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Fiber Reinforced Self Compacting Concrete Using Domestic Waste Plastics as Fibres

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Abstract: Fiber Reinforced Self Compacting Concrete (FRSCC) is a composite material consisting of cement based matrix with an ordered or random distribution of fiber which can be steel, nylon and polythene, etc., which offers several economical and technical benefits. In this study, domestic waste plastics (Polythene fibres) were used and the properties of concrete (viz., compressive strength, flexural strength, split tensile strength) are studied. The tests have been carried out as per EFNARC for fresh concrete and Indian Standard Code for hardened concrete.

Key words: Fibre reinforced self compacting concrete, domestic waste plastics, flowability, superplasticizer, compressive strength, flexural strength, split tensile strength

INTRODUCTION

Self-Compacting Concrete (SCC) can be defined as a fresh concrete which possesses superior flowability under maintained stability (i.e., no segregation), thus allowing self-compaction that is material consolidation without addition of energy. Self-compacting concrete was developed in Japan in 1988 as a response to the growing problems associated with concrete durability and difficulty in attracting and retaining skilled workers. SCC admixtures cannot simply be added to an existing normal concrete mix to achieve self-placing characteristics. The new mix design must be developed specifically for SCC. The addition of fibres into self-compacting concrete will take advantages of its high performance in the fresh state to achieve more uniform dispersion of fibres which is critical for a wide and reliable structural use of fibre reinforced cement composites.

In India, domestic waste plastics are causing considerable damage to the environment and hence an attempt has been made to understand whether they can be successfully used in concrete to improve some of the mechanical properties as in the case of the steel fibres. The primary objective of this investigation is to study experimentally the properties of fiber reinforced self- compacting concrete containing polythene (domestic waste plastics) fibers. The properties of concrete, namely, compressive strength and flexural strength were studied. A simple method for mix design of self-consolidating fiber reinforced concretes has been presented (Ferrara *et al*., 2007) and assessed through comparison with analogously designed plain self-consolidating concretes. Qucief *et al*. (2006) reported that the main advantage of polypropylene fiber addition is the resulting high compressive and splitting tensile strengths while the main advantage of steel fiber addition is the resulting high MOR and flexural toughness. As per the statement of Mazaheripour *et al*. (2011) polypropylene fibres presence in light weight concrete decreases the slump flow, no effect on compressive strength and increases the splitting tensile strength and flexural strength for maximum volume percentage of the fibres (0.3%). Burak *et al*. (2009) assessed that the Polypropylene (PP) fibres elongate and slip from the matrix easily. Incorporation of fly ash resulted in a frictional bond improvement between matrix and fibre. On the other hand, Polyvinyl Alcohol Fibres (PVA) performed similar in both matrices because of its relatively rough surface structure. The flexural strength values and toughness improved significantly by incorporation of PVA fibres. However, the stability of this improvement depends on the proper adjustment of matrix and fibre properties. The concrete containing recycled plastics fiber showed promising results in compression, flexure but inconsistent results in freeze-thaw testing (Stier and Weede, 1998). Ultimate load carrying capacity of concrete, compressive strength and flexural strength is increased by using HDPP fibre and PET fibre (Venu and Rao, 2010) when compared to ordinary high performance concrete. Asad *et al*. (2011) concludes in his experiments that the mixture of SCC with fine rubber tire fibre recorded the best performance on flowability, passing ability, self-leveling compared to other SCC with fibres.

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Bhogayata and Arora (2010) reported that the usage of post-consumer plastic waste in concrete as ingredient can solve its disposal problems to significant extent. Ismail and AI-Hashmi (2010) experimentally found that the use of iron and plastic waste materials is indeed, a viable solution to recycling such waste materials in concrete mixes.

Naik *et al*. (1996) reported that the compressive strength decreased with increase in the amount of the plastic in concrete, particularly above 0.5% plastic addition. Kandasamy and Murugesan (2011) reported that addition of domestic waste plastics in concrete for 0.5% by weight of cement gives better strength.

