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An Experimental Study on Effect of Bottom Ash as partial Replacement of Sand on Properties of Concrete

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Abstract:

Concrete is the most significant engineering material, and its qualities can be altered by adding additional materials. Studies have been carried out to see if a wide range of materials could be used as partial replacements for cement, sand, and aggregate in the manufacturing of concrete. The current experimental investigation attempts to reduce waste and conserve resources. The goal of this research was to see how using coal bottom ash as a partial replacement for fine particles at different percentages (0–25%) affected concrete qualities like workability, compressive strength, split tensile strength, and flexural strength.Workability declines as the proportion of coal bottom ash increases, but compressive strength, split tensile strength, and flexural strength increase up to 20% replacement of coal bottom ash, according to the findings. Bottom ash can be used up to 20% along with sand in concrete with a relatively low strength requirement, according to the study.

Keywords **—Bottom Ash, Sand Replacement, Compressive Strength, Split Tensile Strength.**

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I. INTRODUCTION

The availability of power determines a country's economic and industrial growth. Coal is an important source of energy generation in India as well. Coal is used to generate about 60% of the electricity. Indian coal has a low calorific value (3000-3500 Kcal) and a high ash content (30-45%), resulting in a large amount of ash being produced in coal-fired thermal power plants. In the years 2005-06, 125 of these power plants produced around 112 million tonne of ash. With the current increase in the power sector, ash production is predicted to reach 175 million tonnes per year by 2012. The following four types of ash may be found in any coal-fired thermal power plant:

Ash, the Fly: This type of ash is collected in dry form from flue gases using an Electrostatic Precipitator. This ash is a high-quality substance with excellent pozzolanic properties. Fly Ash: This type of ash is collected in dry form from flue gases using an Electrostatic Precipitator. This ash is a high-quality substance with excellent pozzolanic properties.

Bottom Ash is ash that collects at the bottom of the boiler furnace. It is a coarser substance with a higher percentage of unburned carbon. It has no or very little pozzolanic properties.

Pond Ash is created when fly ash and bottom ash, or both, are combined in any proportion with a considerable amount of water to form a slurry, which is then deposited in ponds where the water is drained away. Pond ash is the term for the ash that has been deposited.

Mound ash is made up of fly ash and bottom ash (or both) combined in any proportion and deposited dry in the shape of a mound.

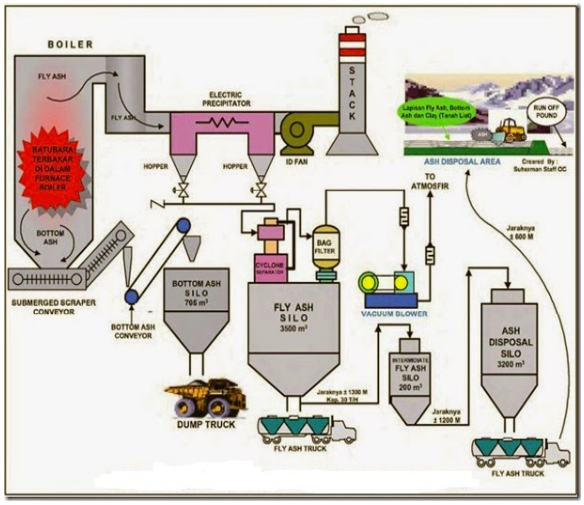

Fig. 1 Production of Coal Bottom Ash

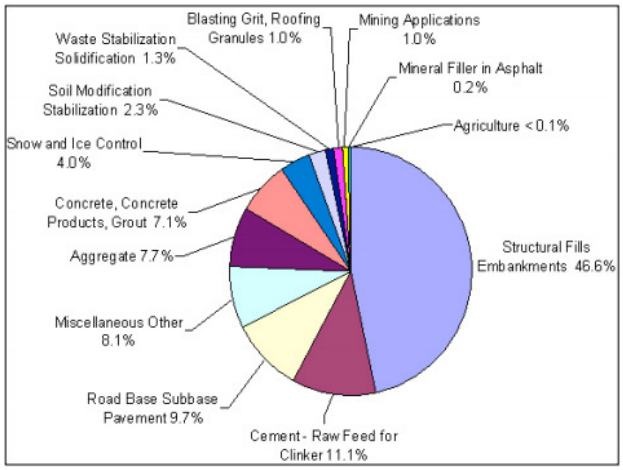

Fig. 2Coal Bottom Ash applications as a percentage of total reused (ACAA, 2006)

The construction of coal-fired power stations was prompted by rising electricity demand. The production of coal and its by-products has expanded in tandem with the increase in coal use. The ash must be disposed of in an open area near the plant, either dry or wet, or by combining the fly ash and bottom ash with water and pumped into an artificial lagoon or dumping yard. The disposal of such a significant amount of ash has taken up thousands of hectares of land, including agricultural and forest land, as well as polluting water sources. There will be insufficient space if these combustion by-products are not appropriately utilised, and disposal of these by-products will be a concern. Promoting large-scale coal ash utilisation is the best option for minimising all of these consequences.

