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An Experimental Investigation on Partial Replacement of Fine Aggregate by Bottom Ash in Cement Concrete

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Abstract: Concrete is an irreplaceable material which is being used in infrastructural development. The cost of building construction is increasing by use of conventional materials like cement, river sand and coarse aggregates. This leads to reduction of naturally available materials. In this study, an effort is made to produce cost effective concrete by replacement of fine aggregates with bottom ash in proportions of 0%, 10%, 20%, 30%, 40% and 50%. Considering the all test results it is concluded that the optimum utilization of Bottom ash is 10% in concrete as replacement to the fine aggregate to obtain a considerable design mix.

Keywords: Concrete, cement, water, fine aggregates, Bottom ash

I. INTRODUCTION

Concrete is a material synonymous with strength and longevity. It has emerged as the dominant construction material for the infrastructure needs of the twenty-first century. In addition to being durable, concrete is easily prepared and fabricated from readily available constituents and is therefore widely used in all types of structural systems. In general the fine aggregates used in the production of concrete was natural river sand.

Now a days these natural sources like river sand are exhausting gradually around the world so, their protection of environment and saving of natural resources the construction industry is look for the alternative constituent material for making concrete so, there is need for replacement of sand in India.

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 over, and the electric power from thermal power stations is a major source of energy, in the form of electricity.

In India, over 70% of electricity generated in India, is by combustion of fossil fuels, out of which nearly 61% is produced by coal-fired plants. This results in the production of roughly 100 ton of ash. Most of the Bottom the ash has to be disposed of either dry, or wet to an open area.

A. Role of Fine Aggregate in Concrete

The fine aggregate plays a very important role for imparting better properties of concrete in its fresh and hardened state. Aggregate in concrete is structural filler. Aggregate occupies most of the volume of the concrete. It is the stuff that the cement paste coats and binds together. The composition, shape, and size of the aggregate all have significant impact on the workability, durability, strength, weight, and shrinkage of the concrete. Aggregate can also influence the appearance of the cast surface, which is an important consideration in mixes.

B. Alternative Fine Aggregates

Following are the some of the alternative fine aggregates

Quarry dust, Manufactured sand, Foundary sand, Crushed bricks, Crushed granite, Glass powder, Bottom Ash.

C. Bottom Ash.



Fig 1 Bottom Ash

Table I and II shows Physical and chemical characteristics of Bottom Ash

Table I Physical properties of Bottom Ash

Sl. No	Properties	Description
1	Specific gravity	2.12
2	Bulk density (gm /cc)	0.642-0.747
3	Fines modules	6.28
4	Maximum dry density (KN/M ³)	7.20
5	Water absorption (%)	14.10
6	Sizes produced (mm)	3.47-4.75
7	Aggregate impact value (%)	18.25
8	Aggregate crushing strength (%)	19.30
9	Aggregate abrasion value (%)	30.12

Table II Chemical characteristics of Bottom Ash

SL.NO	Constituents	Percentage (by weight)
1	SiO ₂	68.0
2	Al ₂ O ₃	25.0
3	Fe ₂ O ₃ + Fe ₃ O ₄	2.18
4	TiO ₂	1.45
5	CaO	1.66
6	MgO	0.02
7	So ₄	Nil
8	Loss on ignition	1.69

D. Tests on Bottom Ash

Bottom ash is a by-product of combustion of pulverized coal. This coal bottom ash is physically coarse, porous, glassy, granular, greyish and incombustible materials that are collected from the bottom of furnaces that burn coal. The physical properties of coarse bottom ash given in the below Table 4.5.

Table III Physical properties of Bottom ash

Sl. No	Material property	Test Results
1	Specific gravity	1.98
2	Fineness modulus (%)	2.55
3	Bulk density (kg/m ³)	1448
4	Water absorption (%)	1.52

E. Methodology

The methodology has been adopted to study the fresh and hardened properties of bottom ash (replacement of fine aggregate). The study work includes the following procedure. The M30 grade mix design was prepared by using as per IS 10262:2009 codal provisions. The concrete mixes are prepared varying the bottom ash content as 0%, 10%, 20%, 30%, 40% and 50% by weight with replacement of fine aggregate. The prepared mixes are studied for both fresh as well as hardened properties.