MATERIALS AND METHODS

The properties of the materials used in different mix of concrete were tested.

Cement: In the present investigation, ordinary portland cement 53 grade was used. The physical properties of the cement used are shown in Table 1.

Fly ash: For this investigation fly ash supplied by Ashtech (India) Pvt., Ltd. was used. The physical properties of fly ash were specific gravity 1.982, surface area 1982 m^2 kg^{-1} and colour was light grey.

Fine aggregate natural sand: In the present investigation, natural sand available from Palar river near Kanchipuram, Tamil Nadu, India conforming to zone II was used and the tests were carried out as per Indian standard in 1982. The test results are shown in Table 2 (IS: 10262, 1982).

Coarse aggregate: In the present investigation locally available blue granite crushed stone aggregates of size 20 mm and down was used and the various tests carried out as per Indian standard, 1963 and the test results are shown in Table 3.

Fibres: Domestic waste plastics were made into fibres and used for fibre reinforced concrete (Fig. 1).

Chemical admixtures: To achieve self-compacting concrete chemical admixtures, such as superplasticizer and viscosity modifying agents were used. With the use of superplasticizer, the water content could be reduced; thereby effective control on the water binder ratio could be maintained to achieve the design strength. Carboxylic ether polymer (viz., Glenium TMB233) was used in the present investigation. With use of viscosity modifying agents (Glenium TMS tream2) bleeding of concrete mix, segregation and sedimentation could be reduced. The properties of superplasticizer are shown in Table 4 as shown by the manufacturer. The properties of viscosity modifying agent as given by manufacturer is shown in Table 5.

Table 1: Physical properties of cement (53 grade)

Physical properties	Results
Specific gravity	3.15
Standard consistency (%)	33%
Initial setting time (min)	35 min
Final setting time (min)	320 min
Compressive strength	55.2

Table 2: Properties of sand

Properties	Results
Specific gravity of sand	2.60
Fineness modulus	2.61
Bulk density (kg m^{-3})	1620

Table 3: Properties of coarse aggregate

Property	Results
Specific gravity	2.60
Bulk density (kg m^{-3})	1575
Fineness modulus	7.30

Table 4: Properties of superplasticizer

Technical name	Poly carboxylic ether
Appearance	Yellowish free flowing liquid
pH	7±1
Relative density	1.09±0.01 kg L^{-1} at 25°C
Dosage	500-1500 mL per 100 kg of cementitious materials
Chloride ion content	<0.2%
Alkali content	Very low
Operating temperature	2-50°C

Table 5: Properties of viscosity modifying agent

Appearance	Water white viscous liquid
pH	6.6-7.5
Volumetric mass at 20°C	1.08 kg L^{-1}
Dosage	1.00-4.00 L m^{-3}
Chloride content	<0.1%
Specific gravity	1.06 at 27°C
Operating temperature	2-50°C

Fig. 1: Domestic waste plastics are made in to fibre

Table 6: Mix proportion

Ingredients	Normal Concrete (NC)	Fibre Reinforced Concrete (FRC)	Fibre Reinforced Self Compacting Concrete (FRSCC)
Cement (kg m^{-3})	360	360	400
Fly ash (kg m^{-3})	-	-	100
Powder content (kg m^{-3})	360	360	500
Coarse aggregate (kg m^{-3})	1126.52	1126.52	821
Fine aggregate (kg m^{-3})	734.32	734.32	741
FA/CA ratio	0.652	0.652	0.903
Water (kg m^{-3})	179	179	231
Water/Powder ratio	0.497	0.497	0.462
Domestic waste plastic fibres (kg m^{-3})	-	1.80	1.80
Superplasticizer (L m^{-3})	-	-	2.16
Viscous modifying agents (L m^{-3})	-	-	0.36

Table 7: Details of specimens

Name of test	Specimen	NC (No.)	FRC (No.)	FRSCC (No.)
Compressive strength test	Cube 150×150×150 mm	9	9	9
Flexural strength test	Prism 150×150×700 mm	3	3	3
Split tensile test	Cylinder 150 dia and 300 mm height	3	3	3

Water: Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. The strength of cement concrete comes from the bonding action of the hydrated cement gel. The requirement of water should be reduced to that required for chemical reaction of hydrated cement as any excess water would end up in formation of undesirable voids (and/or capillary pores) in the hardened cement paste of concrete (Neville and Brooks, 1987). In the present investigation, potable water was used.

