Study on Strength Properties of Fly Ash Concrete Incorporating Bottom Ash

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***Abstract*—**Concrete is the most important engineering material and the addition of some other materials may change the properties of concrete. Studies have been carried out to investigate the possibility of utilizing a broad range of materials as partial replacement materials for cement and aggregate in the production of concrete. The present experimental study was conceived following the general purpose of testing new sustainable building processes and modern production systems, aims not only at saving natural raw materials and reducing energy consumption, but also to recycle industrial by-products. The objectives of this study was to investigate the effect of use of coal bottom ash as partial replacement of fine aggregates in various percentages (0–30%) and also fly ash as a partial replacement of cement in various percentage (0-30%), on concrete properties such as compressive strength, flexural strength and also the effect of micro silica in bottom ash concrete having maximum compressive strength.

The most important purpose of this research is concerning about the environment. Each year, vast amounts of natural resources are consumed to manufacture ordinary Portland cement which itself causes considerable environmental problems. It can be considered as the key factor which does not utilize Portland cement, nor releases greenhouse gases. Sufficient data is available about researches on fly ash based concrete, but using both fly ash and bottom ash has a new era.

Compressive strength of bottom ash concrete at the curing age of 28 days was increased compared to control concrete. To find 3, 7 and 28 days compressive strength, three 150×150×150mm specimens with 0, 10, 20, and 30 percent replacement of bottom ash were prepared and cured at ambient condition (28^{o}C). Same condition of curing was provided for 150×150×600mm beam & flexural strength of three mixes are determined. The optimum rate of replacement was 20% which produced bottom ash concrete with 28-day compressive strength of 34.2MPa and flexural strength of 7.11MPa.

Keywords: Bottom Ash, Fly Ash, Concrete, Compressive Strength, Flexural Strength.

I. Introduction

Due to growing of population and construction, subsequently, it is obvious that the demand for space, natural resources, water, and energy will grow. The production of ordinary Portland cement (OPC) is rising with a rate of approximately 3% per year. This huge production has two main reasons, first of all, due to the availability of the materials for its production all around the world and partly due to its versatile behavior which gave architectural freedom. Nowadays, concrete industry is known to be the major consumer of natural resources, such as water, sand and aggregates, and manufacturing Portland cement also requires large amounts of each of them. Due to its high energy consumption and environmental pollution rates, the Portland cement industry was the subject for many investigations by regulatory agencies and the public.

It would be a great success in case of manufacturing a concrete with lesser consumption of ordinary Portland cement, this can be achieved by partial replacement of cement with fly ash. Other substitutes for cement are silica fume, slag, rice-husk ash, and red mud, bottom ash etc.

Bottom ash meets two of the critical requirements for concrete aggregates: It is uniformly graded, strong, hard, and durable. Coal bottom ash is a coarse granular and incombustible byproduct from coal burning furnaces. It is composed of mainly silica, alumina and iron with small amounts of calcium, magnesium sulfate, etc. The appearance and particle size distribution of coal bottom ash is similar to that of river sand. These properties of coal bottom ash make it attractive to be used as fine aggregate in the production of concrete.

II. AIM AND OBJECTIVES

To study the compressive strength of concrete by **partial replacement of river sand with bottom ash at percentage of 10%, 20%, 30% and also a partial replacement of cement with fly ash at percentage of 10%, 20%, 30%.**This will be carried out by casting cubes of (150 x 150 x 150) mm and testing them at 3, 7 and 28 days.

To study the flexural strength of concrete by partial replacement of river sand with bottom ash and also fly ash as a partial replacement of cement. Casting of three beams of size (150 x 150 x 700) mm of **10%, 20%** and **30%** will be carried out and tested for **28 days**.

To study the behavior of bottom ash in concrete after partial replacement of natural river sand with bottom ash. To study the physical and chemical properties of bottom ash and fly ash & to compare cost analysis of concrete containing bottom ash and natural sand

III. DESCRIPTION OF MATERIAL

- **Cement**

Cement in concrete acts as a binding material that harden after the addition of water. It plays an important role in construction sector. Ordinary Portland cement (53grade) ACC cement was used.

- **Fine aggregates:**

Locally available natural sand with 4.75mm maximum size was used as fine aggregate.

Physical Properties of Fine Aggregate

Sr.no.	Properties	Values
1	Specific gravity	2.74
2	Fineness modules	3.40
3	Water absorption (%)	1.2

- **Coarse Aggregates**

Locally available crushed stone of 10-20 mm size use as acoarse aggregate.

