

# Effect of cement and fine aggregate replacement with Alccofine and Bottom ash on mechanical properties of concrete

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**Abstract** - The present investigation is planned to study the properties of concrete at fresh and hardened stage containing both Alccofine as a partial replacement of cement as well as coal bottom ash as a partial replacement of fine aggregates in concrete together in different combinations. An experimental programme is planned in which controlled concrete (MB1 mix) of grade M40 is designed, casted and tested for compressive strength after 28-days of curing. Three different mixes were prepared containing 20% (MB2 mix), 30% (MB3 mix) and 40% (MB4 mix) bottom ash as partial replacement of fine aggregates. From the workability and compressive strength test results, it was observed that both the workability and compressive strength reduced much for MB4 mix. Therefore, to study the effect of Alccofine as a partial replacement of cement, MB4 mix was selected. The cement was partially replaced by Alccofine by 5% (MB4AL5 mix), 10% (MB4AL10 mix), 15% (MB4AL15 mix) and 20% (MB4AL20 mix) along with the 40% bottom ash as a partial replacement of fine aggregate. Based on the analysis of test results, a reduction in workability and strength was observed by partially replacing fine aggregates with coal bottom ash. Workability, compressive strength and flexural strength improved in the concrete mix containing bottom ash as a partial replacement of fine aggregates along with the incorporation of Alccofine as a partial replacement of cement in concrete. The workability is decreased with the increase in the replacement level of fine aggregates with bottom ash but workability improved on partially replacing cement with alccofine upto 15% in the mix already containing bottom ash as a partial replacement of fine aggregates, after which it decreased. A high strength concrete was developed by using Alccofine as a partial replacement to cement along with the partial replacement of fine aggregates with bottom ash.

**Keywords** — Fine aggregates, coal bottom ash, cement, Alccofine, workability, compressive strength, flexural strength.

## I. INTRODUCTION

Natural river sand is considered most suitable to be used as fine aggregates in concrete but unfortunately it is depleting gradually. Moreover, one of the most critical problems of the world has been related to removal of wastage and reutilizing it. The challenge for the civil engineering community in the near future is to realize projects in harmony with the concept of sustainable development and this involves the use of high performance materials and products manufactured at reasonable cost with the lowest possible environmental impact. Therefore, in the present circumstances of scant sources and boom in infrastructure development, it becomes essential and more significant to find out the substitute material for fine aggregates in concrete and simultaneously reutilizing the waste.

Bottom ash is a by-product of combustion of pulverized coal. Lots of research has been carried out for effective utilization of fly ash in construction industries due to its fine particles and pozzolonic properties. But little literature is available on bottom ash utilization. Bottom ash being coarser and less pozzolonic than fly ash can be used as fine aggregates in concrete by partial replacement of sand. Particles of bottom ash range from fine sand to fine gravel. Bottom ash is composed of mainly silica, alumina and iron with small amounts of calcium, magnesium sulphate, etc. The appearance and particle size distribution of coal bottom ash is similar to that of river sand. These properties of bottom ash make it attractive to be used as fine aggregate in the production of concrete.

The cement is one of the main ingredients used for the production of concrete. Producing one tonne of cement requires about 2 tonnes of raw materials and releases 0.95tonne ( $\approx$  1 tonne) of CO<sub>2</sub>. The global release of CO<sub>2</sub> from all sources is estimated at 23 billion tonnes a year and the Portland cement production accounts for about 7% of total CO<sub>2</sub> emissions. As the production of cement involves emission of large amounts of carbon-dioxide gas into the atmosphere, a major contributor for green house effect and the global warming, hence it is inevitable either to search for another material or partly replace it by some other material.