Mix design: The Normal Concrete (NC) mix was designed as IS: 10262 (1982) for M30 grade. For the same mix, domestic waste plastic fibres of 0.5% by weight of cement is added for fibre reinforced cement concrete FRC. Nan *et al.* (2001) gave a simple procedure for self-compacting concrete mix design based on the packing factor. In this study, the Japanese method of self- compacting concrete mix design (Kumar, 2006) was followed and domestic waste plastic fibres of 0.5% by weight of cement FRSCC are added. Table 6 shows the different mix proportions adopted in the present study.

Preparation of test specimens: The concrete cubes, cylinders and beams were cast using standard steel moulds. Concrete was mixed in a tilting type mixer machine. Concrete was placed uniformly in three layers and each layer was compacted by ramming rod. Excess concrete was removed and top was finished by trowel. The sides of the mould were removed 24 h after casting and the test specimens were cured in water. Cubes of size 150×150×150 mm were cast to evaluate the compressive strength of concrete, cylinders of size 150 mm dia and 300 mm height were cast for split tensile strength and beams of size 150×150×700 mm were cast (Fig. 2) to evaluate the flexural strength. The specimens were taken out from water after 3, 7 and 28 days for testing. Table 7 shows the details of specimens used in the study.

Table 8: Test result of fresh concrete

Methods	Unit	Typical range of values: Minimum	Typical range of values: Maximum	Mix-1
Slump-flow by Abram's cone	mm	650.0	750	680.00
$T_{500\ mm}$ slump flow	S	2.0	5	3.50
J-Ring	mm	0.0	10	9.00
V-funnel	S	8.0	12	10.50
V-funnel@$T_{5\ min}$	S	0.0	+3	2.50
L-box	(H2/H1)	0.8	1	0.92
U-box	(H2/H1)	0.0	30	12.00

Fig. 2: Casting of beams

Fresh concrete: Experiments on fresh and hardened concrete were conducted. In fresh SCC concrete, the properties such as filling and passing ability of concrete were investigated. The test setup for the fresh concrete was done as per the SCC EFNARC guidelines. Aggarwal *et al.* (2004) results are shown in Table 8.

Fig. 3: Testing of beam cubes

Fig. 4: Testing of beam specimens

Hardened concrete

Compressive strength test: Nine cubes in each grade of concrete were prepared and tested as IS: 516 (1959) at 3, 7 and 28 days. The cube specimen was placed in the machine in such a manner that the load is applied to opposite sides of the cubes as cast that is not to the top and bottom. The axis of the specimen was carefully aligned with the centre of thrust of the spherically seated platen. The load was applied without shock and increased continuously at a rate of approximately 14 N/mm^2/min until the resistance of the specimen to the increasing load breaks down and no greater load sustained. The maximum load applied to the specimen was recorded (Fig. 3).

Flexural strength test: Three prisms of size 150×150×700 mm were prepared in each type of concrete and tested after 28 days curing. The test was carried out in the Universal testing machine as IS: 5816 (1999). The bearing surfaces of the supporting and loading rollers was wiped clean and the specimen was placed in the machine in such

Fig. 5: Split tensile strength testing

a manner that the load applied to the uppermost surface as cast in the mould, along two lines spaced 20 cm apart. The axis of the specimen was carefully aligned with the axis of the loading device. The load was applied without shock and increasing continuously at a rate such that the extreme fibre stress increases at approximately 0.7 N/mm^2/min that is at a rate of loading of 4000 N min^{-1}. The load was increased until the specimen fails and the maximum load applied to the specimen during the test was recorded (Fig. 4).

