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Research paper



Rheology, Strength and Durability Characteristics of Alccofine Blended Fibre Reinforced Self Consolidating Concrete

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Abstract

In this study, observations were made on the effect of blending cement with fly ash and Alccofine on the fresh and hardened properties of micro steel fibre reinforced self-consolidating concrete (SCC). SCC mixes were prepared based on EFNARC guidelines. Blending has been done by replacing 5%, 10% and 15% of cement with Alccofine. Slump flow, L-box and V-funnel tests were conducted to study the flow characteristics of SCC. Compressive strength, split tensile strength, and flexural strength tests were performed to assess the strength characteristics. It was observed that the SCC with 10% replacement of cement with Alccofine showed better results than the other mixes. Further, the modification of the optimum blend with 10% Alccofine was made by adding variable percentages (0.5%, 1% and 1.5% by volume) of micro steel fibres and strength tests were conducted to optimise the fibre content. The strength degradation of the SCC with optimum Alccofine and fibre content exposed to alkaline, chloride and sulphate solutions was also studied.

1. Introduction

Self-Consolidating Concretes (SCC) are special concretes with high deformability and less segregation. SCCs find application in the cases of highly congested reinforcements where mechanical compaction becomes tedious. As the name indicates the prime concern while designing SCC mixes is its workability. Though strength properties are also equally important [1].

The properties of SCC can be enhanced by using a blended cementing medium. Water reducing admixtures will help in gaining more strength without compromise on the workability. Kemal et. al. studied about the effectiveness of addition of fly ash and lime stone powder as supplementary cementitious materials. The resulting concretes were having better strength as well as durability characteristics [2].

Ha et. al. studied about the effectiveness of ternary blended cementing system with various mineral admixtures in SCC. A comparison was made among the result showed by different mineral admixtures[3].

This study was meant to characterize Alccofine as a supplementary cementitious material for blending the cementing medium in SCC. The study was focused on the strength enhancement by the addition of micro steel fibres also. The strength and durability characteristics of the resulting concretes were assessed.

2. Materials and Methods

Conventional SCC mix was designed based on the guidelines of European Federation of National Associations Representing for Concrete (EFNARC) [4]. The targeted compressive strength for SCC was 30N/mm^2. The control concrete was made with a binary blended cementing medium containing cement and fly ash. Cement used for the concrete was Ordinary Portland Cement (OPC) of grade 53. Class F fly ash (F) was used as a supplementary cementitious material. Crushed granite stones of average size 12.5mm were used as coarse aggregate (CA). Locally available sand with specific gravity 2.72 was used as fine aggregate (FA). Potable water was used for the hydration of the cementing medium. Carboxylic ether polymer based super plasticizer was also used for SCC mix. Alccofine (AL) was also used as a supplementary cementitious material. Further micro steel fibres (MSF) were used to enhance the strength properties of SCC. The mix proportion for the M30 SCC mix was finalized by examining the fresh properties of different trial mixes. The SCC which offers maximum slump flow without undergoing segregation was selected as the control mix. Further the conventional mix was modified by replacing the cement content by 5%, 10% and 15% with AL by weight. Water to binder ratio (W/B) was kept 0.4 for all the mixes. The dosage of super plasticizer for conventional mix was taken as 5% (by volume of binder) whereas the dosage of super plasticizer for ternary blended concrete was 3% as AL imparts more workability for concrete.

Fresh properties of SCC were observed by performing slump flow test, V- funnel test and L-box test. Strength characteristics of these mixes were assessed by performing compressive strength conforming to IS 516 [5], split tensile conforming to IS 5816 [6] and flexural strength tests conforming to IS 516 [5]. As concrete with 10% Alccofine showed better results, it was considered as optimum concrete. The mix which gave optimum results was selected for the further modification by adding micro steel fibres in it.

The optimum mixes which showed better strength characteristics were tested for the durability. Concrete cube specimens of size 150mm x 150mm x 150mm was exposed to a maximum concentration of 5% of alkaline, sulphate and chloride solutions. The strength loss and weight loss for different exposure conditions in 56 days and 90 days were observed.

The mix details are duly presented in a previous publication of two of the authors' previous publication[7].The mix proportions used in this study are given in the following table 1.