ALCCOFINE 1203 is a new generation, ultrafine, low calcium silicate product, manufactured in India. It has distinct characteristics to enhance 'performance of concrete' in fresh and hardened stages. Alccofine 1203 is a specially processed product based on slag of high glass content with high reactivity obtained through the process of controlled granulation. The raw materials are composed primary of low calcium silicates. The processing with other selected ingredients results in controlled particle size distribution (PSD). The computed blain value based on PSD is around 12000 cm<sup>2</sup>/gm and is truly fine. Due to its unique chemistry and fine particle size, Alccofine 1203 provides reduced water demand for a given workability, as per requirement of concrete performance. Alccofine 1203 can also be used as a high range water reducer to improve compressive strength or as a super workability aid to improve flow. Alccofine1203 may perform in superior manner than all other mineral admixtures used in concrete within India.

**II. EXPERIMENTAL PROGRAM**

The present work is planned to study the properties of concrete at the fresh and hardened stage containing both Alccofine as a partial replacement to cement and Coal bottom ash as partial replacement of fine aggregates together in different combinations.

**A. Materials**

Sufficient quantity of the coarse aggregates, fine aggregate and cement was collected from local market. The cement used in this study was Ordinary Portland cement (OPC 43 grade) of brand Shree ultra, specific gravity of which was 3.13. Coarse aggregate of maximum size 20 mm was used and fine aggregate confined to ZONE II. The specific gravity and fineness modulus of coarse aggregates was 2.66 and 6.68 respectively and that of fine aggregate was 2.63 and 2.53 respectively. Coal bottom ash was collected from Guru Gobind Singh Super Thermal Power Plant, Ropar, Punjab. The specific gravity of coal bottom ash used in the study was 1.71. Alccofine bag was purchased from the local dealer store of Ambuja cement. The specific gravity of Alccofine was 2.98. Super plasticizer used in this study was Glenium – 51, based on modified polycarboxylic ether. Glenium was purchased from BASF INDIA LIMITED, Chandigarh.

**B. Methodology**

An experimental programme is planned in which controlled concrete of grade M40 mix will be designed, casted and tested for compressive strength after 28-days of curing. Three different mixes will be prepared containing 20%, 30% and 40% bottom ash as partial replacement of fine aggregates. These mixes will be tested for compressive strength. Based on the workability and compressive strength results,

one optimum mix will be selected. In this optimised mix, four different combinations of mix containing 5%, 10%, 15% and 20% Alccofine as a partial replacement of cement will be prepared. These mixes will be prepared to study the workability and compressive strength of concrete containing both bottom ash as a partial replacement of fine aggregates and Alccofine as a partial replacement of cement. Beams from the mix of optimum combination will be casted and tested for flexural strength.

**C. Mixture Proportions**

The mixture proportions of various concrete mixes are given in Table I and Table II. Table I shows the detail of concrete mix containing Bottom ash as a partial replacement of Fine aggregates. Table II depicts the detail of concrete mix containing 40% bottom ash as a partial replacement of Fine aggregates and Alccofine as a partial replacement of cement. Concrete Mix Design for M 40 Grade of Concrete was done as per IS 10262:2009 and IS 456:2000. Fine aggregates and cement were partially replaced with coal bottom ash and Alccofine, respectively by mass in concrete. Fixed quantity of coarse aggregate i.e. 1092.61 kg/m<sup>3</sup> was used in the manufacturing of all the concrete samples. Water cement ratio was kept constant, i.e. 0.38 for all the concrete samples.

**TABLE I** Detail of concrete mix containing Bottom ash as a partial replacement of Fine aggregates

Mix Designation	Bottom Ash %	Cement (kg/m <sup>3</sup> )	Fine Aggregates (kg/m <sup>3</sup> )	Bottom Ash (kg/m <sup>3</sup> )
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 II** Detail of concrete mix containing 40% bottom ash as a partial replacement of Fine aggregates and Alccofine as a partial replacement of cement

Mix Designation	Alccofine	Cement	Fine Aggregate	Alccofine	Bottom Ash
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