Splitting tensile test: Three cylinders of size 150 mm diameter and 300 mm height were prepared in each grade of concrete and tested as IS:383 (1970) at 28 days. The bearing surface of the testing machine and of the loading strips was wiped clean.

The test specimen was placed in the centring jig with packing strip and loading pieces carefully positioning along the top and bottom of the plane of loading of the specimen. The jig was placed in the machine so that the specimen is located centrally. The load was applied without shock and increased continuously at a nominal rate within the range 1.2-2.4 N/mm^2/min. Maintain the rate, once adjusted, until failure. The maximum load applied was recorded (Fig. 5).

RESULTS AND DISCUSSION

Effects on compressive strength: The cube compressive strength for different types of concrete was obtained. Comparison of compressive strength of different types of concrete after 3 days curing is shown in Fig. 6. It can be shown that after 3 days curing, average compressive strength of fibre reinforced concrete FRC is 5.23% higher than Normal Concrete (NC) and compressive strength of Fibre Reinforced Self-Compacting Concrete (FRSCC) is improved further by 3.26%.

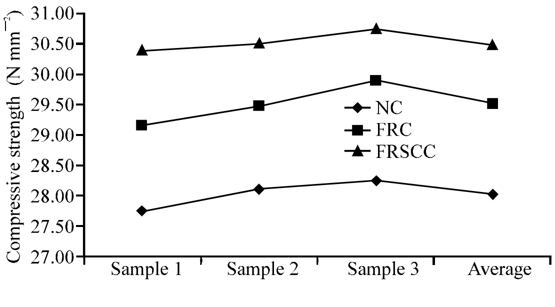

Fig. 6: Comparison of compressive after 3 days

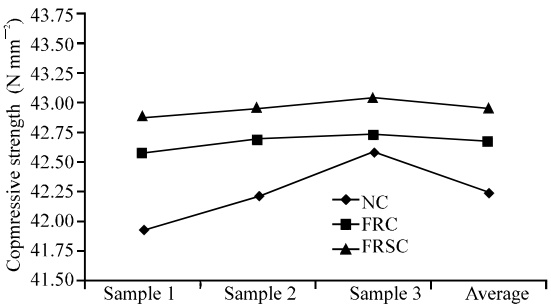

Fig. 7: Comparison of compressive strength after 7 days

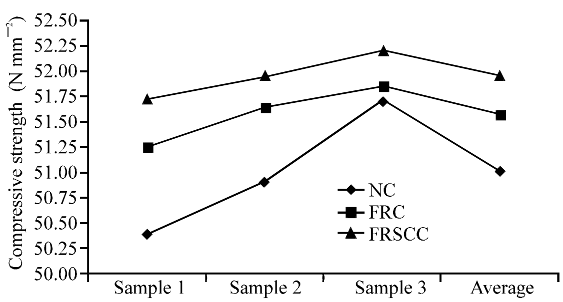

Fig. 8: Comparison of compressive strength after 28 days

Figure 7 shows the compression of compressive strength after 7 days curing different types of concrete. It can be shown that after 7 days curing, average compressive strength of fibre reinforced concrete FRC is 1.19% higher than Normal Concrete (NC) and compressive strength of Fibre Reinforced Self-Compacting Concrete (FRSCC) is improved further by 0.81%.

Figure 8 shows the comparison of compressive strength of different types of concretes after 28 days curing. It shows the average compressive strength of fibre reinforced concrete FRC is 0.90% higher than Normal Concrete (NC) and compressive strength of Fibre Reinforced Self-Compacting Concrete (FRSCC) is improved further by 0.64%.