Sr.no.	Properties	Values
1	Specific gravity	2.76
2	Fineness modules	1.14

- **Water:** Water plays an important role as it contributes in chemical reaction with cement. Water is used for mixing as well as for curing purpose also it should be clean and free from salts, acids, alkalis and other harmful materials. Potable water was used. Observed value pH 8.0.

- **Fly ash**

Fly ash, also known as "pulverized fuel ash" in the India, is one of the coal combustion products, composed of the fine particles that are driven out of the boiler with the flue gases. Ash that falls in the bottom of the boiler is called bottom ash. In modern coal-fired power plants, fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys.

Physical Properties of FLY ASH

Property	Value
Specific gravity	1.90-2.96
Fineness modulus	2.00-2.25
Unit Weight (kg/m^3)	960(kg/m^3)

Chemical properties of FLY ASH

Constituent	Value (%)
Silica oxide SiO_2	55.3
Aluminum oxide Al_2O_3	25.7
Iron oxide Fe_2O_3	5.3
Calcium oxide CaO	5.6
Magnesium oxide MgO	2.1
Potassium oxide K_2O	0.6
Sodium oxide Na_2O	0.4
Titanium Oxide TiO_2	1.3
Sulphur trioxide SO_3	1.4
Loss on ignition LOI	1.9

- **Bottom Ash**

Bottom ash is formed in coal furnaces. It is made from agglomerated ash particles that are too large to be carried in the flue gases and fall through open grates to an ash hopper at the bottom of the furnace.

Physical Properties of BOTTM ASH

Property	Value
Specific gravity	1.39-1.93
Fineness modulus	1.37-1.83
Unit Weight (kg/m^3)	948

Chemical properties of BOTTOM ASH

Constituent	Value (%)
Silica oxide SiO_2	56.44-61.0
Aluminium oxide Al_2O_3	17.80-29.24
Iron oxide Fe_2O_3	6.56-13.00
Calcium oxide CaO	0.75-3.25
Magnesium oxide MgO	0.40-3.20
Sodium oxide Na_2O	0.02-0.82
Loss on ignition LOI	1.08-2.12
Potassium oxide K_2O	0.086-0.95
Titanium oxide TiO_2	0.88-0.95
CI	0.01
P_2O_5	0.2
Fe	13
Loss of ignition	0.89-5.80
Sulphur S	0.604

IV. LITERATURE REVIEW

Malhotra (1990), studied in detail the properties of concrete with a wide range of Canadian fly ashes at 58% of the total cementitious materials. These concretes were tested for compressive strength, creep strain and resistance to chloride ion penetration at various ages up to one year. The results of study by Joshi et al (1994), indicated that with fly ash replacement level up to 50% by cement weight, concrete with 28 days strength ranging from 40 to 60 MPa and with adequate durability can be produced with cost saving of 16% by 50% replacement level.

Mishra et al. (1994) studied the effect of blast furnace slag, fly ash and silica fume on permeability of concrete and concluded that on use of these waste materials in concrete, the chloride permeability decreased.

Sarath Chandra Kumar (October, 2011) observed that the utilization of fly ash in concrete as partial replacement of cement is gaining immense importance today, mainly on account of the improvement of the long term durability of concrete combined with ecological benefits. Technological improvements in thermal power plants operation and fly ash collection systems have resulted in improving the consistency of fly ash. To study the effect partial replacement of cement by fly ash, studies have been conducted on concrete mixes with 300 to 500 kg/cum cementitious material at 20%, 30%, 40% and 50% replacement level. In their work the effect of fly ash on workability, setting time, density, air content, compressive strength, modulus of elasticity, shrinkage and permeability by Rapid Chloride Permeability Test (RCPT) are studied.

Yogesh Aggarwal and Rafat Siddique et al.(2013) were studied microstructure and properties of concrete using bottom ash and waste foundry sand as partial replacement of fine aggregates. They concluded that the mechanical behavior of the concrete with fine aggregate replacements was comparable to that of conventional concrete except for 60% replacement. The inclusion of waste foundry sand and bottom ash as fine aggregate does not affect the strength properties negatively as the strength remains within limits except for 60% replacement.

