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Steel Fibre Incorporated Self Compacting Concrete

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Abstract

Self-compacting concrete is a new kind of high performance concrete in improving the product quality and efficiency of building industry because self-compacting concrete does not require vibration for placing and compaction. It is able to flow under its own weight. Steel fibers acts as a bridge to retard the cracks propagation, and improve several characteristics and properties of concrete. An investigation was performed to compare the properties of ordinary conventional concrete (OCC) and self-compacting concrete (SCC) with steel fibre. The mix design arrived is for M30 grade. Fiber content was varied by 0.5%, 1% and 1.5%. Fresh properties including slump flow, V-funnel, L-Box, U- Box, J- Ring are carried out for self-compacting concrete. Hardened properties like compressive strength, flexural strength are carried out for conventional concrete and compared withself-compacting concrete.Results showed significant improvement in strength.
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Keywords: *self-compacting concrete, steel fibre, fresh properties, hardened properties of concrete*

1. Introduction

For several years, the problem of the durability of concrete structures has been a major problem posed to engineers. To make durable concrete structures, sufficient compaction is required. Compaction for conventional concrete is done by vibrating. Over vibration can easily cause segregation.

In conventional concrete, it is difficult to ensure uniform material quality and good density in heavily reinforced locations. If steel is not properly surrounded by concrete it leads to durability problems. The answer to the problem may be a type of concrete which can get compacted into every corner of form work and gap between steel, purely by means of its own weight and without the need for compaction. The SCC concept was introduced to overcome these difficulties. Self-compaction (SC) property of concrete is able to flow and consolidate on its own due to high workability and gravitational effect[1].This concept can be stated as the concrete that meets special performance and uniformity requirements that cannot always be obtained by using conventional ingredients normal mixing procedure and curing practices. The SCC is an engineered material consisting of cement, aggregates, water and admixtures with several new constituents like colloidal silica, pozzolanic materials, possible fly ash (PFA), ground granulated blast furnace slag (GGBS), micro silica, metakaolin, chemical admixtures to take care of specific requirements, such as, high-flow ability, compressive strength, high workability, enhanced resistances to chemical or mechanical stresses, lower permeability, durability, resistance against segregation, and possibility under dense reinforcement conditions[3]. The properties, such as, fluidity and high resistance to segregation enables the placement of concrete without vibrations and with reduced labour, noise and much less wear and tear of equipment.

Use of SCC overcomes the problem of concrete placement in heavily reinforced sections and it helps to shorten construction period. Although concrete is a widely used construction material, it has major disadvantages such as low tensile strength and low strength to weight ratio, and it is liable to cracking. The brittle nature of plain concrete cannot be neglected and an approach to make concrete a ductile material is necessary. In this regard, steel is no doubt a useful reinforcement material for concrete whether it is in the form of a steel fiber or a reinforcing bar. The addition of steel fibers to concrete can improve the tensile strength and ductility, but it will also reduce the workability. Research work is being conducted in Taiwan, since 1993, to improve the workability of steel fiber reinforced concrete (SFRC)[2]. A task force has been formed in Taiwan to develop High Performance Concrete (HPC) and self-consolidating concrete (SCC) for solving the problems of honeycombing due to improper concrete practices.

It is now well established that one of the important properties of steel fibre reinforced concrete (SFRC) is its superior resistance to cracking and crack propagation. As a result of this ability to arrest cracks, fibre composites possess increased extensibility and tensile strength, both at first crack and at ultimate, particular under flexural loading; and the fibers are able to hold the matrix together even after extensive cracking.