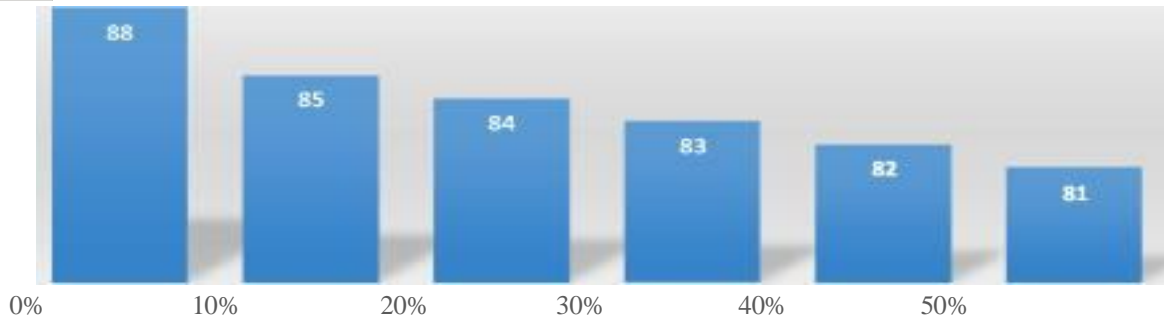
II. RESULTS AND DISCUSSION

A. Workability Test Results

Table IV
Workability Test Results

Percentage replacement of Fine Aggregate by Bottom Ash	Fresh properties tested		
	Slump (mm)	Compaction Factor	Vee-Bee Degree (Sec)
0%BA+100% FA	88	0.90	6
10% BA+90% FA	85	0.89	8
20% BA+80% FA	84	0.87	12
30% BA+70% FA	83	0.86	20
40% BA+80% FA	82	0.84	22
50% BA+50% FA	81	0.83	30

Slump Cone Test



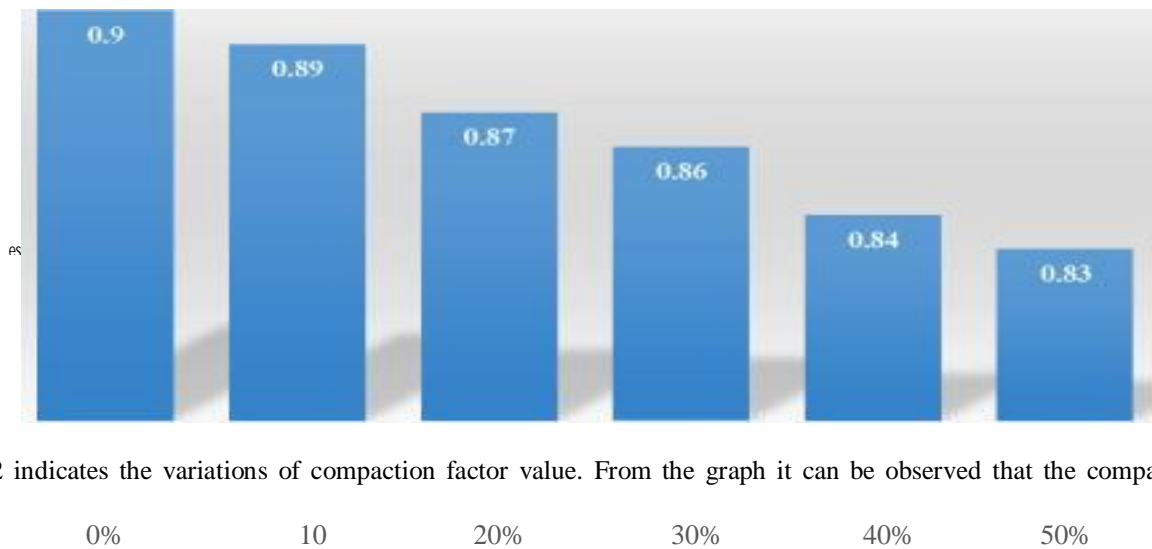
% of replacement of Fine Aggregate by Bottom ash Fig.1: Variation of Slump

The Fig.1 indicates the variations of slump value. From the graph it can be observed that the slump is gradually decreasing with increase of bottom ash content and the maximum slump is obtained for 0% BA + 100% F.A.

Compaction Factor Test

% of replacement of Fine aggregate by Bottom ash Graph No.

Fig.2: Variation of Compaction Factor



The Fig.2 indicates the variations of compaction factor value. From the graph it can be observed that the compaction factor is

gradually decreasing with increase of bottom ash content and the maximum compaction factor is obtained for 0% BA + 100% F.A.

