Utilization of Alccofine and Bottom Ash in Cement Concrete

Abhishek Sachdeva(✉) and Ashutosh Sharma

Civil Engineering Department, Lovely Professional University,
Phagwara 144411, India
abhishek.sachdeva1990@gmail.com,
ashutosh.21686@lpu.co.in

Abstract. Current research is aggravated as a result of environmental problems in association with the clearance of waste and crisis in the availability of sand. Also, green house emissions from manufacturing of concrete are reduced by partially replacing cement with industrial by-product. Current research evaluates the combined outcome of Alccofine and bottom ash with the part substitution of cement and fine aggregates, respectively, in concrete. An experimental program is formulated in which four different mixtures are prepared containing 0% (MB1 mix), 20% (MB2 mix), 30% (MB3 mix) and 40% (MB4 mix) bottom ash as part substitution of fine aggregates. It was found that both workability and compressive strength dwindled with the raise in substitution level, which reduced much for MB4 mix. Therefore, to evaluate the outcome of Alccofine as a part substitution of cement, MB4 mix was selected. The cement was partially replaced with Alccofine by 5% (MB4A5 mix), 10% (MB4A10 mix), 15% (MB4A15 mix) and 20% (MB4A20 mix) in the mix containing 40% bottom ash as a part substitution of fine aggregates. After analyzing the results, it was concluded that workability and strength, both improved on partially replacing cement with Alccofine up to 15%, after which it decreased. A high strength concrete was developed using Alccofine as a mineral admixture.

Keywords: Fine aggregates · Coal bottom ash · Alccofine · Workability
Compressive strength · Flexural strength

1 Introduction

Massive quantity of solid waste material is being generated by various industries and clearance of these solid waste material posses a great threat for the surrounding living beings as it leads to the environmental pollution and loss of productivity of the soil (Aggarwal et al. 2007; Sani et al. 2010). Advancement in the construction industry resulted in use of this material and industrial by-products leading to the invention of 'Green Concrete' (Arumugam et al. 2011). The main source of fine aggregates is natural river sand. Ban has been imposed on illegal mining activities by many countries which has resulted in non – availability of river sand (Soman et al. 2014). Due to the lack of availability of sand and upliftment in the advancement of infrastructure, it

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becomes indispensable and more important to discover a new or alternate material for fine aggregates to be used in concrete work.

Bottom ash is an end-product obtained by burning of coal. 20% of the total ash accounts for the coal bottom ash, which is procured from the bottom of power plants (Singh and Siddique 2014). Huge volumes of bottom ash accumulate on the ground and cause various adverse effects on the nature (Maliki et al. 2017). Various researches have been done for successful consumption of fly ash for construction works because of pozzolonic property of the material but very less literature is presented on bottom ash usage. Coal bottom ash and river sand have great similarities to each other in terms of appearance and particle size. Due to these properties and similarities, bottom ash is effectively incorporated in place of fine aggregates in the concrete production (Sivakumar et al. 2015).

Major amount of carbon-dioxide gas is emitted in the production process of cement. This green house gas adversely affects the environment and leads to the global warming. Therefore, it becomes very important to search for a new material or find a replacement for cement in concrete so as to cut the carbon-dioxide emissions in the atmosphere. ALCCOFINE 1203 is a product of new generation, manufactured in India, having ultrafine particles with low calcium silicates. It has discrete characteristics to improve concrete properties in all aspects. Alccofine 1203 is particularly a processed material formed basically on the slag of high glass content which is procured through the procedure of controlled granulation with high reactivity (Hamraj 2014; Kumar et al. 2015). Outcome of usage of Alccofine in concrete is eco-friendly and sustainable concrete production which also leads to the decline in total expenditure of manufacturing of concrete (Reddy and Meena 2017).

In the recent past, a lot many analyses have been conducted on the properties of concrete by using either the Alccofine as a part substitution of cement or Coal bottom ash as part substitution of fine aggregates separately. But current work is planned to assess the concrete containing both Alccofine as a part substitution to cement and Coal bottom ash as part substitution to fine aggregates together involving different combinations.

2 Materials and Methods

2.1 Materials

Adequate quantity of the coarse aggregates, fine aggregates and cement was procured from local market. Ordinary Portland cement (OPC 43 grade) of brand Shree ultra was utilized in this research work, specific gravity of which was 3.13. Coarse aggregate (maximum size 20 mm) was used and fine aggregate was confined to ZONE II. Coal bottom ash was obtained from Guru Gobind Singh Super Thermal Power Plant, Ropar, Punjab, having specific gravity of 1.71. Alccofine bag was acquired from the local dealer. Specific gravity of Alccofine was 2.98. Super plasticizer utilized was Glenium – 51 (modified polycarboxylic ether based).