2. Materials and Their Properties

2.1 Materials

2.1.1 Cement

Cement is a binding material in concrete which binds the other materials to forms a compact mass. Generally OPC is used for all engineering construction works. In this study, 53 grades OPC cement is used.Different laboratory tests conducted on cement to determine the physical and mechanical properties of the cement used and the results are shown in Table-1

Table 1: Properties of Cement

SL NO	PROPERTIES	TEST RESULT
1	Specific Gravity	3.15
2	Standard Consistency (%)	30
3	Fineness (%)	3
4	Initial setting time(min)	80
5	Final setting time(min)	300

2.1.2Coarse Aggregate and Fine Aggregate

Locally available crushed granite stone aggregates have been used as coarse aggregate. The maximum size of the aggregates used was 20mm. Table-2 gives the physical properties ofthecoarse and fine aggregates.

Table 2: properties of fine aggregate and coarse aggregate

SL NO	PROPERTIES	FINE AGGREGATE	COARSE AGGREGATE
1	Specific Gravity	2.63	2.73
2	Fineness Modulus	2.79	2.34

2.1.3 Water

Water is the most important ingredient of concrete. It actively participates in the chemical reaction with cement. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. Potable water is generally considered satisfactory for mixing concrete. For the present study,clean drinking water available in the college water supply system was used for the casting aswell as the curing of the test specimens.

2.1.4 Fly Ash

Fly ash, also known as pulverized fuel ash is a glassy light grey coloured powdery substance, cement like in appearance. Its main constituents are silica, alumina, and oxides of iron, calcium and magnesium. Fly ash is obtained from burning of pulverized coal or lignite as rich in above constituents and is classified as class F. The physical properties are given in table 3.

Table 3: physical properties of fly ash

Colour	Whitish Gray
Bulk density	1.2 g/cc
Specific gravity	1.9 to2.0
Fineness	2000 to 2200 cm/g
Moisture	NIL

2.1.5 Super plasticizer

Sika ViscoCrete-R550 (I) is a third generation super plasticizer for concrete and mortar. It meets the requirements for super plasticizers according IS9103-1999**.**The physical properties of superplasticizer are shown in table 4.

Table 4: Physical Properties of Superplasticizer

Appearance	Brownish
Basis	Aqueous solution of modified polycarboxylate
Density	Approx. 1.10
pH	Approx. 6.5
Dosage limit	0.6 – 2.0% by weight of cement

2.1.6Viscosity Modifying Agent

Viscosity modifying admixtures (VMA) are water-soluble polymers that increase the viscosity of mixing water and enhance the ability of cement paste to retain its constituents in suspension. VMS are used to enhance the stability of self-compacting. The physical properties of VMA are shown in table 5.

Table 5: Properties of VMA

Appearance	Colourless clear to opaque liquid
Basis	Biopolymer
Density	1.09 kg/l
pH - value	7.0(+/-1.0)
Dosage	0.1 to 1.0%

2.1.7 Steel Fibre

Fibre is a small piece of reinforcing material possessing certain characteristics properties. They can be circular or

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flat. The fibre is often described by a convenient parameter called aspect ratio. The aspect ratio of the fibre is the ratio of length and its diameter. Typically aspect ratio ranges from 30 to 150. Fibre efficiency increases with increase in "Aspect ratio". The properties of steel fibre as shown in table 6.

Table 6: Properties Of Steel Fibre

Specific gravity	7.86
Tensile strength N/mm^2	400 -1200
Young's modulus GN/ m^2	200
Elongation at failure %	3.5

3. Experimental Work and Tests

3.1 Mix Design:

Mix design is the process of selecting suitable ingredients of concrete and determining their relative proportion with the object of producing concrete of certain minimum strength and durability as economically as possible. The mix design of grade (M30) concrete was made and self-compacting concrete was arrived with the same by trial mixes and final mix proportion is arrived. The details of mix proportions are given in table 7.

