Study on the Properties of Alccofine-1203 Based Self Compacting Concrete

A. A. Ruksana and S. Sreerath

Abstract Self Compacting Concrete (SCC) is a significant advancement in the concrete industry that has the ability to flow uniformly into formwork without vibration, segregation, or bleeding, and to create a good working environment without the need of vibration. However, the main ingredient, cement, has a huge carbon footprint owing to its manufacture and transport. The primary mitigation measure to counteract that would be reducing the use of cement. Supplementary Cementitious Materials (SCMs) can help to achieve that. Another key ingredient in the manufacture of SCC would be admixtures. The choice will depend on the compatibility. Alccofine-1203 is a mineral admixture of ultra-fine particle size and with great pozzolanic reactivity achieved through the method of controlled granulation. This study aims to investigate the partial replacement of cement with Alccofine-1203 in SCC. The fresh properties and compressive strength of SCC mixes prepared with varying doses of Alccofine-1203 content were studied. The fresh properties were assessed by slump flow, V-funnel & L-box tests and compressive strength test is also done as it is the key mechanical property. The results show that the utilization of Alccofine-1203 in SCC has great influence on engineering as a promisable construction material.

Keywords SCC (SCC) · Alccofine-1203 · Strength · Fresh properties · Compressive Strength

1 Introduction

Self Compacting Concrete (SCC) is an important invention for overcoming the problem of compaction in densely reinforced concrete constructions. Due to its unique qualities of flowability, SCC has shown to be a perfect alternative to traditional concrete in the construction industry over the years without vibrators. SCC has a similar composition as that of the traditional concrete, but with a higher amount of sand. Cement, fine aggregates, and a superplasticizer are used for its production.

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One of the main disadvantages of SCC is its high cost, which was because of the use of large quantities of cement and chemical admixtures. Hence, there comes a need to decrease this high consumption of cement in SCC by resorting to any other kinds of cementitious materials.

Meanwhile, cement production in the whole world accounts for around 7% of worldwide Green House Gas (GHG) emissions. When compared to other GHGs in the energy sector, CO_2 has a very high proportion. The percentage of CO_2 emissions not only demonstrates the negative influence on the ecosystem, but it also increases the GHG effect, producing global warming. Despite the fact that cement production emits GHGs as a byproduct, there is still a great need for this material in the global infrastructure construction. If this continues, the natural resources available for cement manufacture will get depleted, producing significantly furthermore environmental impacts and loss of natural resources. These two conditions necessitate the use of other cementitious materials that can totally or partially replace cement; these materials are known as Supplementary Cementitious Materials (SCMs). The addition of a few alternative pozzolanic elements to concrete has improved its strength, durability, workability and permeability.

Ambuja Cements has established the production of Alccofine-1203, a micro fine cementitious material produced from the industrial by-product of GGBS produced in a controlled manner. Alccofine-1203 is a specially treated product of slag with high amount of glass content and high range of pozzolanic reactivity prepared by the method of controlled granulation [5]. Available literatures have a common observation: due to higher specific surface area and high pozzolanic activity nature of Alccofine-1203, mechanical properties of SCC can be improved with the incorporation of Alccofine-1203 blended with other mineral admixtures. It has been also seen that the usage of SCMs instead of cement helps in the reduction of cement, also making SCC environmental friendly [1–4].

In the current study, a research was done on the possibility of creating an SCC by the replacement of cement with Alccofine-1203 alone, as a mineral admixture. Fresh properties and compressive strength studies of SCC mixtures were conducted. In all the mixes, Alccofine-1203 was replaced in varying proportions: 0, 6, 8, 10, 12 and 15% by weight of cement. Fresh concrete tests such as slump flow, V-funnel and L-box tests were conducted to confirm self compactability parameters. This study looks at how SCC can be combined with SCM to improve workability and compressive strength, resulting in a high-strength, cost-effective, and environment friendly concrete mix.

