Performance of Fiber Reinforced Self Compacting Concrete made with Manufactured Sand

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Abstract - *Concrete is one of prime constituent used in the field of construction around the world. Day by day the consumption of concrete for construction of RC structures increases rapidly due to the rapid urbanization and industrialization. Self compacting concrete is a innovative technology, that can be used in the construction industry when the conventional method of concreting is not possible. In this paper, self compacting concrete was made with the manufactured sand and with the addition of steel and polypropylene fibers. Grade of concrete utilized in this study is M30 and natural river sand was partially replaced from 0% to 100% at an interval of 20% while the application of steel and polypropylene fibers into the mix was kept constant as 0.5 to 2% at an interval of 0.5%. In order to change the viscosity of the SCC mixes, Class F Fly ash was used as a viscosity modifying agents. Performance of fiber reinforced self compacting concrete (FRSCC) was assessed by workability and mechanical strength properties of concrete specimens.*

Key Words: Fiber Reinforced Concrete, Self Compacting Concrete, Steel Fiber, Polypropylene Fiber, Mechanical Strength

1. INTRODUCTION

Concrete is one of the most widely used durable and versatile building materials. It has good compressive strength, durability and fire resistance and can be cast for any type of structure. It is not only strong, economical and aesthetically pleasing.

1.1 Self Compacting Concrete (SCC)

Okamura (1996) a leading scientist in Japan, after years of stringent research developed a new concrete known as SCC. It can capable of flowing and filling all parts and corners of the formwork, even if there is a tight reinforcement, using only its own weight and no vibration or other compaction is required. Since the use of SCC is highly desirable when the problems arises in the field are taken into account due to inadequate and adequate compaction as shown in Figure 1.

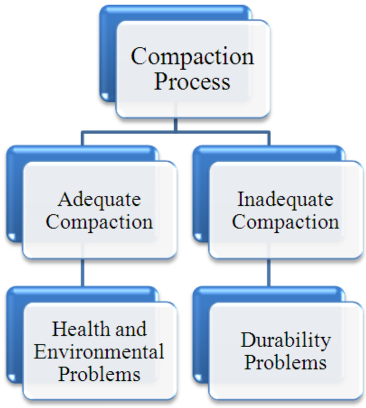


Fig -1: Problems caused due to Compaction

Fig -2: Self Compacting Concrete

1.2 Fiber Reinforced Concrete (FRC)

Concrete lends itself to a variety of innovative designs as a result of its many desirable properties. Not only can it be cast in diverse shapes, but it also possesses high compressive strength, stiffness, low thermal and electrical conductivity. Fiber reinforced concrete is the concrete in which fibers have been incorporated to strengthen a material that would otherwise be brittle. Fibers are added to a concrete mix, which normally contains cement, water and fine and coarse aggregate.

1.3 Manufactured Sand

Drastic deterioration in the availability of construction sand besides, the environmental persuasion to curtail the dredging of river sand has given a novel existence to the M-

Sand. The M-Sand is a secondary product of crushing and screening processes pursued in the quarries. Actually, MSand is an appreciable alternate in the construction industries as it best serves in reducing pollution with desirable efficacy. M-Sand has turned to be an apparent and apt admixture in concrete proportioning. The production of M Sand is a mandatory requisite to cater to the demands of the civil engineering industries.

1.3 Fiber Reinforced Self Compacting Concrete (FRSCC)

Fiber Reinforced SCC (FRSCC) combines the benefits of both SCC and FRC and has incredible potential to be used in the construction industry. Conventional reinforcing concrete structures can significantly deteriorate with time, necessitating regular and often costly maintenance.

Self-compacting concrete contains a fibrous material to increase its structural integrity. It contains short and discrete fibers that are evenly distributed and randomly aligned. The fibers used in the study, includes steel fibers and polypropylene fibers. With the use of these different fibers, the character of self-compression of concrete changes. The composition of SCC mixtures contains substantial proportions of inorganic fine-grained materials and chemical additives used for viscous phenomena.

2. REVIEW OF LITERATURES

A literature review or narrative review is a type of review article. A literature review is a scholarly paper, which includes the current knowledge including substantive findings, as well as theoretical and methodological contributions to a particular topic.

Khaloo et al (2014) have compared the workability of SFRSCC with four different volume fractions: 0.5%, 1%, 1.5% and 2%. Two mixes, medium strength and high strength, are used and it is found that as the percentage of volume fraction increases, the compressive strength decreases whereas the tensile strength, flexural strength and flexural toughness are increased with the increase in volume fraction.

