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Use of Steel Fibers as Reinforcement in Fiber Reinforced Concrete

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ABSTRACT: In now a days construction practice, repair and rehabilitation of structures has taken a famous role. Mortar plays a important part in these works. As the flow ability of mortar can be an added lead when inaccessibility comes into picture like in case of congested reinforcement or narrow cracks or fissures. Due to the application easiness and mechanical advantages, Self Compacting Mortar is preferred for repair purposes especially in reinforced concrete structures these days. The cement as well as the ingredients of the paste, mineral admixtures (pozzolanic or inert nature) and plasticizing chemical admixtures should be cautioned, chosen in order to obtain a suitable paste composition to enrich the granular composition of the mix. There is no universally accepted agreement on the effect of these factors due to the complexity of combined action; thus, it is hard to make a generalization.

Compared to fiber reinforced concrete (FRC), self-compacting concrete (SCC) is a comparatively new type of concrete with high flowability and better cohesiveness. It offers very attractive economical and technical benefits, which can be further continued when combined with FRC. In this article steel fibers were used in the self compacting concrete and the workability of concrete is determined with various fiber contents by using flow test and compaction factor test.

Index terms: Workability, Self-compacting concrete, Fiber reinforcement.

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1 INTRODUCTION

By adjusting the aggregate content and using a combination of chemical and mineral admixtures, self-compacting concrete mixes behave in a manner not normally observed in standard concrete. These admixtures, typically consisting of high-range water-reducing (HRWR, or super plasticizing) and viscosity-modifying admixtures, gather the requirements of ASTM C494. Filler materials are often used for replacing some of the aggregates and modifying the viscosity. High doses of HRWR produce a mix with high fluidity and allow for a reduced water-powder ratio. Without a viscosity-modifying admixture, the mixture would tend to segregate.

We can achieve some benefits by the use of SCC like:

- Ergonomics - less noise from vibrators and reduced danger from hand-arm vibration syndrome (HAVS).
- Speed of placement, resulting in increased production efficiency.
- Ease of placement, requiring fewer workers for a particular pour.
- Better assurances of sufficient consolidation.
- low wear and tear on forms from vibration.
- Can be used in exposed aggregate finishes.
- Rise in early strengths.
- Consistent water-cement (w/c) ratios of less than 0.35.
- Reduced energy consumption from vibration equipment (although the energy required for longer mix times will offset this somewhat).
- Lower permeability.
- Outstanding pump ability.

2 OBJECTIVES

The main objective of this study is to determine the workability of self compacting concrete for different fiber contents and to find the segregation indices of the mix for the respective fiber contents.

2.1 MATERIALS

(a) Cement:

The properties of cement, which are of relevance to good performance of concrete, are its Specific gravity, initial and final setting time and compressive strength. Grade of cement is also another important factor. For conducting experiments, OPC-43 grade cement was used.

(b) Fine Aggregate

All normal concreting sands are suitable for SCC. In this experimental work the sand having a maximum size of 1.18 mm is used to conduct the tests.

(c) Coarse Aggregate

All types of aggregates are suitable for SCC. The normal maximum size is generally 16-20 mm; however particle sizes up to 40 mm or more have been used in SCC. In this experimental work the aggregate used is in the range of 20-37.5 mm.

(d) Fly ash

Fly ash is a by-product of the combustion of pulverized coal in the thermal power plants. It acts as a pozzolanic material in concrete. It reacts with calcium hydroxide to form stable, insoluble and cementious compound. Specific gravity of Fly ash used in the experimental work is 2.24.

(e) Water

Potable water was used in the experimental work for mixing.

(f) Super plasticizer

Super plasticizer used in the experimental work was Poly Carboxylic Ether (PCE) based. It has excellent dispersion properties which makes it the ideal admixture for ready mixed concrete where low water content ratios are required. This property allows the production of very high early strength.

(g) Fiber

Steel fiber of Specific gravity 7.86 and of the aspect ratio 80 was used in the experimental work.

2.2 Mix Design for FRSCC

Using the equation as proposed by Su-Hsu and Chai(2), several trial mixes were made in order to reach the suitable mix proportion so as to satisfy the criteria for making successful SCC.

