Replacement of Fine Aggregate with Bottom Ash in Concrete and Investigation on Compressive Strength

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Abstract - **Coal bottom ash is a coarse granular and incombustible byproduct from coal burning furnaces. The appearance and particle size distribution of coal bottom ash is similar to that of river sand and makes it attractive to be used as fine aggregate in the production of concrete. The other advantage of using bottom-ash is that it can be dust free, the sizes of bottom-ash can be controlled easily so that it meets the required grading for the given construction. Bottom ash also exhibits a relatively high permeability and grain size distribution that allows the design engineer to use it in direct contact with impervious material. Bottom ash is used as concrete aggregate or for several other civil engineering applications where sand, gravel and crushed stone are used. In the present work M_{20}, M_{25} and M_{30} grade of concrete is considered for the experimental investigation. Fine aggregate is fully replaced with 100% percentage of bottom ash. Comparative result of workability and compressive strength of conventional concrete cube and bottom ash added concrete cube are reported. From the results it is concluded that bottom-ash can be used as a replacement for fine aggregate. The results proved that the replacement of 100% of fine aggregate by bottom-ash achieved higher compressive strength. Thus the environmental effects due to illegal extraction of sand and cost of conventional fine aggregate can be significantly reduced.**

Key Words: bottom ash, fine aggregate, replacement, concrete

1. INTRODUCTION

Coal-based thermal power plants all over the world face serious problems in the handling and disposal of the ash produced. The utilization of fly ash is about 30% in various engineering requirements that is for low technical applications such as in construction of fills and embankments, backfills, pavement base and sub base course. 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. Bottom ash based artificial lightweight aggregate offer potential for large scale utilization in the construction work. The other advantage of using bottom-ash is that it can be dust free, the sizes of bottom-ash can be controlled easily so that it meets the required grading**.**

Mohd Syahrul Hisyam bin Mohd Sani et al. [1] studied the compressive strength of concrete mixes made with various % of Washed Bottom Ash as fine aggregate replacement. The compressive strength of control sample (fully natural sand) was determined at 3, 7, 28, and 60 days of curing. It was seen that the compressive strength of concrete mixes of sand replacement is much lower than control sample at all tested days. According to M. Purushothaman et al. [2] Bottom Ash added Concrete mixes showed enhanced compressive strength than the conventional concrete and showed uniformly higher compressive strengths at almost all ages. The ample gain in strength is thought to be due to very high pozzolanic reactivity of the two mineral admixtures silica fume and bottom ash. P. Tang et al. [3] studied the compressive and flexural strength of concrete drain with the augmentation of the bottom ash fines at the identical curing age, particularly after 3 and 7 days. M.P. Kadam et al. [4] carried out Compressive strength tests of concrete mix made with and without coal bottom ash of cubes size 1.5 cm × 1.5 cm × 1.5 cm and the results were determined at 7, 28, 56, and 112 days. It was observed that for 10 % and 20 % sand replacement the compressive strength was increased by 4.6 %, 3.99 %, 0.61%, 0.20 % for 7, 28, 56 and 112 days respectively as compared with controlled concrete. The compressive strength was decreased from 30% to 100 % replacement 2.07 % to 22.30%, 4.97 % to 33.66 %, 1.23 % to 38.99%, and 0.78 % to 36.83 % for 7, 28, 56 and 112 days respectively as compared with controlled concrete. The study of K. Soman et al. [5] shows that 30% replacement of sand with bottom ash has given a 28 day compressive strength of 38.43 kN/m^2 (target mean strength is $38.25 kN/m^2$). The result showed that bottom ash can be used to substitute sand and the ideal replacement level was 30%. Remya Raju et al. [6] observed that Compressive strength reduced marginally on the inclusion of bottom ash in concrete.

