Workability Analysis of Glass Fiber Reinforced Self-Compacting Concrete Using J-Ring Test

Praveen.N.R[1]
PG Student,
Department of civil engineering,
Kongu engineering college,
Perundurai, Tamil nadu,

Dr. Krishnamoorthi.S[2]
Professor,
Department of civil engineering,
Kongu engineering college,
Perundurai, Tamil nadu,

Abstract— **Self-compacting concrete (SCC) compacts itself alone due to its self-weight and flows through the formwork and fills it completely even in structural members with high percentage reinforcement. Many studies over the years have shown that the use of FRC increases the mechanical properties of the concrete up to certain level. The effects of fibers are quantified based on the fiber length, volume and aspect ratios of the fibers. The purpose of this experiment is to investigate how the fresh properties of the concrete are affected when they are incorporated with glass fibers of different aspect ratios. Mainly the passing ability of the concrete is investigated using J-Ring test which shows the concretes potential to pass through reinforcements and its flowability. Glass fibers are added as 0.25%, 0.5%, 0.75% and 1% to the volume of concrete and their flowability is tested.**

Keywords - Self-Compacting Concrete, Glass fibers, J Ring test.

INTRODUCTION

The development self-compacting concrete in the late 1980s opened more opportunities in the field engineering. Self-compacting concrete can be used in the highly congested reinforced structures because of its property of compaction under its own weight. There is no fixed mix proportion is available for self-compacting concrete so the Ready mix companies, institutions and other contracting companies developed their own mix designs. The volume of the concrete is considered as a key parameter and whatever may be the mix design they should satisfy certain specification and criteria that are given by the EFNARC and other guidelines for self –compacting concrete.

SCC is known for its brittle nature and under low levels of tensile force it can get cracked easily. A plain unreinforced concrete is a brittle material, which have a low tensile load and a low strain capacity. The brittle nature of the concrete can be overcome by use of randomly oriented short discrete fibers. Fibers in the concrete not only reduce the formation of cracks, but also abate their propagation and growth. Fiber reinforced concrete becomes an option whenever durability or safety of the concrete is considered as design criteria. They improve the performance of cement-based materials by bridging cracks, transmitting the stress and counteracting the crack growth. There are different types of fibers in the building industry such as steel, plastic, glass and carbon fibers. There are various types of glass fibers such as E-Glass, S-Glass, AR glass, D-Glass and C-Glass. These are the commonly used structural strengthening glass fibers used in the construction industry. With regard to workability, the main parameters affecting it are the fiber shape, aspect ratio, fiber length and the volume of fibers per m^3 of concrete. In General the parameters which reduces the workability conversely improves the performance. Addition of fiber proved to be very effective in counteracting drying shrinkage of self-compacting concrete, which is usually a great problem for this material, rich in powders and poor in the coarse aggregate fraction.[4]

MATERIALS AND PROPERTIES

Cement: Ordinary Portland cement of 53 grade conforming to IS 12269:1987[9] with specific gravity of 3.12 was used.

Coarse aggregate: Crushed granite aggregate available from local sources with 100% passing through 12.5mm and retained on 10mm sieve and water absorption 0.4% was used. The specific gravity was found to be 2.7.

Fine aggregate: Locally obtained river sand passing through 4.75 mm IS Sieve as mentioned in IS 383:1970[10] with a fineness modulus of 3.25 was used. The specific gravity of the sand was found to be 2.64.

Flyash: Class F-Type flyash has been obtained from the Mettur Thermal power plant with specific gravity of 2.41 and fineness modulus of 3200 cm2/gm is used in this project.

Water: Potable fresh water available from local sources free from deleterious materials was used for mixing and curing of all the mixes tried in this investigation.

Super plasticizer: Glenium 8233 is used as a super plasticizer which is Polycarboxylic ether based chemical admixture.
Fibers: S-Glass fiber is a high strength glass made with magnesium aluminosilicates. Used where high strength, high stiffness, extreme temperature resistance, and corrosive resistance is needed there. In Table.1 the general properties of the glass fibers are given.

TABLE.1 Properties of glass fibers

Properties	*GF1*	*GF2*	*GF3*
Type	S-Glass fiber	S-Glass fiber	S-Glass fiber
Shape	Straight	Straight	Straight
Length	10 mm	15 mm	20 mm
Diameter	0.15 mm	0.15 mm	0.15 mm
Aspect ratio	66 mm	100 mm	133 mm
Density	7850 kg/m^3	7850 kg/m^3	7850 kg/m^3
Tensile strength	2600 N/mm^2	2600 N/mm^2	2600 N/mm^2

MIX PROPORTION AND TEST PROCEDURE

A. *Mix Proportions*

Various kinds of mix design procedures are followed for self-compacting concrete. Based on the volume of the materials, key constituents and strength requirement the design mix may vary. Many construction companies and institutions develop their own mix design with respect to specification criteria for self-compacting concrete. The works carried out by Nan su et al "A simple mix design method for self- compacting concrete"[4] in that SCC designed and produced contains more sand but less coarse aggregates, thus the passing ability through gaps of reinforcement can be enhanced. The mix proportion from their work is considered as base and trail mixes where tested.

TABLE.2 Trail mix proportion

Trail mix	*Cement (kg/m^3)*	*Flyash (kg/m^3)*	*Fine agg. (kg/m^3)*	*Coarse agg. (kg/m^3)*	*Water (l/m^3)*	*SP %*
TR1	200	150	950	730	170	4.5
TR2	250	150	950	730	170	5.0
TR3	300	150	950	730	170	5.5
TR4	350	180	950	730	170	6.0
TR5	400	180	950	730	170	6.5

Tests were carried out for the self-compacting concrete mixes in table 1. As per EFNARC[8] the workability of the SCC can quantified based on by the following properties

- Filling ability
- Passing ability
- Segregation resistance

These three properties defines the workability and the nature of the self-compacting concrete.