<u>Trial mix 1(M_0):</u> (Mix with out fiber)

Cement=400 kg/m^3
Fly ash=40 % of cement=160 kg/m^3
Super plasticizer= 2.25% of cement and fly ash=12.60 kg/m^3
Water powder ratio =0.3
Water content= 0.3*(400+160)= 168 kg/m^3
Assume 2% of entrapped air
Yield of SCC (1m^3)
$=1/1000(C/S_C+FA/S_{FA}+Agg/S_{Agg}+SP/S_{SP}+W/S_W)+A_C$
1=1/1000(400/3.15+160/2.24+Agg/2.62+12.60/1.12+168/1) +0.02
It gives, total aggregate content=1587 kg/m^3
Assume, coarse aggregate = 52 % of total aggregate content
Therefore, coarse aggregate = 826 kg
Fine aggregate = 761 kg.

Check 1:

Water powder ratio on volume basis.
Water/powder = 168/(400/3.15+160/2.24) = 0.846 (.08-1.1)
Hence satisfied.

Check 2:

Fine aggregate to mortar on volume basis.
Volume of fine aggregate = 761/2.61= 291.57m^3
Total mortar volume = fine aggregate volume + cement + fly ash + water
= 761/2.61+400/3.15+160/2.24+168/1 = 657.98 m^3
Volume of fine aggregate/total mortar volume = 0.44 (<0.45)
Hence the design mix is OK.

<u>Trial mix 2(M_1):</u>

Cement=400 kg/m^3
Fly ash=40 % of cement=160 kg/m^3
Super plasticizer= 2.25% of cement and fly ash=12.60 kg/m^3
Water powder ratio =0.3
Water content= 0.3*(400+160)= 168 kg/m^3
Fiber= 0.75 % of total mix
= 0.75 % (400+160+168+12.60+Agg)
Assume 2% of entrapped air
Yield of FRSCC (1m^3)
$=1/1000(C/S_C+FA/S_{FA}+Agg/S_{Agg}+SP/S_{SP}+W/S_W+F/S_F)+A_C$
1=1/1000(400/3.15+160/2.24+Agg/2.62+12.60/1.12+168/1+0.75 % (741+Agg)/7.86) +0.02
It gives, total aggregate content=1586 kg/m^3
Assume, coarse aggregate = 52 % of total aggregate content
Therefore, coarse aggregate = 825 kg
Fine aggregate = 761 kg.
Fiber = 0.75 % (741+1586) =17.45 kg.

Check 1:

Water powder ratio on volume basis.
Water/powder = 168/(400/3.15+160/2.24) = 0.846 (.08-1.1)
Hence satisfied.

Check 2:

Fine aggregate to mortar on volume basis.
Volume of fine aggregate = 761/2.61= 291.57m^3
Total mortar volume = fine aggregate volume + cement + fly ash + water
= 761/2.61+400/3.15+160/2.24+168/1 = 657.98 m^3
Volume of fine aggregate/total mortar volume = 0.44 (<0.45)
Hence the design mix is OK.

<u>Trial mix 3(M_2):</u>

Cement=400 kg/m^3
Fly ash=40 % of cement=160 kg/m^3
Super plasticizer= 2.25% of cement and fly ash=12.60 kg/m^3
Water powder ratio =0.3
Water content= 0.3*(400+160)= 168 kg/m^3
Fiber= 1.00 % of total mix
= 1.00 % (400+160+168+12.60+Agg)
Assume 2% of entrapped air
Yield of FRSCC (1m^3)
$=1/1000(C/S_C+FA/S_{FA}+Agg/S_{Agg}+SP/S_{SP}+W/S_W+F/S_F)+A_C$
1=1/1000(400/3.15+160/2.24+Agg/2.62+12.60/1.12+168/1+1.00 % (741+Agg)/7.86) +0.02
It gives, total aggregate content=1585 kg/m^3
Assume, coarse aggregate = 52 % of total aggregate content
Therefore, coarse aggregate = 822 kg
Fine aggregate = 763 kg.
Fiber = 1.00 % (741+1585) =23.20 kg.

Check 1:

Water powder ratio on volume basis.
Water/powder = 168/(400/3.15+160/2.24) = 0.846 (.08-1.1)
Hence satisfied.