2.2 Methodology

The study was planned in which four different mixtures were prepared initially containing 0% (MB1 mix of grade M40), 20% (MB2 mix), 30% (MB3 mix) and 40% (MB4 mix) bottom ash as part substitution of fine aggregates. Based upon workability and compressive strength test results, the mix having poor workability and compressive strength was selected. In this selected mix, cement was partly substituted with Alccofine to judge the consequence on concrete properties. Four different combinations of mixtures containing 5, 10, 15 and 20% Alccofine, as a part substitution of cement, were prepared in the mix already containing bottom ash. Slump tests were commenced to check workability and to achieve 100 mm slump value by varying the dosage of super plasticizer. Samples were organized to test for compressive strength and flexural strength respectively. SEM-EDS analysis was conducted on the bottom ash and Alccofine to study the morphology and chemical composition.

3 Mixtures Proportions

Concrete mix of M 40 was designed as per IS 10262:2009 and IS 456:2000. Fine aggregates and cement were partially substituted with bottom ash and Alccofine respectively. Quantity of coarse aggregate was fixed at 1092.61 kg/m^3 and 0.38 constant w/c ratio was kept for all the casted samples. Tables 1 and 2 show mixture proportions of various samples casted.

Table 1. Particulars of concrete mixtures containing bottom ash as a part substitution of fine aggregates

Mix designation	Bottom ash %	Cement (kg/m^3)	Fine aggregates (kg/m^3)	Bottom ash (kg/m^3)
MB1	0	415	782.27	0
MB2	20	415	625.816	156.454
MB3	30	415	547.589	234.681
MB4	40	415	469.362	312.908

Table 2. Particulars of concrete mixtures containing Alccofine as a part substitution of cement in mix containing 40% bottom ash as a part substitution of fine aggregates

Mix designation	Alccofine %	Cement (kg/m^3)	Fine aggregate (kg/m^3)	Alccofine (kg/m^3)	Bottom ash (kg/m^3)
MB4A5	5	394.25	469.362	20.75	312.908
MB4A10	10	373.5	469.362	41.5	312.908
MB4A15	15	352.75	469.362	62.25	312.908
MB4A20	20	332	469.362	83	312.908

4 Results and Discussions

4.1 Scanning Electron Microscope (SEM)

Analysis reported the morphological characteristics of bottom ash and Alccofine. Angular and irregular shape of bottom ash particles can clearly be observed in Fig. 1 having porous nature of ash particle. Figure 2 depicts the rounded shape of the Alccofine particles. The ultrafine nature of the Alccofine particles can also be seen and compared with the bottom ash particles at 500 magnifications.

