Experimental Study on Partial Replacement of Fine Aggregate by Bottom Ash in Concrete

A.V.Chitharth Kannappan
P.G Student,
M.E Structural Engineering
Kongu Engineering College
Perundurai, India- 638052

S. Venkatachalam
Assistant Professor,
Department of Civil Engineering
Kongu Engineering College
Perundurai, India- 638052

***Abstract*—The natural resources of the sand are getting depleted gradually. Mining of sand also leads to various environmental hazards. The demand for the protection of the natural environment and the ban on mining in some areas is further aggravating the river sand. Bottom ash is a byproduct of composition of pulverized coal composed mainly of silica, alumina and iron with small amounts of calcium, magnesium sulphate. This paper presents the experimental investigation carried out to study the effect of use of coal bottom ash as a partial replacement of fine aggregate. An experimental program is planned in which controlled concrete of grade M30 is used. Fine aggregate is replaced with bottom ash by 10%, 20%, 30%, 40%, 50% and the properties like compressive strength, split tensile strength, flexural strength are evaluated. Test results show that bottom ash can be used as an effective replacement of fine aggregates. Workability decreases with the increase of bottom ash content. The compressive strength , tensile strength , flexural strength was effective upto 30% replacement level. Therefore 30% of the fine aggregates maybe replaced with bottom ash effectively.**

***Keywords*— *Bottom ash, Compressive strength, Split tensile strength, Flexural strength, optimum replacement*.**

I. INTRODUCTION

Concrete is a material with great strength and has a very long life. It has emerged as the very basic construction material for the needs of the twenty-first century. Concrete being durable, is easy to prepare and fabricate from readily available constituents. Energy is the backbone of modern civilization of every country and the electric Power from thermal power stations is a major source of energy, in the form of electricity. In India, over 75% of electricity generated in India, is by combustion of fossil fuels, out of which nearly 55% is produced by coal-fired plants. This results in the production of more than 100 tons of ash everyday. Most of the ash are disposed to an open area available near the plant or by pumping into dumping yards which causes the pollution in water bodies and loss of productive land.

The continuous reduction of natural resources and the environmental hazards due to the disposal of coal ash has reached tremendously. The use of coal ash in normal concrete is a new dimension in concrete and if it provides satisfying results it can be used as the major constituent of concrete which helps in the decrement of the ash content and also reduces the usage of natural resources. This paper presents the experimental investigation carried out to study the effect of use of bottom ash as a replacement of fine aggregates. Although, fly ash obtained from the chimneys are being generally used as replacement of cement and in the manufacture of cement, the study on the use of bottom ash has been very limited

II. LITERATURE REVIEW AND MATERIAL PROPERTIES

Soman et al. (2014) have carried out the research work including an experimental investigation on strength properties of concrete made with 10% to 50 % replacement of manufactured sand by bottom ash. The tests were carried out to find the compressive strength, splitting tensile strength and flexural strength on specimens. Results showed that up to 30 % replacement of sand by bottom ash there was only marginal reduction in compressive strength, splitting tensile strength and flexural strength. The experimental works were carried out with manufactured sand and bottom ash confirming to zone II at various proportions as fine aggregate in concrete. The study showed that bottom ash can be used along with sand in concrete with comparatively low strength requirement.

Raju et al. (2015) have investigated the effect of use of coal bottom ash as partial replacement of fine aggregates in various percentages (0–30%), on concrete properties such as compressive strength, split tensile strength test, flexural strength and modulus of elasticity. Compressive strength of bottom ash concrete at the curing age of 28 days was increased compared to control concrete. Splitting tensile strength of concrete improved at percentages of replacement of bottom ash. The modulus of elasticity decreased with the use of coal bottom ash at all replacement levels.

Nadig et al. (2015) have studied the reviews of the characteristics of concrete incorporated with bottom ash as partial replacement for fine aggregates, with a main focus on the mechanical properties such as Compressive strength, splitting tensile strength, flexural strength etc. Ten different research papers are reviewed. The practical use of Bottom ash shows a great contribution to waste minimization as well as resources conservation.

Kim et al. (2016) has reported the results of a study on the internal-curing efficiency of cold-bonded bottom ash aggregates (CBBA) used in high-strength mortar. The flow and compressive strength of high-strength mortar with CBBA were measured.

