AN EXPERIMENTAL STUDY ON MICROSTRUCTURE AND STRENGTH PROPERTIES OF HYBRID FIBER REINFORCED SELF COMPACTING CONCRETE

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Abstract - *Self-compacting concrete (SCC) is one of special type of concrete gained popularity due to its higher workability compare to normal concrete, and at the same time because of its cohesiveness it can be able to flow itself on all corner of the form which results in reduction of vibration effect without segregation and bleeding. Use of industrial by-products like GGBFS and Fly ash as cement replacement each of by 30% results in achieves an economical SCC but also reduces pollution created by these wastes. Use of combination of steel and polypropylene (PP) fibers in SCC mix of 0.5 %(0.3% of Crimped steel fibers and 0.2% of PP fibers) has been tried which effect strength and other properties in different ways. To achieve better workability of SCC, Master Glenium Sky 8630 has been used and dosage of 1% for Plain SCC and 1.5% for hybrid SCC. The study has been done on M40 grade of concrete was designed using Nan Su method with water-cement ratio of 0.40. Some of the tests conducted on slump flow, L and U box and V funnel to determine the parameters for self compactability of mixtures.*

Key Words: **SCC, Compressive strength, Flexural strength, Tensile strength, Hybrid fibers, Scanning Electron Microscopic.**

1. INTRODUCTION

Self-compacting concrete (SCC) is a type of concrete which is able to flow and compact under its own weight which doesn't require any mechanical vibration and enough cohesive which is exceedingly flowable to be handled without segregation or bleeding.

In 2001, *Nan Su* et al proposes design mix method on Self compacting concrete. Mainly it derives from using necessary quantities of aggregates and cement paste is mixed so that concrete that attains flowability, compactability and other important properties of SCC. To ensure these actions of SCC in terms of test conducted on compressive, flexural and split tensile strength and the results obtained will indicate that this methodology gives lucratively high quality of SCC.
Dry shrinkage is one of the main shrinkage causes cracks in structures that affect the durability and strength of concrete structures due to change in the environmental moisture from the concrete. Addition of fibers used as reinforcements which can be effective in reduction of initial cracks of the concrete structure which also strengthens the concrete structure.

2. Materials used

Cement: Ordinary Portland cement of mortar compressive strength at 28 days curing period of 53MPa has been used in the present study and specific gravity was 3.15.

Fine aggregate: Local river sand has been used. The specific gravity, fineness modulus and bulk density of sand were 2.63, 2.73 and 1.356g/cc used respectively.

Coarse aggregate: Crushed aggregate of maximum size of 12.5mm was used. The specific gravity, fineness modulus and bulk density of sand were 2.65, 6.36 and 1.33g/cc used respectively.

GGBFS: GGBFS has been used as a 30% partial replacement of cement.

Fly ash: Class F fly ash has been used as a 30% partial replacement of cement.

Super plasticizers: Master Glenium Sky 8630 is used. Optimum dosage is confirmed by various trail mixes.

Water: Potable water is used for mixing of concrete and curing.

3. Fresh State Properties of SCC

The SCC should possess some important functions at plastic stage are as follows

Filling Ability: SCC should fill up to every corner of formwork and where congested spaced reinforcement present and also at other places with maintaining homogeneity in horizontal and vertical directions of formwork.

Passing ability: SCC should pass through congested formwork with closely spaced reinforcement area without interlocking between reinforcement and aggregates.

Resistance to segregation and bleeding: SCC should maintain uniformity throughout mixing, transportation and at the time of casting on site without bleeding, segregation and surface settlement of concrete and after casting on site.

4. Methodology

NAN SU mix design method is considered to be very simple mix design method and therefore it is used for designing SCC mix of M40 grade in this experimental work. This method was used to prepare trial mixes for M40 grade SCC to calculate strength properties by replacing cement by Fly ash and GGBFS with addition of hybrid fibers (combination of crimped steel and polypropylene fibers) with W/C of 0.4 and keeping all parameters like fine aggregate and coarse aggregate were constant. Each mix was tested to achieve workability property, then cubes, cylinders and prisms are casted for conducting tests on compressive strength, split tensile strength and flexural strength tests respectively at age of curing period 7 and 28 days.

