A STUDY ON M30 GRADE CONCRETE USING BOTTOM ASH AS PARTIAL REPLACEMENT FOR FINE AGGREGATE

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ABSTRACT: Concrete is a material synonymous with strength and it has emerged as the dominant construction materials 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. 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. Bottom ash is the residue or non-combustible substance formed after the combustion of lignite or coal in the furnace is removed as slag from the bottom of the furnace.. The fly ash produced is used as pozzolanic material in cement, fly ash bricks etc. nevertheless the bottom ash is being merely deposited in piles which is becoming hazardous to the environment. Sand is major constituent of concrete is diminishing in its quantity around the world, which creates a need for finding an alternative. Bottom ash has particle size similar to sand. Hence this can be used as a replacement for fine aggregate in concrete.
Keywords : Cement, fine aggregate , coarse aggregate, water, bottom ash.

I. INTRODUCTION

Energy is the main backbone of modern civilization of the world over, and the electric power from thermal power stations is a dominant source of energy, in the order of electricity. In India, over 70% of electricity generated is by combustion of fossil fuels, out of which approximately 61% is contrived by coal-fired plants. This results in the origination of around 100 ton of ash. Most of the ash has to be disposed of either dry, or wet to an open area serviceable near the plant or by grounding both the fly ash and bottom ash and mixing it with suitable amount of water and pumping into artificial lagoon or dumping yards. This brings out the pollution in water bodies and ruin of productive land. The untiring slackening of natural resources and the environmental imperils posed by the disposal of coal ash has approached appalling proportion such that the use of coal ash in manufacturing of concrete is imperative than a desire. Bottom ash is the coarser material, which drops into the bottom of the furnace in latest large thermal power plants and constitute about 20% of gross ash content of the coal fed in the boilers. It consists of non-combustible materials, and is the residual part from the incineration of household and similar waste. Raw bottom ash is a granular material that consists of a mix of inert materials such as sand, stone, glass, porcelain, metals and ash from burnt materials. The utilization of coal ash in normal strength concrete is a new scope in concrete mix design and if put to use on large scale would ameliorate the construction industry, by minimizing the construction cost and abating the ash content. Bottom ash is the residue or non-combustible substance formed after the combustion of lignite or coal in the furnace is removed as slag from the bottom of the furnace.. The fly ash produced is used as pozzolanic material in cement, fly ash bricks etc. nevertheless the bottom ash is being merely deposited in piles which is becoming hazardous to the environment. Sand is major constituent of concrete is diminishing in its quantity around the world, which creates a need for finding an alternative. Bottom ash has particle size similar to sand. Hence this can be used as a replacement for fine aggregate in concrete.

LITERATURE REVIEW

Aggarwal et al.(2007) studied various strength properties for various percentages of replacement of sand with bottom ash, results indicated that workability of concrete decreased with the increase in bottom ash content. Abdul hameed Umar Abubakar et al. (2012) found that the workability of the concrete in fresh state decreased as the percentage of Coal Bottom Ash increases. RemyaRaju et al.(2014) observed workability, flexural strength and modulus of elasticity were decreased and compressive strength and split tensile strength was increased. K.N. Virendra Kumar et al.(2015) indicated a decrease in workability by surrogating bottom ash content. Andrade et al. (2009)found that the presence of bottom ash as sand replacement in concrete increased the quantity of water loss by bleeding, the bleeding time and also the water release rate. Higher the bottom ash contents in the concrete the greater this effect. The total loss of water for 25% and 50%bottom ash content concrete mixes were very close to the control mix but in case of concrete mixes containing 75% and 100% bottom ash there was remarkable increase in loss of water. Ghafoori and Bucholc (1996)observed that the bottom ash concrete mixtures exhibited greater dimensional stability than the control mixture. This may be due to increased water requirement for achieving the similar consistency. Higher bleeding displayed by bottom ash concrete resulted in an average shrinkage of 35% below than that of control concrete. With a low dosage of admixture, average early shrinkage of bottom ash mixtures remained approximately the same as that of control concrete.

II. EXPERIMENTAL PROGRAM

2.1 Materials Used

In this thesis work various materials like Cement, Fine Aggregate ,Coarse Aggregate, water and bottom ash were used and their properties are examined by taking the help of IS [INDIAN STANDARD] codes .