**D. Results and Discussions**

In the present work, cement and fine aggregate is partially replaced with Alccofine and coal bottom ash, respectively. The first phase of the study includes the selection of the bottom ash percentage on the basis of workability and compressive strength test results. The second phase includes the replacement of cement with Alccofine in the mix already containing bottom ash as a partial replacement of fine aggregate, selected during the first phase. Slump test was performed on different mixes for the workability of concrete. Strength evaluation has been done based on the compressive strength test and flexural strength test for different concrete mix. The experimental set up for various tests and their results are described below:

**Workability for bottom ash concrete mixes**

The workability of concrete mixtures was measured by performing slump test. The fixed quantity of water was added in all the concrete mixes and the dosage of super plasticizer was varied in every mix to achieve 100 mm slump value. The test results show that slump values of bottom ash concrete mixtures decreased with the increase in levels of fine aggregate replacement by coal bottom ash. The dosage of super plasticizer required for different concrete mixes to achieve 100 mm slump value and the variation of slump for different concrete mixes at 1.2 % dosage of super plasticizer is shown in Table III and Table IV respectively.

**TABLE III** Required dosage of super plasticizer to achieve 100 mm slump for concrete mix containing bottom ash as a partial replacement of fine aggregates

Mix Designation	Required dosage (%)
MB1	1.2
MB2	1.5
MB3	2.2
MB4	2.5

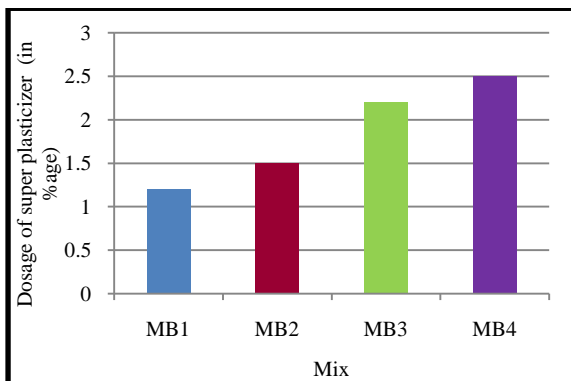


Fig. 1 Required dosage of super plasticizer to achieve 100 mm slump for concrete mix containing bottom ash as a partial replacement of fine aggregates

**TABLE IV** Variation of slump for concrete mix containing bottom ash as a partial replacement of fine aggregates at 1.2 % dosage of super plasticizer

Mix Designation	Slump value (mm)
MB1	105
MB2	80
MB3	40
MB4	25

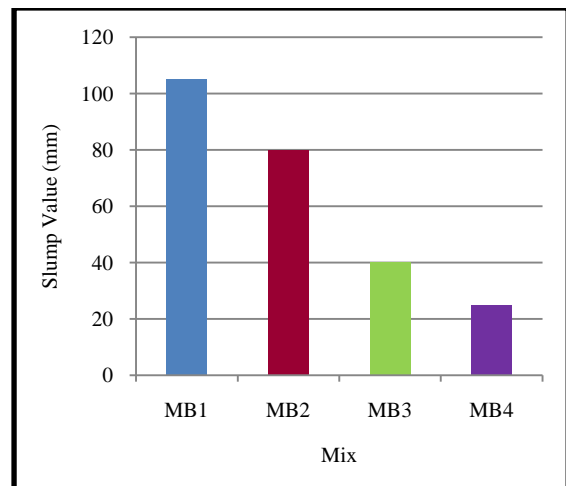


Fig. 2 Variation of slump for concrete mix containing bottom ash as a partial replacement of fine aggregates at 1.2 % dosage of super plasticizer

**Compressive strength for bottom ash concrete mixes**

Compressive strength test was performed on standard cube of size 150 x 150 x 150 mm after 28 days curing as per IS 516-1959. Specimens were taken out from curing tank at 28- days of water curing. Surface water was then allowed to drip down. Specimens were then tested on 200 tones capacity Compression Testing Machine. The compressive strength is calculated by dividing the maximum compressive load by the cross sectional area of the cube specimens. The results are shown in Table V