Table 7 :Mix proportions for 1 m^3

Ingredients	unit	OCC +0%F	OCC +0.5%F	OCC +1%F	OCC +1.5%F	SCC +0%F	SCC +0.5%F	SCC +1%F	SCC +1.5%F
Water	Lit/m^3	214	214	214	214	214	214	214	214
Cement	Kg/m^3	564	564	564	564	339	339	339	339
Fine aggregate	Kg/m^3	554	554	554	554	554	554	554	554
Coarse aggregate	Kg/m^3	1000	1000	1000	1000	1000	1000	1000	1000
Water cement ratio	By mass	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Fly ash	% of cement	-	-	-	-	225	225	225	225
Super plasticizer	% of cement	-	-	-	-	1	1	1	1
VMA	%of cement	-	-	-	-	0.2	0.2	0.2	0.2
Steel fibre	% of cement	0	0.5	1	1.5	0	0.5	1	1.5

3.2 Slump Flow and T50cm Test:

This is a simple, rapid test procedure, though two people are needed if the T50 time is to be measured. It can be used on site, though the size of the base plate is somewhat unwieldy and level ground is essential. It is the most commonly used test, and gives a good assessment of filling ability. It gives no indication of the ability of the concrete to pass between reinforcement without blocking, but may give some indication of resistance to segregation. In this experimental work, the slump value of freshconcrete was obtained in the range of 680mm to730mm. The result shows in Table-8. The higher the slump flow (SF) value, the greater its ability to fill formwork under its own weight. A value of at least 650mm is required for SCC. The T50 time is a secondary indication of flow. A lower time indicates greater flow ability.

3.3 V - Funnel Test and V Funnel Test at T 5 Minutes

Though the test is designed to measure flowability, the result is affected by concrete properties other than flow. The inverted cone shape will cause any liability of the concrete to block to be reflected in the result. High flow time can also be associated with low deformability due to a high paste viscosity, and with high inter-particle friction. While the apparatus is simple, the effect of the angle of the funnel and the wall effect on the flow of concrete are not clear. The result shows in Table-8. This test measures

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the ease of flow of the concrete, shorter flow times indicate greater flow ability. For SCC a flow time of 10 seconds is considered appropriate. After 5 minutes of settling, segregation of concrete will show a less continuous flow with an increase in flow time.

3.3 L Box Test Method

This is a widely used test, suitable for laboratory, and perhaps site use. It assesses filling and passing ability of SCC, and serious lack of stability (segregation) can be detected visually. Segregation may also be detected by subsequently sawing and inspecting sections of the concrete in the horizontal section. The passing ability is calculated from the following equation: PA=H2/H1. In this experimental work, the. L-Box value of fresh concrete was obtained in the range of 0.8cm to 0.95cm.The result shows in Table-8. If the concrete flows as freely as water, at rest it will be horizontal, so H2/H1 = 1. Therefore the nearer this test value, the 'blocking ratio', is to unity, the better the flow of the concrete. The EU research team suggested a minimum acceptable value of 0.8.

3.4 U Box Test Method

The test is to measure the filling ability of concrete. This is a simple test to conduct, but the equipment may be difficult to construct. The 35mm gap between the sections of reinforcement may be considered too close. The question remains open of what filling height less than 30cm is still acceptable. If the concrete flows as freely as water, at rest it will be horizontal, so H1 - H2 = 0. Therefore the nearer this test value, the 'filling height', is to zero, the better the flow and passing ability of the concrete.

3.5 Compressive Strength

The cube-compressive test was conducted in compression testing machine as per IS 516-1964. The compressive strength of concrete is one of the most important of concrete. The cubes were tested in compressive testing machine at the rate of 140 Kg/cm^2/min.

3.6 Flexural strength

Flexural strength tests are carried out at the age of 28 days on 100 x 150 x 1500 beam specimen using 500 KN loading frame by subjecting the specimen to two point loading to determine the flexural strength. Each beam specimen was tested under a simply supported condition. The beam was loaded by two concentrated load by means of a cross beam to provide a load on pure bending region in the central portion of the beam. Loading was applied by means of 15 ton hydraulic jack. Dial gauge of sensitivity 0.01mm were used to measure the deflection of beams. One dial was kept at the mid span of the beam and the other two were kept under the point loads. The strain gauge was used to determine the strains at the top and bottom most fibers of the beam at mid span section.