2.1.1 Cement

Ordinary Portland cement of 53 Grade was preferred for this study. The physical properties of cementare categorized in table 1 as per IS:12269-1987.

Table 1 Properties of Ordinary Portland cement

S.No.	Particulars of test	Test Results
1	Standard Consistency	32%
2	Initial setting time (min)	60
3	Final setting time (min)	250
4	Specific gravity	3.12
5	Fineness (weight of cement retained on IS 90 μ sieve)	2 %

2.1.2 Fine aggregate:

Natural sand conforming to zone 3 with specific gravity 2.59 and fineness modulus of 2.49 was used. The testing of sand was done as per Indian standard specifications IS 383-1970. The sieve analysis results are shown in

Table 2 Sieve analysis of fine aggregate

S.NO	Sieve	Weight retained	Cumulative weight retained	Cumulative % weight retained	% passing
1	10mm	0	0	0	10
2	4.75mm	25	25	25	97.5
3	2.36mm	35	60	6.0	94.0
4	1.18mm	136	196	19.6	80.4
5	600micron	220	416	41.6	58.4
6	300micron	385	801	80.1	19.9
7	150micron	197	998	99.8	0.2

Fineness modulus of fine aggregate =249.6/100=2.49

2.1.3 Coarse aggregate:

Coarse aggregate was used with 20 mm nominal size and specific gravity 2.67, and fineness modulus 6.9 and were tested as per Indian standard specifications IS: 383-1970. The sieve analysis results are shown in Table.

Table 3 Sieve analysis for coarse aggregate

S.No.	Sieve size (mm)	Weight retained (gm)	% Weight retained	Cumulative % retained	% passing
1	80 mm	0	0	0	0
2	40 mm	0	0	0	0
3	20 mm	1700	34	34	66
4	10 mm	3300	66	100	-
5	4.75 mm	0	0	100	-
6	2.36 mm	0	0	100	-
7	1.18 mm	0	0	100	-
8	600 μ	0	0	100	-
9	300 μ	0	0	100	-
10	150 μ	0	0	100	-

Fineness modulus of coarse aggregate=734/100=7.34

2.1.4 BOTTOM ASH: Bottom ash obtained from thermal power plant at NTPC Visakhapatnam was used in the investigation. The specific gravity of bottom ash was 2.564.

Table 4: Sieve analysis of bottom ash

S.No.	Sieve size	Weight retained grams	Cumulative weight retained	% cumulative weight retained	% passing
1	10 mm	0	0	0	100
2	4.75 mm	0	0	0	100
3	2.36 mm	10	10	1 %	99
4	1.18 mm	5	15	1.5 %	98.5
5	600 micron	0	15	1.5 %	98.5
6	300 micron	65	80	8.0 %	92
7	150 micron	910	990	99 %	1

Fineness modulus of bottom ash =111/100=1.11

2.2 CONCRETE MIX PROPORTION:

The mix design has carried out by following the specifications and limitations of Indian Standard Code IS 10262-1982.

Table 5: Material requirement for cubic meter of concrete for various percentages of Bottom ash(B.A)

	Mix with 0 % bottom ash	Mix with 5% bottom ash	Mix with 10 % bottom ash	Mix with 15 % bottom ash	Mix with 20 % bottom ash	Mix with 25 % bottom ash	Mix with 30 % bottom ash
Cement kg/m^3	370.0	370.0	370.0	370.0	370.0	370.0	370.0
Bottom ash kg/m^3	0.0	34.3	68.6	103.0	137.3	171.6	205.9
Sand kg/m^3	686.4	652.1	617.8	583.4	549.1	514.8	480.5
20 mm HBG kg/ m^3	837.0	837.0	837.0	837.0	837.0	837.0	837.0
10 mm HBG kg/ m^3	417.0	417.0	417.0	417.0	417.0	417.0	417.0
Water litres	177.6	177.6	177.6	177.6	177.6	177.6	177.6
Total weight kg/ m^3	2488	2488	2488	2488	2488	2488	2488

III. RESULTS AND DISCUSSIONS

3.1 WORKABILITY:

The workability measured in terms of compaction factor and slump, decreases with the increase of the replacement level of the fine aggregates with the bottom ash as given in Table 5. Thus, increase in the specified surface due to increased fineness and a greater amount of water needed for the mix ingredients to get closer packing, results in decreased in workability of mix.