A. *Cement*

Cement is an important ingredient in concrete. In this investigation Cement OPC of 53 Grade locally available is used in this investigation. The Cement is tested for various properties and found to be confirming to various specifications of IS: 12269–1987. The properties of cement were tabulated in Table I

TABLE I PROPERTIES OF CEMENT

S.No	Properties	Value
1	Consistency	32.5%
2	Specific gravity	3.15
3	Initial setting time	32 minutes
4	Final setting time	588 minutes

B. *Fine aggregate*

Sand used is either round or angular in grains and it is found mixed in various grades of fineness. River sand is usually used. In this project, the locally available sand around Tirupur of zone II is used. The fine aggregate are conformed to the provisions of Indian standard specification. The properties of fine aggregate were as tabulated in Table II.

TABLE II PROPERTIES OF FINE AGGREGATE

S.No	Properties	Value
1	Size	Passing through 4.75 microns
2	Fineness modulus	3.225
3	Specific gravity	2.64
4	Grading zone	Zone II

C. *Coarse aggregate*

Coarse aggregate is used to reduce the drying shrinkage and other dimensional changes.. The size of the aggregate used is 20 mm nominal size from the local source was used. Coarse aggregate crushed angular aggregate should be sound, free from deleterious materials and must have crushing strength at least 1.5 times that of concrete. The properties of coarse aggregate were tabulated in Table III.

TABLE III PROPERTIES OF COARSE AGGREGATE

S.No	Properties	Value
1	Fineness modulus	7.81
2	Impact value	19.4%
3	Crushing value	19.18
4	Specific gravity	2.66

D. *Bottom ash*

The Bottom ash is collected from Sree Rengaraj Ispat Industries, Perundurai. They are collected from the 30MW power plant. Nearly 5000 tons of the bottom ash are produced during the power generation process. The washed bottom ash is collected and made to dry in the sunlight. The dried bottom ash is then sieved and the desired size is taken for the replacement of sand.The physical and chemical composition of the bottom ashes are studied.The physical properties of the bottom ash were tabulated in Table IV.

TABLE IV PHYSICAL PROPERTIES OF BOTTOM ASH

S.No	Properties	Value
1	Colour	Grey
2	Specific gravity	2.24
3	pH	7-10
4	Fineness modulus	2.82

E. *Water and admixtures*

Water is generally used for making concrete. Water should be free from acids, oils and other organic impurities. It reacts chemically with the cement to form a cement paste and it serves as a lubricant in the mixture of fine aggregates and cement.

Conplast SP430 (G) is used as the chemical admixture where a high degree of workability and its retention are required. It facilitates production of high quality concrete. The properties of the super plasticizer are analyzed and studied. The properties of admixture were tabulated in Table V.

TABLE V PROPERTIES OF ADMIXTURE

S.No	Properties	Value
1	Appearance	Brown liquid
2	Specific gravity	1.224
3	Chloride content	Nil to IS456
4	Air entrainment	1%

III. MIX PROPORTION AND EXPERIMENTAL PROGRAMME

This study consists of six mixes of concrete with different proportions of bottom ash. The different proportions include 0%,10%,20%,30%,40%,50% of replacement of fine aggregates on which experimental investigations were carried out. The mix designs were named as CC, C1,C2 , C3, C4, C5.

A. *Mix proportions*

Mix design is a process of selecting suitable ingredients and determining their relative proportions with the objective of producing concrete of having certain minimum workability, strength and durability as economically as possible. Concrete mix has been designed based on Indian Standard Recommended Guidelines IS 10262:2009.

M30 mix was considered for the conventional mix design, under severe exposure condition, placing of concrete by pumping, using a chemical admixture and a water cement ratio of 0.38 is considered. Based on trial with superplasticizer a free water content of 180liters gave a slump of 100 mm.

The tests carried out were for compressive strength on cubes, splitting tensile strength and flexural strength on standard specimens. Testing was carried out on conventional mix (control mix) without any replacement and on mixes with 10, 20, 30,40 and 50% sand replaced by bottom ash. Testing was also carried out on mixes with 10, 20, 30,40 and 50%sand replaced by bottom ash for replacement. The table VI shows the various replacement of bottom ash with the sand for the mixes. The values are provided by the unit kg/m^3.