The compressive strength is calculated by the following formula:

$$f_{cu} = P_c / A$$

Where,

$f_{cu}$  = compressive strength of specimen, N/mm<sup>2</sup>  
 $P_c$  = Failure Load in compression, KN

$A$  = Loaded area of cube, mm<sup>2</sup>

**TABLE V** 28-days Compressive Strength Results for concrete mix containing bottom ash as a partial replacement of fine aggregates

Mix Designation	Compressive strength (N/mm <sup>2</sup> )
MB1	47.92
MB2	46.52
MB3	45.92
MB4	39.59

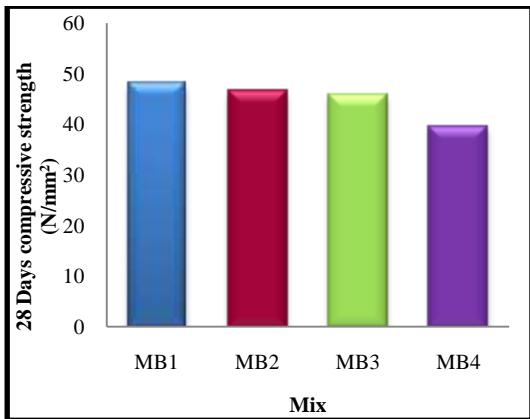


Fig.3 28-days Compressive Strength results for concrete mix containing bottom ash as a partial replacement of fine aggregates

**Selection of percentage of bottom ash as a partial replacement of fine aggregate**

Based on the slump test results, it was observed that the workability decreases with the increase in the percentage of bottom ash. Moreover the compressive strength also dipped with the increase in the percentage of bottom ash. Therefore, to study the effect of Alccofine as a partial replacement of cement, MB4 mix is selected. The properties examined were workability of the different mix, compressive strength and flexural strength.

**TABLE VI** Required dosage of super plasticizer in percentage by weight of cement to achieve 100 mm slump

Mix Designation	Required dosage (%)
MB1	1.2
MB4	2.5
MB4A5	2.4
MB4A10	2.1
MB4A15	1.9
MB4A20	2

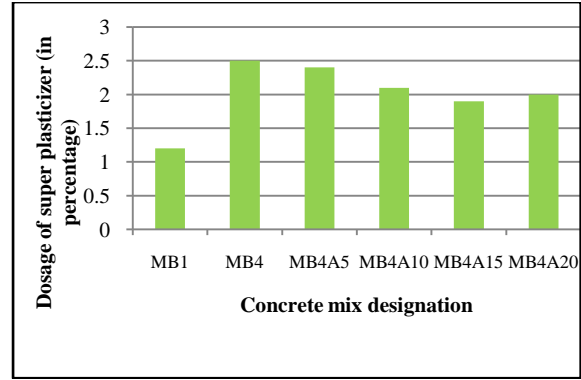


Fig.4 Required dosage of super plasticizer in percentage by weight of cement to achieve 100 mm slump

**TABLE VII** Variation of slump value for different concrete mix at 1.2 % dosage of super plasticizer

Mix Designation	Slump value (mm)
MB1	105
MB4	25
MB4A5	25
MB4A10	35
MB4A15	45
MB4A20	40

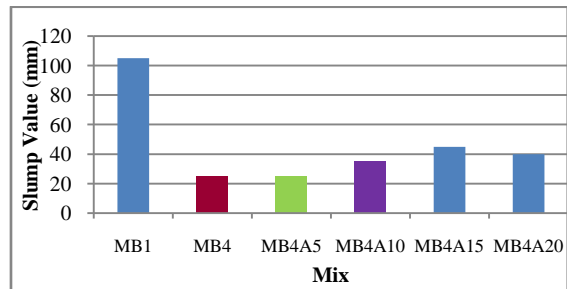


Fig.5 Variation of slump value for different concrete mix at 1.2 % dosage of super plasticizer

**TABLE VIII** Compressive strength test results after 28- days of curing for concrete mix containing 40% bottom ash as a partial replacement of Fine aggregates and Alccofine as a partial replacement of cement