II. OBJECTIVE AND SCOPE OF PRESENT WORK

The present research work has following main objectives:

- Study the effect of coal bottom ash as partial replacement of natural river sand on the properties of fresh concrete.
- Study the effect of coal bottom ash as partial replacement of natural river sand on strength properties of Hardened concrete

The scope of present work includes the following

- Material characterization
- Concrete mix design
- Concrete mixture preparation with variable sand replacement levels
- Investigating the characteristics of both fresh control concrete and bottom ash concrete mixtures.
- Casting of fresh control concrete and bottom ash concrete mixture specimens
- Strength qualities of hardened control concrete and bottom ash concrete mixtures were tested.

III. LITERATURE

Thirumalai.R, Anantharajan.V, Kaleeswaran.M, Lakshmanakumar.R, Logeswaran.V.G investigated the impact of using coal bottom ash as a partial replacement for fine aggregates in two percentages (5 and 10%) on concrete properties such as compressive strength, splitting tensile strength test, and flexural strength. The use of coal bottom ash as a replacement for fine aggregate in concrete lowered workability at a given water cement ratio, according to the results of this research. When compared to control concrete, bottom ash concrete had a higher compressive strength after 28 days of curing. Concrete's splitting tensile strength improved as bottom ash replacement percentages increased.

Bottom Ash as Partial Sand Replacement in Concrete was reviewed by **Vikas R Nadig et al (2015)**. This study examines the mechanical

qualities of concrete incorporating Bottom Ash as a partial replacement for fine particles, with an emphasis on compressive strength, splitting tensile strength, flexural strength, and other mechanical properties. This study examines ten different research publications. The practical use of Bottom ash contributes significantly to waste reduction and resource conservation, and it is concluded that the workability of Bottom ash concrete decreases as the bottom ash concentration increases due to increased water demand.Because bottom ash has a lower specific gravity than fine particles, the density of Bottom Ash concrete drops as the content of bottom ash increases. At all ages, the compressive strength of sand-replaced bottom ash concrete will be lower than regular concrete specimens, and the splitting tensile strength of sand-replaced bottom ash concrete will also be lower.

Critical Observations from the literature:

- When sand was replaced with fly ash mixes, the compression strength gain and corrosion resistance were higher.
- At all ages, 50 percent fly ash content resulted in the highest compressive strength, flexural strength, splitting tensile strength, and modulus of elasticity.
- When bottom ash is used in concrete, the amount of water required for mixing increases dramatically; yet, bottom ash has no effect on the entrapped air content or the setting times of fresh concrete.
- The compressive strength parameters of the bottom ash and combined bottom ash and natural sand mixtures are lower than those of the control samples due to the higher water demand and yield.
- Considering the range of cement factors utilised, samples incorporating dry bottom ash had outstanding strength, stiffness, and deformation qualities.
- Wet abrasion testing regularly performed worse than dry abrasion testing.

IV. MATERIALS USED

The following materials are used in the present investigation. A brief description is given below regarding the materials used.

A. Cement

Fig. 3 Ultra Tech Ordinary Portland Cement

TABLE I
PHYSICAL PROPERTIES OF OPC USED

Sl. No	**Properties**	**Test Results**	**Requirements as per IS :12269-1987**
1	Normal consistency	30%	--
2	Specific gravity	3.15	--
3	Initial setting time	55 min.	Not less than 30 min.
	Final setting time	565 min	Not more than 600 min
4	Soundness by Le Chatelier	2 mm	Not more than 10 mm
5	Fineness of Cement	3%	Less than 10%
6	Compressive Strength	54.7 MPa	53 Mpa

B. Aggregates

TABLE III
PROPERTIES OF FINE AGGREGATES

Sl. No	Properties	Result
1	Fineness modulus	3.012
2	Specific gravity	2.7
3	Bulk density in loose state	1520 kg/m3

TABLE IIIII
PROPERTIES OF COARSE AGGREGATES

Sl. No	Properties	Result
1	Fineness modulus	7.91
2	Specific gravity	2.74
3	Bulk density in loose state	2440 kg/m3