Athiappan. and Vijaychandrakanth. (2014) have studied concrete beam reinforced with sisal fiber flexural behavior. M40 grade concrete with varying fiber dosage of 0.1%, 0.2%, 0.3%, 0.4% and 0.5% is taken and the mechanical properties, stress strain relation of the beam and crack pattern are studied. Super-plasticizer Enfiq super plast-400 is used. The use sisal fiber enhances the mechanical performance. Optimum percentage of sisal fiber for maximum strength is 0.3% is obtained. Modulus of rupture and workability decreases with increases of sisal fiber. Optimum dosage increases the ductility performance of concrete beam.

Kannan & Ganesan (2014) made different SCC mixes with RHA (5 to 30%), MK (5 to 30%) and a combination of MK and RHA (RHA5+MK5, RHA10+MK10, RHA15+MK15 and RHA20+MK20) using EFNARC (2005) specifications. Their study includes fresh state properties, compressive strength, water absorption, sorptivity and chloride ion penetration test. They reported that all the SCC mixes satisfied the fresh concrete properties.

Vejmelkova et al. (2011) investigated the properties such as rheological, mechanical and durability of SCC mixtures containing MK and blast furnace slag. Their results showed that MK blended SCC exhibited significant value of yield stress and low viscosity whereas blast furnace slag blended SCC showed zero yield stress and high viscosity. MK blended SCC showed good performance in all aspects like higher compressive, lower water transport properties, excellent freeze resistance and very good durability than blast furnace slag blended SCC.

Pai & Sujith (2009) have revealed the effects of silica fume on fiber reinforced SCC and found significant improvement in various strength of the concrete with the inclusion of steel fibers and silica fume. Maximum gain in strength depends on the optimum dosage of silica fume and fiber content.

A. Ravichandran, K. Suguna and P.N. Ragunath (2009) concluded that the use of 80% steel fibers and 20% polyolefin fibers at each volume fraction gave optimism mechanical properties. At hybrid Fibre of 2.0% volume fraction with 80-20% steel-polyolefin combination have more significant effect on mechanical properties. Strength models established by regression analysis give predictions matching the measurements of mechanical properties.

Crouch and Philips (2009) have used both river sand and manufactured limestone sand as fine aggregate in concrete mixtures. The mixtures exhibit comparable costs and increase the compressive strength of the concrete.

Cortes et al (2008) have studied the rheological and mechanical properties of mortar prepared with natural and M-Sand. Results show that the adequate flow and compressive strength could be attained when the volume of paste exceeds the volume of voids in the loosely packed aggregate, i.e. just above the maximum void ratio e_{max} of the fine aggregate.

Hajime and Masahiro (2003) discussed about mechanism for achieving self - compactability, factors of self - compactability in terms of test results, rational mix design method, new type of super plasticizer suitable for SCC and segregation-inhibiting agent. They concluded that rational mix design method and an appropriate acceptance testing method at job site have both largely been established for SCC.

3. MATERIALS USED & MIX DESIGN

3.1 Cement

Locally available Ordinary Portland Cement of 53 grade was used in this investigation.

Table -1: Properties of Cement

Property	Values	Recommendations
Standard consistency	31.5%	≥ 30%
Grade of Cement	53	For OPC 53, $f_{ck} \nless$ 53MPa
Specific Gravity	3.12	-
Initial Setting time	37 min	≮ 30 min
Final Setting Time	548 min	≯ 600 min

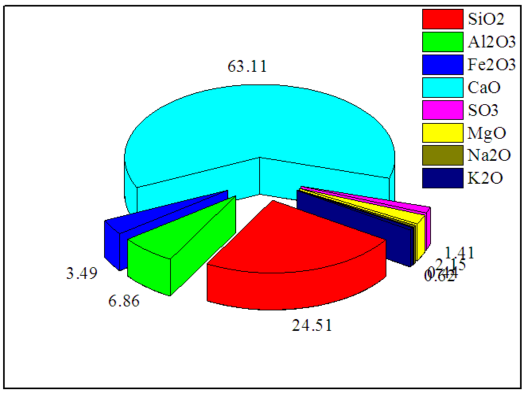


Fig -2: Chemical Composition of Cement

3.2 Natural River Sand

River sand passing through the 4.75mm sieve is used in this study. Natural river sand was obtained from the local source. The tests were carried out on river sand following the standards given in IS: 2386 1968 part 3.