3.1 CUBE COMPRESSIVE STRENGTH: Compressive strength of concrete mixes made with and without bottom ash was determined at 3,7 and 28 days. The test results are gives in Table 8. The bottom ash concrete gains strength at a slower rate in the initial period and acquires strength at faster rate.

Table 6Compressive Strengths of Cubes in N/mm^2

Sample Bottom ash @	0%	5%	10%	15%	20%	25%	30%
Cubes 3 days							
1	31.56	33.78	34.67	31.11	36.44	36.44	37.33
2	32.00	33.11	34.00	33.50	33.33	35.56	39.11
3	33.78	32.44	32.56	39.78	35.56	34.22	37.33
Avg	32.45	33.11	33.74	34.79	35.11	35.40	37.92
Cubes 7 days							
1	35.56	36.44	34.67	37.33	36.44	38.67	39.11
2	35.44	35.56	36.44	35.56	37.33	39.11	40.00
3	34.67	36.44	37.33	36.44	37.33	38.22	41.78
Avg	35.56	36.15	36.15	36.44	37.03	38.66	40.30
Cubes 28 days							
1	38.70	38.67	42.22	40.44	46.22	49.78	56.00
2	39.30	42.22	43.11	42.22	38.22	38.22	50.22
3	39.00	37.78	40.44	43.56	45.78	48.88	47.11
Avg	39.00	39.56	41.92	42.07	43.40	45.63	51.11

Table 6.1 Compression behavior of bottom ash concrete with age(cubes)

Mix type Bottom ash @	Compressive strength N/mm^2		
	3 days	7 days	28 days
0.0%	32.45	35.56	39.00
5%	33.11	36.15	39.56
10%	33.74	36.15	41.92
15%	34.79	36.44	42.07
20%	35.11	37.03	43.40
25%	35.40	38.66	45.63
30%	37.92	40.30	51.11

Table 6.2 Compressive behavior of bottom ash concrete v/s plain concrete

Bottom ash %	Compressive strength as % of 28 days compressive strength of concrete with 0 % bottom ash ,		
	3 days	7 days	28 days
0 %	63.49	69.58	76.30
5%	64.78	70.72	82.02
10%	66.01	70.73	84.91
15%	68.07	71.30	82.31
20%	68.69	72.45	82.02
25%	69.26	75.64	77.40
30%	74.19	78.84	76.30

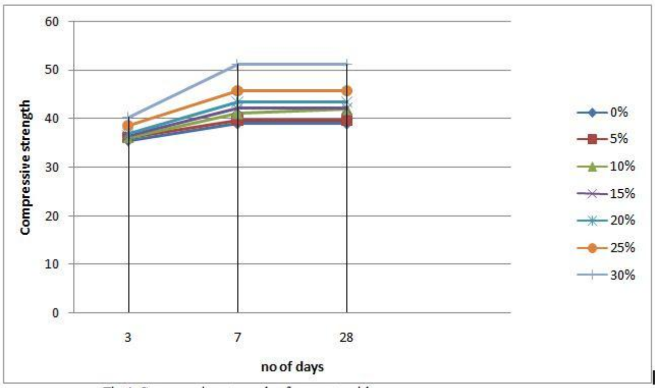

Fig.1 Compressive strength of concrete with age

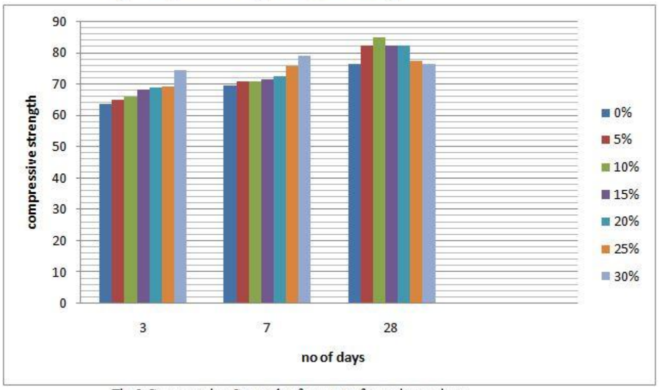

Fig.2 Compressive Strength of concrete for various mixes

3.2 SPLIT TENSILE STRENGTH :The results of splitting tensile strength of concrete mixes with and without bottom ash measured at3,7and 28 days are given in table 10 and shown in figure 7, 8. Figure 7 shows the variations of splitting tensile strength with age for different bottom ash percentages. It is observed from the table that the splitting tensile strength of concrete decreases with the increase in the percentage of fine aggregate replacement with the bottom ash, but the splitting tensile strength increase with the age of curing. The rate of increase of splitting tensile strength decrease with the age.