2. MATERIALS

Bottom ash which is a by-product of burning coal at thermal power plants has particles much coarser than the fly ash. It is a coarse, angular material of porous surface texture predominantly sand-sized. This material is composed of silica, alumina, and iron with small amounts of calcium, magnesium, and sulfate. Grain size typically ranges from fine sand to gravel in size. Chemical composition of bottom ash is similar to the fly ash but typically contains greater quantity of carbon. Bottom ash

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also exhibits a relatively high permeability and grain size distribution that allows the design engineer to use it in direct contact with impervious material. Bottom ash is used as concrete aggregate or for several other civil engineering applications where sand, gravel and crushed stone are used. The chemical and chemical composition of bottom ash are shown in Table-1 and Table -2 respectively

Table- 1: The chemical composition of bottom ash

Content (%)	Cement	Bottom ash
SiO_2	20.5	57.03
Al_2O_3	4.0	22.86
Fe_2O_3	4.02	7.05
K_2O	0.8	0.3
CaO	64.0	1.03
TiO_2	-	0.17
SO_3	1.8	6.15
MgO	1.2	0.85
Na_2O	-	4.29

Table- 2: Physical properties of bottom ash

Properties of Bottom ash	Values
Specific gravity	2.30
Bulk density(gm/cc)	0.642-0.747
Maximum dry density (KN/m^3)	7.20
Water absorption (%)	14.10
Aggregate impact value (%)	18.25
Aggregate crushing strength (%)	19.30
Aggregate abrasion value (%)	30.12

Ordinary Portland cement of 43 Grade and having specific gravity 3.03 was used for the experimental work. The bulk density of Bottom-ash was 1.75 kg/m3, specific gravity and fineness modulus was found to be 2.73 and 4.66, respectively.

Table-3: Sieve analysis of bottom-ash

Sieve size	Materials retained on each sieve in	Cumulative mass in grams	Cumulative % mass retained	% passing	Requirements as per IS 383-1970 % passing
4.75mm	194	19.4	19.4	92.2	90 – 100
2.36mm	101	10.1	29.5	88.3	85 -100
1.18mm	292	29.2	58.7	76.3	75 – 100
600µ	178	17.8	76.5	66.6	60 -79
300µ	109	10.9	87.4	13.0	12 – 40
150µ	18	1.8	89.2	2.5	0 – 10
Pan	108	10.8	100	0	0

Table-3: Sieve analysis of natural sand

Sieve size	Materials retained on each sieve in grams	Cumulative mass in grams	Cumulative % mass retained	% passing	Requirements as per IS 383-1970 % passing
4.75mm	19	19	1.9	98.1	90 – 100
2.36mm	17	36	3.6	96.4	85 -100
1.18mm	140	176	17.6	82.4	75 – 100
600µ	158	334	33.4	66.6	60 -79
300µ	506	840	84.0	16.0	12 – 40
150µ	144	985	98.5	1.5	0 – 10
Pan	15	1000	100	0	0

The percentage of particles passing through various sieve were compared with natural sand and it was found to be similar (refer Table-3 and Table-4). Crushed angular aggregate with maximum grain size of 20 mm and downgraded having bulk density 1.38 kg/m^3, specific gravity 2.82 and fineness modulus 8 was used

3. EXPERIMENTAL STUDIES

In the present work M_{25}, $M_{20,}$ M_{30} grade of concrete is considered for the experimental investigation. Fine aggregate fully replaced with 100% percentage of bottom ash (refer Figure-1 and Figure-2). Comparative result of workability and compressive strength of conventional concrete cube and bottom ash added concrete cube are reported.

Constant parameters:
Grade of concrete: M_{25}, $M_{20,}$ M_{30}
Size of specimen: 150mm×150mm×150mm

Variable parameters:
Bottom ash: fine aggregate is replaced with bottom ash in different grade of concrete.
Curing period: 7days, 14days, 28days and 56 days

Figure-1: Bottom-ash

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Figure- 2: Bottom-ash of different grading

3.1 COMPRESSIVE STRENGTH

The specimen of standard cube of (150 mm x150 mm x 150 mm) was used to determine the compressive strength of concrete. Three specimens were tested for 7, 14, 28 and 56 days with varying proportion of bottom-ash replacement. The constituents were weighed and the materials were mixed in a mixer. The mixes were compacted with the help of tamping rod. The specimens were de-molded after 24h, cured in water for 7, 14, 28 and 56 days and then tested for its compressive strength as per Indian Standards. The compressive strength test on cubes in the CTM machine is conducted as shown in Figure-3

