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Performance of Portal Frame Using Bottom Ash in Self Compacting Concrete

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Abstract: *Bottom ash is the coarse material, which falls into furnace bottom and is getting collected in huge quantities in modern large Thermal Power Plants. One of the ways of utilizing this bottom ash is to use it as a partial replacement of sand in reinforced cement concrete. In this investigation, Bottom ash was obtained from Neyveli Lignite Corporation Ltd India.*
Self-compacting concrete (SCC) is an innovative concrete that does not require vibration for compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement.
Fresh and hardened concrete properties were studied. Test Results shows that the workability characteristics of SCC are within the limiting constraints of SCC. The variation of different parameters of hardened concrete with respect to various proportions of bottom ash contents was analysed. Portal frame specimens were cast with varying proportions of bottom ash were tested results are compared.
Keywords *- Bottom ash, fine aggregate, Fly ash, Modifying Agent, Self Compacting Concrete, Strength., Super plasticizer, Viscosity, Workability.*

I. Introduction

The main challenge for the civil engineering community is to realise 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 lower possible environmental impact. Energy is a material backbone of modern civilization of the world over. The electric power from thermal power station is a major source of energy, in the form of electricity.

Self-compacting concrete (SCC): SCC offers a rapid rate of concrete placements, with faster construction time and ease of flow around congested reinforcement. The fluidity and segregation resistance of SCC ensures a high level of homogeneity, minimal concrete voids and uniform concrete strength, providing the potential for a superior level of finish and durability to the structure.

Bottom ash: It is the coarse material, which falls into furnace bottom and is getting collected in huge quantities in modern large Thermal Power Plants. In India, over 70% of electricity generated is by combustion of fossil fuel, out of which nearly 61% is produced by coal fired plants, This results in the roughly 110 million ton of ash. Most of the ash has to be disposed off either dry or wet to an open area available near the plant or by grounding both the fly ash and bottom ash and mixing it with water and pumping into dumping yards.

Experimental program: This paper presents the experimental investigation carried out to study the feasibility and various properties of self compacting concrete when of usage of bottom ash in replacement of fine aggregate. The flow characteristics are measure from slump flow test apparatus, V-funnel test apparatus. The strength characteristics of SCC like compressive strength and split tensile strength are found. Portal frames were casted for conventional and varying proportions of bottom ash and the load carrying capacity were found.

II. Properties of materials used

The material used for the study was the same as those for the conventional concrete with the addition of mineral and chemical admixture.

Cement

In the present study an ordinary Portland cement (OPC 53 grade) was used. The physical properties of the cement tested according to Indian standards procedure confirms to the requirements of IS12269 and the specific gravity was found to be 3.15 and the standard consistency was found as 28%.

Fine aggregate
The river sand conforming to zone III as per IS-383-1987 was used for making reference concrete and its specific gravity was found to be 2.68. The loose and compacted bulk density values of sand were 1560 kg/m^3 and 1794 kg/m^3 respectively.

Coarse aggregate
Crushed coarse aggregate conforming to IS 383-1987 of size 12.5 mm and down having a specific gravity of 2.66 and fineness modulus 6.9 was used. The loose and compacted bulk density values of coarse aggregate were 1328 kg/m^3 and 1680 kg/m^3, respectively, for different grade of concrete.

Fly Ash
Fly ash is finely divided residue resulting from the combustion of powdered coal and transported by the flue gases and collected by electric precipitator.

Class F: It normally produced by burning anthracite, usually has less than 5% CaO. Class F fly ash has pozzolanic properties only.
Class C: Fly ash normally produced by burning lignite. Some class C fly ash has CaO content in excess of 10%. In addition to Pozzolanic properties, class C fly ash also possesses cementitious property.
In this investigation Fly ash class F is used for producing SCC.

Table 1: Chemical Properties of Fly Ash

S.No.	Chemical Compound	Fly Ash F (%)
1	SiO2	54.90
2	Al2O3	25.80
3	Fe2O3	6.90
4	CaO	8.70
5	MgO	1.80
6	SO2	0.60
7	Na2O&K2O	0.60

Bottom ash
The basic tests on bottom were conducted as per IS-383-1987and its specific gravity was around 2.68. The loose and compacted bulk density values of sand were 1344 kg/m3 and 1580 kg/m3 respectively. Gradation of Bottom ash is similar to sand which makes the possibility to be use as a replacement.