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Table 1: Details of mix proportions

Mix	Cement (kg)	AL (kg)	F (kg)	FA (kg)	CA (kg)	W/B	Water (kg)	SP (%)	MSF
CC	360	-	210	758	758	0.4	230	0.5	-
A5	342	18	210	759	759	0.4	230	0.3	-
A10	324	36	210	760	760	0.4	230	0.3	-
A15	306	54	210	761	761	0.4	230	0.3	-
A10F0.5	324	36	210	760	760	0.4	230	0.3	2.85
A10F1.0	324	36	210	760	760	0.4	230	0.3	5.7
A10F1.5	324	36	210	760	760	0.4	230	0.3	8.5

3. Results and Discussions

Fresh Properties

The fresh properties of the mixes are given in the following figures.

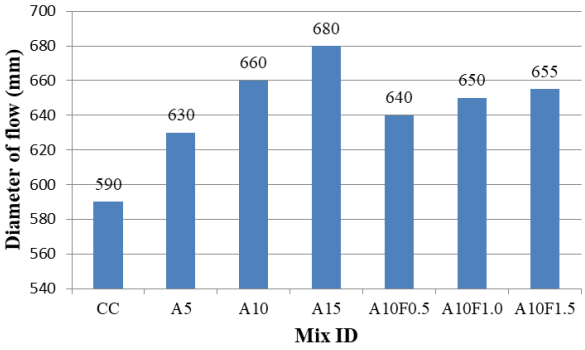

Fig. 1: Comparison of flow diameter

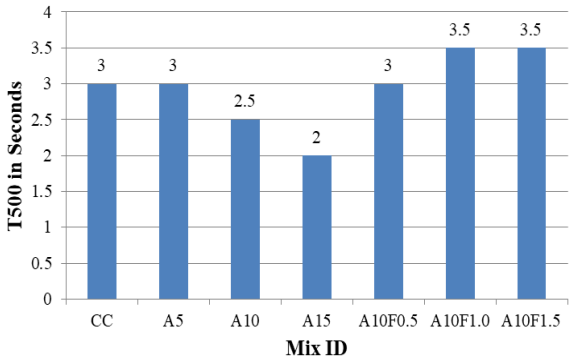

Fig. 2: Comparison of T500 time

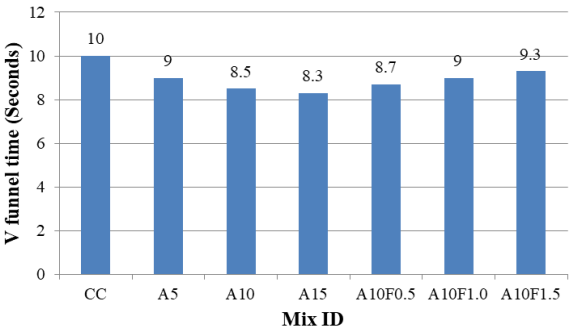

Fig. 3: Comparison of V-funnel time

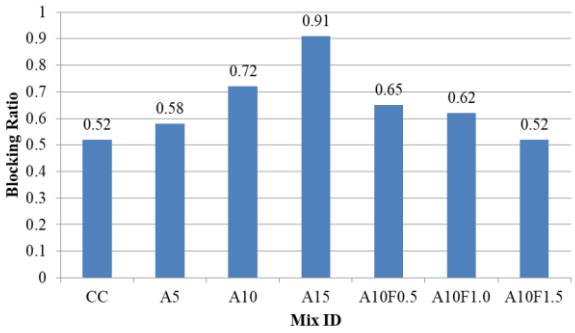

Fig. 4: Comparison of passing ability

From the comparison diagrams it is clear that the mix A15 shows maximum flow diameter, lesser T500 value, lesser V-funnel time and better passing ability also. This shows the effectiveness of Alccofine in improving workability of the mix. It may be attributed to the ultra-fine nature of Alccofine.