TABLE VI MIX PROPORTIONS OF THE VARIOUS CONCRETE MIXES

Mix	Cement	FA	BA	CA	Water	Admixture
CC	414.73	728.49	0	1214.8	157. 6	4.147
C1	414.73	655.64	72.849	1214.8	157. 6	4.147
C2	414.73	582.79	145.69	1214.8	157. 6	4.147
C3	414.73	509.94	218.54	1214.8	157. 6	4.147
C4	414.73	437.094	291.39	1214.8	157. 6	4.147
C5	414.73	364.24	364.24	1214.8	157.6	4.147

B. *Experimental investigation*

Ordinary Portland cement of 53 grade conforming to relevant Indian Standard specifications has been used for making the concrete along with fine and coarse aggregates. Six mix proportions were prepared in which the first was conventional mix and the remaining are bottom ash concrete mix and . Bottom ash concrete mix containing 10% to 50% of bottom ash as partial replacement of fine aggregate .The fresh and hardened state properties of bottom ash and washed bottom ash concrete were studied and optimum mix was found out.

The materials were mixed thoroughly in a produce fresh concrete. The cube specimens were prepared for compressive strength test of size 150 mm x 150 mm x 150 mm. The cylindrical specimen of height 300 mm and 150 mm diameter was prepared for splitting tensile strength test. The specimens were demoulded after 24 hours and 28days of curing. The compressive strength, spilt tensile strength and flexural strength of concrete cubes of each mixes was determined . All testing were done according to Indian Standard specification.

IV. RESULTS AND DISCUSSION

An experimental investigation is carried out to determine or study the mechanical properties of bottom ash concrete and results are compared to nominal concrete. The mechanical properties of concrete includes the compressive, split tensile and flexural strength of the concrete.

A. *Compressive strength*

The compressive strength of the cubes are determined in the universal testing machine. The compressive strength had been evaluated from the peak load obtained by crushing the specimen. The Figure 1 shows the compressive test results of the cubes.

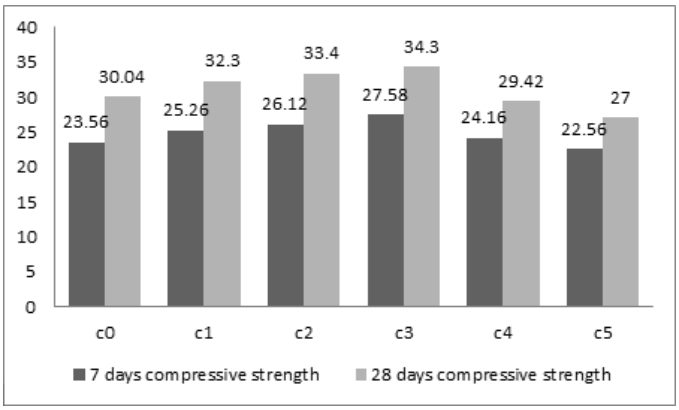


Figure 1 compressive strength results

B. *Split tensile strength*

The splitting tests are well known indirect tests used for determining the tensile strength of concrete sometimes referred to as split tensile strength of concrete .The split tensile strength had been evaluated from the peak load obtained by crushing the specimen. The Figure 2 shows the split tensile strength of the cylinder.

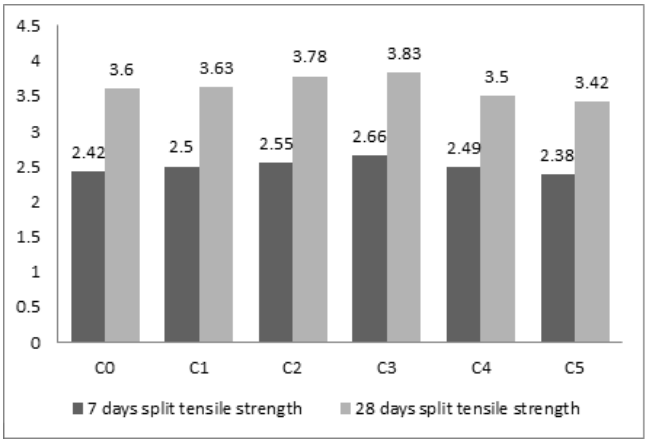
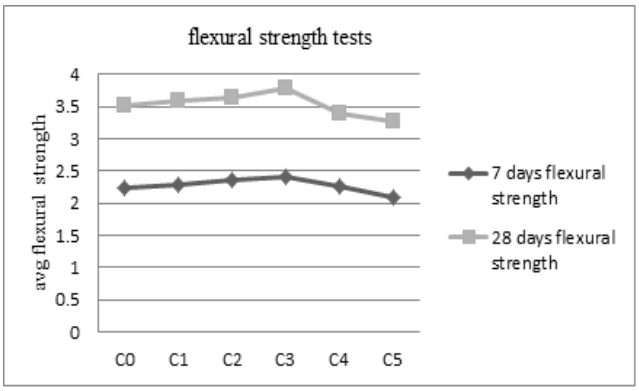


