and the results were tabulated. Table.2.shows the physical properties of fine aggregate.

Table.2.Physical properties of fine aggregate

Properties	Values
Specific gravity	2.45
Bulk Density in loose state	1294.87 kg/m³
Bulk Density in compacted state	1442.16 kg/m³
Fineness Modules	3.2
Zone	II

Cement: For the present investigation, ordinary Portland cement (Coromandel King) of 53 grade conforming to IS 12269-1987 was used. Physical properties of cement are shown in Table.3.

Table.3.Physical properties of cement

Properties	Values
Specific gravity	3.15
Consistency	31%
Initial setting time	40 minutes
Final setting time	300 minutes

Fly Ash: Class F Fly ash conforming to IS 3812-1999 is used as a Mineral admixture for partial replacement of cement. Fly ash is procured from Ennore Thermal power station. The value of specific gravity of Fly ash is found to be 2.46. Chemical properties & Physical Composition of Class F fly ash are shown in Table 4& Table 5.

Table.4.Chemical composition of class f fly ash (as per ASTM c618)

Compound	Content in % of weight
Silicon di oxide, SiO_2	59
Alumina, Al_2O_3	21
Iron Oxide, Fe_2O_3	3.7
Calcium Oxide, CaO	6.9
Magnesium Oxide, MgO	1.4
Sulphur Trioxide, SO_3	1
Potassium Oxide, K_2O	0.9

Table.5.Physical properties of class f fly ash

Properties	Value
Colour	Whitish Grey
Bulk Density (g/cm3)	0.994
Specific Gravity	2.288
Moisture	3.14%
Average particle size (µm)	6.94

Glass Fibre: S-glass fibre which is used in this study is an alumino silicate glass without CaO but with high MgO content. S stands for its tensile strength. S-Glass fibre has high tensile strength, compressive strength and softening temperature when compared to other types of fibres. Physical and chemical properties of S-glass fibre are shown in Table 6 and Table 7.

Table.6.physical properties of S- glass fibre

Properties	Values
Type	S- GLASS
Density (g/cm^3)	2.46
Compressive Strength (MPa)	4890
Tensile Strength (MPa)	1600
Thermal Expansion (µm/˚C)	2.9
Softening Temperature (˚C)	1056

Table.7.Chemical composition of S- glass fibre

Compound	Content in % of weight
Silicon di oxide, SiO_2	65
Alumina, Al_2O_3	25
Magnesium Oxide, MgO	10

Superplasticiser: Polycarboxylic ether based superplasticiser (Conplast SP430) complying with ASTM C-494 type F was used in this study.

Test Methods: Fresh properties of SCC are studied by Slump Flow, V-Funnel and L-Box. Hardened properties of SCC are characterized by compressive strength test and spilt tensile strength test.

Experimental Investigation:

Mix Proportion for SCC and GFRSCC: After conducting the several trial mixes in the lab, the following mix proportion satisfies all the requirements of SCC in fresh state. The final Mix proportion is shown in Table VIII and water powder ratio is 0.36:1. About 30% of cement was replaced by Fly Ash. This SCC mix satisfies all conditions for SCC as per Annex-J in IS 456. Since there is no proper design procedure is available for SCC, the final mix proportions were designed based on the method of trial and error in which various proportions of fly ash and super plasticizer have been tried to find the mix giving the appropriate workability to meet the self-compacting standards. The different lengths of fibres (1.2mm, 1.8mm and 2.4mm) were added to the self-compacting mix with different percentages (0%, 0.25%, 0.5%, 0.75% and 1%) and mix trials of GFRSCC are shown in Table 10.

Table.8.Mix proportion of SCC

SCC Constituents	Values
Water	180 Kg/m^3
Cement	350 Kg/m^3
Fly ash	150 Kg/m^3
Fine aggregate	850 Kg/m^3
Coarse aggregate	920 Kg/m^3
Super Plasticiser	1% of cementious material

Table.9.Mix Trial of GFRSCC

Designation	Mix proportion
SCC 1	S0.25%G1a
SCC 2	S0.50%G1
SCC 3	S0.75%G1
SCC 4	S1%G1
SCC 5	S0.25%G2
SCC 6	S0.50%G2
SCC 7	S0.75%G2
SCC 8	S1%G2
SCC 9	S0.25%G3
SCC 10	S0.50%G3
SCC 11	S0.75%G3
SCC 12	S1%G3