Properties of Hardened Concrete

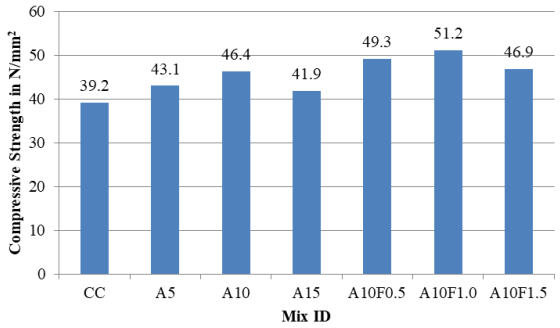

Fig. 5: Comparison of Compressive Strength

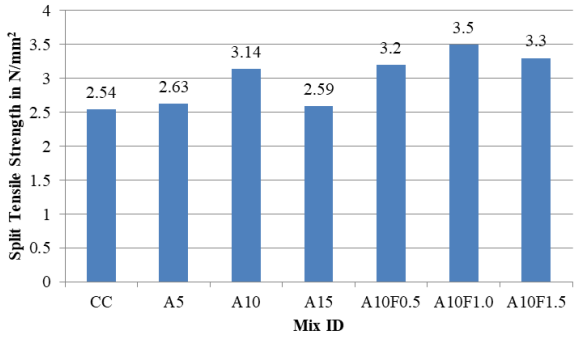

Fig. 6: Comparison of Splitting Tensile Strength

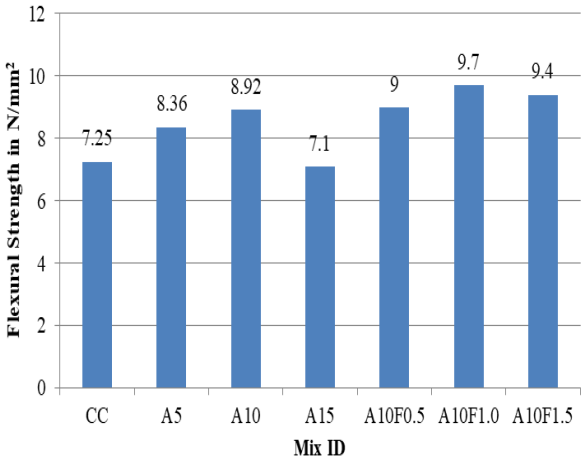

Fig. 7: Comparison of Flexural Strength

From the results it is clear that among all the mixes made without adding fibres, A10 shows better result. So the replacement of cement with 10% Alccofine can be considered as optimum modification. The optimum mix was further modified by adding MSF. Among the three mixes with fibres, mix with 1% of fibre by volume showed a better result. So the mix A10F1.0 can be considered as the optimum mix. The high strength of the mix can be attributed to the ultra-fine nature of AL, thereby having more surface area. The ultra-fine nature will help in the better pozzolanic reaction.

Durability Characteristics

The durability of the SCC mixes was assessed by exposing cube specimens to alkaline, chloride and sulphate medium. The weight loss and strength loss of cubes made of mixes CC, A10 and A10F1.0 after 56 days and 90 days of exposure to the above mentioned media were assessed.

Specimens exposed to Chloride solution

For assessing the effects of exposure of the SCC mixes to chlorides, the cube specimens were cured in a solution with 5% Sodium Chloride (NaCl). The changes in strength were observed after 56 days and 90 days of curing. The figure 8 shows the comparison between compressive strength values of cubes cured in potable water and that of specimens cured in NaCl solution at 56 days. Figure 9 gives the same comparison but after 90 days of curing.

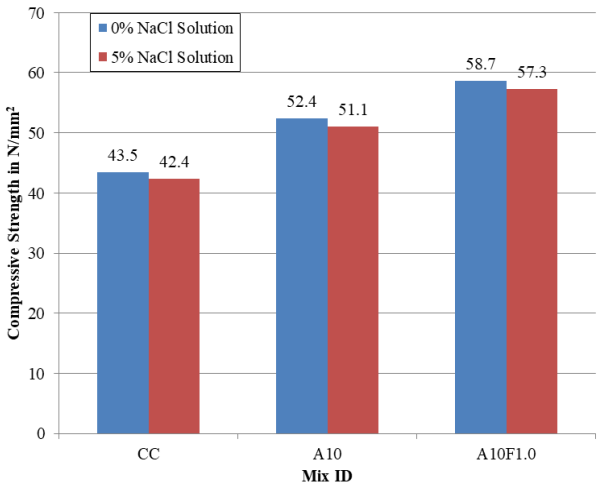

Fig. 8: Compressive strength of various mixes after 56 days of exposure to NaCl

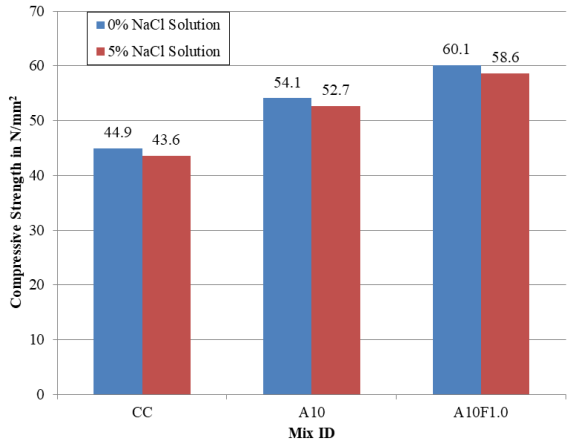

Fig. 9: Compressive strength of various mixes after 90 days of exposure to NaCl

All the mixes showed slight decrease in the compressive strength for both the curing periods when exposed to NaCl solution compared to that of specimens cured in water.