Mix Designation	Compressive strength (N/mm <sup>2</sup> )
MB4A5	46.43
MB4A10	56.42
MB4A15	62.67
MB4A20	61.83

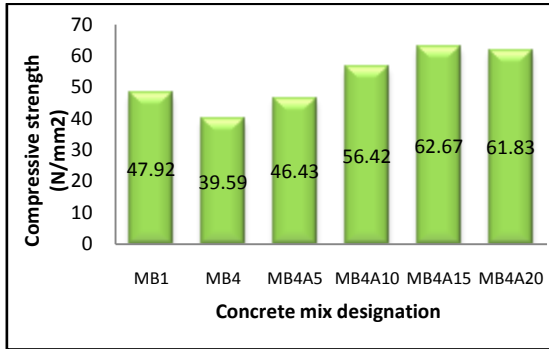


Fig.6 Compressive strength test results after 28- days of curing for different concrete mix

**Flexural Strength**

Flexural strength test was performed on beam specimens according to IS 516:1959. Specimens were taken out from curing tank at 28- days of water curing. Surface water was then allowed to drip down. Standard beams of size 500mm x 100mm x 100mm were subjected to two pints loading till failure of specimen. It was performed after 28 days of curing on a flexural testing machine.

The Flexural Strength is given by,  

$$R = \frac{PL}{bd^2}$$

R= Modulus of Rupture or flexural strength (N/mm<sup>2</sup>)

P=Maximum applied load (N)

L= effective span between the supports (mm)

b=width of the beam specimen (mm)

TABLE IX Flexural strength test results after 28 –days of curing for different concrete mix

Mix Designation	Flexural Strength (N/mm <sup>2</sup> )
MB1	4.63
MB4	4.12
MB4A15	4.77

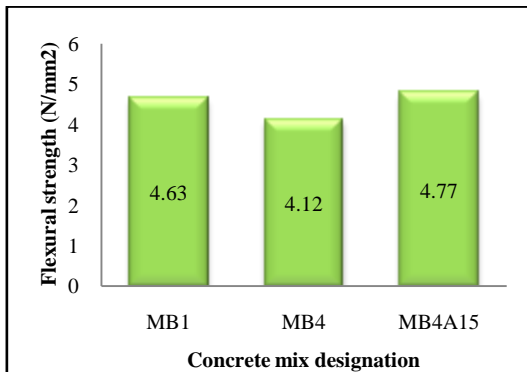


Fig.7 Flexural strength test results after 28 –days of curing for different concrete mix

**III CONCLUSION**

1. Workability of the concrete mix containing bottom ash as a partial replacement of fine aggregates decreases with the increase in the quantity of bottom ash.
2. Workability is decreased with the increase in the quantity of bottom ash because bottom ash is more porous, therefore absorb more water than sand.
3. Compressive strength of concrete mix containing bottom ash as a partial replacement of fine aggregates reduced with the increase in level of fine aggregate replacement by bottom ash. This is due to the replacement of the stronger material with the weaker material and the increased porosity of concrete.
4. Workability of the concrete mix containing 40% bottom ash as a partial replacement of fine aggregate is increased with the increase in the percentage of cement replacement by Alccofine upto 15% after which it decreased.
5. Compressive strength and flexural strength of concrete mix containing 40% bottom ash as a partial replacement of fine aggregate along with the 15% Alccofine as the partial replacement of cement (MB4AL15) surpassed that of controlled concrete (MB1). The compressive strength and flexural strength for MB1 mix was 47.92 N/mm<sup>2</sup> and 4.63 N/mm<sup>2</sup> respectively but for the MB4AL15 mix, strengths improved to 62.67 N/mm<sup>2</sup> and 4.77 N/mm<sup>2</sup> respectively.
6. Due to its unique chemical chemistry and particle size distribution, Alccofine results in the formation of dense pore structure, which results in improved workability and strength at all ages.

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