Table 7 :SPLITING TENSILE STRENGTH OF CYLINDERS in N/mm^2

Bottom ash @	0%	5%	10%	15%	20%	25%	30%
3 days							
1	2.83	2.69	3.39	2.55	2.55	3.11	3.54
2	2.90	2.83	2.55	2.83	2.83	2.83	2.83
3	2.69	2.97	2.61	3.67	3.67	3.67	3.95
Avg	2.80	2.83	2.85	3.01	3.01	3.20	3.44
7 days							
1	2.62	2.83	2.62	3.39	3.11	4.31	4.73
2	2.55	3.46	3.11	3.11	3.39	3.11	3.96
3	3.11	2.55	3.18	2.83	3.25	2.68	3.54
Avg	2.76	2.94	2.97	3.11	3.25	3.36	4.07
28 days							
1	4.10	3.11	3.25	3.39	3.26	4.10	4.10
2	3.25	2.97	3.11	3.12	3.55	3.04	3.25
3	3.96	3.25	2.97	3.25	3.55	3.96	3.96
Avg	3.77	3.11	3.11	3.25	3.45	3.70	3.77

Table 7.1Splitting behavior of bottom ash concrete with age(cylinders)

% Bottom ash	Splitting tensile strength N/mm^2		
	3 days	7 days	28 days
0.0%	2.83	2.76	3.77
5%	3.01	2.94	3.70
10%	3.20	2.97	3.11
15%	3.44	3.11	3.25
20%	3.56	3.25	3.45
25%	3.58	3.36	3.70
30%	3.77	3.81	4.07

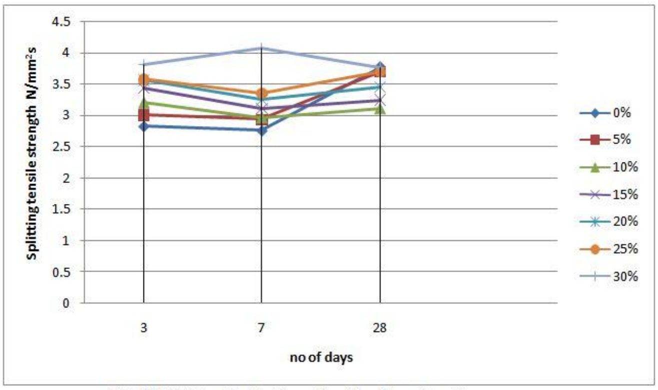

Fig.24 Splitting Tensile Strength of the Concrete with age

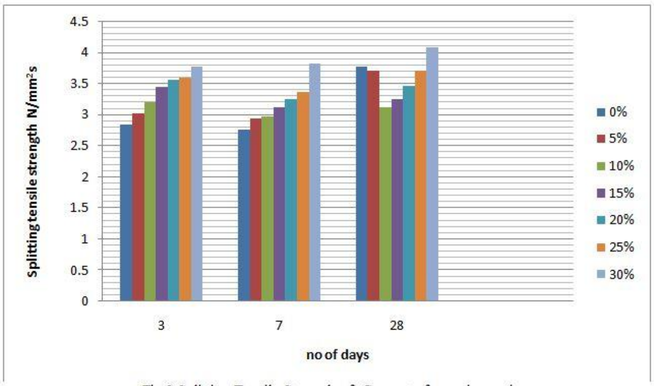

Fig 2 Splitting Tensile Strength of Concrete for various mixes

3.3 FLEXURAL STRENGTH: The flexural strength test result of bottom ash concrete are given in Table 9 and shown in Fig.5 and 6, respectively. Figure 5 shows the flexural strength development with age, and figure 6 shows the variation of flexural strength for various percentage of bottom ash. The bottom ash concrete gains flexural strength with the age that is comparable but less than that plain concrete. It is believed to be due to poor interlocking between the aggregates, as bottom aparticles are spherical in nature.