3.2 RESULTS AND DISCUSSIONS

Table-4: Compressive Strength for M20 grade

Age	0% Bottom-ash (N/mm^2)	100% Bottom-ash (N/mm^2)	% Strength variation
7 days	14	18	28.57
14 days	16	21	31.25
28 days	20	22	10.00
56days	24	26	8.33

Table-5: Compressive Strength for M25 grade

Age	0% Bottom-ash (N/mm^2)	100% Bottom-ash (N/mm^2)	% Strength variation
7 days	17	20	17.65
14 days	21	23	9.52
28 days	24	26	8.33
56days	27	30	11.11

Table-6: Compressive Strength for M30 grade

Age	0% Bottom-ash (N/mm^2)	100% Bottom-ash (N/mm^2)	% Strength variation
7 days	20	23	15.0
14 days	24	28	16.67
28 days	31	33	6.45
56days	37	37	0.0

From the results obtained it can be seen there is not more than 28.57% increase in the compressive strength in 100% fine aggregate replaced concrete in case of M20 grade concrete at 7days.Similarly it can be observed that in no case the strength of bottom ash concrete cubes has fallen below the control sample (0% ash concrete cubes).In case of strength attainment over the age of 56days in case of bottom ash concrete cubes, it is lower than that of 0% bottom ash concrete cubes. In case of M30 it can be seen that the strength attained at the age of 56days by both type of cubes is same. Even the early strength of concrete with 100% ash concrete cubes i.e at 7days is between 40% to 55% and is better than that of no bottom ash concrete (15% to 40%)

