MECHANICAL STRENGTH OF CONCRETE USING BOTTOM ASH AS FINE AGGREGATE

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Abstract
Concrete material possess strength and longevity. The durability concerns, concrete can be prepared and manufactured from anon constituents and however widely used in all major types of construction. The Indian Construction Industry is today consuming about 400 million tons of concrete every year and it is expected that this may reach a billion tones in less than a decade. All the materials required to produce such a huge quantity of concrete come from the earth's crust. Thus, it depletes its resources every year creating ecological strains. Recent technological development has shown that the waste solid materials are valuable as inorganic and organic resources and can be used to produce various useful products.

Bottom ash is a byproduct of coal combustion. The largest producers of bottom ash are coal fired power plants, which burn a very high volume of coal annually to generate electricity. Many byproducts of combustion are generated when coal is burned. Bottom ash and a component known as fly ash consist of coal components which did not combust during the burning phase. Fly ash is light enough that it is carried up the flue with the flue gases, and ideally trapped in filters before reaching the environment. Bottom ash forms clinkers on the wall of the furnace, with the clinkers eventually falling to the bottom of the furnace.

Keywords: **Bottom Ash, concrete testing, concrete technology, strength and longevity.**

I. INTRODUCTION

Concrete material possesses strength and longevity. The durability concerns, concrete can be prepared and manufactured from anon constituents and however widely used in all major types of construction. The Indian Construction Industry is today consuming about 400 million tons of concrete every year and it is expected that this may reach a billion tones in less than a decade. All the materials required to produce such a huge quantity of concrete come from the earth's crust. Thus, it depletes its resources every year creating ecological strains. Recent technological development has shown that the waste solid materials are valuable as inorganic and organic resources and can be used to produce various useful products. Among the solid wastes, the most prominent materials are fly ash, bottom ash, blast furnace slag, rice husk ash, silica fume and materials from construction demolition. 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.

Energy is the main backbone of modern civilization of the world, and the electric power from thermal power stations is a major source of energy, in the form of electricity. In India, over 70% electricity generated is by combustion of fossil fuels, out of which 61% is produced by coal fired plants. This results in production of roughly 100 tons of ash per day. Most of the ash has been disposed of either dry or wet at an open area available near the plant or by grounding both fly ash and bottom ash and mixing it with water and pumping into artificial lagoon or dumping yards. This cause pollution in water bodies and loss of productive land.

Therefore, the issues related to environmental conservation have gained great importance in our society in recent years. The utilization of solid wastes in construction materials is increasing day by day because of high demand, scarcity of raw materials, and high price of energy. From the standpoint of energy saving and conservation of natural resources, the use of alternative constituents in construction materials is now a global concern.

1.1 BOTTOM ASH

Bottom ash is a byproduct of coal combustion. The largest producers of bottom ash are coal fired power plants, which burn a very high volume of coal annually to generate electricity. There are several disposal options for bottom ash, ranging from recycling to land filling, and several advisory councils and industry advocacy groups around the world promote methods of bottom ash disposal which are viewed as more environmentally friendly. Many byproducts of combustion are generated when coal is burned. Bottom ash and a component known as fly ash consist of coal components which did not combust during the burning phase. Fly ash is light enough that it is carried up the flue with the flue gases, and ideally trapped in filters before reaching the environment. Bottom ash forms clinkers on the wall of the furnace, with the clinkers eventually falling to the bottom of the furnace.

TABLE I

Typical ranges for geotechnical properties of bottom ash.