Check 2:

Fine aggregate to mortar on volume basis.
Volume of fine aggregate = 763/2.61= 292.34m^3
Total mortar volume = fine aggregate volume + cement + fly ash + water
= 763/2.61+400/3.15+160/2.24+168/1 = 658.75 m^3
Volume of fine aggregate/total mortar volume = 0.44 (<0.45)
Hence the design mix is OK.

<u>Trial mix 4(M_3):</u>

Cement=440 kg/m^3
Fly ash=30 % of cement=132 kg/m^3
Super plasticizer= 2.25% of cement and fly ash=12.87 kg/m^3
Water powder ratio =0.29
Water content= 0.29*(440+132) = 166 kg/m^3
Fiber= 0.75 % of total mix
= 0.75 % (440+132+166+12.87+Agg)
Assume 2% of entrapped air
Yield of FRSCC (1m^3)
$=1/1000(C/S_C+FA/S_{FA}+Agg/S_{Agg}+SP/S_{SP}+W/S_W+F/S_F)+A_C$
....
1=1/1000(440/3.15+132/2.24+Agg/2.62+12.87/1.12+166/1+0.75 % (743+Agg)/7.86) +0.02

It gives, total aggregate content=1593 kg/m^3
Assume, coarse aggregate = 52 % of total aggregate content
Therefore, coarse aggregate = 828 kg
fine aggregate = 765 kg.
Fiber = 0.75 % (743+1591) = 17.53 kg.

Check 1:
Water powder ratio on volume basis.
Water/powder = 166/(440/3.15+132/2.24) = 0.836 (.08-1.1)
Hence satisfied.

Check 2:
Fine aggregate to mortar on volume basis.
Volume of fine aggregate = 765/2.61= 293.10m^3
Total mortar volume = fine aggregate volume + cement + fly ash + water
= 765/2.61+440/3.15+132/2.24+166/1 = 657.71 m^3
Volume of fine aggregate/total mortar volume = 0.44 (<0.45)
Hence the design mix is OK.

Trial mix 5(M_4):
Cement=440 kg/m^3
Fly ash=30 % of cement=132 kg/m^3
Superplasticizer= 2.25% of cement and fly ash=12.87 kg/m^3
Water powder ratio =0.29
Water content= 0.29*(440+132) = 166 kg/m^3
Fibre= 1.00 % of total mix
= 1.00 % (440+132+166+12.87+Agg)
Assume 2% of entrapped air
Yield of FRSCC (1m^3)
$=1/1000(C/S_C+FA/S_{FA}+Agg/S_{Agg}+SP/S_{SP}+W/S_W+F/S_F)+A_C$
1=1/1000(440/3.15+132/2.24+Agg/2.62+12.87/1.12+166/1+1.00 % (743+Agg)/7.86) +0.02
It gives, total aggregate content=1591 kg/m^3
Assume, coarse aggregate = 52 % of total aggregate content
Therefore, coarse aggregate = 827 kg
fine aggregate = 764 kg.
Fibre = 1.00 % (743+1591) =23.35 kg.

Check 1:
Water powder ratio on volume basis.
Water/powder = 166/(440/3.15+132/2.24) = 0.836 (.08-1.1)
Hence satisfied.

Check 2:
Fine aggregate to mortar on volume basis.
Volume of fine aggregate = 764/2.61= 292.72m^3
Total mortar volume = fine aggregate volume + cement + fly ash + water
= 764/2.61+440/3.15+132/2.24+166/1 = 657.33 m^3
Volume of fine aggregate/total mortar volume = 0.44 (<0.45)
Hence the design mix is OK.

Trial mix 6(M_5):
Cement=420 kg/m^3
Fly ash=35 % of cement=147 kg/m^3
Super plasticizer= 2.25% of cement and fly ash=12.75 kg/m^3
Water powder ratio =0.3
Water content= 0.3*(420+147) = 170.1kg/m^3
Fiber= 0.75 % of total mix
= 0.75 % (420+147+170.1+12.75+Agg)
Assume 2% of entrapped air
Yield of FRSCC (1m^3)
$=1/1000(C/S_C+FA/S_{FA}+Agg/S_{Agg}+SP/S_{SP}+W/S_W+F/S_F)+A_C$
1=1/1000(440/3.15+132/2.24+Agg/2.62+12.87/1.12+166/1+0.75 % (743.34+Agg)/7.86) +0.02
It gives, total aggregate content=1581 kg/m^3
Assume, coarse aggregate = 52 % of total aggregate content
Therefore, coarse aggregate = 822 kg
fine aggregate = 759 kg.
Fiber = 0.75 % (743+1591) = 17.43 kg.

