International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 - 5161

Available at http://inpressco.com/category/ijcet

Research Article

Uses of Bottom ash in the Replacement of fine aggregate for Making Concrete

Dilip Kumar[A*], Ashish Gupta[B] and Sri Ram[A]

[A]Department of Civil Engineering, M.M.M.U.T. Gorakhpur, India
[B]Department of Civil Engineering, B.I.E.T. Jhansi, India

Accepted 05 Nov 2014, Available online 01 Dec2014, **Vol.4, No.6 (Dec 2014)**

Abstract

Many researchers have been carried out in the area of bottom ash utilization in the past. In present study A mix design has been done for M30 Grade of concrete by IS method. Ordinary Portland cement of 43 Grade is selected and prepared by mixing bottom ash with cement and water for making concrete. Which is a waste material of coal firing Thermal power plants (TPPs) and its accumulation near power plant.The bottom ash is obtained from National Thermal Power Plants (NTPC) Anpara in Sonbhadra District in Uttar Pradesh state. In this paper author investigate the Compressive Strength and Flexural strength test of the concrete at different ages i.e. 7 days,14 days,28 days and 56 days. Bottom Ash is replaced 10%, 20%, 30%, 40% and 50% in the place of fine aggregate. These explain the various utilization of Bottom ash and its ordinary Portland cement and properties in concretecauses severe pollution problems. Its utilization as a raw material for cube (Brick) making will be a very usefully solution in our economical and environmental aspects. This paper presents the experimental investigations carried out to study the effect of use of bottom ash as a replacement of fine aggregate.

Keyword: *Bottom ash, Cement, Coarse aggregate, concrete, sands, strengths.*

1. Introduction

India produces approximately more than 100 million tonnes of Coal ash annually. Coal-based thermal power plants all over the world facing serious problems of handling and disposal of the ash produced.The utilization of fly ash is about 30% as various engineering properties requirements that is for low technical applications such as in construction of fills and embankments, backfills, pavement base and sub base course.bottom ash based artificial lightweight aggregate offer potential for large-scale utilisation in the construction work. Apart from using it in concrete industry as cement replacement, fly ash usages by other related industries have been for cube (Bricks) manufacture, cellular concrete, prefabricated items and road construction. Yet about 80% of bottom ash remains unutilised.

The management of coal fly ash produced by coal thermal power station is a major problem in many parts of the word. However, its generation tends to increase every year. Although some coal fly ash is used in a range of applications, particularly as a substitute for cement in concrete. Large amount remain unused and thus required disposal. At present, coal fly ash is used in civil engineering for production of cement, concrete, cube and artificial aggregate. Safe disposal of the ash without adversely affecting the environment and the large storage area required are major concerns.

*Corresponding author **Dilip Kumar**, **Ashish Gupta** are working as Assistant Professors and **Sri Ram** as Associate Professor

Bottom ash is a by-product of burning coal at thermal power plants. Bottom ash particles are 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 contain greater quantity of carbon.

Bottom ash exhibits high shear strength and low compressibility. These engineering properties make bottom ash an ideal material in design construction of dam and for other civil engineering applications. 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 has proved to be an economical material because it has demonstrated to have not only good engineering property but also to have constructability benefits. Bottom ash can be used as concrete aggregate or for several other civil engineering applications where sand, gravel and crushed stone are used.

Government should encourage the use of bottom ash related products so that bottom ash can be used in huge quantities in many civil engineering construction purpose.

2.4 Factor Affecting the Utilization of Coal ash

Some of the factors due to which, utilization of coal ash is not increasing at desired rate are:

- Lack of awareness of coal ash properties.

- High transportation cost.
- Non-availability of dry fly ash and bottom ash.
- Lack of proper co-ordination.
- Easy availability of top soil.
- Variations in the quality of coal ash.

2.5 Application of Bottom ash in major areas

Ash has been investigated for its suitability for utilization in major areas as building material and other civil engineering sectors. The areas mentioned below have tremendous scope of large scale use of Bottom ash.