Property	**Bottom Ash**
Specific Gravity	2.3 -3.0
Bulk Density (compacted), Ibs/k^3	65-110
Optimum Moisture Content, %	12 -26
Porosity	0.25 -0.40
Angle of Internal Friction,	35-45

1.2Chemical Composition of Bottom Ash

The chemical composition of coal ash is determined primarily by the chemistry of the source coal and the combustion process. Because ash is derived from the inorganic minerals in the coal, such as quartz, feldspars, clays, and metal oxides, the major elemental composition of coal ash is similar to the composition of a wide variety of rocks in the Earth's crust (Figure 1). Oxides of silicon, aluminum, iron, and calcium comprise more than 90% of the mineral component of typical fly ash (Figure 1). Minor constituents such as magnesium, potassium, sodium, titanium, and sulfur account for about 8% of the mineral component, while trace constituents such as arsenic, cadmium, lead, mercury, and selenium, together make up less than 1% of the total composition. Table 2 shows the chemical composition of Bottom Ash

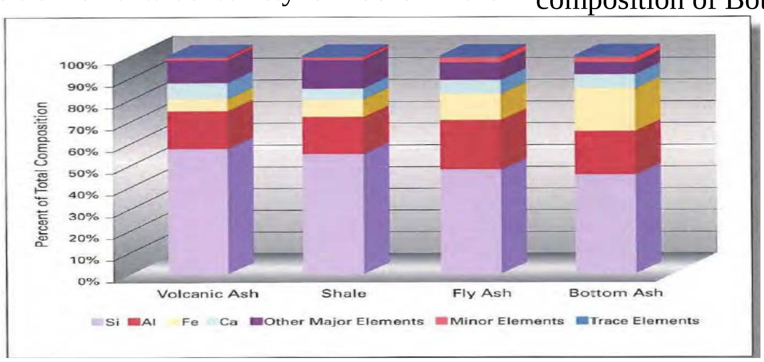

Figure.1 Elemental composition for bottom ash

Table.2

Chemical compositions

Chemical Composition	Bottom Ash
SiO_2 (%)	38.07
Al_2O_3 (%)	22.89
Fe_2O_3 (%)	12.12
CaO (%)	18.40
MgO (%)	2.26
SO_3 (%)	1.77
Na_2O (%) <	1.09
K_2O (%)	2.29
Free lime (%)	0.72
Loss on ignition (%)	0.03

1.3Beneficial Use

The physical and chemical properties of coal ash make it suitable for many construction and geotechnical uses, in 2007, 32 million tons of fly ash was beneficially used, representing 44% of the total fly ash produced. Similarly, 7.3 million tons of bottom ash (40%) and 1.7 million short tons of boiler slag (80%) were used.

2. POTENTIAL AND CURRENT USES OF BOTTOM ASH

In contrast to sand, a primary raw material, the black sandy material obtained is a secondary raw material. Using this material is more sustainable and environmentally friendly and avoids the use of natural resources such as sand and gravel. Bottom ash is used in road construction, as a foundation material, in noise barriers, as a capping layer on landfill sites and in some countries as an aggregate in asphalt and concrete.

a. Road construction

Bottom ash is used in road construction as a fill material, mainly in large motorway embankments.

b. Foundation material

Bottom ash is a popular foundation and fills material in all works involving large areas of asphalt pavement and where there is no danger of direct contact with the groundwater. Many of these are huge car parks or large storage hangars where fill material is needed.

c. Noise barriers

Bottom ash can be used as a raw material in the construction of noise barriers with a natural appearance, especially along motorways. An example is the 1.2 kilometer noise barrier along the A12 motorway at De Meern in the Netherlands, the core of which consists entirely of Waste-to-Energy bottom ash.

d. Aggregate

The use of bottom ash as an aggregate in asphalt and concrete is still in the early stages. For use as an aggregate, the bottom ash is sieved, separated into coarse and fine fractions, coated with bitumen and added to asphalt instead of stone chippings. The bitumen coating removes any danger of leaching and no further isolation measures are needed.

OBJECTIVE AND SCOPE OF THE PROJECT

In this project the objective is to study the effect of bottom ash as fine aggregate with varying percentage on strength for M25 concrete mix. There are four mixes except control mix. The each mix contains varying percentage of bottom ash as fine aggregate. The variation of percentage of bottom ash in concrete will be 25%, 50%, 75% and 100%.The tests will conduct for every mix with varying percentage of bottom ash as fine aggregate. The properties of hardened concrete will investigate by the tests such as compressive strength test, flexural and split tensile strength test and also modulus of elasticity test.