3.3 Manufactured Sand

M-Sand is made by crushing rock depositions to create fine aggregate which is a lot more angular in shape and has rougher surface texture than river sand particles. The shape and texture of crushed sand particles could lead to improvements in the strength of concrete due to greater interlocking between particles.

Table -2: Properties of Fine Aggregate

Property	River Sand	M-Sand
Type	Natural	Crushed
Shape	Spherical	Spherical
Specific Gravity	2.42	2.88
Fineness Modulus	2.85	2.91
Bulk density	1835kg/m³	1805 kg/m³
Zone of Passing	Zone II	Zone II

3.4 Coarse Aggregate

Locally available, angular aggregate passing through 20 mm sieve and retained on 12.5 mm sieve and having a specific gravity of 2.69 as given in IS: 383 – 2016 is used.

3.5 Steel Fibers (SF)

Steel Fibers are filaments of wire, deformed and cut to lengths, for reinforcement of concrete, mortar and other composite materials. It is a cold drawn wire Fiber with corrugated and flatted shape. Steel fibers intended for reinforcing concrete are defined as short, discrete lengths of steel having an aspect ratio of 40.

Table -3: Properties of Steel Fibers

Specification	Values
Length	35 mm
Modulus of Elasticity	200 GPa
Fiber type	Straight, corrugated, hooked end

3.6 Polypropylene Fibers (PF)

Polypropylene Fibers, the most popular of the synthetics, are chemically inert, hydrophobic, and lightweight. They are produced as continuous cylindrical monofilaments that can be chopped to specified lengths or cut as films and tapes and formed into fine fibrils of rectangular cross section.

Table -4: Properties of Polypropylene Fibers

Specification	Values
Length	6 mm
Melt point	165°C
Fiber type	Monofilament

3.7 Viscosity Modifying Agents (VMA)

Fly ash was utilized as a VMA in the preparation of SCC. Fly ash is a residue from the combustion of pulverized coal collected by mechanical or electrostatic separators from the flue gases of thermal power plants. The spherical form of fly ash particles improves the flow ability & reduces the water demand. Fly ash obtained from Mettur thermal power station was used.

Table -5: Properties of Fly Ash

Property	Value
Color	Dark grey
Moisture content	3.0

Specific surface	320 m^2/kg
Fineness	18.2

3.7 Mix Proportioning

Mix design for Self compacting concrete has been adopted as per the guidelines given in IS 10262:2009 and EFNARC Specifications, to design for M30 grade of concrete.

Table -6: Mix Proportioning

Materials For CC Mix	By Weight (kg/m^3)	By Proportion
Cement	415.2	1
Fine aggregate	972.9	2.34
Coarse aggregate	687	1.65
Water	186.58	0.45
VMA	108.1	-
Super Plasticizer	3.25	-

4. EXPERIMENTAL INVESTIGATION

In order to determine the performance of fibers in the M30 grade fiber reinforced self compacting concrete was assessed by the tests on workability and strength properties.

4.1 Workability Tests

To examine the SCC fresh properties, recent properties such as the Slump flow test, the L-box test, U the box surface test and the V-funnel test were carried outwith Water cement ratio for fixed water for each SCC mixture and for better flowability super plasticizer was added into the mix.

Table -7: Workability Test Results

Specimen ID	Slump Flow (mm)	T50cm Slump Flow (Sec)	V – Funnel test (Sec)	J-Ring test H1-H2 (mm)	L-Box test H1/H2
CC	797	2.58	8.3	4	0.93
SFSC0.5	737	3.41	8.7	6	0.93
SFSC1.0	698	4.68	9.8	8	0.98
SFSC1.5	656	5.34	12.2	11	1.13
SFSC2.0	644	6.59	13.8	18	1.55
PFSC0.5	757	3.30	9.2	7	0.88
PFSC1.0	725	4.03	10.0	8	0.96
PFSC1.5	709	5.25	11.5	10	1.00
PFSC2.0	645	5.42	13.2	15	1.11

Table -8: Summary of Workability Test Results

Specimen ID	Slump Flow (mm)	T50cm Slump Flow (Sec)	V – Funnel test (Sec)	J-Ring test H1-H2 (mm)	L-Box test H1/H2
Typical Range	**650 - 800**	**2 - 5**	**6 - 12**	**0 - 10**	**0.8 – 1.0**
CC	✓	✓	✓	✓	✓
SFSC0.5	✓	✓	✓	✓	✓
SFSC1.0	✓	✓	✓	✓	✓
SFSC1.5	✓	x	x	x	x
SFSC2.0	x	x	x	x	x
PFSC0.5	✓	✓	✓	✓	✓
PFSC1.0	✓	✓	✓	✓	✓
PFSC1.5	✓	x	✓	✓	✓
PFSC2.0	x	x	x	x	x

Based on the various workability test, it was concluded that the optimum dosage of steel and polypropylene fiber content in the self compacting concrete was 1.0% and 1.5 % respectively.