B. Test methods

There are many different test methods available to find the workability of the self-compacting concrete and series of combination of these tests can also be used to observe the workability of the concrete. These are tests that are recommended by EFNARC [8]

- Slump flow
- T 50cm slump flow
- J Ring
- V Funnel
- V Funnel- T $_{5min}$
- L Box
- U Box
- Orimet test

The requirement values for these tests are given in the table.3

TABLE.3 Typical values for tests

Tests	*Typical range of values*
Slump flow	650 – 800 mm
T 50cm slump flow	2 – 5 sec
J Ring	0 – 10 mm
V Funnel	8 – 12 sec
V Funnel	+3 secs
L Box	H2 / H1 = 0,8-1,0
U Box	H2-H1 = 30 mm max
Orimet test	0 – 5 sec

From these tests slump flow, J Ring test, V Funnel test and V Funnel-T_{5min} are considered for the workability tests. The workability tests for the considered trail mixes are carried out and their values are given in the Table.4

Trail mix	*Slump flow (mm)*	*J – Ring (mm)*	*V – Funnel (secs)*	*V – Funnel secs (T_{5min})*
TR1	650	12.5	13.2	16.9
TR2	675	10	12	15.7
TR3	715	7	10.1	13.3
TR4	765	4.5	8	10.8
TR5	790	3	6.9	9.8

TABLE.4 Workability test results

After the workability tests the trail mix value TR4 had been taken for further proceedings. Since the incorporation of fibers might reduce the deformability of the concrete, hence the trail mix TR4 which satisfied EFNARC criteria is taken. TR4 mix is tested with J Ring when fibers of three different aspect ratios are added to the volume of concrete as 0.25%, 0.5%, 0.75% and 1%.

RESULTS AND DISCUSSION

A. *Fresh state properties*

The J-Ring test had been conducted on the fresh concrete to observe how the inclusion of fibers affects the deformability concrete. As per EFNARC the J Ring can be used in conjunction with the Slumpflow, the Orimet test, or eventually even the V Funnel [8]. These combinations test the flowing ability the passing ability of the concrete. The J Ring bars can principally be set at any spacing to impose a more or less severe test of the passing ability of the concrete. After the test, the difference in height between the concrete inside and that just outside the J Ring is measured. This is an indication of passing ability, or the degree to which the passage of concrete through the bars is restricted [8]. Table.4, Table.5, Table.6 shows the results obtained from the tests on fresh concrete.

TABLE.5 J Ring test value for GF1 fiber

Mix	*GF1 Fiber %*	*J Ring test (mm)*
TR4	0.25	5
TR4	0.5	6.5
TR4	0.75	7.5
TR4	1	8

TABLE.6 J Ring test value for GF2 fiber

Mix	*GF2 Fiber %*	*J Ring test (mm)*
TR4	0.25	6.5
TR4	0.5	7.0
TR4	0.75	10
TR4	1	12

TABLE.7 J Ring test value for GF3 fiber

Mix	*GF2 Fiber %*	*J Ring test (mm)*
TR4	0.25	8
TR4	0.5	10.5
TR4	0.75	12.5
TR4	1	13.5

The J Ring test has been conducted because of is great potential to quantify the passing ability and the flowability, since it's a conjunction of slump flow test. The rings acts like the reinforcement in the structural members and its ability to pass through them can be observed. The fig.1 shows the variations in the passing ability of the concrete added with the fibers of different aspect ratios.

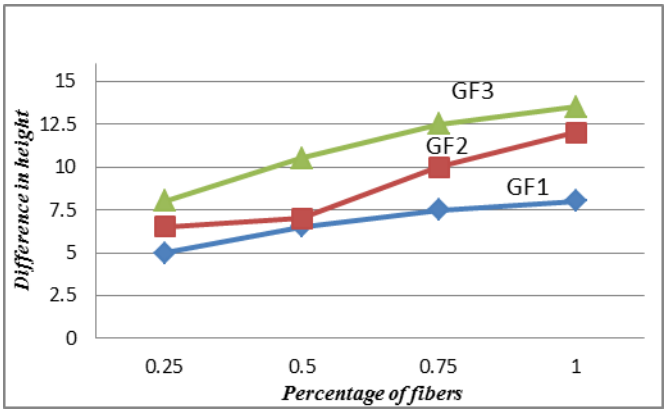

Fig.1 J Ring test values

CONCLUSION

- The usage of fibers of different aspect ratio to the concrete showed that the aspect ratio is a key parameter to be considered and the workability of the concrete reduces when the aspect ratio of the fiber is increased.
- GF1 fibers had a lesser aspect ratio when compared to the other fibers. When the fiber percentage is increased the flowability of the concrete is affected even the smaller aspect ratio of the fiber couldn't help it.
- The use of S-Glass fiber in the self-compacting concrete with the aspect ratio around 60-70mm can be used up to1%. The GF2 fiber under J Ring test shows that this kind of fibers with aspect ratio around 100mm can be used up to 0.75%. The fibers (GF3) having aspect ratio around 130-135mm can used up to 0.25%.
- The fibers GF1, GF2 and GF3 showed that the passing ability of the concrete is greatly reduced because of length of the fiber. The lengthy fibers stuck to the rings of J Ring apparatus and blocks movement of the concrete and the flow is affected highly.

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