Figure 2 split tensile strength of cylinder in 7 and 28 days

C. Flexural strength

For the flexural test of concrete, prism specimens of size 500mm x 100mmx 100mm was used. The specimen was placed in the flexural strength testing machine and loaded gradually. The load at failure is noted. Then the flexural strength is determined at 7 days and 28 days. The Figure 3 shows the flexural strength of the prism during loading



D. Discussions

The mechanical properties like compressive strength, split tensile strength, flexural strength are obtained for the replacement of bottom ash in concrete for the various percentages(from 0-50%). The various discussions after obtaining these results are

- Bottom ash can be used as an effective replacement of natural sand.
- In the compressive strength bottom ash replaced concrete shows good results compared with the normal conventional concrete.
- The average maximum compressive strength obtained is 29.58 N/mm^2 and 34.30 N/mm^2 in 7 and 28 days and is found to be 17.06% and 9.7% more than the conventional concrete.
- The average maximum split tensile strength obtained is 2.66 N/mm^2 and 3.83N/mm^2 in 7 and 28 days and is found to be 10% and 6.38% more than the conventional concrete.
- The average maximum flexural strength obtained is 2.42 N/mm^2 and 3.78 N/mm^2 in 7 and 28 days and is found to be 8% and 7.3% more than the conventional concrete.
- However beyond 30% replacement of the bottom ash the strength fails.
- The workability also gets reduced by the increase of the bottom ash content.

REFERENCES

[1] Andrade L.B. and Rocha J.C. (2009) 'Influence of coal bottom ash as fine aggregate on fresh properties of concrete' Construction and Building Materials 23 (2009), pp.609–614.

[2] Ciarán Lynn J., Ravindra Dhir A.,Gurmel Ghataora S. (2016) 'Municipal incinerated bottom ash characteristics and potential for use as aggregate in concrete' Construction and Building Materials 127 (2016), pp.504–517.

[3] Edem Baite , Adamah Messan , Kinda Hannawi , François Tsobnang , William Prince(2016) 'Physical and transfer properties of mortar containing coal bottom ash aggregates from Tefereyre' Construction and Building Materials 125 , pp. 919–926

[4] IS383(1970) 'Specifications for coarse and fine aggregates from natural sources for concrete' Second revision,Bureau of Indian standards,New Delhi.

[5] IS: 456-2000, 'Indian Standard Code for Practice for Plain and Reinforced Concrete' Bureau of Indian Standards, New Delhi, India.

[6] IS: 516-1959 'Indian Standard Code for Practice- Methods of Test for Strength of Concrete' Bureau of Indian Standards, New Delhi, India.

[7] IS: 10262-2009 'Recommended Guidelines for Concrete Mix Design' Bureau of Indian Standards, New Delhi, India.

[8] IS: 12269-1987 'Specifications for 53-Grade Portland Cement' Bureau of Indian Standards, New Delhi, India.

[9] Jumah Jessica Jaleel V. and Maya T.M. (2015) 'Influence of Metakaolin on Concrete Containing Bottom Ash as Fine Aggregate' International Journal of Research in Advent Technology (E-ISSN: 2321-9637), pp. 41-46.

[10] Kim H.K and Lee H.K. (2011) 'Use of power plant bottom ash as fine and coarse aggregates in high-strength concrete' Construction and Building Materials 25 (2011), pp.1115–1122.

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

[12] Remya Raju, Mathews Paul K. &. Aboobacker K.A. (2014) 'strength performance of concrete using bottom ash as fine aggregate', International Journal of Research in Engineering & Technology Vol. 2, Issue 9, Sep 2014, pp. 111-122.

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

[14] M.S Shetty, S.Chand(2010) 'Concrete technology , theory and practice' Tata McGrah Hill Company Ltd, New Delhi.

[15] Vikas R Nadig, Sanjith J , Ranjith A, Kiran B M(2015) ' Bottom Ash as Partial Sand Replacement in Concrete- A Review', IOSR Journal of Mechanical and Civil Engineering, Volume.12, Issue 2 Ver.6 (Mar - Apr. 2015), pp.148-151.