Vee Bee Test



Fig.3: Variation of Vee bee

% of replacement of Fine Aggregate by Bottom ash

The Fig.3 indicates the variations of vee bee time. From the graph it can be observed that the compaction factor is gradually increasing with increase of bottom ash content and the maximum compaction factor is obtained for 50% BA + 50% F.A.

Table V

Overall results of Compressive Strength Test for 7 days and 28 days curing period.

% Replacement of Bottom ash	7 days		28 days	
	Compressive Strength (N/mm ²)	% increase or decrease in Compressive strength compared to Nominal Mix	Compressive Strength (N/mm ²)	% increase or decrease in Compressive strength compared to Nominal Mix
0% (Nominal Mix)	24.5	0	37.2	0
10%	27.65	14.02	42.8	15.05
20%	26.5	9.27	40.6	9.13
30%	24.55	1.23	38.0	2.15
40%	22.33	-8.32	34.0	-8.60
50%	18.5	-23.7	28.3	-23.92

Compressive Strength at 7 and 28 days

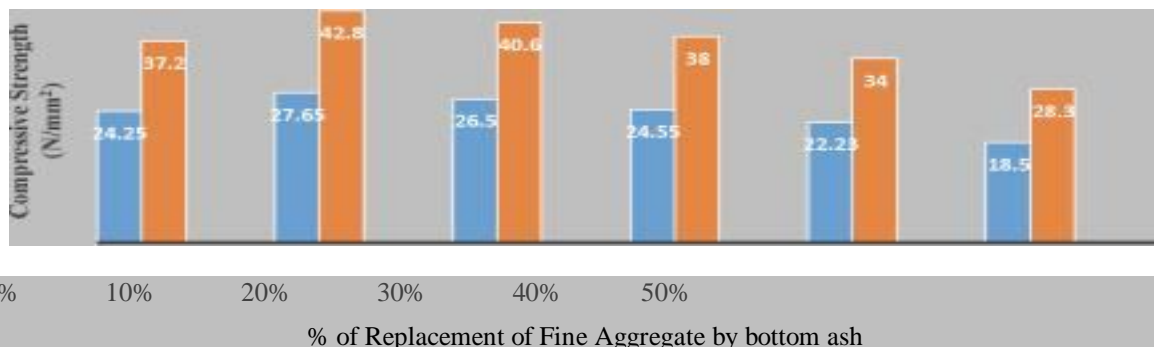


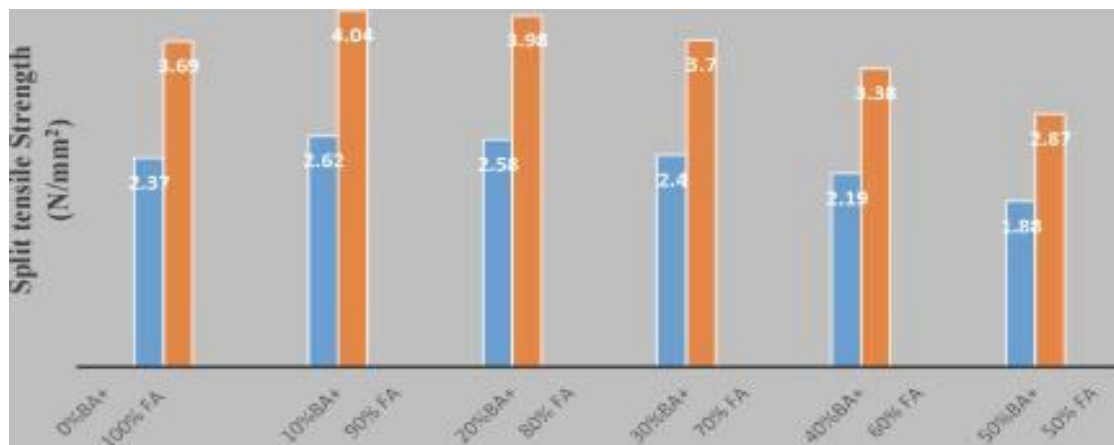
Fig 4. Overall Compressive Strength of Cubes of curing period 7 and 28 days