Dilip Kumar & Ashish Gupta et al.(2015) investigate the compressive strength & flexural strength test of the concrete at different ages i.e. 7 days, 14 days, 2 days & 56 days. Bottom ash is replaced 10%,20%,30%,40%, & 50% In place of fine aggregate this explain various utilization of bottom ash & its ordinary Portland cement & properties causes severe pollution problems. Its utilization as a raw material for cube making will be very usefully solution in our economical environmental aspects.

A research was conducted by **Abdulhameed et al.(2.015)** on properties of concrete using tanjung bin power plant coal bottom ash and fly ash. Coal bottom ash and fly ash were utilized in partial replacement for fine aggregates and cement respectively in the range of 0, 5, 10, 15 & 20% (equal percentages). Their results showed that for a grade M35 concrete with a combination of coal bottom ash and fly ash can produce 28 day strength above 30MPa. They concluded that the use of coal bottom ash and fly ash in concrete has the potential to produce long term durable and good strength concrete.

V. CASTING OF SPECIMEN

All the specimens were cast having mix proportions as given in Tables. For these mix proportions, required quantities of materials were weighed. The mixing procedure adopted as follows:

a. The cement/fly ash and bottom ash were dry mixed in a tray for about 5 minutes.
   A uniform colour was obtained without any clusters of cement, bottom ash fly ash.
b. Weighed quantities of coarse aggregates and sand were then mixed in dry state.
c. The mix of cement, fly ash and bottom ash was added to the mix of coarse aggregates and sand and these were mixed thoroughly until a homogeneous mix was obtained.
d. Water was then added in three stages as given below:
e. 50% of total water to the dry mix of concrete in first stage.
f. 40% of water and admixture to the wet mix.
g. Remaining 10% of water was sprinkled on the above mix and it was thoroughly mixed in the mixer.

All the moulds were properly oiled before casting the specimens. The casting immediately followed mixing, after carrying out the tests for fresh properties. The top surface of the specimens was scraped to remove excess material and achieve smooth finish. The specimens were removed from moulds after 24 hours and cured in water till testing or as per requirement of the test.

VI. TEST

- **Workability test**

Workability is defined as the easiness with which a concrete can be transported, placed and consolidated without excessive bleeding or segregation.
Factors affecting concrete workability:

a) Water-Cement ratio
b) Amount and type of Aggregate
c) Amount and type of Cement
d) Weather conditions
e) Temperature
f) Wind Chemical Admixtures
g) Sand to Aggregate ratio

- **Compressive strength test**

This test is performed to determine compressive strength of concrete. The compressive strength is most important characteristic of concrete. The compressive strength increases if the cement content is increased. Compressive strength is influenced by several factors such as:

a) W/C ratio
b) Type of cement and its quality
c) Type and structure of aggregate
d) Degree of compaction
e) Efficiency of crushing
f) Time required for hardening

Total 30 concrete cubes are prepared. 3 cubes with natural concrete and other 27 cubes are prepared with fly ash and bottom ash concrete as replacement of cement and sand in proportion of 10, 20, and 30% by absolute volume method. 9 cubes of 150 x 150 x 150 mm size are prepared for each mix.

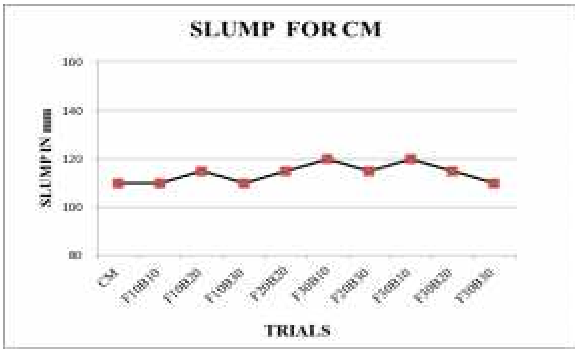
- **Flexural strength test**

Concrete as we know is relatively strong in compression and weak in tension. In reinforced concrete members, little depends on the tensile strength of concrete since steel reinforcing bars are provided to resist all tensile forces. However tensile stresses likely to developed in concrete due to shrinkages, rusting of steel reinforcement, temperature gradients and many reasons. The knowledge of tensile strength of the concrete is of importance. The standard size of the specimens are 15cm x 15cmx 70cm.
Total 3 beams were casted of size 150 x 150 x 700mm and tested for 28 days strength.