Table 1 Physical properties of cement

Experiment	Result	Standard method as per Indian Standard Code
Fineness	6.5%	IS:4031(Part-IV)-1988
Specific gravity	2.69	IS:4031(Part-XI)-1988
Initial setting time	85 min	IS:1489(Part 1)-1991
Consistency	33%	IS:4031(Part-IV)-1988

Table 2 Physical properties of fine aggregates

Sl. No	Properties	Test results
1	Specific gravity	2.75
2	Water absorption	1.31%
3	Fineness modulus	2.83

2 Experimental Investigation

2.1 Materials

2.1.1 Cement

Portland Pozzolana Cement (PPC) of Grade 53 conforming to IS:1489 (Part 1)-1991 is used for the preparation of various mixes. The physical properties of the used cement are listed in Table 1.

2.1.2 Fine Aggregate

M-Sand is used as fine aggregate and are tested as per IS:2386 (Part III)-1963. Physical properties of the used fine aggregates are tabulated in Table 2. Gradation of fine aggregates done by sieve analysis conformed to Zone-II as per IS:383–2016 and the gradation curve is shown in Fig. 1. M-sand of average particle size passing through 4.75 mm sieve is used in this study.

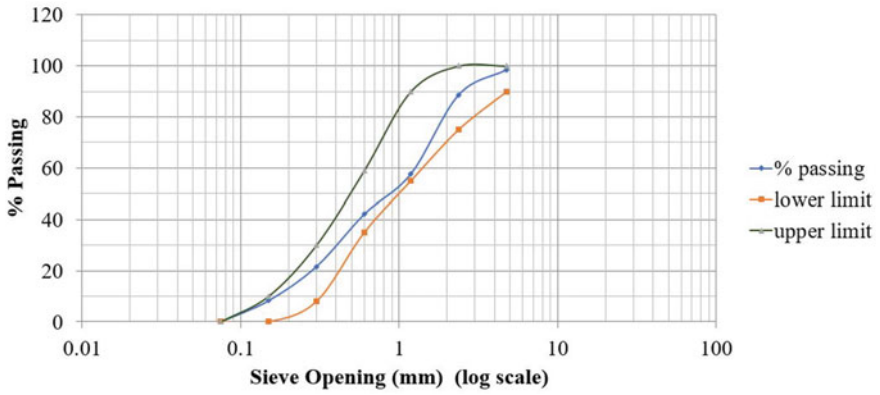

Fig. 1 Gradation curve of M-Sand

Table 3 Physical properties of coarse aggregates

Sl. No	Properties	Test results
1	Specific gravity	2.85
2	Water absorption	0.101%
3	Bulk density	1.33 kg/L

2.1.3 Coarse Aggregate

Crushed granite angular aggregates were available from a local source had a maximum size of 12.5 mm, is used for the present study. Tests on coarse aggregate are conducted according to IS:2386 (Part III)-1963. Physical properties of the used coarse aggregates are shown in Table 3.

2.1.4 Alccofine-1203

Alccofine-1203 was procured from Ambuja Cement Ltd., Goa, and was used throughout the investigation in accordance with ASTM C989-1999. Figure 2 shows a sample of the Alccofine-1203 material. Table 4 lists the physical and chemical properties of ALC.

Fig. 2 Alccofine-1203

Table 4 Physical and chemical properties of Alccofine-1203

Physical Properties of Alccofine-1203 *					
Fineness (cm^2/gm)	Specific gravity	Bulk density (kg/m^3)	Particle size distribution		
			D10	D50	D90
>12,000	2.9	700–900	1.5 micron	5 micron	9 micron
Chemical Properties of Alccofine-1203 *					
CaO	SO_3	SiO_2	Al_2O_3	Fe_2O_3	MgO
61–64%	2–2.4%	21–23%	5–5.6%	3.8–4.4%	0.8–1.4%

* As per manufacture's booklet

2.1.5 Polycarboxylate Ether Superplasticizer

Conflo-LN is a superplasticizer made from polycarboxylate ethers. With a relatively low dosage (0.3–0.4% by cement weight) they enable a water reduction up to 30%, due to their chemical structure which enables good particle dispersion. They increase the efficiency of cement by improving the workability of the cement mix. Table 5 lists the characteristics of Conflo-LN.

2.1.6 Water

The specimens are mixed and cured with potable water, as suggested by IS:456–2000. The presence of any kind of sulphates & salts can reduce the concrete strength and have to be avoided.