Table 2: Chemical Properties of Bottom Ash

S.No.	Elements/Oxide Composition	Percentage (%)
1	Silica (SiO2)	47.0-55.0
2	Aluminimum (Al2O3)	25.0-35.0
3	Iron (Fe2O3)	3.0-4.0
4	Manganese (Mn2O3)	0.1-0.2
5	Calcium (CaO)	4.0-10.0
6	Magnesium (MgO)	1.0-2.5
7	Phosphorus (P2O5)	0.5-1.0
8	Potassium (K2O)	0.5-1.0
9	Sodium (Na2O)	0.2-0.8
10	Titanium (TiO2)	0.5-2.0
11	Sulphur (SO3)	0.1-0.5
12	Loss on Ignition (LOI)	0.5-2.0

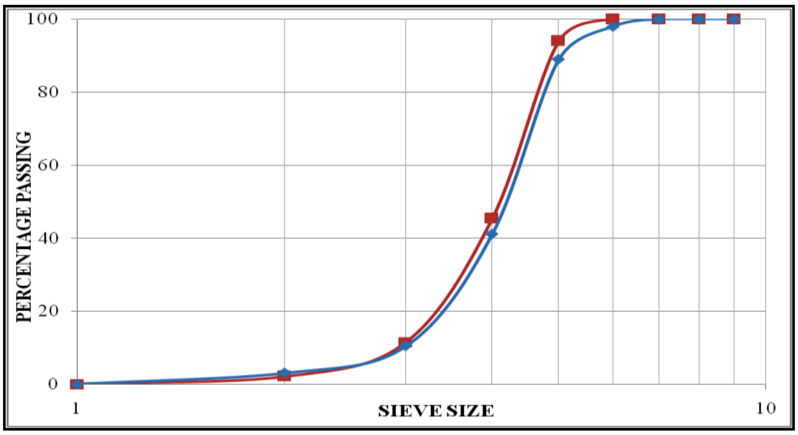


Figure 1 Particle size distribution curve for sand and bottom ash

Water

Water conforming to the requirement of BIS: 456 – 2000 is found to be suitable for making concrete mix. For the present investigation, Potable water (from Siruvani reservoir) supplied by the local Municipality was used for casting and curing the specimens.

Chemical Admixture

Super plasticizer

Super plasticizer Conplast SP 430 is used to increase the consistency and workability of the concrete. It reduces the water content for increased strength and reduces the permeability and increases the durability. Conplast SP 430 had a Specific gravity 1.225 and is a brownish liquid.

Viscosity Modifying Agent

Glenium Stream 2 is a Viscosity Modifying Agent which can be used with the combination of Super plasticizer. Glenium Stream 2 consists of mixture of water soluble polymers which is adsorbed onto the surface of the cement granules, thereby changing the viscosity of water and influencing the rheological properties of the mix. It resists the segregation due to aggregation of the polymer chains when the concrete is not moving. Glenium Stream 2 is a colourless liquid with a relative density of 1.01 and pH of 6.

1. Concrete Mixture Proportions

In this study, the mix proportion of SCC was determined by fixing the air content in SCC as 1.5% and the water to powder ratio at 0.34 in order to maintain the same paste content. The mixture using only river sand as fine aggregate was considered to be the control concrete and bottom ash was used to replace fine aggregate at the ratios of 0 %, 10 %, 20 %, by weight, and the notations of mixtures were specified as BA 0% (control), BA 10 %, BA 20 %, respectively.

Table 3: Trial mix proportions for self-compacting concrete

TRIAL	CEMENT (Kg)	FLY ASH (Kg)	F.A (Kg)	C.A (Kg)	WATER (Kg)	S.P (%)	VMA (%)	W/C
MIX-1	420	0	937	754	246	0.8	0.20	0.44
MIX-2	420	0	918	769	246	0.8	0.21	0.44
MIX-3	420	125	880	735	235	1	0.21	0.42
MIX-4	420	122	900	708	246	1	0.23	0.4
MIX-5	420	117	918	694	204	1.1	0.23	0.38
MIX-6	420	110	960	680	189	1.1	0.23	0.35

Table 4: Mix proportions of self-compacting concrete

Mix SCC		**BA 0% (Control)**	**BA 10%**	**BA 20%**
Cement	kg/m^3	420	420	420
Fly Ash	kg/m^3	110	110	110
Fine Aggregate	kg/m^3	960	865	770
Bottom Ash	kg/m^3	0	95	190
Coarse Aggregate	kg/m^3	680	680	680
Super plasticizers SP	kg/m^3	5.4	5.4	5.4
Glenium Stream 2	kg/m^3	1.22	1.22	1.22
Water	kg/m^3	189	209	230

III. FRESH SCC CONCRETE PROPERTIES

Flowing Ability

It is the ability of the concrete to flow freely within the form work. The maximum flow value can measured from the "SLUMP FLOW" test shown in Figure 2(a). The slump flow test aims at investigating the filling ability of SCC. The former indicates the free, unrestricted deformability and the latter indicates the rate of deformation within a defined flow distance.