VII.RESULT ANALYSIS & DISCUSSION

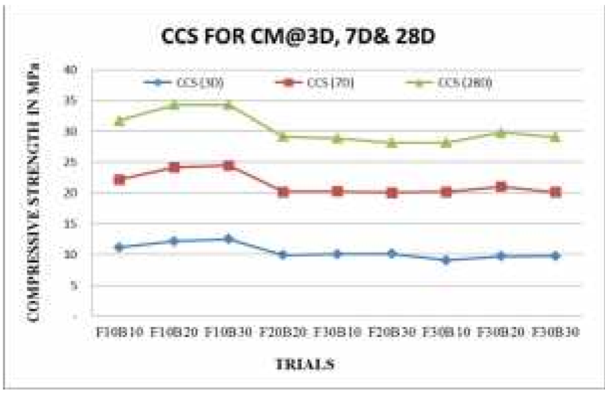
- SLUMP CONE TEST

Sr.no.	Fly Ash (%)	Bottom Ash (%)	Slump (mm)
1	0	0	110
2	10	10	110
3	10	20	115
4	10	30	110
5	20	10	115
6	20	20	120
7	20	30	115
8	30	10	120
9	30	20	115
10	30	30	110



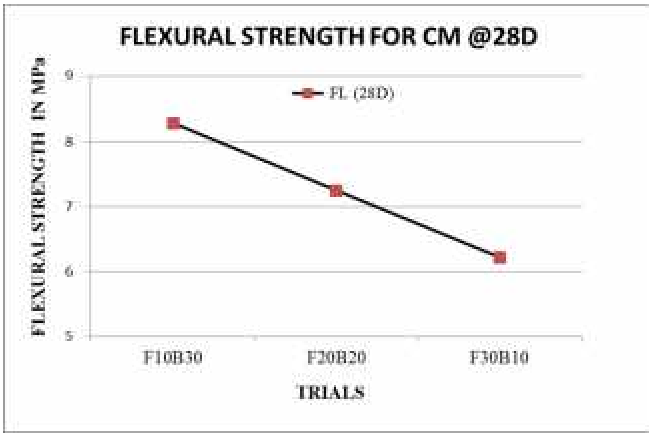
- **Compressive strength @3, 7 & 28 Days**

Type of concrete	Avg. 3 days (N/mm^2)	Avg. 7 days (N/mm^2)	Avg. 28 days (N/ mm^2)
CM	13.12	25.8	36.8
F10B10	11.16	22.17	31.77
F10B20	12.17	24.15	34.32
F10B30	12.5	24.44	34.28
F20B10	9.92	20.14	29.18
F20B20	10.05	20.18	28.89
F20B30	10.10	20.03	28.18
F30B10	9.06	20.13	28.21
F30B20	9.71	20.98	29.86
F30B30	9.73	20.12	29.12



) **Flexural Strength of Beams For M25 grade@28 Days**

Flexural Strength@ 28 Days	F10B30	F20B20	F30B10
Grade of Concrete	M25	M25	M25
Dimensions	70x15x15	70x15x15	70x15x15
Flexure Length	24	23	21
Weight of specimen	39.62	39.68	39.04
Crushing Load	40	35	30
Flexural Strength	8.29	7.25	6.22



VIII. CONCLUSIONS & RECOMENDATIONS

- The present work investigated the influence of bottom ash and fly ash as partial replacement of fine aggregate (sand) and cement respectively on the properties of M25 of concrete. On the basis of the results from the present study, following conclusions are drawn.
- The compressive strength of fly ash and bottom ash concrete for 0%, 10%, 20%, and 30% decreases from 25N/mm² to 20N/mm² at 7 days, and 35 N/mm² to 28N/mm² at 28 days, almost linearly.
- For all % of replacements Compressive strength as nearly increased by 30% from 7days to 28 days, due to pozzolanic action of bottom ash.
- The 28 days targeted compressive strength is obtained up to 20% replacement, behind which it is below the targeted strength.
- Based on investigation concerning the flexural strength test of concrete (M25 Grade) containing bottom ash and fly ash , the following observations are made in the ray of objectives of the study:
- Increase in flexural strength of the concrete with increases in used bottom ash and fly ash each 20% and the maximum flexural strength is achieved at 20% replacement of natural fine aggregate with used bottom ash and 20% replacement of cement with used fly ash which comes to be 7.11N/mm^2.
- The slump obtained is nearly the same for all replacements of fly ash and bottom ash from 0% to 30%. For 20% replacement of bottom ash & fly ash maximum slump value is obtained. This may be due to decrease in workability by bottom ash is compensated by increase in workability due to fly ash.
- Environmental friendly and compatible concrete is produced.

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