- Building bricks and block.
- Road construction, Drainage media and Sound insulating walls.
- It is used in mining mortar in such application as rock stabilization or filling of cavities.
- It is used as a construction material for highway and pavement.
- It is used for pressure grouting in concrete highways and for other purposes *viz*, tunnel lining.
- It is used as mineral filler in asphalt roads to minimize void content and increase the stability of bituminous wearing course during road construction.
- It is used as a light weight synthetic aggregate in block and concrete.
- It is used along with bottom ash as a growing media for plants.
- In concrete, bottom ash is used as replacement of fine aggregate in which concrete has advantageous properties like improved workability, resistance to chemical attack.

3. Literature Review on Bottom ash

Jaturapitakkul*et al.* (2003) studied the potential of using bottom ash from the Mae Moh power plant in Thailand as pozzolonic material. He found bottom ash which was used in concrete due to its pozzolonic reaction, improved its quality by grinding until the particle size retained on sieve 325 was less than 5% by weight. Bottom ashes before and after being ground were investigated and compared for their physical and chemical characteristics. The bottom ashes were used to replace Portland cement in mortar and concrete mixtures. He found that the particle of bottom ash was large, porous and a regular shapes. The grinding process reduced the particle size as well as porosity of bottom ash. Compressive strengths of mortar containing 20 to 30% of bottom ash as cement replacement were much less than that of cement mortar at all edges, but use of ground bottom ash produce higher compressive strength than the cement mortar after 60 days. He used bottom ash at 20% replacement of cement to make concrete, the concrete with higher cement content produce higher percentage of compressive strength. He concluded that ground bottom ash could be used Bottom ash as a good pozzolonic material.

Huang *et al.* (**1990**) investigated the shear strength of Indiana bottom ash and boiler slag compacted to different densities using direct shear testing. The reported friction angles varied in a wide range from 35 to 55% depending on the density.

Seals *etal*. (1972) presented data obtained from West Virginia bottom ash. The standard Proctor maximum densities varied between 11.6 and 18.4 kN/m3; the optimum water content ranged from 12 to 34%. They also performed a series of one-dimensional compression tests on West Virginia bottom ash. They showed that, at low stress levels, the compressibility of bottom ash was comparable to natural granular soils placed at the same relative density.

Abernethy *et al*. (1969) investigated the common constituents of more than 600 ash samples from commercial coals in the United States. They found that coal ash was composed primarily of silica (SiO_2), ferric oxide (Fe_2O_3), and alumina (Al_2O_3), with smaller quantities of calcium oxide (CaO), potassium oxide (K_2O), sodium oxide (Na_2O), magnesium oxide (MgO), titanium oxide (TiO_2), phosphorous pent oxide (P_2O_5), and sulfur trioxide (SO_3). In bituminous coal, three major components (SiO_2, Fe_2O_3 and Al_2O_3) accounted for about 90% of the total components, whereas lignite and sub-bituminous coal ashes had relatively high percentages of CaO, MgO, and SO_3.

Cheriaf*etal* (**1999**) reported the morphological characteristics of bottom ash by scanning electron micrograph in terms of the shape and surface characteristics of the particles; bottom ash was quite different from fly ash. Bottom ash particles were angular and irregular in shape and had rough surface. In next page the Fig. no. 2.1 of morphology of bottom ash is shown and has been taken from Brazilian coal ash.

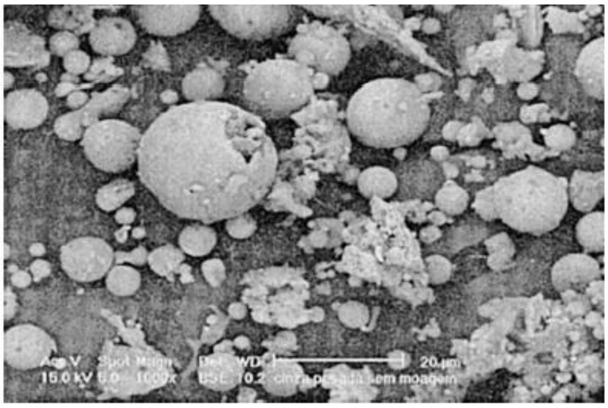

Fig 2.1 Morphology of Bottom Ash

Table 3.4 Chemical characteristics of Anpara bottom ash

Constituents	Percentage (by weight)
SiO_2	68.0
Al_2O_3	25.0
$Fe_2O_3 + Fe_3O_4$	2.18
TiO_2	1.45
CaO	1.66
MgO	0.02
SO_4^{--}	Nil
Loss on ignition	1.69

Data as supplied by Anpara Thermal Power Project Authority.

