Experimental investigation of Rheological and Mechanical properties for high strength self compacting concrete using ternary blend

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Abstract

In this paper objective of experiment, findings and its application are as follows.

***Objective**: In the production of High Strength Self Compacting concrete (HSSCC), the use of ternary blend of supplementary cementitious materials (SCM's) has not found enough applications. For this purpose, an effort has been made to present a mix design for M80 grade HSSCC with ternary blending of Fly Ash(FA) and Micro Fine(MF) in accordance with EFNARC guidelines.*

***Findings:** In this experiment, cement has been replaced with SCM's FA from 0% to 30% and/with MF 0%, 2.5%, 5%, 7.5%, 10%, 12.5%and 15%. Here total maximum replacement of cement is 45% by SCM's. Rheological properties of HSSCC were tested for slump flow, T50cm test and U box. The Mechanical properties of concrete at hardened state were tested for compressive strength test. The compressive strength tests were performed for 7 and 28 days. The results indicate that the use of ternary blend has improved the workability and compressive strength properties of specimens.*

***Application**: The primary application is to fill the congested reinforcement with eliminating honeycombing defect and increase finishing with increase life span of the structure*

Keywords: *High strength self-compacting concrete; M80 grade; Fly ash; Micro fine; Rheological property; Mechanical property*

INTRODUCTION

Self Compacting Concrete (SCC) is a concrete which flows and compact under its own weight without the need of external vibrator. Due to resistance towards bleeding and segregation with high fluidity it is able to pumped to longer distance and it is not affected by type of congested reinforcement bars and skill of labour. Even if there is congested reinforcement it can fill the gap and spaces. That is clear difference between the normal concrete and SCC. In HSSCC and SCC main difference is about their strength. The SCM's include FA and MF. HSSCC requires high proportions of SCM's and incorporation of polycarboxylate based super plasticizer. The SCM's are added to the concrete to enhance the properties of the concrete, and also to improve the rheological properties and mechanical strength also reduce the environmental impact.

Now a day, SCC is getting more attention by researchers due to the various construction problems such as inconsistent construction quality, noise pollution due to vibration of equipment, reduce in the durability and life span of the structure, increase cost of labour and materials, inadequate compaction in congested reinforcement, inadequate compaction leads to large number of voids which can reduce the strength and durability of the structures. It also lowered down the finishing quality of concrete. To overcome these problems special concrete known as Self Compacting Concrete (SCC) is developed. The main reasons for employment of SCC are to shorten the time period, to eliminate the noise during vibration, to ensure compaction of structures even in congested reinforcement. To achieve SCC, it should meet the following needs its filling ability (flow ability), passing ability and resistance to segregation during placing and transportation. The disadvantage of the SCC is no standards are available for the mix design and cost is slightly higher than normal concrete. High strength is associated with compressive strength property of SCC. So, it is termed as HSSCC. M80 grade is taken as high compressive strength SCC.

This research work mainly emphasis on the rheological and mechanical criteria of SCC using partial replacement of cement by SCM's in the concrete.

MATERIAL PROPERTIES

Cement: 53 grade OPC cement is used. The properties of cement are confirmed to IS 12269-2013.
Fine aggregate: Locally available river sand is used. Sieve analysis has been carried out. The results were as per IS 383-1970. River sand is of Zone II. The fineness modulus of river sand is 2.83 and specific gravity of the river sand is 2.58.
Coarse aggregate: Natural aggregate of maximum size 10mm are used. Selecting maximum size as 10mm by keeping in mind congested reinforcement. The aggregates were tested and sieve analysis has been confirmed to IS 2386(Part 1, 2, 3)-1963. The specific gravity is 2.88 and fineness modulus of coarse aggregate is 6.94.
Chemical admixture: To reduce the water binder ratio admixture, BASF MasterGlenium SKY 8777 is used. The dosage of admixture has been decided by marsh cone test. Which is 0.9% by weight of cementitious material.
Water: Fresh water with PH 6.79 is used for casting and curing.
SCM's: The properties of the SCM's are as follow: -

MF: MF is processed form of Ground Granulated Blast Furnace Slag (GGBS). MF is finer material than GGBS particles. So, MF needs less time to react with other ingredients of HSSCC. Specification of MF is as per BS:6699-1992.