3. RESULTS AND DISCUSSION

In this chapter, a fresh concrete property such as compaction factor was determined and the mechanical properties like compressive strength, split tensile strength and flexural strength and durability properties like acid attack, alkali attack of concrete mixtures with and without bottom ash were discussed.

WORKABILITY

The workability measured in terms of compaction factor, decreases with the increase of the replacement level of the fine aggregates with the bottom ash as given in Table 3 and chart 1. It can be due to the extra fineness of bottom ash as the replacement level of fine aggregates is increased

Table 3.Workability in terms of Compaction Factor

Mix Type	M1	M2	M3	M4	M5
C.F	0.84	0.82	0.79	0.78	0.76

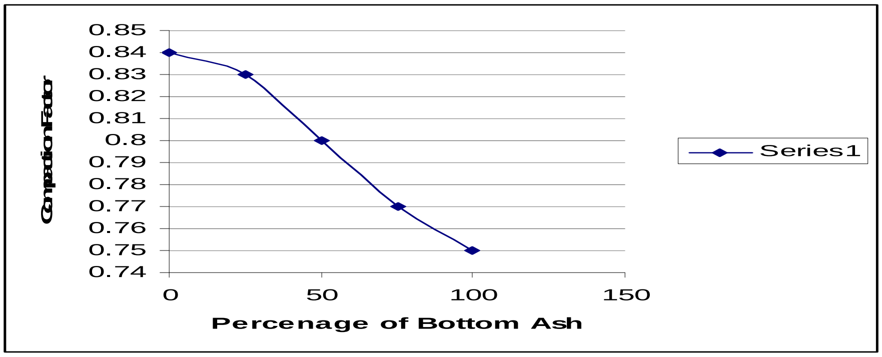

Chart 1.Compaction factor for the fresh concrete

COMPRESSIVE STRENGTH

The compressive strength variation with respect to the percentage of replacement of sand by bottom ash and number of days curing was shown in Table 4. Table 5 shows the percentage gain of compressive strength by different types of bottom ash concrete with respect to their compressive strength of normal concrete.

Table 4.Compression behaviour of bottom ash concrete with age

Mix Type	Compressive strength (fc) N/mm2	
	28 Days	56Days
M1	30.1	33.10
M2	29.93	31.98
M3	33.26	35.74
M4	23.59	24.05
M5	21.21	22.22

Table 5.Compression behaviour of bottom ash concrete v/s plain concrete

Mix Type	Strength gain =(Strength of Bottom Ash/Strength of Plain concrete)x100	
	28 Days	56 Days
M2	99.44	106.25
M3	110.50	118.74
M4	78.37	79.90
M5	70.47	73.82