Specimens exposed to Sulphate solution

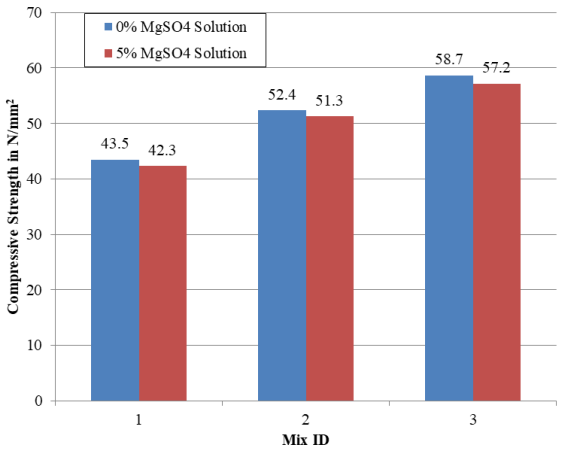

Fig. 10: Compressive strength of various mixes after 56 days of exposure to $MgSO_4$

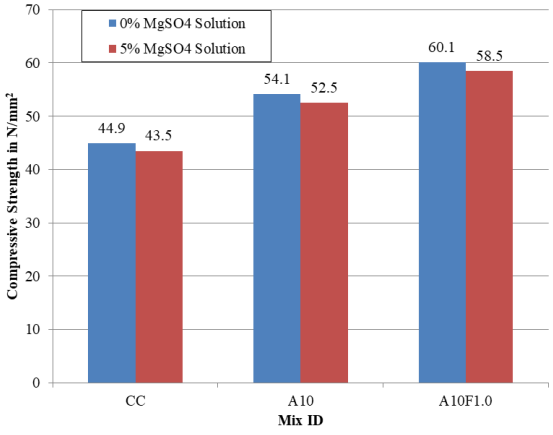

Fig. 11: Compressive strength of various mixes after 90 days of exposure to $MgSO_4$

For assessing the effects of exposure of the SCC mixes to Sulphates, the cube specimens were cured in a solution with 5% Magnesium Sulphate ($MgSO_4$). The changes in strength were observed after 56 days and 90 days of curing. The figure 10 shows the comparison between compressive strength values of cubes cured in potable water and that of specimens cured in $MgSO_4$

solution at 56 days. Figure 11 gives the same comparison but after 90 days of curing.
All the mixes showed slight decrease in the compressive strength for both the curing periods when exposed to $MgSO_4$ solution compared to that of specimens cured in water.

Specimens exposed to alkaline solution
For assessing the effects of exposure of the SCC mixes to alkalies, the cube specimens were cured in a solution with 5% Sodium Hydroxide (NaOH). The changes in strength were observed after 56 days and 90 days of curing. The figure 12 shows the comparison between compressive strength values of cubes cured in potable water and that of specimens cured in $MgSO_4$ solution at 56 days. Figure 13 gives the same comparison but after 90 days of curing.

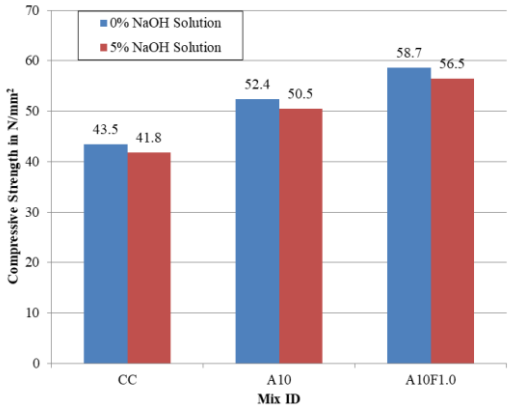

Fig. 12: Compressive strength of various mixes after 56 days of exposure to NaOH

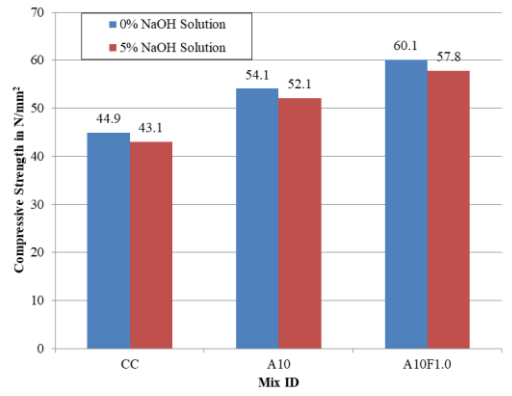

Fig. 13: Compressive strength of various mixes after 90 days of exposure to NaOH

All the mixes showed slight decrease in the compressive strength for both the curing periods when exposed to NaOH solution compared to that of specimens cured in water.