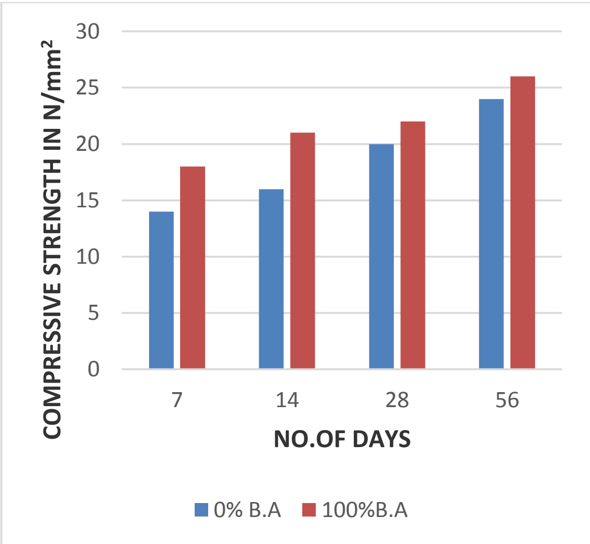

Chart-1: Comparison of compressive strength M20 concrete

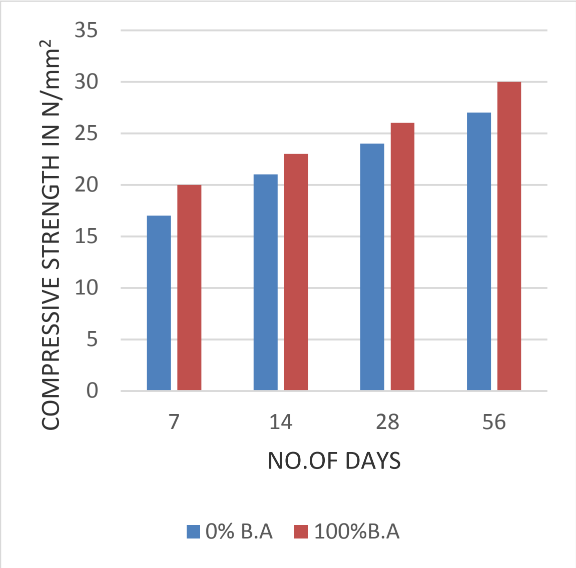

Chart-2: Comparison of compressive strength M25 concrete

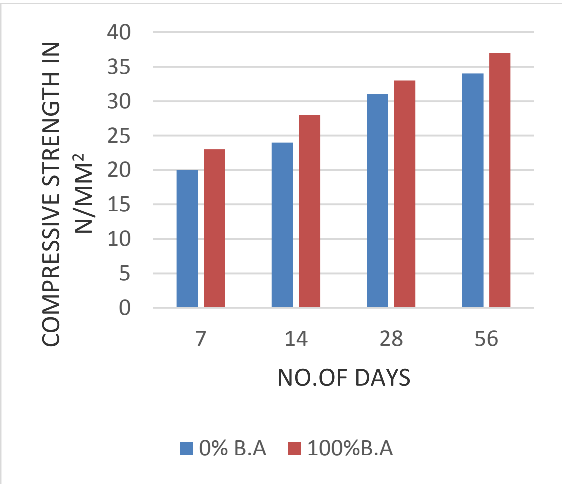

Chart-3: Comparison of compressive strength M30 concrete

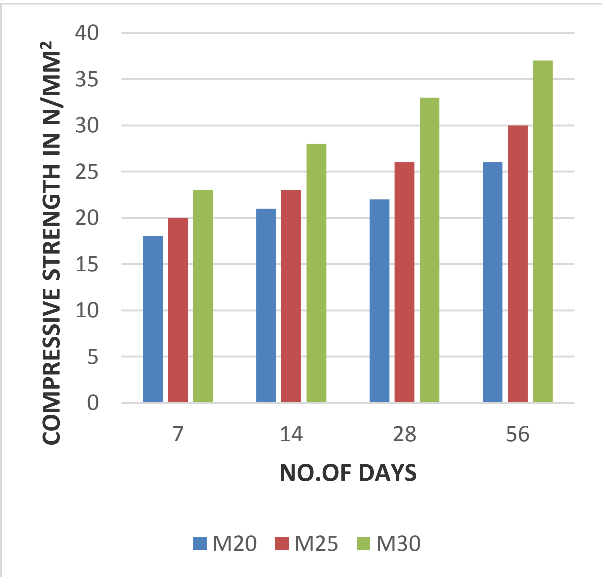

Chart-3: Comparison of compressive strength M20,M25 and M30 concrete

CONCLUSIONS

From the results it is concluded that the Bottom Ash can be used as a replacement for fine aggregate. The results prove that the replacement of 100% of fine aggregate by Bottom Ash induced higher compressive strength. Thus the environmental effects, illegal extraction of sand and cost of fine aggregate can be significantly reduced. By keeping in mind the acute shortage of river sand, heavy short coming on quality of river sand, high cost, greater impact on road damages and environmental effects. Thus the construction industry shall start using the bottom-ash to full extent as an alternative and reduce the impacts on environment by not using river sand.

REFERENCES

[1] Mohd Syahrul Hisyam bin Mohd Sani, Fadhluhartini bt Muftah and Zulkifli Muda, "The Properties of Special Concrete Using Washed Bottom Ash (WBA) as Partial Sand Replacement", International Journal of Sustainable Construction Engineering & Technology (IJSCET), ISSN: 2180-3242, Volume 1, No. 2, December 2010, pp.65-76

[2] M. Purushothaman and R.M. Senthamarai, "Strength Properties of High Performance Concrete using Bottom Ash as Fine Aggregate", International Journal of Civil Engineering (IJCE), ISSN 2278-9987, Volume 2, Issue 3, July 2013, pp.35-40

[3] P. Tang, Q.L. Yu, R. Yu and H.J.H. Brouwers, "The application of MSWI bottom ash fines in high performance concrete", 1st International Conference on the Chemistry of Construction Materials, Berlin, October 2013, pp.435-438

[4] M.P. Kadam and Y.D. Patil, "Effect of Coal Bottom Ash as Sand Replacement on the properties of Concrete with different W/C ratio", International Journal of Advanced Technology in Civil Engineering, ISSN: 2231-5721, Volume 2, Issue 1, 2013, pp.45-50

[5] K. Soman, Divya Sasi and K.A. Abubaker, "Strength properties of concrete with partial replacement of sand by bottom ash", International Journal of Innovative Research in Advanced Engineering (IJIRAE), ISSN: 2349-2163, Volume 1, Issue 7, August 2014, pp.223-227.

[6] Remya Raju, Mathews M. Paul and K. A. Aboobacker, "Strength Performance of Concrete using Bottom Ash as Fine Aggregate", International Journal of Research in Engineering & Technology (IJRET), ISSN (e): 2321-8843, ISSN (p): 2347-4599, Volume 2, Issue 9, September 2014, pp.111-122.

BIOGRAPHY

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