4. Results and Discussions

4.1 Fresh Properties of Self-Compacting Concrete

Various test conducted for trial mixes to check for their self-compacting properties.The values are given in table 8.

Table 8: Fresh Properties of Self-Compacting Concrete

TEST	Unit	SCC	SCC -0.50%	SCC -1%	SCC -1.50%	EFNARC specification
Slump flow test	mm	735	690	675	680	650 to 800
T50cm slump flow test	sec	3	4	4	2	2 to 5
V – funnel test	sec	9	8	8	10	6 to 12
V – funnel at 5minutes	sec	11	10	12	11	0 to +3
L – box test	(h1/h2)mm	0.95	0.82	0.82	0.8	0.8 to 1
U –box test	(h1-h2)mm	10	13	18	20	0 to 30
J – ring test	mm	8	6	6	4	0 to 10

4.2 Hardened Properties of Concrete

4.2.1 Compressive Strength Test Results at 28 Days

Table 9, fig 1 give the cube compressive strength of concrete at 28 days. It can be seen that the compressive strength of self-compacting concrete with steel fibre was higher than the ordinary concrete with steel fibre. Compressive strength of SCC with 1.5% of steel fibre have 66.90N/mm^2 which is about 51% more than M30 grade concrete with 1.5% of steel fibre. Compressive strength of SCC with 1.5% of steel fibre has 66.90N/mm^2 which is about 56% more than SCC without steel fibre.

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Table 9: Compressive Strength Test Results At 28 Days

% of steel fibre	**28 days compressive strength (N/mm^2)**	
	OCC	**SCC**
0%F	39.77	42.81
0.5%F	41.83	47.34
1%F	43.85	54.85
1.5%F	44.31	66.90

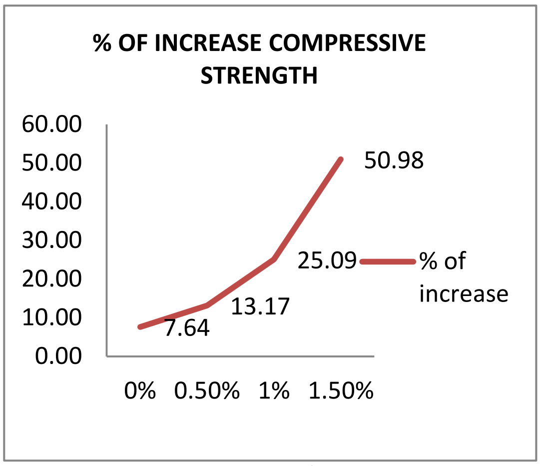

Fig 2 : % increase of 28 days compressive Strength

Table 10:% increase of compressive strength

% of steel fibre	**28 days compressive strength (N/mm^2)**		**% of increase**
	OCC	**SCC**	
0%F	39.77	42.81	7.64
0.5%F	41.83	47.34	13.17
1%F	43.85	54.85	25.09
1.5%F	44.31	66.90	50.98