Weight Loss when exposed to NaCl
As a measurement of degradation of the concrete the loss of weight after the exposure to chloride solution was observed. Figure 14 gives the comparison of weight loss.

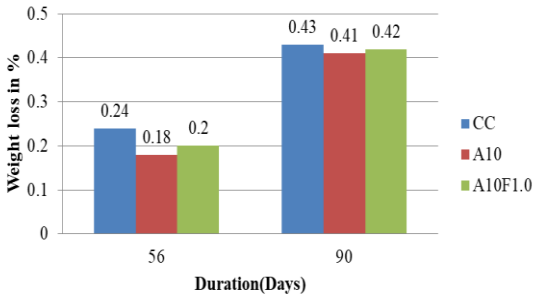

Fig. 14: Percentage weight loss when exposed to NaCl

From the results it is clear that the conventional SCC showed more loss of weight due to exposure. The improved property of the other two mixes may be because of the use of Alccofine.

Weight Loss when exposed to $MgSO_4$
When exposed for 56 days to $MgSO_4$, all the mixes showed negligible reduction in weight. However, among the results, conventional mix showed more reduction in weight. Weight reduction got increased when observed at after 90 days. The value showed by each mixes were almost similar.Figure 15 shows the comparison of results.

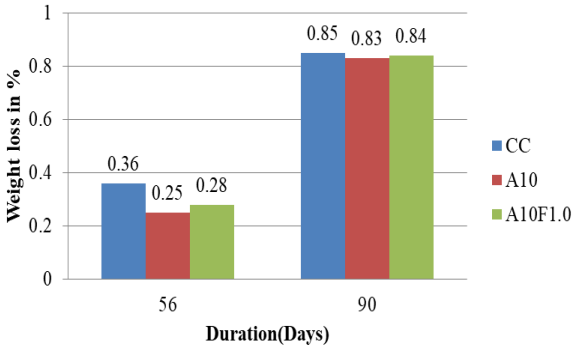

Fig. 15: Percentage weight loss when exposed to $MgSO_4$

The better results of blended mixes show the effectiveness of Alccofine as supplementary cementitious material.

Weight Loss when exposed to NaOH
When exposed to NaOH, conventional SCC mix showed greater loss in weight for both the curing period. From the results, it is clear that addition of Alccofine helps in overcoming the loss of weight effectively. Figure 16 gives the comparison of results.

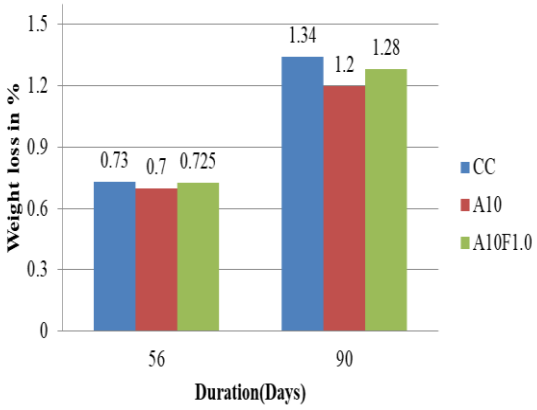

Fig. 16: Percentage weight loss when exposed to NaOH

4. Conclusions

- In the mixes without fibres the one with 10% Alccofine as supplementary cementitious material showed better strength results.
- Among fibre reinforced mixes the one with 10% Alccofine and 1.0% of micro steel fibre showed better strength characteristics.
- The strength reduction of all the mixes when exposed to chloride, sulphate and alkaline media was nominal for both 56 days and 90 days of curing.
- Conventional SCC showed greater loss in weight when exposed to chloride, sulphate and alkaline media for 56 days and 90 days of curing.
- Mixes with Alccofine showed lower values of weight loss.
- The improved properties of mixes with Alccofine can be attributed to its greater specific surface. This will help in more effective hydration of the blend thereby better pozzolanic reaction will be occurred. This will lead to the gain in strength. Moreover, it helps in reduction of permeability thereby enhanced durability characteristics.

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