4. Materials Used

The following materials were used for preparing the test specimens

- Ordinary Portland cement
- Aggregates (Coarse Aggregate)
- Sand (Fine Aggregate)
- Bottom ash

5. Experimental Program

Properties of Material

The materials used in this experiment were Ordinary Portland Cement (OPC), bottom ash as fine aggregate and Potable water was used for mixing and curing.

Cement: Ordinary Portland cement 43 grade in one lot was procured and stored in air light container and it is very fresh cement i.e., used within three month of manufacture .The physical properties of cement are determined as per the IS 8112–1989 and result are physical property was given below:

Table 5.1 Physical Properties of Cement

Sr. No.	Physical Properties	Test results
1.	Consistency	32%
2.	Initial setting time	90 min
3.	Final Setting time	315 min
4.	Specific Gravity	2.15
5.	Water Absorption (%)	0.14
6.	Fineness modulus	6.85

Fine Aggregate (Sand): The Fine aggregate use for casting in clean river sand from Ganga river Varanasi and it was clean and dry. It is of size pass through 1.20 mm sieve. Sand conforming to Zone-III was used as the fine aggregate, as per I.S 383-1970. The properties of the fine aggregates are given in following Table No.2.

Table 5.2 Physical Properties of Fine Aggregates (Sand)

Sr. No.	Physical Property	Test Result
1.	Fineness modulus	2.40
2.	Specific Gravity	2.65
3.	Bulk Density(gm/cc)	1.53-1.58
4.	Water Absorption (%)	0.72

Coarse Aggregates: The coarse aggregate used was broken granite-crushed stone and it was free from clay, weeds, and any other organic matters, they are non-porous. The water absorption capacity is less than 1%. The size of which pass through 26 mm sieve and retained on 19 mm sieve. The properties of the coarse aggregate are given in following Table No.3.

Table 5.3 Physical Properties of Coarse Aggregates

Sr. No.	Physical Property	Test Result
1.	Maximum Size (mm)	20
2.	Fineness modulus	7.10
3.	Specific Gravity	2.64
4.	Bulk Density(gm/cc)	1.42-1.61
5.	Water Absorption (%)	0.15
6.	Aggregate Crushing Value (%)	17.50
7.	Aggregate Impact Value (%)	14.40
8.	Maximum dry density (kN/m^3)	13.70
9.	Aggregate abrasion value (%)	28.10

Bottom Ash: Bottom ash is a hazardous by-product from coal based National thermal power plants.The properties of bottom ash are given in Table No. 4.

Table 5.4 Physical Properties of Bottom ash

Sr. No.	Properties of Bottom ash	Values
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)	3.40-4.75
7.	Aggregate impact value (%)	18.25
8.	Aggregate crushing strength (%)	19.30
9.	Aggregate abrasion value (%)	30.12

6. Results and Discussions

Compressive Strength

Compressive strength of the specimen shall be calculated by dividing the maximum compressive load taken by the specimen by its cross-sectional area. Values of compressive strength at different percentage of replacement at different age are given below.