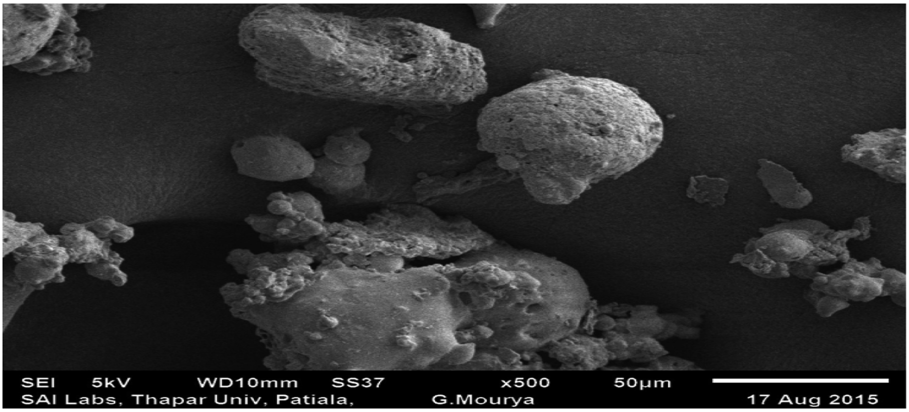

Fig. 1. Morphology of bottom ash

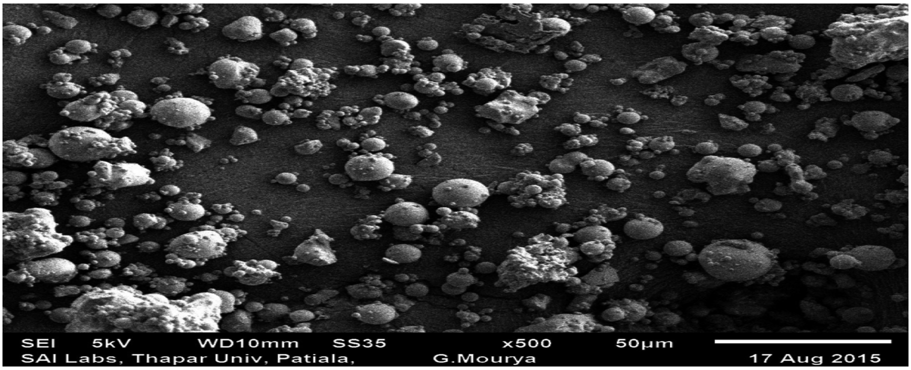

Fig. 2. Morphology of Alccofine

4.2 Energy Dispersive X-Ray Spectroscopy (EDS)

This is a method applied for elemental examination or chemical characterization. EDS analysis was done on bottom ash and Alccofine. The composition of the bottom ash and Alccofine incorporated in present research is described in Tables 3 and 4 respectively.

Table 3. Chemical composition of bottom ash

Compound	SiO_2	Al_2O_3	MgO	CaO	FeO	K_2O
Percentage	35.13	25.63	0.54	0.46	1.50	0.58

Table 4. Chemical composition of Alccofine

Compound	SiO_2	Al_2O_3	MgO	CaO
Percentage	35.05	24.34	9.66	28.86

4.3 Workability

Concrete's workability has been estimated through slump test. Water quantity was kept constant in all mixtures and the dosage of super plasticizer was varied in every mix to achieve 100 mm slump value. The test result shows the dip in slump value as coal bottom ash is incorporated in place of fine aggregates. The workability greatly dipped for MB4 mix. On the other hand, workability improved with the incorporation of Alccofine in concrete. Workability improved upto 15% substitution of cement with Alccofine and at 20% substitution percentage, the workability again reduced but it was on a higher side as compared to MB4 mix. The maximum workability was achieved for MB4A15 mix. The dosage of super plasticizer required for different concrete mixtures to achieve 100 mm slump value and the variation of slump for different concrete mixtures at 1.2% dosage of super plasticizer is depicted in Tables 5 and 6 respectively (Fig. 3).

Table 5. Dosage of super plasticizer required for different concrete mixtures to achieve 100 mm slump

Mix designation	MB1	MB2	MB3	MB4	MB4A5	MB4A10	MB4A15	MB4A20
Required dosage (%)	1.2	1.5	2.2	2.5	2.4	2.1	1.9	2

Table 6. Variation of slump for different concrete mixtures at 1.2% dosage of super plasticizer

Mix designation	MB1	MB2	MB3	MB4	MB4A5	MB4A10	MB4A15	MB4A20
Slump value (mm)	105	80	40	25	25	35	45	40

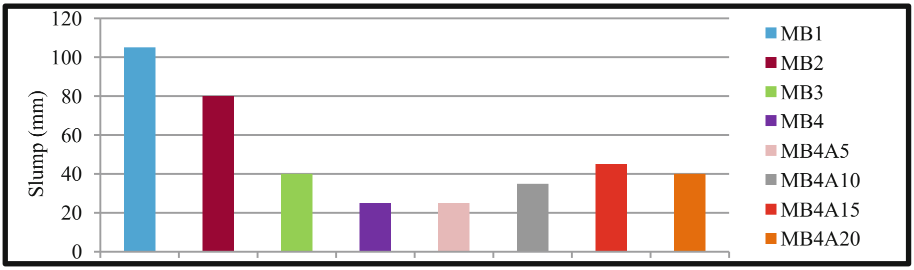

Fig. 3. Variation of slump for different concrete mixtures at 1.2% dosage of super plasticizer

4.4 Compressive Strength

This test was performed on standard cube of dimension 150 × 150 × 150 mm. After 28-days of curing, specimens were tested in 200 tones capacity Compression Testing Machine. 40% substitution of fine aggregate with bottom ash showed the maximum drop in strength. Great improvement in strength was observed after partially replacing cement with Alccofine in concrete. Maximum compressive strength was achieved for MB4A15 mix. Table 7 illustrates the compressive strength test results (Fig. 4).