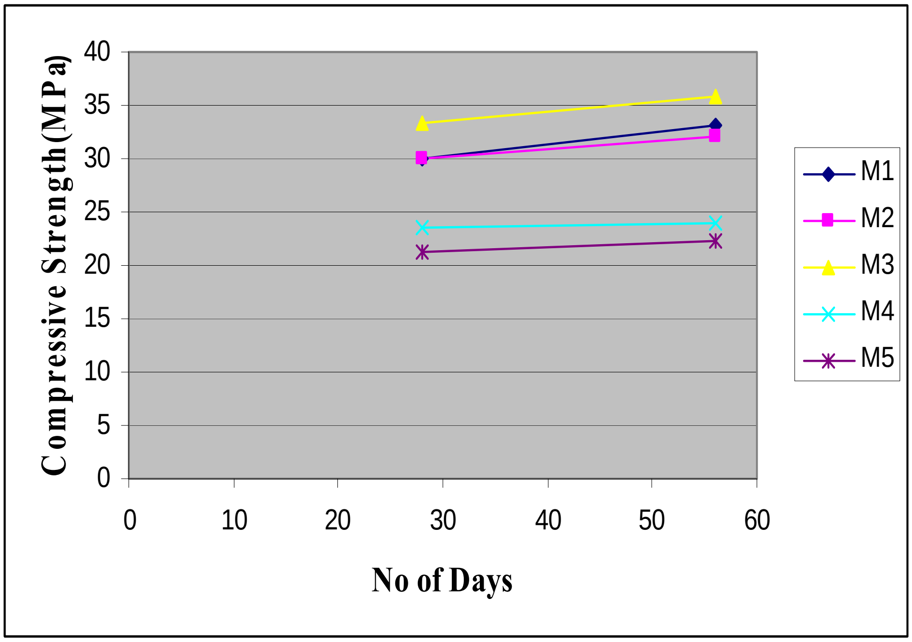

Chart 2.Compressive strength of concrete with age

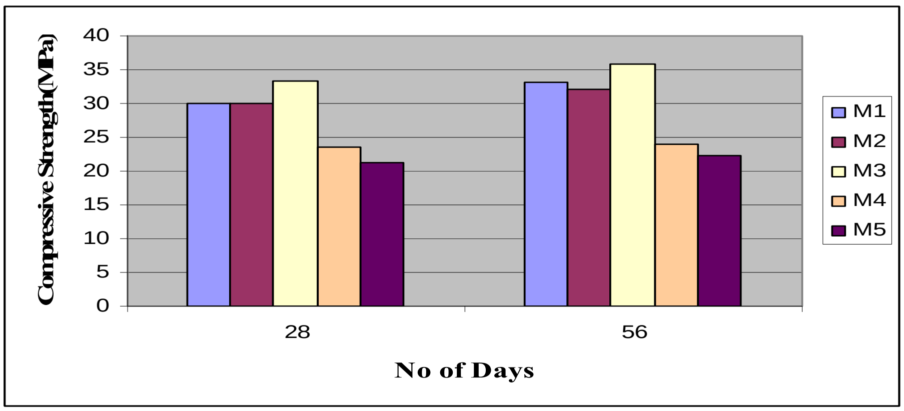

Chart 3.Compressive strength of concrete for various mixes

5. Effect of bottom ash on compressive strength

Compressive strength of concrete mixed made with and without bottom ash of cubes size 100 mm × 100 mm × 100 mm was determined at 28 and 56 days. The average compressive strength was calculated using the following relation.

Compressive strength (MPa) =Ultimate load in N/ Area of Cross section (Sq.m)

Here 0 to 100 % of bottom ash was replaced with sand. It is observed that there is reduction in compressive strength at earlier stages by increasing BA content in M25 grade concrete and optimum percentage of replacement was obtained at 50 % replacement of bottom ash with sand. After that compressive strength was decreased in 75% and 100 % replacement. For controlled concrete the compressive strength was found to be 30.10 and 33.10 N/mm2 for 28 and 56 days respectively. The bottom ash concrete gains strength at a slower rate in the initial period and acquires strength at faster rate after 28 days, due to pozzolanic action of bottom ash. Also, at early age bottom ash reacts slowly with calcium hydroxide liberated during hydration of cement and does not contribute significantly to the densification of concrete matrix at early ages.

SPLIT TENSILE STRENGTH

The split tensile variation with respect to the percentage of replacement of sand by bottom ash and number of days curing was shown in Table 6. Chart 4 shows the split tensile strength development with age and chart 5 shows the variation of split tensile strength for various percentages of bottom ash

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Table 6.
Splitting tensile behaviour of bottom ash concrete with age

Mix Type	Split Tensile strength (ft) N/mm2	
	28 Days	56Days
M1	2.58	2.92
M2	2.39	2.64
M3	2.95	3.23
M4	2.20	2.55
M5	2.04	2.40