Check 1:
Water powder ratio on volume basis.
Water/powder = 170.1/ (420/3.15+147/2.24)
= 0.855 (.08-1.1)
Hence satisfied.

Check 2:
Fine aggregate to mortar on volume basis.
Volume of fine aggregate = 759/2.61= 290.80 m^3
Total mortar volume = fine aggregate volume + cement + fly ash + water
= 759/2.61+420/3.15+147/2.24+170.1/1 = 659.85m^3
Volume of fine aggregate/total mortar volume = 0.44 (<0.45)
Hence the design mix is OK.

Trial mix 7(M_6):
Cement=420 kg/m^3
Fly ash=35 % of cement=147 kg/m^3
Super plasticizer= 2.25% of cement and fly ash=12.75 kg/m^3
Water powder ratio =0.3
Water content= 0.3*(420+147) = 170.1kg/m^3
Fiber= 1.00 % of total mix
= 1.00 % (420+147+170.1+12.75+Agg)
Assume 2% of entrapped air
Yield of FRSCC (1m^3)
$=1/1000(C/S_C+FA/S_{FA}+Agg/S_{Agg}+SP/S_{SP}+W/S_W+F/S_F)+A_C$
1=1/1000(440/3.15+132/2.24+Agg/2.62+12.87/1.12+166/1+0.75 % (743.34+Agg)/7.86) +0.02
It gives, total aggregate content=1579 kg/m^3
Assume, coarse aggregate = 52 % of total aggregate content
Therefore, coarse aggregate = 821 kg
fine aggregate = 758 kg.
Fiber = 1.00 % (743+1579) = 23.22 kg.

Check 1:
Water powder ratio on volume basis.
Water/powder = 170.1/ (420/3.15+147/2.24) = 0.855 (.08-1.1)
Hence satisfied.

Check 2:
Fine aggregate to mortar on volume basis.
Volume of fine aggregate = 758/2.61= 290.42 m^3
Total mortar volume = fine aggregate volume + cement + fly ash + water
= 758/2.61+420/3.15+147/2.24+170.1/1 = 659.53m^3
Volume of fine aggregate/total mortar volume = 0.44 (<0.45)
Hence the design mix is OK.

Table 2.1. Trial Mix design for FRSCC

Sno	Material	Trial Mix1 (M_0)	Trial Mix2 (M_1)	Trial Mix3 (M_2)	Trial Mix4 (M_3)	Trial Mix5 (M_4)	Trial Mix6 (M_5)	Trial Mix7 (M_6)
1	Cement	400	400	400	440	440	420	420

		kg/m^3	kg/m^3	kg/m^3	kg/m^3	kg/m^3	kg/m^3	kg/m^3
2	Fly ash	40% of cement	40% of cement	40% of cement	30% of cement	30% of cement	35% of cement	35% of cement
3	Super plasticizer	2.25 % of powder	2.25 % of powder	2.25 % of powder	2.25 % of powder	2.25 % of powder	2.25 % of powder	2.25 % of powder
4	Fine aggregate	48%	48%	48%	48%	48%	48%	48%
5	Coarse aggregate	52%	52%	52%	52%	52%	52%	52%
6	Water/Powder ratio	0.3	0.3	0.3	0.29	0.29	0.3	0.3
7	Fiber	---	0.75 % of total mix	1.00 % of total mix	0.75 % of total mix	1.00 % of total mix	0.75 % of total mix	1.00 % of total mix

3 Testing Methods

(a) Slump flow test

(b) Compaction factor test

(c) G.T.M. Screen Stability Test for Segregation Index

Table.3.1.Test Results at Fresh Stage of FRSCC

S.No	Type of Mix	W/P ratio	S.P/P ratio	Fiber (% of total mix)	Slump flow dia. (mm)	Compaction factor	Segregation index (%)
1	M_0	0.3	2.25	---	642	0.914	7.95
2	M_1	0.3	2.25	0.75	640	0.928	9.40
3	M_2	0.3	2.25	1.00	652	0.919	9.2
4	M_3	0.29	2.25	0.75	654	0.930	9.5
5	M_4	0.29	2.25	1.00	666	0.915	8.7
6	M_5	0.3	2.25	0.75	641	0.919	9.3
7	M_6	0.3	2.25	1.00	648	0.925	9.3