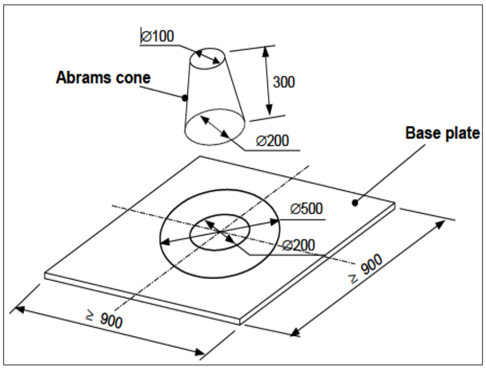
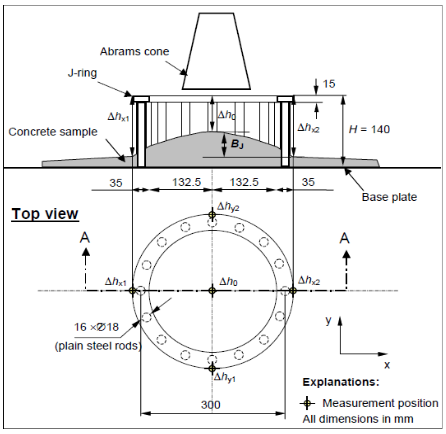


Figure 2 (a) Slump Flow

Passing Ability

Passing ability is the capacity of the concrete to change form and pass across reinforcement or obstacles and fill the available space without segregation or causing blockage to flow. This property is obtained by conducting the "J-RING" test shown Figure 2(b). The J-ring flow spread indicates the restricted deformability of SCC due to blocking effect of reinforcement bars.

Figure 2 (b) Slump Flow



Segregation Resistance

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It is the property of concrete to keep the coarse aggregates and the mortar together during the flow. This property is obtained by conducting the "V -FUNNEL" test shown in Figure 2(c). The V-funnel flow time is the period a defined volume of SCC needs to pass a narrow opening and gives an indication of the filling ability of SCC provided that blocking and/or segregation do not take place; the flow time of the V-funnel test is to some degree related to the plastic viscosity.

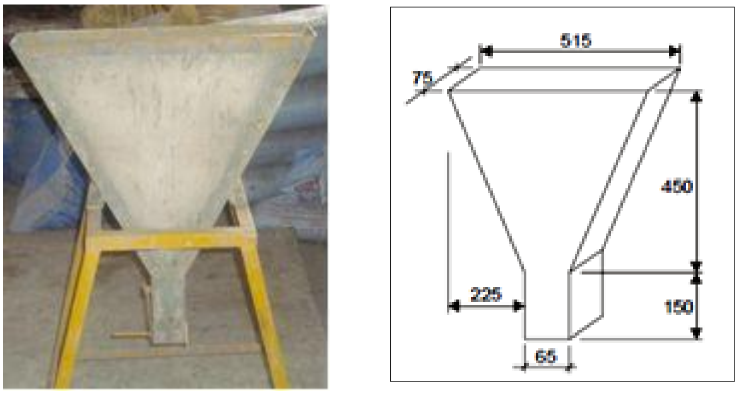
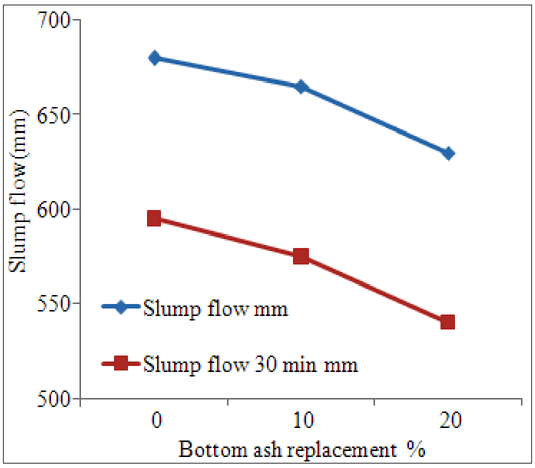