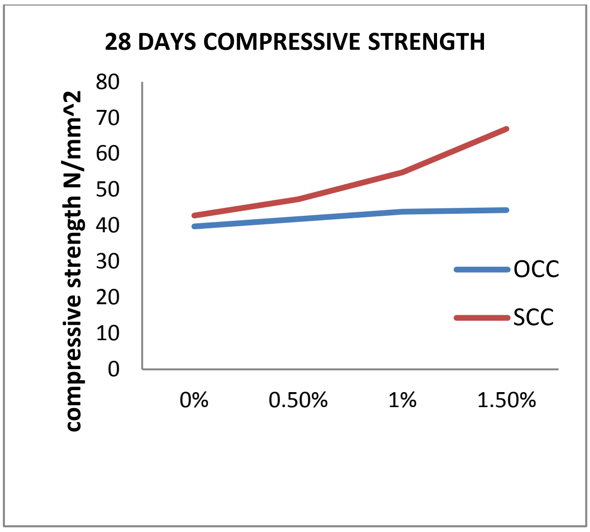

Fig 1: Variation Of Compressive Strength Result For OCC and SCC

4.2.1 Flexural Strength of Concrete

The flexural test result for conventional concrete a self-compacting concrete as shown in table 11 and table 12.The flexural strength of self-compacting concrete with steel fibre was higher than the ordinary concrete with steel fibre. Flexural strength of SCC with 1.5% of steel fibre have 27.57 N/mm^2 which is about 25% more than SCC without steel fibre. Flexural strength of OCC with 1.5% of steel fibre have 26.40 N/mm^2 which is about 36% more than OCC without steel fibre. Flexural strength of SCC with 1.5% of steel fibre have 27.57 N/mm^2 which is about 4.43% more than OCC with 1.5% of steel fibre. At 1% of steel fibre in % of increase flexural strength was larger than other % of steel fibre in SCC.

Table 11: flexural strength test results

Mix	**First initial crack load kN**	**Ultimate load kN**	**Max deflection mm**		**Flexural strength N/mm^2**
			L/3	**L/2**	
OCC+0%F	16.05	36.51	12.66	15.83	19.47
OCC+0.5%F	19.70	39.60	11.82	13.03	21.12
OCC+1%F	22.96	41.05	11.62	12.92	21.89
OCC+1.5%F	29.48	49.51	11.59	11.74	26.40

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Table 12: % increase in flexural strength

% of steel fibre	Flexural strength (N/mm^2)		% of increase
	OCC	SCC	
0%F	19.47	22.13	13.66
0.5%F	21.12	23.17	9.71
1%F	21.89	24.74	13.02
1.5%F	26.40	27.57	4.43

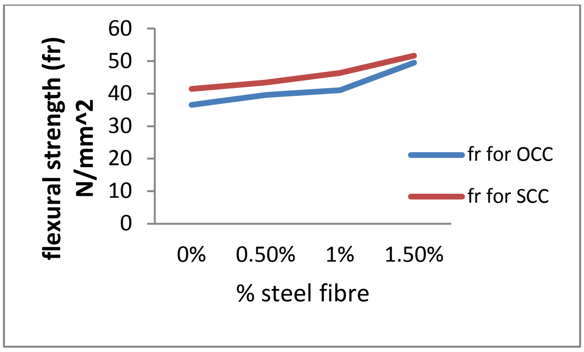

Fig 3: flexural strength result

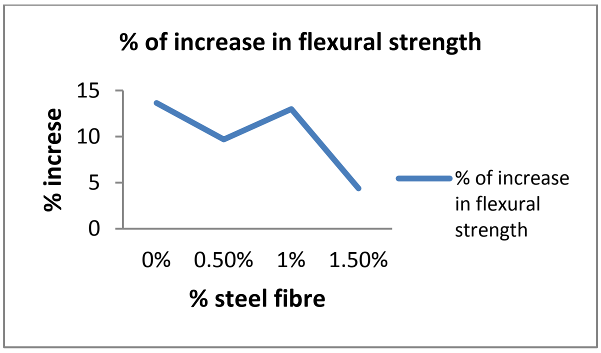

Fig 4: %increase in flexural strength result

5. Conclusions

This study examines the hardened strength parameters like compressive and flexural strength of self compacting concrete with steel fibre.The following conclusion are drawn from the experimental results:

- The fresh SCC flow decreases with increase the % of steel fibre
- Compressive strength increases with increase the % of steel fibre. For SCC with 1.5% of steel fibre. The strength showed an increase of 56% compared to OCC
- The compressive strength of self-compacting concrete with steel fibre was higher than the ordinary concrete with steel fibre.
- The flexural strength of self-compacting concrete with steel fibre was higher than the ordinary concrete with steel fibre.
- Flexural strength increases with increase the % of steel fibre. Flexural strength of SCC with 1.5% of steel fibre have 27.57 N/mm^2 which is about 4.43% more than OCC with 1.5% of steel fibre.

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