4.2 Mechanical Strength Tests

Following are the tests were conducted on the self compacting concrete (SCC) with fibers, to determine its mechanical strength properties on various curing duration of 3 days, 7 days, 14 days and 28 days.

Table -9: Compressive Strength Test Results

Specimen ID	Average Compressive Strength (N/mm^2)			
	3 days	7 days	14 days	28 days
CC	16.5	24.2	38.2	42.6
SC1.0SF0MS	18.1	29.6	41.5	46.2
SC1.0SF20MS	18.9	31.1	42.6	47.4
SC1.0SF40MS	19.7	32.2	44.1	49.5
SC1.0SF60MS	20.8	33.4	46.2	51.8
SC1.0SF80MS	21.6	34.0	47.2	53.1
SC1.0SF100MS	22.5	35.2	48.1	54.1
SC1.5PF0MS	17.6	29	39.7	44.3
SC1.5PF20MS	18.0	29.6	40.3	45.1
SC1.5PF40MS	18.4	30.6	41.7	46.3
SC1.5PF60MS	19.3	31.2	43.2	47.4
SC1.5PF80MS	19.9	32.2	44.5	48.9
SC1.5PF100MS	20.5	33.4	45.8	50.5

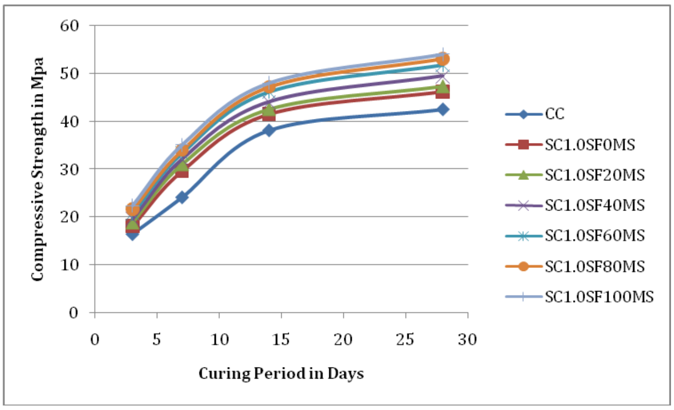


Chart -1: Compressive Strength of Specimens with SF

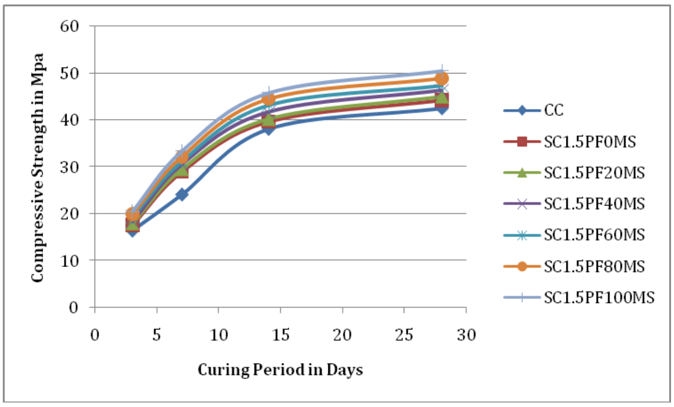


Chart -2: Compressive Strength of Specimens with PF

Table -10: Split Tensile Strength Test Results

Specimen ID	Average Split Tensile Strength (N/mm²)			
	3 days	7 days	14 days	28 days
CC	2.78	3.18	3.24	3.51
SC1.0SF0MS	2.91	3.66	3.84	3.97
SC1.0SF20MS	3.02	3.80	3.98	4.12
SC1.0SF40MS	3.12	3.93	4.12	4.26
SC1.0SF60MS	3.21	4.06	4.25	4.40
SC1.0SF80MS	3.30	4.18	4.29	4.54
SC1.0SF100MS	3.43	4.35	4.46	4.72
SC1.5PF0MS	2.87	3.6	3.8	3.91
SC1.5PF20MS	2.95	3.70	3.89	3.93
SC1.5PF40MS	3.04	3.81	4.01	4.05
SC1.5PF60MS	3.15	3.94	4.11	4.19
SC1.5PF80MS	3.24	4.08	4.23	4.34
SC1.5PF100MS	3.36	4.20	4.38	4.47