Table 7. 28-days compressive strength test results for different concrete mixtures

Mix designation	MB1	MB2	MB3	MB4	MB4A5	MB4A10	MB4A15	MB4A20
Compressive strength (N/mm^2)	47.92	46.52	45.92	39.59	46.43	56.42	62.67	61.83

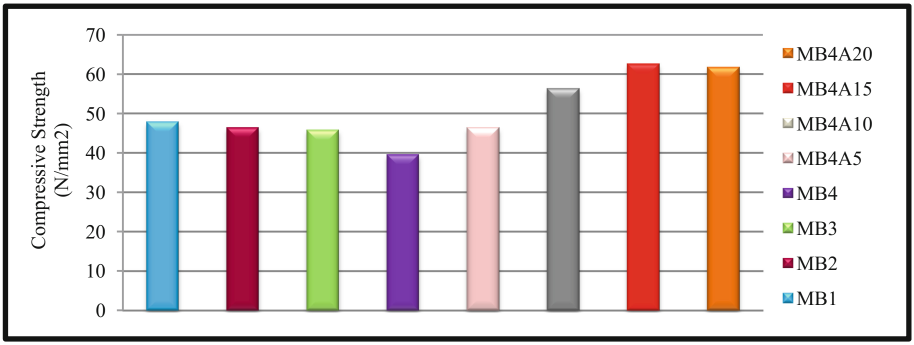

Fig. 4. 28-days compressive strength test results for different concrete mixtures

4.5 Flexural Strength

This test was performed on beam specimens as per IS 516:1959 in the flexural strength testing machine. Strength dipped on increasing the substitution level of fine aggregate with bottom ash. But after the incorporation of Alccofine as a replacement to cement, the flexural strength improved for the mix already containing 40% bottom ash as a part substitution of fine aggregates. Maximum flexural strength was achieved for MB4A15 mix. Table 8 represents the flexural strength test results (Fig. 5).

Table 8. 28-days flexural strength test results for different concrete mixtures

Mix designation	MB1	MB2	MB3	MB4	MB4A5	MB4A10	MB4A15	MB4A20
Flexural strength (N/mm^2)	4.63	4.58	4.33	4.12	4.15	4.42	4.77	4.71

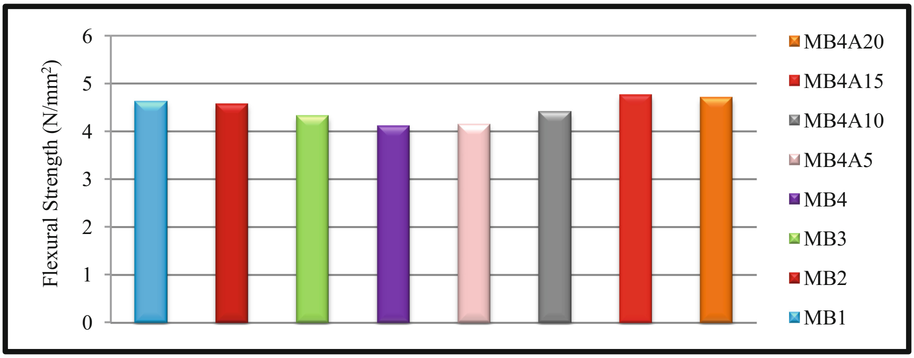

Fig. 5. 28-days flexural strength test results for different concrete mixtures

5 Conclusion

Concrete mixes containing bottom ash results in the drop off in workability as particles of the bottom ash are porous when compared with the river sand. Bottom ash possesses a complicated irregular texture of particles, therefore inter particle friction is increased, hence workability decreased.

Increase in workability of concrete was observed for 40% bottom ash concrete cubes when cement was partially replaced with Alccofine up to 15%, after which it decreased. Rounded shape of the Alccofine particles along with the water repelling nature of Alccofine due to the presence of glass content results in the increase in workability.

Compressive strength dipped with raise in level of fine aggregate substitution by bottom ash because of the substitution of stronger matter with the weak material and increased porosity of concrete.

Both compressive and flexural strength of concrete mixtures comprising 40% bottom ash as a part substitution of fine aggregate along with the 15% Alccofine as the partial replacement of cement (MB4AL15) surpassed that of controlled concrete (MB1).

Strength and workability of concrete enhanced at all the ages with the incorporation of Alccofine as a part replacement to cement. This is due to the fact that a dense pore structure of concrete is achieved for Alccofine concrete mixtures due to its distinctive chemical chemistry and grain size distribution.

Bottom ash can be effectively used in manufacturing of high strength concrete when used along with Alccofine as a mineral admixture.

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