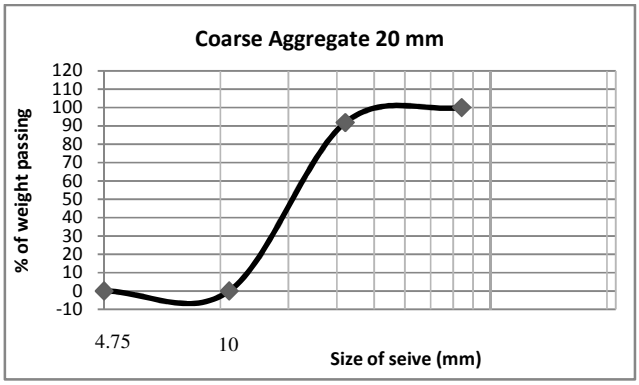

Fig. 4 Graduation chart for coarse aggregate (20mm)

C. *Coal Bottom Ash*

For the present study coal bottom ash is collected from Thermal Power plant Ramagundam, Telangana, India

The chemical composition and physical properties of bottom ash are shown below:

TABLE IVV
CHEMICAL COMPOSITION OF BOTTOM ASH

Content (%)	Bottom Ash
Silicon dioxide (SiO_2)	57.03
Aluminium oxide ($Al2O_3$)	22.86
Iron oxide ($Fe2O_3$)	7.05
Potassium oxide (K_2O)	0.3
Calcium oxide (CaO)	1.03
Titanium oxide (TiO_2)	0.17
Sulphur Trioxide (SO_3)	6.15
Magnesium Oxide (MgO)	0.85
Sodium oxide (Na_2O)	4.29

TABLE V
PHYSICAL PROPERTIES OF BOTTOM ASH

Properties of Bottom ash	Values
Specific gravity	2.30
Fineness modulus	2.66
Bulk density(gm/cc)	0.642-0.747
Maximum dry density (Kg/m3)	1450
Water absorption (%)	0.8-2.0%
Aggregate impact value (%)	18.25
Aggregate crushing strength (%)	19.30
Aggregate abrasion value (%)	30.12

D. *Admixtures*

1) *Mineral Admixtures*

- Fly Ash
- Silica Fume
- Metkaolin
- Rice Husk Ash
- Ground Granulated blast furnace Slag

2) *Chemical Admixtures*

- Super Plasticizers
- Water reducing admixtures
- Retarding admixtures
- Strength increasing admixtures

TABLE VI
COAL BOTTOM ASH CONCRETE MIX PROPORTIONS

Mix Proportions	Cement kg/m^3	Fine aggregate kg/m^3		Coarse Aggregates kg/m^3	Water /cement ratio	Water volume
		Sand	CBA			
0 % Bottom Ash	420	758	Nil	1138	0.4	168
10 % Bottom Ash	420	682	76	1138	0.4	168
15 % Bottom Ash	420	644	114	1138	0.4	168
20 % Bottom Ash	420	606	151	1138	0.4	168
25 % Bottom Ash	420	569	190	1138	0.4	168

V. EXPERIMENTAL PROCEDURE

The main objective of the present experimental investigations is to obtain specific experimental data, which helps to understand the Coal Bottom Ash concrete and its strength characteristics.

A. *Slump Cone Test*

Slump cone test is very common test for determination of workability of concrete. This test was carried out in both mix cases i.e., M40 before casting the cubes, cylinders and prisms.

B. *Compressive Strength*

This investigation is carried out to study the compressive strength of M40 grade concrete of normal water and magnetic water used concrete at 7 and 28days.

C. *Split Tensile Strength*

This investigation is carried out to study the compressive strength of M40 grade concrete of

normal water and magnetic water used concrete at 7 and 28days.

D. *Flexural Strength*

After the splitting tensile test another common test performed for determination of tensile strength is the flexure test. It is the ability of a beam or slab to resist failure in bending. It is measured by loading un-reinforced concrete beams with a span three times the depth. The flexural strength is expressed as "Modulus of Rupture" (MR).

VI. RESULTS AND DISCUSSION

A. *Slump Cone Test*

TABLE VII
SLUMP VALUES FOR COMPRESSIVE STRENGTH OF CONCRETE FOR 28 DAYS

Percentage of coal Bottom Ash added	Slump Value (mm)
0%	75
10%	70
15%	68
20%	66
25%	60

TABLE VIII
SLUMP VALUES FOR SPLIT TENSILE STRENGTH OF CONCRETE FOR 28 DAYS

Percentage of coal Bottom Ash added	Slump Value (mm)
0%	76
10%	70
15%	70
20%	67
25%	65

TABLE IX
SLUMP VALUES FOR FLEXURAL STRENGTH OF CONCRETE FOR 28 DAYS

Percentage of coal Bottom Ash added	Slump Value (mm)
0%	77
10%	75
15%	70
20%	67
25%	65

B. *Compressive Strength Test Results*

The cube compressive strength results of Concrete mixes at ages of 7, 28 days are presented in table. The development of compressive strength for M40 grade of concrete mixes containing 0, 10, 15, 20 and 25 percent of Coal Bottom Ash replaced by sand at the various stages of normal curing are plotted in the form of graphs are shown.