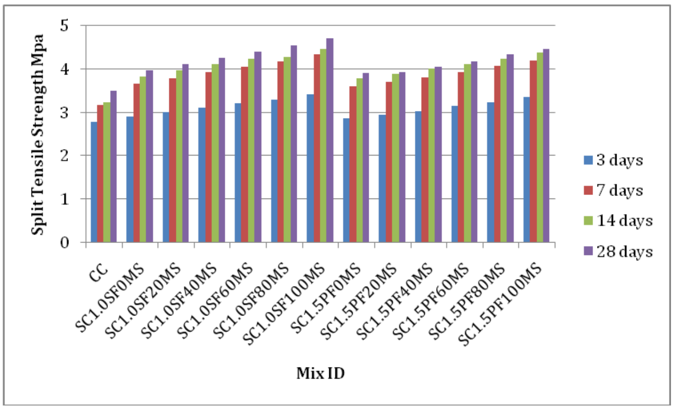
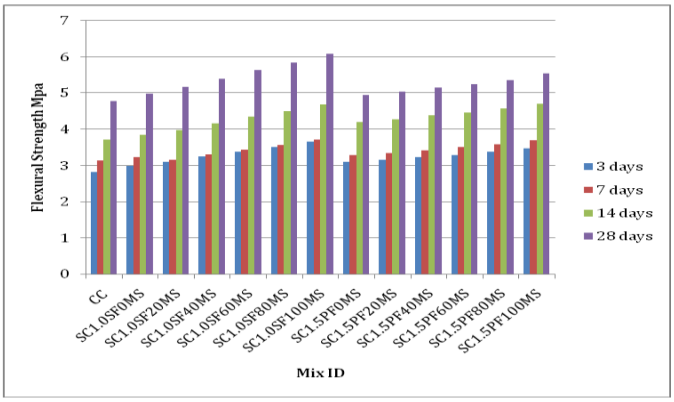


Chart -3: Split Tensile Strength of Specimens

Table -11: Flexural Strength Test Results

Specimen ID	Average Flexural Strength (N/mm²)			
	3 days	7 days	14 days	28 days
CC	2.82	3.13	3.72	4.78
SC1.0SF0MS	2.99	3.23	3.84	4.98
SC1.0SF20MS	3.10	3.15	3.98	5.17
SC1.0SF40MS	3.24	3.30	4.16	5.40
SC1.0SF60MS	3.38	3.44	4.34	5.63
SC1.0SF80MS	3.50	3.56	4.49	5.84
SC1.0SF100MS	3.66	3.72	4.69	6.09
SC1.5PF0MS	3.1	3.28	4.2	4.95
SC1.5PF20MS	3.16	3.34	4.28	5.04
SC1.5PF40MS	3.23	3.42	4.38	5.15
SC1.5PF60MS	3.28	3.50	4.46	5.24
SC1.5PF80MS	3.37	3.59	4.57	5.36
SC1.5PF100MS	3.47	3.69	4.70	5.54



5. CONCLUSIONS

The following are the conclusions are drawn from the experimental investigation done on the M30 grade fiber reinforced self compacting concrete made with partial replacement of river sand with M-Sand.

- The conventional mix satisfies all the workability tests without adding the fibers.
- Addition of 1% volume fraction of SF in SCC, satisfy the entire workability test whereas the addition of 1.5% volume fractions of PF in SCC also satisfies all the workability tests. But the addition of fibers beyond this fraction doesn't satisfy the workability parameters. Because the addition of fibers reduces the passing and filling ability and segregation resistance.
- The addition of fibers in the self compacting concrete will increases the mechanical strength properties.
- Compressive strength of FRSCC mixes with full replacement of M-Sand with the addition of SF and PF increases by 26.99% and 18.54% than the conventional concrete mixes at 28 days.
- Split Tensile strength FRSCC mixes with full replacement of M-Sand with the addition of SF and PF increases by 34.47% and 27.35% than the conventional concrete mixes at 28 days.
- Flexural strength of FRSCC mixes with full replacement of M-Sand with the addition of SF and PF increases by 27.4% and 15.9% than the conventional concrete mixes at 28 days.
- Based on the experimental results full replacement of river sand with M-Sand doesn't affects the strength properties of FRSCC.

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