In all the earlier cases, compressive strength of concrete with manufactured sand is slightly higher than that of concrete with sand. Further, the compressive

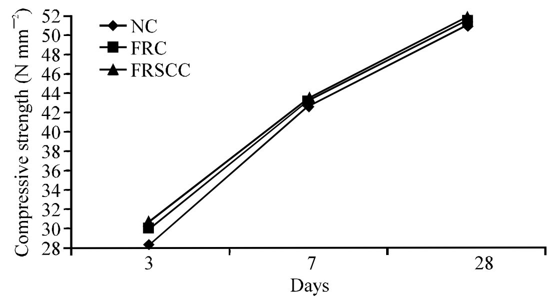

Fig. 9: Comparison of compressive strength after 3, 7 and 28 days

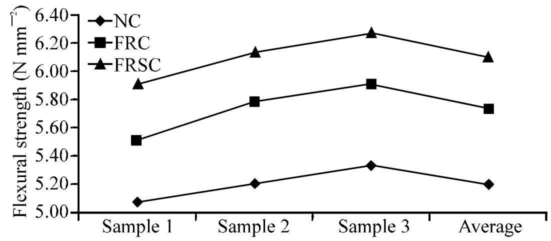

Fig. 10: Comparison of flexural strength

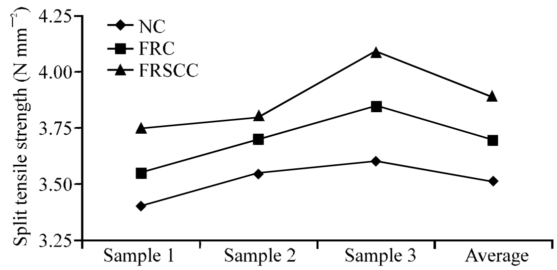

Fig. 11: Comparison of split tensile strength

strength of fibre reinforced concrete with manufactured sand is little more than that of the concrete with manufactured sand. The reason for this is that the compressive strength depends to a large extent depends on quality of cement, shape and size of aggregate which are same for concrete using sand or manufactured sand. Average compressive strength of different mix at 3, 7 and 28 days are shown (Fig. 9).

Effects on flexural strength: The prism flexural strength tests of different type of concrete were obtained. The comparison of flexural strength of different types of concrete after 28 days curing is shown in Fig. 10. It is seen that the average flexural strength of Fibre Reinforced Concrete (FRC) is 10.26 higher than Normal Concrete (NC) and flexural strength of Fibre Reinforced Self-Compacting Concrete (FRSCC) is improved further by 6.46%. The reason for this variation is due to the bond strength of the fibre.

Effects on split tension test: The cylinder split tensile strength tests of different grade of concrete are obtained and Fig. 11 shows the comparison of tensile strength of different types of concrete after 28 days. It is shown that the average splitting tensile strength of Fibre Reinforced Concrete (FRC) is 5.37% higher than Normal Concrete (NC) and tensile strength of Fibre Reinforced Self-Compacting Concrete (FRSCC) is improved further by 5.10%. This may be due to the bond strength of the fibre.

CONCLUSION

Based on the experimental investigation carried out on the three types of concrete namely, ordinary concrete with river sand, concrete with manufactured sand and fibre reinforced concrete with manufactured sand, the following results are drawn. Addition of 0.5% of polythene (domestic waste polythene bags) fiber to concrete:

- There is no much difference in the compressive strength of Fibre Reinforced Self-Compacting Concrete (FRSCC) and that of fibre reinforced concrete FRC or Normal Concrete (NC)
- Flexural strength (Modulus of rupture) of fibre Reinforced Self-Compacting Concrete (FRSCC) is more than that of Fibre Reinforced Concrete (FRC) or Normal Concrete (NC). The difference is quite appreciable
- Tensile strength (Split tensile strength) of Fibre Reinforced Self-Compacting Concrete (FRSCC) and that of Fibre Reinforced Concrete (FRC) or Normal Concrete (NC)
- Pollution control is achieved by disposal of domestic waste plastics as fibres while using for fibre reinforced concrete

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