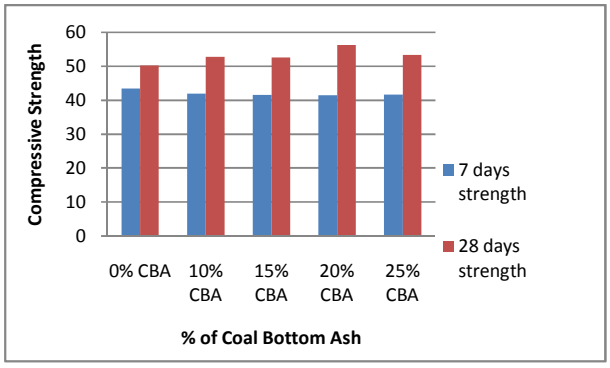

Fig. 5 Comparison of Compressive Strength of Concrete for various mixes

C. *Split tensile Strength Test Results*

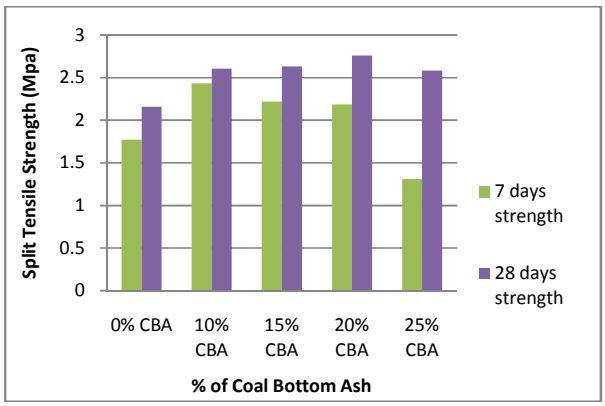

Fig. 6Comparison of Split Tensile Strength for Various mixes

From the above graph it is observed that at curing age of 28 days, the splitting tensile strength of bottom ash concrete mixtures incorporating 10%, 15%, 20%, 25% bottom ash as fine aggregate was 20.69%, 21.94%, 27.7%, 19.5% and for 7days was 37.5%, 25.42%, 23.502, -25.98 higher than that of control concrete mixture respectively. The incorporation of bottom ash in concrete shows significant increase in splitting tensile strength. Thus it is clear that we can replace the fine aggregate by bottom ash up to 20%.

D. Flexural Strength Test Results

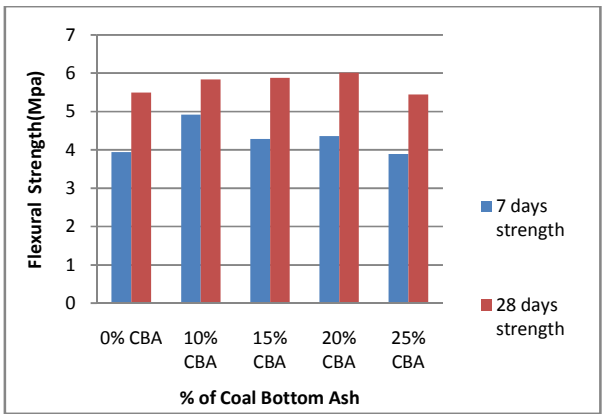

Fig. 7Comparison of Flexural Strength for Various mixes

From the above graph it is observed that the gain of flexural strength by replacement of bottom ash concrete with respect to their age of 28 days was 24.7%, 8.62%, 10.7%, -1.19 and 6.35, 6.99, 9.43, -0.76 at the age of 7 days. As the % replacement of bottom ash to fine aggregate increases flexural strength increases up to 20% .Thus it is clear that we can replace the fine aggregate by bottom ash up to 20%.

VII. CONCLUSIONS

The study was conducted to evaluate the strength characteristics of concrete with bottom ash. The concrete mix design was done for M 40 grade concrete. The following points were concluded from this study.

- The workability of bottom ash concrete decreased on use of coal bottom ash in partial replacement of fine aggregate in concrete.
- The compressive strength, Split Tensile strength and flexural strength for 7 and 28 days were increased up to 20% replacement and after that gradually decreased for further replacement.
- Also the strength increases with the age of curing.
- For developing sustainable concrete, bottom ash proves to be a good alternative. The 20% optimum dosage of bottom ash replacement saves a large consumption of river sand which is used in concrete.

SCOPE FOR FUTURE WORK

The inclusion of coal bottom ash as fine aggregate decreases an early age compressive strength of concrete. As such further research to explore the possible ways to enhance the early age strength of bottom ash concrete is needed.

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