Figure 2 (c) V-Funnel

Table 5: Fresh concrete properties

Mix	BA 0%	BA 10%	BA 20%	Recommended values
Slump flow mm	680	665	630	650mm – 800mm
Slump flow T_{500} Sec	4	5	7	2sec – 5sec
J-ring test	9	13	19	0sec – 20sec
V-funnel test Sec	8	10	14	6sec – 12sec



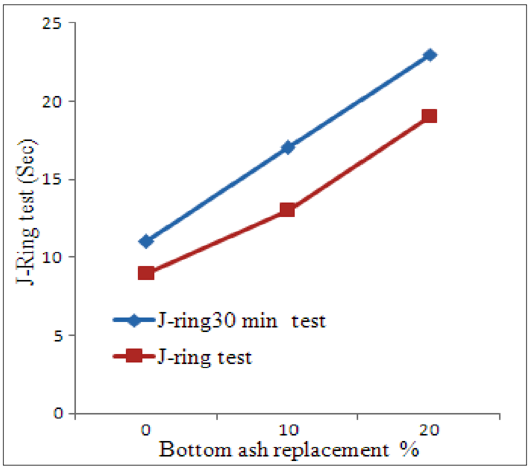


Figure 3 Slump flow of different proportions of bottom ash

Figure 4 J-ring test results for different proportions of bottom ash

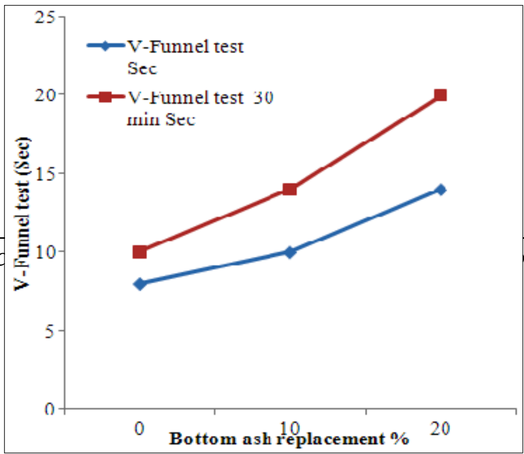


Figure 5 V-funnel test results for different proportions of bottom ash

HARDENED CONCRETE PROPERTIES

Compressive Strength of Concrete:

Compressive strength of concrete is used as a qualitative measure for other properties of hardened concrete. The compressive strength of SCC depends on the mix design. Cubes of dimension 150mm ×150mm ×150 mm were cast cured and tested for 7, 14 and 28days.

Table 6: Results of Compressive strength of concrete

Mix	Bottom ash (%)	Compressive Strength (N/mm²)		
		7 days	14 days	28 days
BA 0%	0	26.18	36	54.58
BA 10%	10	24.44	34.67	52.89
BA 20%	20	24.27	33.56	48.31

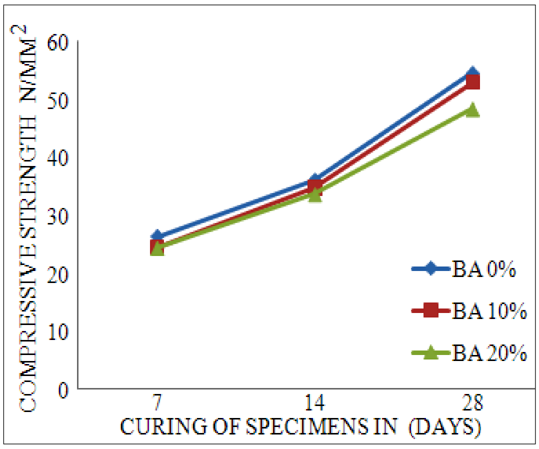


Figure 6 Compressive strength of concrete with and without bottom ash

Split Tensile Strength of Concrete

This is an indirect strength test to determine the tensile strength of the specimen. Splitting tensile strength tests were carried out on specimens of size 100mm x 200mm cylinder at the age of 28 days curing using 3000kN capacity AIMIL compression testing machine as per BIS: 516-1959. The load was applied gradually till the specimens split and the readings were noted.