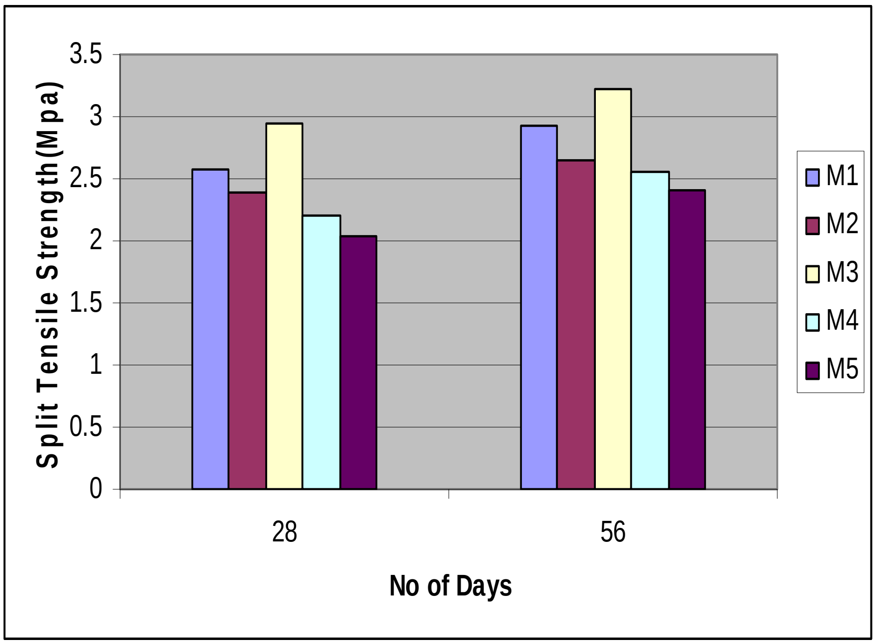

Chart 5.Split Tensile strength of concrete for various mixes

Effect of bottom ash on split tensile strength

The specimen of size 100 mm in diameter and length of 200 mm was casted and tested under the CTM. Split tensile strength of concrete mixed made with and without bottom ash was determined at 28 and 56 days**.** Here 0 to 100 % of bottom ash was replaced with sand. It is observed that there is reduction in split tensile strength at earlier stages by increasing BA content in M25 grade concrete and optimum percentage of replacement was obtained at 50 % replacement of bottom ash with sand. After that split tensile strength was decreased in 75% and 100 % replacement. For controlled concrete the split tensile strength was found to be 2.58 and 2.92 N/mm2 for 28 and 56 days respectively.

It was observed from the result that the splitting tensile strength of concrete decreased with the increase in the percentage of fine aggregates replacement with the bottom ash, but the splitting tensile strength increased with the age of curing. The rate of increase of splitting tensile strength decreased with the age.

FLEXURAL STRENGTH

The flexural strength variation with respect to the percentage of replacement of sand by bottom ash and number of days curing was shown in Table 7. Chart 6 shows the flexural strength development with age and chart 7 shows the variation of flexural strength for various percentages of bottom ash.

Table 7.Flexural strength behaviour of bottom ash concrete with age

Mix Type	Flexural strength (fst) N/mm2	
	28 Days	56Days
M1	2.40	3.05
M2	2.19	2.56
M3	2.32	2.72
M4	2.20	2.42
M5	2.09	2.30