Table 5 Physical properties of Conflo-LN

Property	Value
Colour	Brown liquid
Consistency	Low viscosity
Specific gravity	1.19–1.20
Air entrainment	1–2% depending on sand grading & water content
Chloride content	Nil
Nitrate content	Nil

Table 6 Designation of specimens prepared with Alccofine-1203

Mix ID	Proportion of binding materials
CM	100% Cement
ALC6	94% Cement + 6% Alccofine-1203
ALC8	92% Cement + 8% Alccofine-1203
ALC10	90% Cement + 10% Alccofine-1203
ALC12	88% Cement + 12% Alccofine-1203
ALC15	85% Cement + 15% Alccofine-1203

2.2 Mix Proportions

SCC does not have a precise mix design. M30 grade concrete is developed in this study according to IS:10,262–2019 and EFNARC 2005 [9]. After varying between different dosages supplied by the manufacturer, a water binder ratio of 0.42 and 0.4 percent superplasticizer is finally adopted for all combinations. Control Mix (CM) was prepared without adding any kind of mineral admixtures in SCC as per the referred literatures. Five different SCC mixes were then casted, cured and tested to examine the influence of Alccofine-1203 on SCC, where PPC was replaced with Alccofine-1203 at 0, 6, 8, 10, 12 and 15% by weight of cement content.

The cement content taken is on the higher side of the generally adopted values. There are chances for shrinkage cracks with high percentage of fine content. No such cracks were seen in the casted specimens. If such cracks have formed internally, that would have reduce the strength of the specimen. In the present work, no such reduction in strength was observed. Hence the present mix design is adopted. The presence of shrinkage cracks and their effects is out of scope of this work. Tables 6 and 7 list the mix designations as well as the proportions of each blend.

Table 7 Mix proportions of SCC specimens

Mix ID	w/b	SP (%)	Water (kg/m^3)	Cement (kg/m^3)	Alccofine-1203 (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)
CM	0.42	0.4	210	500	0	1125	515.85
ALC6	0.42	0.4	210	470	30	1125	515.85
ALC8	0.42	0.4	210	460	40	1125	515.85
ALC10	0.42	0.4	210	450	50	1125	515.85
ALC12	0.42	0.4	210	440	60	1125	515.85
ALC15	0.42	0.4	210	425	75	1125	515.85

Table 8 Fresh stage properties of different mix

Test	CM	ALC6	ALC8	ALC10	ALC12	ALC15
Slump Flow (mm)	690	698	705	718	710	680
V-Funnel (s)	9.27	10.02	9.1	8.65	11.2	11.85
L-Box	0.83	0.78	0.82	0.89	0.75	0.8

2.3 Testing of Specimens

Slump flow, V-funnel, and L-box tests were used to evaluate the workability properties of the mixes, according to EFNARC specifications and are summarized in Table 8. Compressive strength test conducted at the 7th day and 28th day of curing was performed according to IS:516–1959. Concrete cubes of size 150 $\times$ 150 $\times$ 150 mm were prepared for the compressive strength test. The casted samples were kept in their moulds covered with a damp cloth at room temperature for 24 h. The specimens were removed from the moulds after 24 h and transported to the curing tank & is kept submerged for the respective time periods.

3 Results and Discussions

3.1 Fresh Properties

The workability properties of SCC were determined using slump flow, L-box and V-funnel tests to determine filling and passing ability. Table 8 shows the results of various workability tests of SCC blends.

Fig. 3 Slump flow test

3.1.1 Slump Flow Test

Slump flow test was conducted to determine the SCC's flow ability in terms of mean spread diameter and is shown in Fig. 3. According to IS:10,262–2019, the acceptable range for slump flow of class SF2 is 660–750 mm. All the test results lied within the range. It was observed that SCC mix containing 10% Alccofine-1203 had the highest slump value. This is because of the presence of high glass content and less water demand of Alccofine-1203.

3.1.2 V-Funnel Test

The flowability and stability of SCC mixes were determined using the V-funnel test. Figure 4 indicates the test setup for V-funnel setup. According to IS:10,262–2019, the acceptable range for flow time of SCC is 8–12 s. The results of V-funnel test are listed in Table 8. Shorter time indicated the greater flow ability. It was observed that the ALC10 mix showed the greatest flow among all the mixes.