Table 7: Results of Split tensile strength of concrete

Mix	Bottom ash (%)	Split tensile Strength (N/mm²)		
		7 days	14 days	28 days
BA 0%	0	1.97	2.99	4.90
BA 10%	10	1.78	2.48	4.39
BA 20%	20	1.75	2.13	3.95

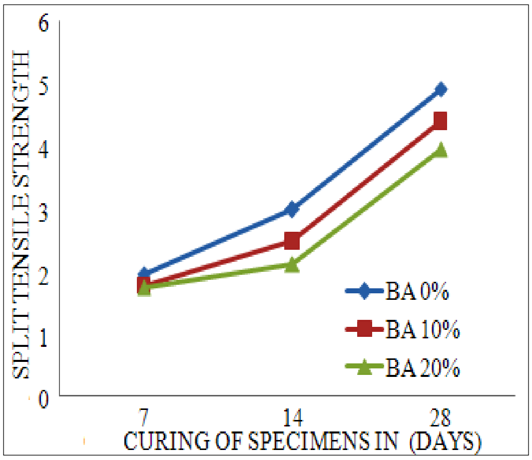
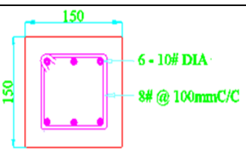
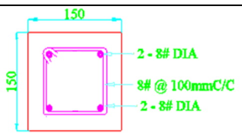
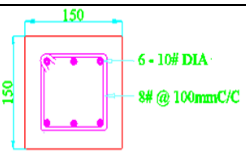
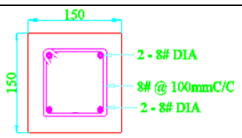


Figure 7 Split tensile strength of concrete with and without bottom ash

TEST SPECIMENS
The experimental program was carried out using portal frame specimens. The details of the specimens are summarized in table 8

Table 8: Details of the test specimens

Shape & size in 'mm'	Specimens Name	Cross Section of specimens	Reinforcement Details
Square column 150x150x900	BA 0%		6 nos 10mm diameter bars and two legged 8mm lateral ties at 100mm c/c
Square Beam 150x150x900			4 nos 12mm diameter bars and two legged 8mm lateral ties at 100mm c/c
Square Column 150x150x900	BA 10%		6 nos 10mm diameter bars and two legged 8mm lateral ties at 100mm c/c
Square Beam 150x150x900			4 nos 12mm diameter bars and two legged 8mm lateral ties at 100mm c/c

FABRICATION OF SPECIMENS

A single batch of SCC concrete was used to cast samples. After a 24 hour of curing the moulds were demoulded and all specimens were checked for irregularities, surface imperfections. The specimens were cure for a period of 28-day.

Figure 8(a) Reinforcement

Figure 8(b) Casting of frames

TESTING OF SPECIMENS

Specimens were tested to failure under a monotonically increased axial load under a load control mode. The frames are placed over the square steel plate at bottom to give rigidity to the base. The column is tied with the loading frame to have stability for loading. A uniformly distributed load is applied on the frames over the beam by placing an I beam fitted with rollers at equal intervals. Over the I-section hydraulic jack of 50 T was placed and the proving ring is fitted to it. The dial gauge is fitted at the mid bottom of the beam and the mid deflection reading were observed and tabulated. The Test setup is shown below in figure 9

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Figure 9 Test setup

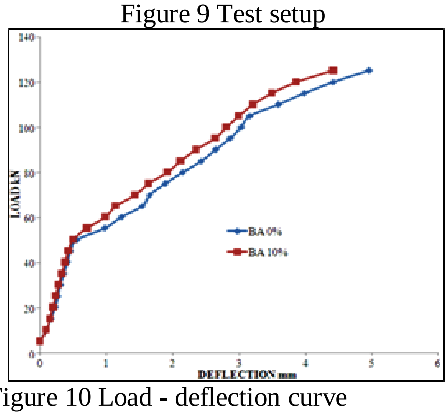

Figure 10 Load - deflection curve

 

Figure 11 Failure of specimens

IV. CONCLUSIONS

Experimental results revealed reduced diameter in the slump flow of the SCC mixtures with bottom ash.

The T_{500} time taken for slump flow (T_{500}) increased with the increase of bottom ash replacement level.

At 10 % bottom ash replacement of fine aggregate, the compressive strength and tensile strength at 28 days was improved. However further increase of bottom ash content resulted in the reduction of compressive and split tensile strength.

Under this limited study, it is reasonable to conclude that the optimum replacement of sand by bottom ash was about 10 % by weight of total fine aggregate.

From the load-deflection curves it is clear that the load carrying capacity and deflection of the portal frame with 10% replace of bottom ash shows better results when compared with controlled SCC concrete.

However, the bottom ash replacement level higher than 10 % may be applied for particular works depending on total concrete cost and construction condition.

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