FA: Specification of FA is as per IS: 3812(part-1)-2003.

Table 1: *SCM'S Properties*

Properties	Fly Ash (Class F)	GGBS	MF
Fineness, specific surface area (m^2/kg)	335.4	402.1	770.12
Loss on ignition (%)	1.07	0.52	0.52
Moisture (%)	0.16	0.03	0.03
Passing on 45 Micron sieve(Wet sieving) (%)	73.87	-	-
Retention on 45 Micron sieve	23.13	2.9	1.42(on 25 Micron sieve)
Specific Gravity	2.21	2.88	2.88

Fig. 1: *Ingredients For M80 HSSCC*

EXPERIMENTAL PROGRAMME

HSSCC mix proportions:

By conducting various trial mix designs final trial mix has been designed. It satisfied EFNARC guidelines for SCC. Table 2 shows the final mix proportions of each HSSCC with different percentage of FA and MF. The water binder ratio is 0.23 for all M80 except B6 mix design. In B6 mix design it is taken as 0.21.

Mix Procedure:

The mixing procedure was done according to the guidelines with adjustment of time and mixing steps. Proper mixing by pan mixer has been carried out. The mixing time depends on the SCM's. In pan mixture initially coarse aggregates and fine aggregates are added in the mix, 60% of total water is added in pan during mixing process. Then binders are added in pan and mixing it. After that remaining water and admixture are added to the mix and rotated for 2 to 3 minutes until uniform mix is formed. The mixing time varies from 2-5 minutes depending on the type of cement and binders. The various mix proportions of SCC have been shown in table 2.

Table 2: *Mix Design*

Design mix	OPC (kg/m^3)	FA (kg/m^3)	MF (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	Water (L/m^3)	SP (L/m^3)
M80					***10mm***		
A	680	-	-	830	812	155.5	6.12
A0	476	204	53	830	812	155.5	6.12
A1	459	204	17	830	812	155.5	6.12
A2	442	204	34	830	812	155.5	6.12
A3	425	204	51	830	812	155.5	6.12
A4	408	204	68	830	812	155.5	6.12
A5	391	204	85	830	812	155.5	6.12
A6	374	204	102	830	812	155.5	6.12
B6	374	204	102	830	812	142.8	6.12

Results and Discussions

Rheological properties: To ensure the SCC, workability test is carried out through Slump flow, T50 flow and U box are conducted immediately after the fresh mix formed. The procedure of the test was conducted as per the guidelines EFNARC.

The slump value was in the range of 610 mm to 980 mm for M80 grade concrete with W/B ratio 0.23. But in mix design A6 during slump flow test shows sign of segregation and bleeding which was unacceptable by the guidelines. So, as per the guideline recommendation water content is reduced and making W/B ratio 0.21 by keeping all the content constant as like A6 mix design and new mix design is named as B6. B6 shows 710mm slump flow. Which was acceptable by guideline.

The T50 test was 2.38-4.25 second for M80 grade concrete. Similar way as in slump flow test in T50cm test carried in B6 mix design which has 3.52 seconds. Which was acceptable as per the guidelines it was 2-5 second.

The U box test also carried for B6 mix design which satisfied the SCC criteria. The results have been showed in table 3.