Data's obtained from experimental mix design

- Packing factor(PF)= 1.1
- Specific gravity of cement(G_c)= 3.15
- Specific gravity of FA(G_{fa})= 2.63
- Specific gravity of CA(G_{ca})= 2.65
- Specific gravity of Fly ash (G_f)= 2.11
- Specific gravity of water(G_w)= 1.0
- Bulk density of FA(W_{fa})= 1356Kg/m^3
- Bulk density of CA(W_{ca})= 1336Kg/m^3
- The volume ratio of fine to total aggregate= 0.53
- Air content (V_a) = 1%.

Mix Proportions for 1m^3

- Cement: 562.893kg/m^3.
- Fine Aggregate (FA): 865.327 kg/m^3.
- Coarse Aggregate(CA):681.379 kg/m^3
- Water: 225.677ltr/m^3
- Super plasticizers
  - 5.62lL(1%)for Plain SCC
  - 8.43L (1.5%) for Hybrid SCC.

5. Tests Results of Fresh State of SCC

Based on EFNARC guidelines some of the tests conducted on fresh properties of concrete such as slump flow, L-box, U-box and V-funnel were conducted to evaluate the fresh properties of concrete. EFNARC specifications for SCC workability on fresh state are given below in the table 1 and results obtained for Plain SCC and hybrid SCC of

Mix1=100%cement,
Mix2=70%cement+30%GGBFS,
Mix3=70%cement+30%Flyash.

Table 1: Plain SCC (Without Fibers)

CONCRETE PROPERTIES	MIX 1	MIX 2	MIX 3	EFNARC GUIDELINES
Slump test (mm)	723	685	693	650 - 800
V funnel (sec)	8	10	9	6 – 12
U box test (mm)	14	12	13	0 – 30
L box test	0.85	0.93	0.92	0.8 – 1

Table 2: Hybrid SCC

CONCRETE PROPERTIES	MIX 1	MIX 2	MIX 3	EFNARC GUIDELINES
Slump test (mm)	724	688	697	650 – 800
V funnel (sec)	7	10	9	6 – 12
U box test (mm)	14	12	11	0 – 30
L box test	0.82	0.93	0.91	0.8 – 1

6. Tests Results of Hardened State of SCC

This chapter represents the experimental results on cube of size 150*150*150mm, cylinder of 150*300mm and prism of 500*100*100mm.

Compressive Strength Results:

Average Compressive strength values of cube test result for Plain SCC and Hybrid SCC in MPa at age of curing 7 and 28 days:

Table 3: Avg Compressive strength

Mixes	7 days		28 days	
	Plain SCC	Hybrid SCC	Plain SCC	Hybrid SCC
MIX 1	45.11	50.18	54.72	60.40
MIX 2	29.44	43.60	42.25	59.33
MIX 3	31.24	36.29	44.67	56.90

Split Tensile Results:

Average Split tensile strength values for Plain SCC and Hybrid SCC in MPa at age of curing 7 and 28 days:

Table 4: Avg Split tensile strength

Mixes	7 days		28 days	
	Plain SCC	Hybrid SCC	Plain SCC	Hybrid SCC
MIX 1	2.794	3.03	3.34	3.806
MIX 2	2.87	2.966	3.54	3.796
MIX 3	2.714	3.155	3.45	3.763

Flexural strength Results:

Average Flexural strength values for Plain SCC and Hybrid SCC in MPa at age of curing 7 and 28 days:

Table 5: Avg Flexural strength

Mixes	7 days		28 days	
	Plain SCC	Hybrid SCC	Plain SCC	Hybrid SCC
MIX 1	7.83	9.85	10.167	11.0
MIX 2	6.0	7.0	10.167	10.667
MIX 3	6.83	7.67	8.167	10.33

7. Microscopic Investigation of Plain and Hybrid SCC

Scanning electron Microscopic (SEM) investigation was done on all mixes at the age of curing period 7 and 28 days for plain and hybrid fibers with showing the formation of cracks, CSH gel, and unhydrated cement particles.