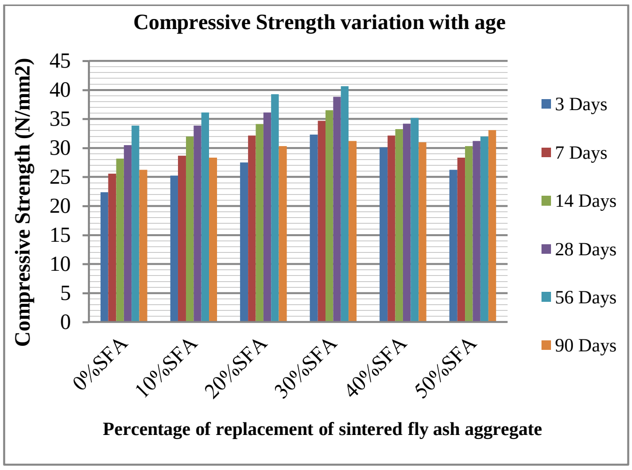

Figure 6.1 Compressive strength at various ages

Table5.5 Compressive Strength of Concrete with Bottom ash

Days	0%BA(N/mm^2)	10% BA (N/mm^2)	20%BA (N/mm^2)	30%BA (N/mm^2)	40%BA (N/mm^2)	50%BA (N/mm^2)
7	23.56	26.67	28.12	31.67	32.14	28.34
14	28.18	30.98	32.14	33.52	34.85	30.42
28	30.40	32.40	33.40	35.17	36.20	32.25
56	32.87	35.28	36.70	38.23	39.16	33.42

Table 5.6 Flexural strength at different ages (N/mm2)

Days	0%BA (N/mm^2)	10%BA(N/ mm^2)	20%BA (N/mm^2)	30%BA (N/mm^2)	40%BA (N/mm^2)	50%BA (N/mm^2)
7	2.20	3.35	5.10	6.80	7.94	4.51
14	3.10	5.11	6.95	8.10	8.80	6.89
28	3.40	6.25	7.66	8.70	9.04	7.40
56	4.27	7.00	8.18	8.98	9.24	7.85

6.2 Flexural Strength

For flexural test beams of 150×150×700 cubic mm size were adopted. The load was applied without shock and was increased until the specimen failed, and the maximum load applied which is on the meter to the prism during the test was recorded. The appearances of the fractured faces of concrete failure were noted. Three-point load method was used to measure the flexural strength of bottom ash aggregate concrete.

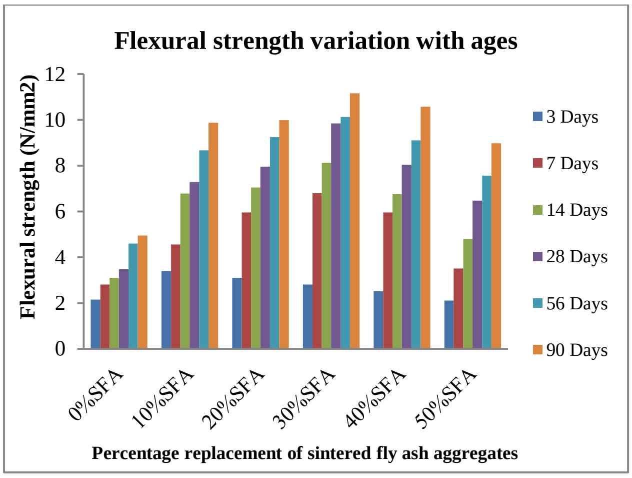

Figure 6.2 Flexural strength at various ages

Conclusion

From above investigation we found that the maximum compressive strength of mix proportion is 32.14 N/mm^2, 34.85 N/mm^2, 36.20 N/mm^{2}and 39.16 N/mm^{2}at 7 days, 14 days, 28 days and 56 days respectively at 40% replacement of bottom ash in concrete while the minimum compressive strength is found 23.56 N/mm^2, 28.18N/mm^2, 30.40 N/mm^2 and 32.87 N/mm^2 is at 7 days, 14 days, 28 days and 56 days respectively when no replacement of bottom ash in concrete. After 40% replacement of bottom ash in the concrete it is found that the compressive strength is decreasing.

The maximum flexural strength of concrete is found 7.94 N/mm^2,8.80 N/mm^2, 9.04 N/mm^{2}and 9.24 N/mm^{2}at 7 days, 14 days, 28 days and 56 days respectively at 40% replacement of bottom ash in concrete while minimum flexural strength of concrete is found 2.20 N/mm^2, 3.10 N/mm^2, 3.40 N/mm^2 and 4.27 N/mm^2 is at 7 days, 14 days, 28 days and 56 days respectively when there is no replacement of bottom ash in concrete. After 40% replacement of bottom ash in the concrete it is found that the flexural strength is decreasing.