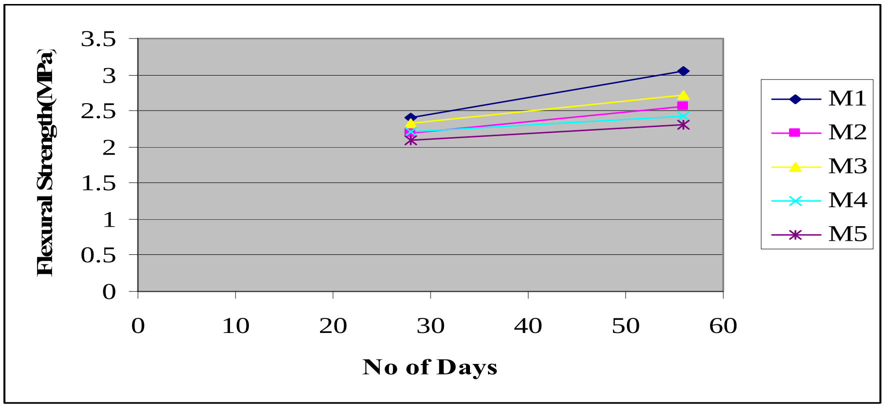

Chart 6.Flexural Strength of concrete with age

Effect of bottom ash on flexural strength

The beam specimen of size 100 mm X 100mm X 200mm was casted and tested. Flexural strength of concrete mixed made with and without bottom ash was determined at 28 and 56 days**.** Here 0 to 100 % of bottom ash was replaced with sand. It is observed that there is reduction in Flexural strength at earlier stages by increasing BA content in M25 grade concrete and optimum percentage of replacement was obtained at 50 % replacement of bottom ash with sand. After that Flexural strength was decreased in 75% and 100 % replacement. For controlled concrete the split tensile strength was found to be 2.32 and 2.72 N/mm2 for 28 and 56 days respectively. The flexural strength is affected to more extent with the increase in bottom ash concrete. The bottom ash concrete gains flexural strength with the age that is comparable but less than that of plain concrete. It is believed to be due to poor interlocking between the aggregates, as bottom ash particles are spherical in nature.

MODULUS OF ELASTICITY

The Modulus of elasticity variation with respect to the percentage of replacement of sand by bottom ash and number of days curing was shown in table 8. Chart 8 shows the Modulus of Elasticity with age and chart 9 shows the variation of Modulus of Elasticity for various percentages of bottom ash.

Table 8.Modulus of Elasticity of bottom ash concrete with age

Mix Type	Modulus of elasticity N/mm2	
	28 Days	56 Days
M1	$0.30X10^5$	$0.32\ X10^5$
M2	$0.27\ X10^5$	$0.30\ X10^5$
M3	$0.29\ X10^5$	$0.31\ X10^5$
M4	$0.25\ X10^5$	$0.26\ X10^5$
M5	$0.23\ X10^5$	$0.25\ X10^5$

Effect of bottom ash on modulus of elasticity

The modulus of Elasticity of cube specimen is calculated according to IS: 456-2000 by the formula

Fc =5000√Fck (Where, fck is 28 days cube compressive strength)

It was found that the modulus of elasticity decreased in accordance with an increase of replacement of sand by bottom ash. The modulus of Elasticity of reference concrete was 0.30×10^5 N/mm^2 at 28 days curing and 0.32 $X10^5$ N/mm^2 at 56 days curing. At 25% and 50% replacement there was a small increase in the Modulus of Elasticity after that it decreased it's value than controlled concrete.

6. CONCLUSIONS

The following conclusions could be arrived from the study:

- The workability of concrete decreased with the increase in bottom ash content due to the increase in water demand.
- The Compressive strength, Splitting tensile Strength and Flexural Strength of fine aggregates replaced bottom ash concrete decreased in earlier stages.
- Compressive strength, splitting tensile strength and Flexural strength of fine aggregate replaced bottom ash concrete continue to increase with age for all the bottom ash contents.
- The compressive strength, Splitting tensile strength and Flexural strength for 28 and 56 days was optimized at 50% replacement and after that compressive strength, splitting tensile strength and Flexural strength were decreased in 75% and 100% replacement.
- Bottom ash of 50% and 100% cement replacement by weight is not suitable for concrete because it has produce a lower strength concrete at the early ages which can results in ruptures during construction.
- In is found that the Modulus of Elasticity decreased in accordance with an increase in replacement of fine aggregate by bottom ash.

7. ACKNOWLEDGEMENT

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