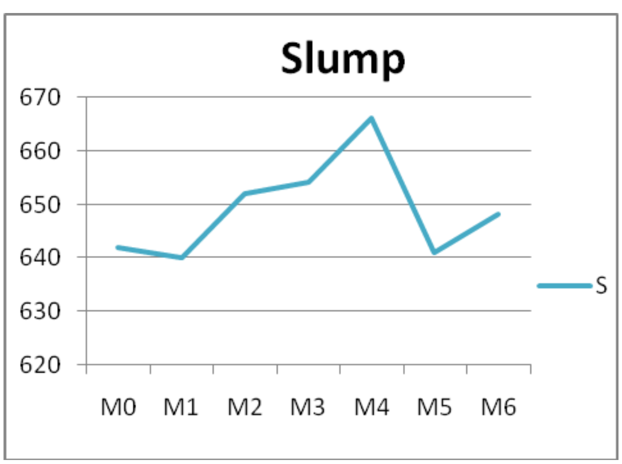

Figure 3.1 Variation of Slump (mm) for different mixes

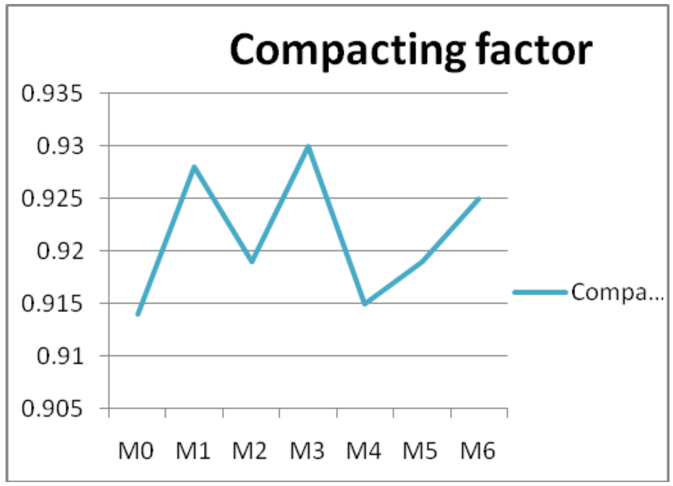

Figure 3.2 Variation of Compacting Factor for different mixes

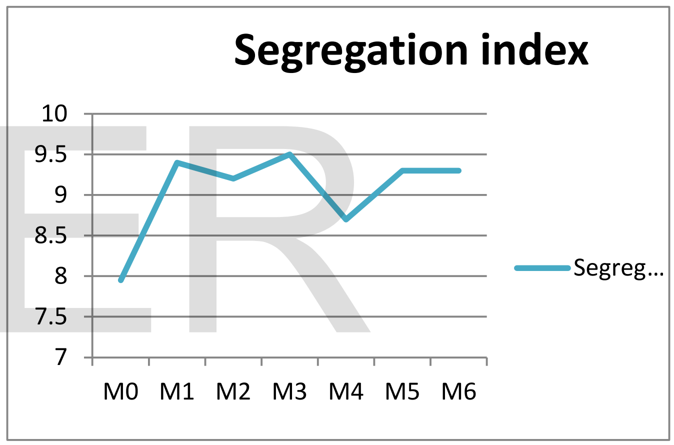

Figure 3.3 Variation of Segregation Index (%) for different mixes

4 Conclusion

The following conclusions have been concluded from the above study:

1) It has been verified, by using slump flow and compaction factor test, that self-compacting concrete achieved consistency and self-compatibility under its own weight without any external vibration of compaction.
2) It was observed that it is possible to achieve self compaction with considerable fiber inclusion and all mixes had good flowability and possessed self-compaction characteristics.
3) In order to retain high level workability with fiber reinforcement, the amount of paste in the mix should be increased to provide better dispersion of fibers. Increasing cement content, increasing fine aggregate content or using pozzolanic admixtures can be alternative solutions to this problem.

4) Bleeding capacity for flowing and self-compacting concretes is influenced by the Super plasticizer dosage.

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