Fig 1: SEM image of Mix 1 at 7days of Plain SCC and Hybrid SCC

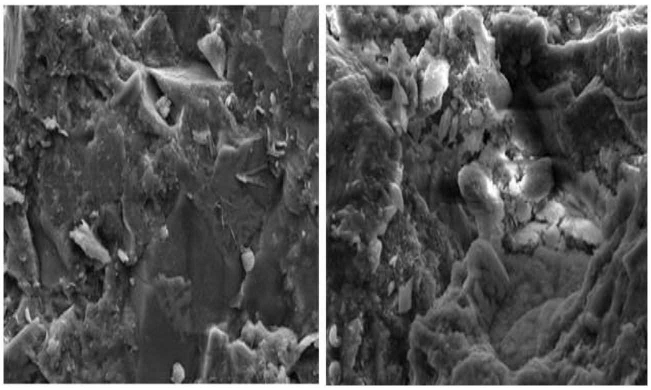


Fig 2: SEM image of Mix 1 at 28days of Plain SCC and Hybrid SCC

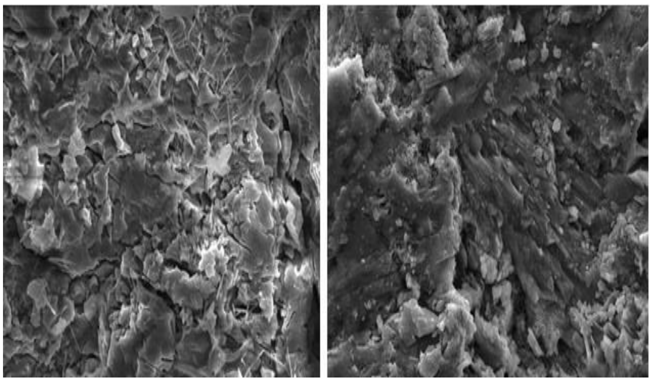


Fig 3: SEM image of Mix 2 at 7days of Plain SCC and Hybrid SCC

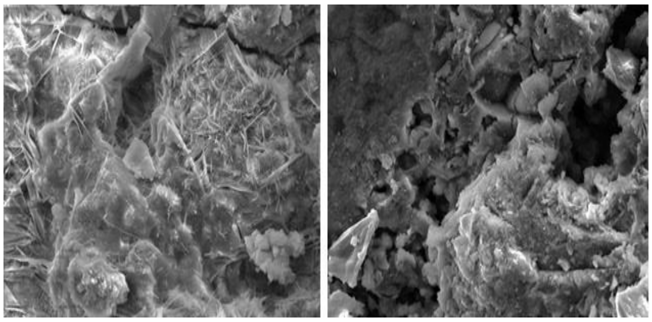


Fig 4: SEM image of Mix 2 at 28days of Plain SCC and Hybrid SCC

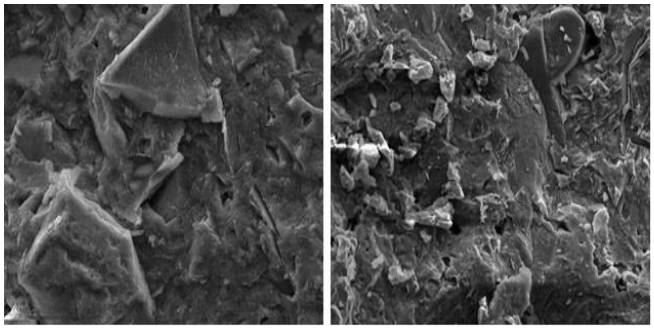


Fig 5: SEM image of Mix 3 at 7days of Plain SCC and Hybrid SCC

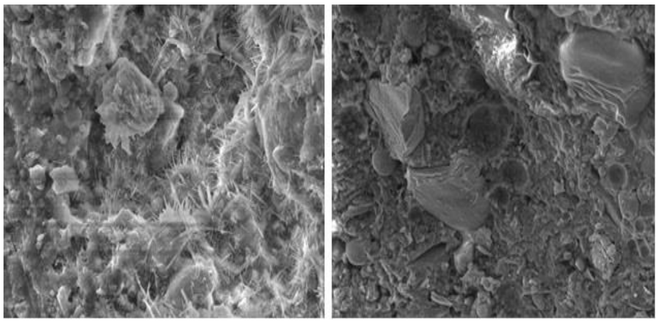
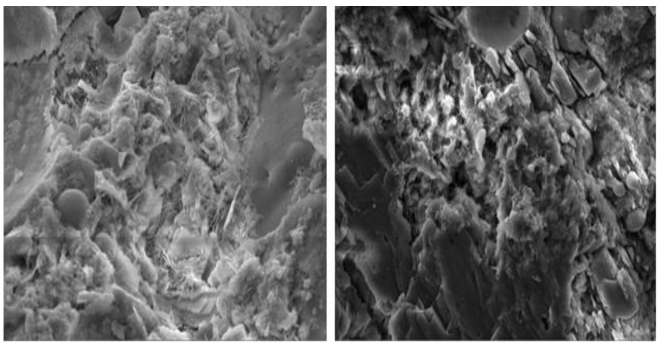


Fig 6: SEM image of Mix 3 at 28days of Plain SCC and Hybrid SCC



Mix 1: From Fig 1 Plain SCC 7 days shows presence of calcium hydroxide (Hexagonal habit/solid type structure) and CSH gel (Flower/ Sheet type structure), whereas hybrid SCC of 7 days shows presence of CSH gel with small amount of calcium hydroxide and fig 2, 28 days Plain SCC has small amount of Ettringite (needle shape structure) and CSH gel along with micro cracks whereas 28 days Hybrid SCC shows presence of calcium hydroxide and CSH gel with micro cracks.

Mix 2: From Fig 3 Plain SCC 7 days shows presence of Ettringite and CSH gel (Flower/ Sheet type structure) with unhydrated cement particles, whereas hybrid SCC of 7 days shows presence of CSH gel with dark spots and Fig 4, 28 days Plain SCC has calcium hydroxide with unhydrated cement particles whereas 28 days Hybrid SCC shows presence of calcium hydroxide with micro cracks along with dark spots as pores of hydrated cement paste.