Table VI

Overall results of Split Tensile Strength for 7 and 28 days curing period

% Replacement of Bottom ash	7 days		28 days	
	Split tensile Strength (N/mm ²)	% increase or decrease in Split tensile strength compared to Nominal Mix	Split tensile Strength (N/mm ²)	% increase or decrease in Split tensile strength compared to Nominal Mix
0% (Nominal Mix)	2.37	0	3.69	0
10%	2.62	10.5	4.04	9.4
20%	2.58	8.86	3.98	7.85
30%	2.40	1.26	3.70	0.25
40%	2.19	-7.59	3.38	-8.4
50%	1.88	-20.6	2.87	-22.2

Split tensile strength at 7 and 28 days



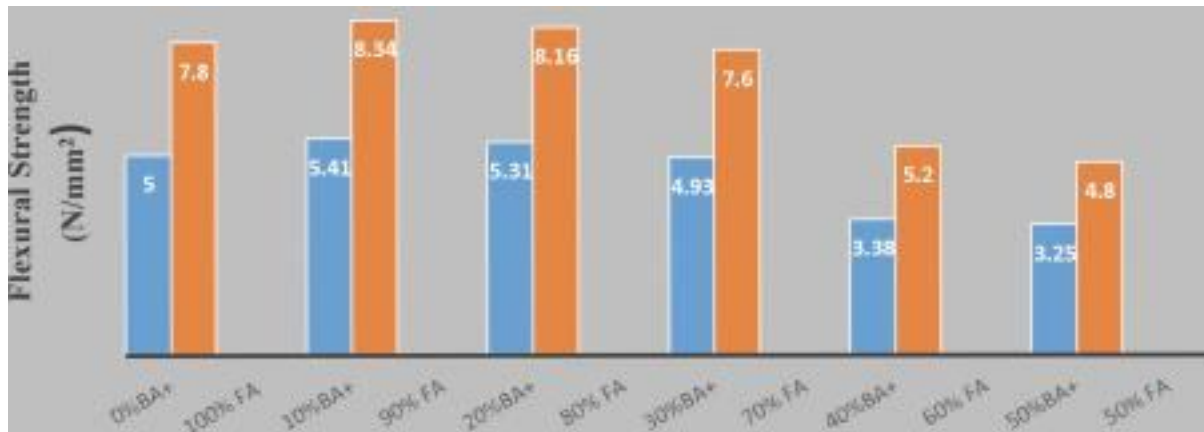
% of Replacement of Fine Aggregate by bottom ash

Fig.5: Overall Split Tensile Strength of Cylinders of curing period 7 and 28days

Table No. VII: Overall results of Flexural Strength test for 7 and 28 days curing period

%Replacement of Bottom ash	7 days		28 days	
	Flexural Strength (N/mm ²)	% increase or decrease in Flexural strength compared to Nominal Mix	Flexural Strength (N/mm ²)	% increase or decrease in Flexural strength compared to Nominal Mix
0% (Nominal Mix)	5.0	0	7.8	0
10%	5.41	8.2	8.34	6.92
20%	5.31	6.2	8.16	4.61
30%	4.93	-1.4	7.6	-2.56
40%	3.38	-32.4	5.2	-33.3
50%	3.25	-35	4.8	-38.5

Flexural Strength at 7 and 28 days



% of Replacement of Fine Aggregate by bottom ash

Fig.6: Overall Flexural Strength of beams of curing period 7 and 28 days

III. CONCLUSION

The workability of fresh concrete with slump cone test is gradually increasing with increase of bottom ash content in concrete and the maximum slump is obtained for 0% Bottom ash+ 100% Fine aggregate and compaction factor is gradually decreasing with increase of bottom ash content in concrete and the maximum compaction is obtained for 0% BA + 100 % F.A. The specimens with bottom ash as replacement with fine aggregate was found to be better in compression which has compressive strength of 14.02% and 15.05% more than that of nominal mix concrete after 7 days and 28 days curing period respectively for 10% Bottom ash + 90% Fine aggregate. Better split tensile strength was achieved with the replacement to fine aggregate with Bottom ash in concrete. The split tensile strength was increased up to 10.5% and 9.4% when compared to that of the nominal mix concrete after 7 days and 28 days curing period respectively for 10% Bottom ash + 90% Fine aggregate. Good flexural strength was achieved with the replacement to fine aggregate with bottom ash in concrete. The flexural strength was increased up to 6.92% and 8.2% when compared to that of the nominal mix concrete after 7 days and 28 days curing period respectively for 10% Bottom ash + 90% Fine aggregate. Considering the all above points it is concluded that the optimum utilization of Bottom ash is 10% in concrete as replacement to the fine aggregate to obtain a considerable design mix.

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