Fig. 2: *Slump Flow Test*

Table 3: *Rheological Test Results.*

Sr No.	Design Mix	% FA + % MF	Slump flow in mm	T-50cm test in second	U-Box in mm
1	***A***	0%	620	4.25	26
2	***A0***	30%+0%	630	4.13	24
3	***A1***	30%+2.5%	640	4.06	24
4	***A2***	30%+5%	680	3.85	23
5	***A3***	30%+7.5%	725	3.47	22
6	***A4***	30%+10%	790	3.17	20
7	***A5***	30%+12.5%	885	2.74	15
8	***A6***	30%+15%	980	2.38	12
9	***B6***	30%+15%	710	3.52	22

In figure 2, slump flow of M80 grade concrete has been presented which satisfies the slump test criteria. According to the EFNARC, the mix design satisfies all the requirements and all under the acceptable criteria except all only A6 mix design fails in rheological property.

Compressive strength test: Except A6 mix design all remaining mix designs are carried forward for the compressive strength. It was determined at 7 and 28 days with the concrete cube of size 150mm x 150 mm x 150mm.

Table 4: *Compressive Strength Test Results In MPa.*

Sr No	Design Mix	% of Fly Ash + % of Micro fine	7 day in MPa	28 day in MPa
1	A	0%	64.5	82.21
2	A0	30%+0%	63.5	82.2
3	A1	30%+2.5%	69.31	82.4
4	A2	30%+5%	70.56	84.68
5	A3	30%+7.5%	72.44	87.52
6	A4	30%+10%	73.73	90.95
7	A5	30%+12.5%	76.43	92.31
8	B6	30%+15%	75.54	91.43

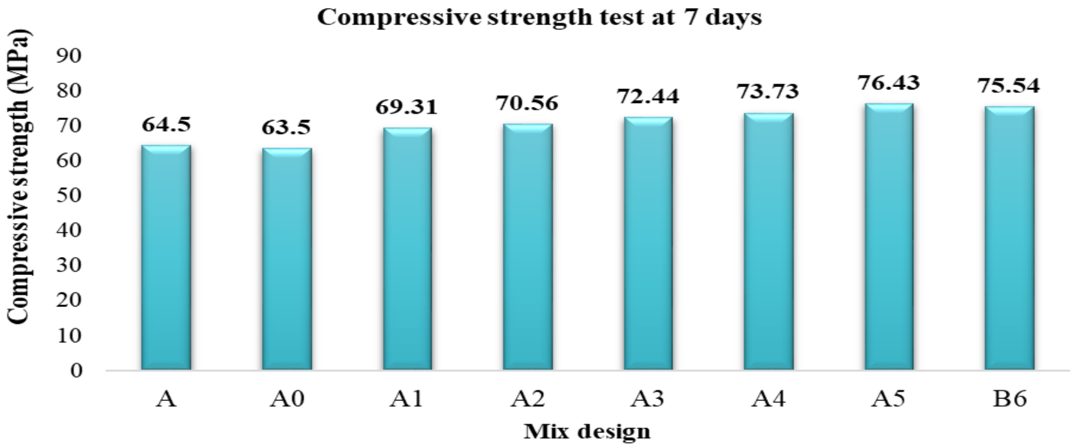

Fig. 3: *Compressive Strength Test At 7 Days' Results In MPa*

From Figure 3 it has been observed that with 0% SCM's the basic M80 has given the desired strength of 64.5 MPa at 7 days as shown in Table 4. There is gradual increase in strength up to 76.43 MPa with SCM's up to 30% Fly Ash, 12.5% MF. In mix design B6 with lowered water binder ratio strength is 75.54 MPa