[a]0.25% of S-glass fibre content with respect to the binder ratio of length G1
(G1-1.2mm; G2-1.8mm; G3-2.4mm)

Casting of Specimen: Cubes of size 150 x 150 x 150 mm for compressive strength test and cylinder of size 150 mm diameter and 300 mm length for split tensile strength test were cast for this study. The moulds were cleaned properly with dry cloth and oil was applied before casting. Cement and Fly ash were mixed together properly. The amount of fine aggregates, coarse aggregates were measured based on their weight and then they were mixed and then powders were added. Water was added gradually till uniform mix was formed. Finally super plasticers and viscosity modifying agent were added to the concrete together with water. After mixing, the fresh concrete were tested for its flow properties like slump flow test, V-box test, and L-box test. For GFRSCC, fibres were added gradually with SCC. Concrete was then filled in mould. After 36 hours the specimens were demoulded and then they were put into the curing tank for required period. Fig 1 shows the casting of specimen.

Figure.1.Casting of specimen

Tests for Fresh Properties of SCC:

Slump flow test: The slump-flow Test is used to measure the horizontal flow and the flow rate of SCC in the absence of any obstruction. Flowability was determined by measuring T_{500} which is the time required for the concrete to spread to a diameter of 500 mm. For higher slump flow value, greater is its ability to fill formwork under its self-weight. Under EFNARC guidelines, a value of at least 650mm is recommended for SCC.

V- Funnel Test: This test determines the ease of flow of the concrete; lesser flow times indicate greater flowability. For SCC 10 seconds of flow time is considered appropriate under EFNARC guidelines. The inverted cone shape restricts flow, and some indication of the vulnerability of the mix to get blocked might be given by prolonged flow times. After 5 minutes of settling, increase in flow time will indicate a less continuous flow with segregation of concrete.

L- Box Test: This test determines the flow of the concrete, and also the extent of blocking by reinforcement. The concrete is filled in the vertical section, and then the gate opened to introduce the concrete flow into the horizontal section. The height of the concrete at the end of the horizontal section is expressed as a proportion of that left out in the vertical section, when flow stops. The slope of the concrete at rest indicates the passing ability. Table X. shows the various recommended limits for different properties of SCC as per EFNARC guidelines.

Table.10.Recommended Limits for Different Properties of SCC

Property	Range	Property
Slump Flow Diameter	500-700 mm	Filling ability
T_{500}	2-5 sec	Filling ability
V-funnel	8-12 sec	Passing ability
V-funnel-T_5	11-15sec	Segregation resistance
L-Box (H_2/H_1)	≥ 0.8	Passing ability

Compressive strength test: Compressive strength test is the most common of all tests on hardened concrete and compressive strength is the most vital parameter in structural design. One standard cube of 150 mm size were produced for each mix. The compressive strength test was carried out according to IS 516-1959 at ages of 7 and 28 days. The specimen were placed in the compression testing machine (CTM) in such a manner that the load were applied at exact center of concrete cube and also to opposite sides of the cubes as cast, that is, not to the top and bottom. The load were applied devoid of shock and increased constantly at a rate of 140 kg/sq cm/min till the resistance of the specimen to the increasing load breaks down and no more load can be withstood. The maximum load applied to the specimen was recorded. The testing apparatus is shown in Figure 2.

Figure.2.Compressive Strength test Setup and Crack Pattern

Split tensile strength test: Cylindrical specimens of height 300 mm and diameter 100 mm were cast and cured for 28 days and then specimens were tested. The test was carried out by placing the cylindrical specimen horizontally between the loading surfaces of compressive testing machine and the load was applied until the failure of the cylinder, along vertical diameter takes place. The following figure 3 shows the experimental set up and crack pattern. Split-tensile strength is calculated using the following formula,

Split tensile strength, $f_t = 2P/\pi LD$

Where, P is the compressive load on the cylinder

L is the length of the cylinder

D is the diameter of the cylinder

Figure.3.Split tensile strength test setup and crack pattern

3. RESULTS AND DISCUSSION

Workaility test results for SCC and GFRSCC: Slump flow, V-funnel and L-box tests were performed in the laboratory on fresh SCC and GFRSCC. The test results were found to be within prescribed limits as per the EFNARC specifications. The fresh properties of SCC and GFRSCC are shown in Tables 11.