Table 8 Flexural Strengths of Beams in N/mm^2

Bottom ash @	0%	5%	10%	15%	20%	25%	30%
3 days							
1	7.75	8.63	9.52	8.93	9.12	7.95	10.59
2	8.93	8.04	7.95	8.63	9.42	9.52	10.50
3	8.24	9.12	8.83	8.63	8.44	10.20	9.90
Avg:-	8.31	8.59	8.77	8.80	8.99	9.22	10.33
7 days							
1	7.46	7.75	7.85	7.95	8.73	9.42	7.85
2	7.75	7.85	9.32	9.03	8.44	9.12	11.38
3	7.75	7.46	8.24	8.57	8.53	10.3	10.79
Avg	7.65	7.69	8.47	8.57	8.57	9.48	10.00
28 days							
1	7.96	9.00	8.14	9.03	10.10	8.92	9.51
2	7.73	8.36	9.12	8.83	8.73	9.81	9.52
3	7.80	7.84	8.24	8.34	7.85	8.63	9.03
Avg	7.83	8.40	8.50	8.73	8.89	9.12	9.35

Table 8.1 Flexural behavior of bottom ash concrete with age(beams)

% Bottom ash	Flexure Strength (f_c) N/mm^2		
	3 days	7 days	28 days
0.0%	8.31	7.65	7.83
5%	8.59	7.69	8.40
10%	8.77	8.47	8.50
15%	8.80	8.57	8.73
20%	8.99	8.57	8.89
25%	9.22	9.48	9.12
30%	9.31	9.35	10.33

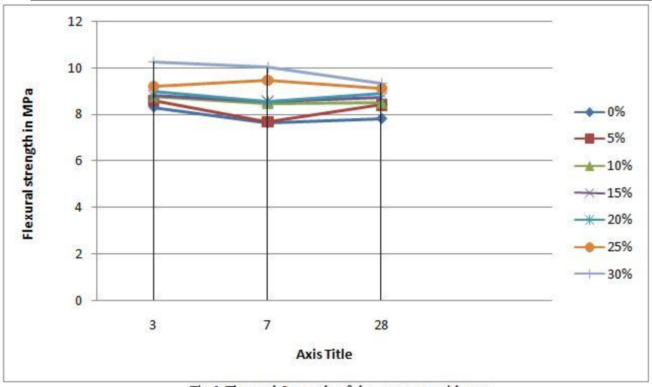

Fig.3 Flexural Strength of the concrete with age

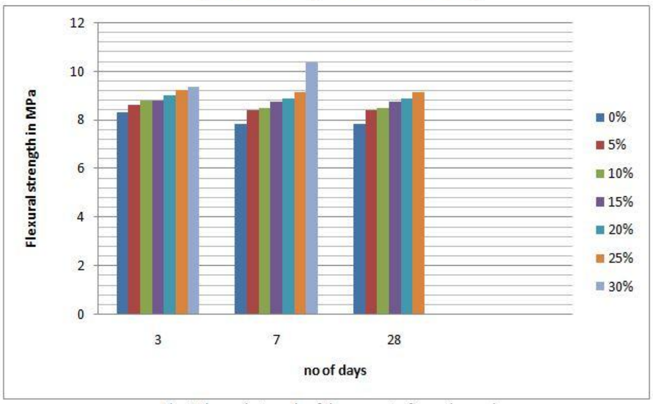

Fig.4 Flexural strength of the concrete for various mixes

IV. CONCLUSIONS

- The compaction factor of bottom ash concrete decreased with the increase in the percentage of bottom ash.
- Compressive strength, splitting tensile strength and flexural strength of bottom ash concrete specimens were lower than those of control concrete specimens at all the ages. The strength difference between bottom ash concrete specimens and control concrete specimens become less distinct after 28 days.
- The compressive strength of bottom ash concrete achieved the 28 days target strength for all the percentages of bottom ash replacements of 5--30% .
- The flexural strength of bottom ash concrete achieved theoretical flexural strength equal to 0.7√ f_{ck} for all the percentages of bottom ash replacements of 5--30% .
- The splitting tensile strength of bottom ash concrete is in the range of 7--8% of its corresponding compressive strength.
- Strength development is less for bottom ash concrete that can be equated to lower grade of normal concrete and the waste material bottom ash may be use in concrete enables the large utilization

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