To increase the speed of construction, enhance green construction environment we can uselightweight concrete. The possibility exists for the partial replacement of coarse aggregatewith bottom ash aggregate to produce in thermal power plants waste materials. Bottomash is compatible with the cement. Uses and applications of bottom ash as fine aggregate can reduce the cost of construction Materials and it is useful in environmental protection also.

References

Ghafoori, N., and Bucholc, J. (1997).Properties of high-calcium dry bottom ashconcrete. ACI Mater.J., 94(2), pp.90–101.

M.P. Kadam, and Y.D. Patil, Effect of Coal Bottom Ash as Sand Replacement on theProperties of Concrete with different W/C ratio, International Journal of AdvancedTechnology in Civil Engineering, vol. 2, Issue 1, 2013, pp.45-50.

Sivasundram and Malhotra, V.M., High performance high volume fly ash concrete,Indian Concrete Journal, Nov (2004) 13-21.

Hiroshi K., Jinhwan J., Hiroki W., Eiichi F., Kiminori T & Akio S. (2008),Development of Artificial High Strength Light Weight Aggregate made from Coal Ashexpanding Shale Powder.,Journal of structural and construction engineering. pp 1425 1432.

P. Aggarwal, Y. Aggarwal, and S.M. Gupta, Effect of Bottom Ash as replacement ofFine Aggregates in Concrete, Asian Journal of Civil Engineering (Building andHousing), vol. 8, No.1, 2007, pp.49-62

RafatSiddique Effect of fine aggregate replacement with Class F fly ash on themechanical properties of concrete, Cement and Concrete Research, vol. 33, 2003,pp.539–547.

YogeshAggarwal, RafatSiddique, Microstructure and properties of concrete usingbottom ash and waste foundry sand as partial replacement of fine aggregateConstruction and Building Materials Volume 54, 15 March 2014, 210-223.

S.Lokesh,M.G.Ranjith Kumar, S.Loganathan Effective Utilization of High Volume Flyash with Light Weight Aggregate in Concrete for Construction industry; 2013.

M.S.Shetty(2013).Concrete Technology,S.Chand& co Publising Company.

IS 10262-1982 recommended guide lines for concrete mix design.

IS 8112:189, Specification for 43 grades OPC, reaffirmed 1997.

Properties of High-calcium Dry Bottom Ash Concrete, ACI Materials Journal, (1997)pp.90-101.

Bai Y, Basheer PAM. Influence of furnace bottom ash on properties of concrete Iceproceedings, structures and buildings, special issue new materials and new uses of forold materials 2003; 156(1): pp 85–92.

Ghafoori, N., Cai, Y., and Ahmadi, B. (1997), Use of dry bottom ash as a fine aggregatein roller compacted concrete, ACI Spec. Publ. (SP-171) pp. 487– 507.

Ghafoori, N., Cai, Y. (1998), Laboratory-Made Roller Compacted ConcretesCointaining Dry Bottom Ash: Part II-Long-term Durability, ACI Materials Journal,Vol. 95, No. 3, pp.244-251.

Bai Y and Basheer P.A.M. (2003) Influence of furnace bottom ash as fine aggregate onproperties of concrete. Structures and Buildings Vol. 156, No. 1,pp 85-92.

Kazuhiro Hasezaki, AkifumiNakashita, Gen-yo Kaneko1and Hideaki Kakuda,(2007),Unburned Carbon Behavior in Sintered Coal Fly-Ash Bulk Material by Spark PlasmSintering, Materials Transactions, Vol. 48, No. 12 pp. 3062 to 3065 ,SpecialIssue on Growth of Ecomaterials as a Key to Eco Society III #2007 The Japan Instituteof Metals.

DjwantoroHardjito.C and Shaw ShenFung(2009) Parametric Study on the Propertiesof Geopolymer Mortar Incorporating Bottom Ash Selected paper from the Asia PacificStructural Engineering Conference, APSEC.