Table.11.Workabilty test results for SCC & GFRSCC

Designation	Slump flow (mm)	T_{500} (sec)	V-Funnel (sec)	V-Funnel at T_5 (sec)	L-Box (H_2/H_1)
SCC	720	2	7	9	0.82
SCC 1	705	2.5	8	10	0.89
SCC 2	695	3	9	11.5	0.93
SCC 3	670	4.1	9.5	13	0.99
SCC 4	650	5	10	15	1.1
SCC 5	701	2.5	7.5	10.5	0.9
SCC 6	690	3	8.5	12	0.95
SCC 7	665	4	9	13	1.0
SCC 8	645	5	10.5	15.5	1.2
SCC 9	690	3	8	11	0.91
SCC 10	680	4.5	8.9	12.5	0.96
SCC 11	660	5	9.6	14	1.1
SCC12	635	6	11	16	1.4

T_{500}: time taken for concrete to reach the 500 mm spread circle

T_f: V-funnel flow time after keeping the concrete in funnel for 10 sec.

T_{5min}: V-funnel flow time after keeping the concrete in funnel for 5 sec

H_1, H_2: Heights of the concrete at both ends of horizontal section of L-box after allowing the concrete to flow

Compressive Strength Test Results for SCC and GFRSCC: Compressive strength tests were carried out on cubes of 150 mm size using a CTM of 1000 KN capacity as per IS 516:1959. The compressive strength test was carried out according to IS 516-1959 at ages of 7 and 28 days and the results were tabulated in Table XII. From the test results, it is found that at 1% volume of fibers (length of fiber 2.4mm), the compressive strength was higher than other lengths of fibers and was 15% higher when compared to the SCC concrete.

Split Tensile Strength Test Results for SCC and GFRSCC: Split tensile strength tests were carried out on cylinders of 150 mm diameter and 300 mm height using a compression testing machine of 1000 KN capacity as per IS 516:1959. From the test results, it is found that at 1% volume of fibres (length of fibre 2.4mm), the flexural strength was higher than other lengths of fibers and was 13% higher when compared to the control concrete. Table XIII shows the split tensile strength test results.

Table.12.Compressive strength results at 7 and 28 days

Designation	Compressive strength (N/mm2)	
	7 days	28 days (f_{ck})
SCC	24	32
S0.25%G1	26	32.5
S0.50%G1	27	33
S0.75%G1	28.5	34
S1%G1	30	35
S0.25%G2	26.5	33
S0.50%G2	28	34
S0.75%G2	29	35.5
S1%G2	30.5	36
S0.25%G3	27	33.5
S0.50%G3	28.5	35
S0.75%G3	29.5	36
S1%G3	31	37

Table.13.Split tensile strength results

Designation	Split tensile strength at 28 days(N/mm2)
SCC	3.13
S0.25%G1	3.20
S0.50%G1	3.29
S0.75%G1	3.34
S1%G1	3.40
S0.25%G2	3.26
S0.50%G2	3.35
S0.75%G2	3.42
S1%G2	3.49
S0.25%G3	3.33
S0.50%G3	3.40
S0.75%G3	3.45
S1%G3	3.52

4. CONCLUSION

Based on the observations made during the various tests conducted on the SCC and GFRSCC specimens and also based on the results obtained from these tests, the salient features are concluded as follows:

1) All the SCC and GFRSCC mixes developed satisfy the requirements of self-compacting concrete specified by EFNARC, up to 1% addition of glass fiber does not affect the fresh concrete properties of SCC.

2) For a given length of S-glass fibre, the compressive strength of GFRSCC increases when the content of the S-glass fibres in the mix increases. For 1.2mm legth fibre 1% addition of glass fibre specimen was found to be 7.1% higher than 0.25% addition of glass fiber. In the same way for 1.8mm glass fiber its 8.3% and for 2.4mm its 9.4%.

3) The maximum percentage increase in compressive strength with respect to the reference SCC mix is 13.5% and it is obtained from the mix containing 1% of S-glass fibres of length 2.4 mm.

4) The splitting tensile strength also shows a similar trend as the compressive strength of the GFRSCC. The maximum percentage of increase in splitting tensile strength with respect to the reference SCC mix is 15% and it is obtained from the mix containing 1% of S-glass fibres of length 24 mm.

5) In general GFRSCC concrete behavior is better in strength characteristics than SCC.

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