Mix 3: From Fig 5 Plain SCC 7 days shows presence Ettringite and CSH gel with ball like structure shows usage of Fly ash, whereas hybrid SCC of 7 days shows presence of calcium hydroxide with Fly ash and fig 6, 28 days Plain SCC has small amount of Ettringite (needle shape structure) and calcium hydroxide along with micro cracks and Fly ash whereas 28 days Hybrid SCC shows presence of calcium hydroxide with pores of hydrated cement paste.

8. CONCLUSIONS

[1] The Compressive strength, Flexural strength and Tensile strength of plain and Hybrid SCC of 7 and 28 days of mix 1 have more strength compared to other two mixes.
[2] The SEM of mix 1 of plain SCC and hybrid SCC of 7 and 28 days indicate presence of CSH gel, Calcium hydroxide in which hybrid SCC has increase in Compressive strength, Tensile strength and Flexural strength than plain SCC.
[3] The SEM of mix 2 of plain SCC of 28 days shows decrease in strength due to presence of unhydrated cement particles compared to hybrid SCC.
[4] The SEM of mix 2 of plain SCC of 7 days shows decrease in Compressive strength due to presence of unhydrated cement particles along with CSH gel compared to hybrid SCC has CSH gel with hydrated cement particles.
[5] The SEM of mix 3 of plain SCC and hybrid SCC shows ball like structure indicates the usage of Fly ash.
All the mixes are satisfying the EFNARC guidelines.

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