Arvind Kumar and Dilip Kumar, (2014) Strength Characteristics of Concrete with Sintered flyash Aggregate Journal of IJSRD Volume 2, Issue 7, Sept-2014.

Yu-shun Guo et al. (2000)Comparison of properties of high performance lightweightaggregate and normal lightweight aggregate. Journal of Concrete (China),(6), pp.22-26.

Majidzadeh, K., EI-Mitiny, R. N., and Bokowski, G. (1977).Power Plant Bottom Ashin black base and bituminous surfacing. Vol.2, Users Mannual, Federal HighwayAdministration, Report No. FHWA/RD-78-148, Washinton, D.C.

S. Shanmugasundaram at al (2010) Study on Utilization of Fly Ash Aggregates inConcrete Modern Applied Science, www.ccsenet.org/mas, Vol. 4, No. 5;pp. 44-56.

Neetesh Kumar, Dilip Kumar,(2014) Strength Properties of Coconut Shell as CoarseAggregate In Concrete International Journal of Computer & Mathematical SciencesIJCMS ISSN 2347 – 8527 Vol. 3, Issue 5.pp43-52.

Geetha, S., Ramamurthy, K., (2011), Properties of sintered low calcium bottom ashaggregate with clay binders Construction and Building Materials, 25, pp2002-2013.

Saikia, N., Cornelis, G., Mertens, G., Elsen, J., Van Balen, K., Van Gerven, T.,Vandecasteele, C. (2008).Assessment of Pb-slag, MSWI bottom ash and boiler and flyash for using as a fine aggregate in cement mortar.Journal of Hazardous Materials.Volume 154, Issue 1-3, pp.766- 777.

Berg, E. and Neal, J.A. (1998) Concrete masonry unit mix designs using municipalsolid waste Bottom ash, ACI Mater. J. 95 (4) pp.470–479.

ChandanaSukesh, KatakamBala Krishna, P. Sri Lakshmi SaiTeja and S. KanakambaraRao,(2013) Partial Replacement of Sand with Quarry Dust in Concrete, InternationalJournal of Innovative Technology and Exploring Engineering, vol. 2, Issue 6, pp.254-258.

A.U Abubaker, KhairulSallehBaharudhen,(2012) Properties of concrete using Tanjhunbin powder plant bottom ash,international journal of construction engineering andtechnology, vol. 3, Issue

K. SomanDivyaSasi K.A Abubaker,(2014) Strength properties of concrete withpartial replacement of sand by bottom ash(IJIRAE) ISSN: 2349-2163 Vol.1Issue7,pp 223-227 http://ijirae.co

Jaturapitakkul C and Cheerarot R (2003),Development of Bottom Ash AsPozzolanic Material, Journal of Materials In Civil Engineering, Jan-Feb.pp.48-53.

P. Bhuvaneshwari* and R. Murali,(2013), Strength characteristics ofglass fibre on bottom ash based concrete International Journal ofScience, Environmentand Technology, Vol. 2, No 1,pp 90 – 10

Kim, H.K. and H.K. Lee, (2011) Use of power plant bottom ash as fine and coarseaggregates in high strength concrete. Constr. Build. Mater., 25: 1115-1122.

Mangaraj, B.K. et al., (1994). Use of ponded fly ash as part of replacement of fineaggregate in mortar and concrete. ICJ, pp: 279-282.

Cheriaf M, Cavalcante J and Pera J (1999) Pozzolanic properties of pulverized coalcombustion bottom ash Cement and Concrete Research Vol. 29, No.9, pp387-391

Targan S, Olgun A, Erdogan Y and Sevinc V (2004)Mineralogy and Organic MatterContent of Bottom Ash Samples from AgiosDemitrios Power Plant, Greece Bulletinof the Geological Society of Greece Vol. 36, Proceeding of the 10th internationalCongress, Thessaloniki, 321-6.

Dilip Kumar, Arvind Kumar, Ashish Gupta (2014)Replacement of Coarse Aggregate with Sintered Fly Ash Aggregates for Making Low Cost Concrete IJSRD - International Journal for Scientific Research & Development| Vol. 2, Issue 08, ISSN (online): 2321-0613,pp307-310.