3.1.3 L-Box Test

The L-box ratio (H2/H1) indicates the filling and passing ability of each mixture. Blocking is more common in L-box test than in other tests. Figure 5 indicates the test setup for L-box setup and Table 8 lists out the results of the test. As per IS:10,262–2019, the L-box blocking ratio (BR) must be less than 0.8 and shall not exceed 1. Higher values of BR represent lesser blockage of aggregates. It was observed that the combination containing 10% Alccofine-1203 had the highest BR value.

Fig. 4 V-funnel test setup

Fig. 5 L-box test setup

Fig. 6 Crack propagation pattern of cube sample at failure

3.2 Compressive Strength

Figure 6 shows the crack pattern of the failed cube sample. The compressive strength test revealed considerable performance differences, with the ALC10 series achieving the highest compressive strength. The compressive strength at different ages of ALC6 found to be decreasing than the control mix. The 7th day compressive strength of the mixes ALC8 and ALC10 was improved by 1.65 and 13.62% respectively, with respect to the control mix & the 28th day compressive strength of the mixes ALC8 and ALC10 was increased by 2.82 and 11.34% in comparison to control mix. The remaining mixes ALC6, ALC12 and ALC15 exhibited a decreasing pattern for the compressive strength in comparison to the control mix. i.e., beyond 10% replacement levels, it has resulted in the decrease in strength of ALC series.

Figure 7 indicates the compressive strength of normal SCC and Alccofine-based SCC mixes [10]. According to the results, the SCC mix created with 10% Alc-cofine-1203 had the highest compressive strength of all the mixes. This could be attributed to Alccofine-1203's ultra-fine nature and its physical characteristic of better packing. Compressive strength has been reduced for higher substitutions of Alccofine-1203 than 10%. It is attributed to the reason that at these addition levels, Alccofine-1203 being very finer than cement will increase the water demand for workable mixes leading to reduction in pore bonding strength; acts just as an SCM filling the pores, without getting involved in the hydration process.

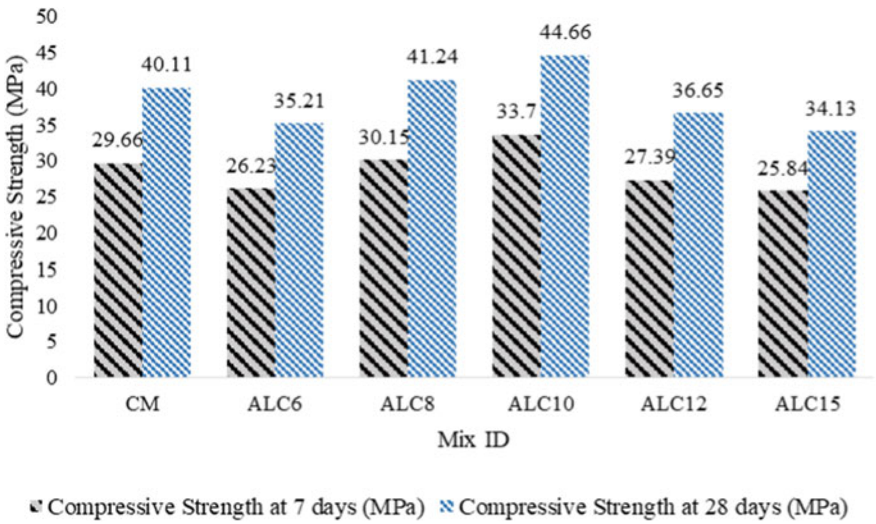

Fig. 7 7th and 28th day Compressive Strength (MPa) of SCC mixes

4 Conclusions

The purpose of the study is intended to analyze the fresh properties and compressive strength of Alccofine-1203-based SCC made with partial replacement of cement with Alccofine-1203. Following conclusions were drawn from the findings of the study:

1. The incorporation of Alccofine-1203 as an SCM enhanced the fresh and hardened properties of the SCC mixes because it has got high amount of silica content with great pozzolanic activity. As a result, more C–S–H gel is produced, resulting in an increase in compressive strength.
2. All the SCC mixes showed good workability properties with high flow ability and segregation resistance.
3. The optimum dose of Alccofine-1203 was found to be 10% by means of compressive strength test. The reason was the optimized size, ultrafine nature, unique chemical composition and high glassy nature of Alccofine-1203.
4. As a result, the Alccofine-1203 based SCC with 10% Alccofine-1203 content outperforms the target strength. Thus, it can be successfully replaced with cement.

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