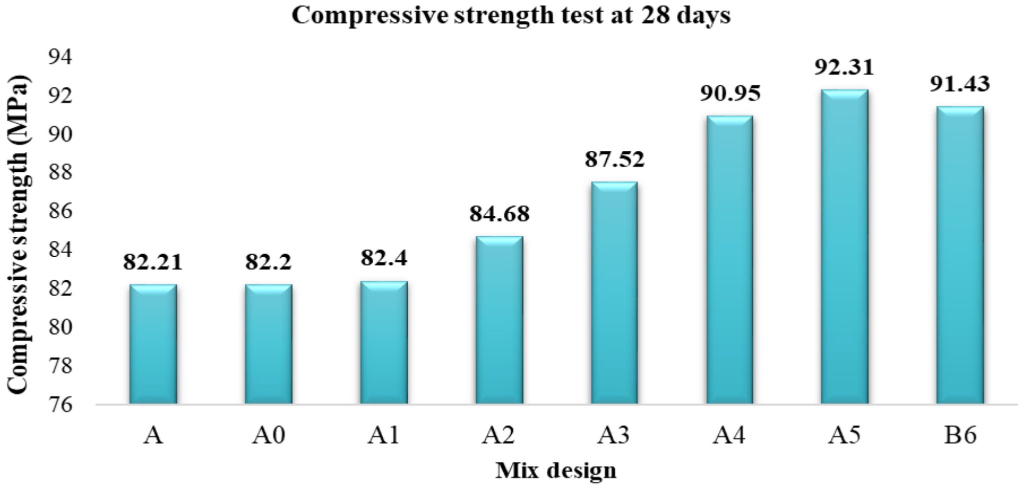

Fig. 4: *Compressive Strength Test At 28 Days' Results In MPa*

It has been analyzed that with 0% SCM's the basic M80 has given the desired strength of 82.21 MPa at 28 days as shown in Table 4. There is gradual increase in strength up to 92.31 MPa with SCM's up to 30% Fly Ash, 12.5% MF. In mix design B6 with lowered water binder ratio strength is 91.43 MPa as in figure 4.

CONCLUSIONS

By conducting various trial mixes effect of FA and MF on high strength SCC has been studied for Rheological and mechanical properties of concrete. SCC is used to eliminate the problem related to noise, compaction and strength becomes sustainable as it saves energy compare to conventional concrete.

The mix design of M80 grade high strength self-compacting concrete is found to be workable and compatible as recommended by the European guidelines.

1. Rheological and mechanical properties of the HSSCC are improved with the inclusion of SCM's.
2. SCC is trial mix method. No codes or standards are available for the mix designs.
3. W/B ratio was chosen as 0.23 by weight for M80 grade with 12.5% microfine and 30% fly ash by weight of total SCM's and 0.21 by weight for M80 grade with 15% microfine and 30% fly ash by weight of total SCM's.
4. The fresh properties of SCC like filling ability, passing ability and segregation resistance which are the basic requirements of SCC were found to be satisfying with 12.5% microfine content with W/B ratio 0.23 but for 15% microfine mix design (A6) with W/B ratio 0.23 shows sign of segregation which didn't satisfy guideline.
5. Reduced water content as W/B ratio 0.21 in 15% microfine mix design (B6) is performed which satisfy criteria for SCC as per guideline.
6. The slump flow is ranging from 620 mm to 885 mm for M80 grade with W/B ratio 0.23. In A6 mix design slump flow is 980mm but also shows sign of segregation as per the guidelines. So, as per the guideline water content is reduced and B6 mix design is performed and 710 mm flow for W/B ratio 0.21 in this mix design achieved. Which satisfy recommended results as per the guideline.

7. The T50 test is ranging from 2.38 sec to 4.25 sec for M80 grade with W/B ratio 0.23. In A6 mix design time is 2.38 sec but also shows sign of segregation in slump flow test as per the guidelines. So, as per the guideline water content is reduced and B6 mix design is performed and 3.52 sec for W/B ratio 0.21 in this mix design achieved which is acceptable as the range is 2 – 5 sec.
8. SCC with 30% Fly Ash and 12.5% MF gave the highest value of concrete compressive strength for M80 grade HSSCC.
9. The compressive strength by adding SCM's was increased from 81.67MPa to 92.31MPa at 28 days for M80 grade concrete.
10. From all above results it is clear that by increasing % of microfine content in SCM workability of concrete as well as compressive strength are improves.
11. Also microfine lower down required the water content for producing HSSCC. Which is a way to save valuable water.

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