International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 09, September-2016

A Comparative Study on the Strength Properties of Concrete Using Bottom Ash and Washed Bottom Ash as Partial Replacement of Fine Aggregate

Sabisha Aliyar
M Tech Student,
ICET
Muvattupuzha, India

Remya Raju
Asst. Professor,
ICET
Muvattupuzha, India

***Abstract*— This paper presents an experimental investigations to compare the strength properties of concrete using bottom ash and washed bottom ash as partial replacement of fine aggregate in concrete. The coal bottom ash for this study obtained from Hindustan Newsprint Limited, Kottayyam, Kerala, India. Keeping bottom ash in water for 3 days and allow it to dry for one day to produce a washed bottom ash. In this paper, bottom ash and washed bottom ash has been partially replaced in ratio of 0%, 5%, 10%, 15%, 20%, 25% and 30% by weight of fine aggregate. The various strength properties studied and compared. The strength properties consist of compressive strength, splitting tensile strength and flexural strength.**

Keywords – Coal Bottom Ash; Washed Bottom Ash; Concrete, Compressive Strength; Splitting Tensile Strength; Flexural Strength.

I. INTRODUCTION

Cement, water and aggregates are the basic constituents of concrete. In terms of volume of concrete, aggregate is the major constituent. Aggregate is very important for many concrete properties including workability, shrinkage, thermal expansion, compressive and tensile strength. Aggregate is subdivided into two sizes coarse and fine. A few studies have been carried out on bottom ashes taken from various power plants and the results shows that the bottom ash particle has better pozzolanic activity with increase in age of concrete. Carbon content of washed bottom ash is less as compared with bottom ash so that use of this washed bottom ash in concrete will helps to reduce environmental impact in the building due to the reduction in the energy of building.

The objectives of this comparative study is to investigate the effect of use of bottom ash and washed bottom ash as partial replacement of fine aggregates in various percentages (0–30%), on concrete properties such as compressive strength, workability, flexural strength etc. and also to compare the strength properties of bottom ash and washed bottom ash concrete at optimum fine aggregate replacement percentages.

A. Cement

The specimens were caste using Ordinary Portland Cement 53 grade. The tests conducted on cement according to relevant Indian Standards [11] were specific gravity, consistency test, initial setting time and fineness.The properties of cement were tabulated in Table I

TABLE I. PHYSICAL PROPERTIES OF CEMENT

Sl. No	Properties	Value
1	Specific gravity	3.125
2	Standard consistency	35%
3	Initial setting time in minutes	240
4	Finess	5%

B. Fine aggregate

M sand was used as the fine aggregate. Properties of fine aggregates are tested as per relevant Indian Standards [13] and the results are tabulated in Table II.

TABLE II. Physical Properties Of Fine Aggregate

Sl. No	Properties	Magnitude
1	Specific gravity	2.69
2	Bulk density, kg/m3	1.226
3	Water Absorption, %	1.5
4	Grading zone	Zone II
5	Fineness modulus	2.63

C. Bottom ash and Washed bottom ash

Bottom ash is a by-product of coal combustion and it's chemical composition is depend on the nature of coal used. Washed bottom ash is obtained by keeping bottom ash in water for 3 days and allow it to dry for one day. The carbon content and finess of washed bottom ash is low as compared with bottom ash. Bottom ash used in this study was obtained from Hindustan Newsprint Limited, Kottayyam, Kerala, India .

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TABLE III. PHYSICAL PROPERTIES OF BOTTOM ASH (BA) AND WASHED BOTTOM ASH (WBA)

Sl.No.	Properties	Value	
		BA	*WBA*
1	Specific Gravity	2.20	2.24
2	Water Absorption	17	18
3	Finess modulus	2.77	2.45

TABLE IV. CHEMICAL PROPERTIES OF BOTTOM ASH (BA) AND WASHED BOTTOM ASH (WBA)

Sl No.	**Element**	**Mass %**	
		BA	***WBA***
1	C	15.04	10
2	O	60.27	58.2
3	Al	9.02	6.01
4	Si	12.62	7.2
5	K	0.64	0.58
6	Ti	0.71	0.61
7	Fe	1.69	1.60

D. Coarse aggregate

The crushed well graded angular shaped of size 20mm as per relevant IS code [14] is used as coarse aggregate. Different properties of coarse aggregates were tabulated in Table V.

TABLE V. PROPERTIES OF COARSE AGGREGATE

Sl No.	Properties	Values
1	Specific gravity	2.67
2	Bulk density	1.324 Kg/l
3	Water absorption	0.80

E. Super plasticizer

Super plasticizers, also known as high range water reducers. Many important characteristics of concrete are influenced by ratio of water to cementitious materials used in the mixture. By reducing the amount of water, the cement paste will have higher density, which results in higher paste quality. In this study Master Glenium Sky 8233 was used as super plasticizer. Master Glenium SKY 8233 is an admixture of modified poly carboxylic ether. The base material used was poly carboxylic ether. This was obtained from BASF Construction Chemicals (India) Pvt. Ltd.

II. EXPERIMENTAL PROGRAMME

Ordinary Portland cement of 53 grade conforming to relevant Indian Standard specifications [11] has been used for making the concrete mixtures. Thirteen mix proportions were prepared. In which the First was control mix (without bottom ash and washed bottom ash)and the remaining are bottom ash concrete mix and washed bottom ash concrete mix. Bottom ash concrete mix contained 5% to 30% of bottom ash as partial replacement of fine aggregate similarly washed bottom ash mix contained 5% to 30% of washed bottom ash. The control mix without bottom ash and washed bottom ash was proportioned as per Indian Standard specification [15] to obtain a 28 day cube compressive strength of 30N/mm^2 . The fresh and hardened state properties of bottom ash and washed bottom ash concrete were studied and optimum mix was found out.

The procedure for mixing high performance concrete is similar to that of conventional concrete. The materials were mixed thoroughly in a drum mixer to produce fresh concrete. To obtain a homogeneous mix, aggregates along with bottom ash and washed bottom ash(for bottom ash concrete and washed bottom ash concrete respectively) were mixed and binder were added to the system. After remixing, water was added to the dry mix. Finally, super plasticizer was introduced to the wet mixture. In the fresh concrete slump cone test was performed to ensure the workability according to an Indian Standard specification [16]. 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. Beam specimens of size 100 mm × 100 mm × 500 mm were prepared for flexural strength test. The concrete was cast into steel moulds using a minimal amount of Greece and compacted well. The specimens were de-molded after 24 hours and water curing for 28days. The compressive strength of concrete cubes of each mixes was determined after 7 days and 28 days of water curing. Flexural strength and splitting tensile strength of each concrete mixes was determined after 28 days of water curing. All testing were done according to Indian Standard specifications [17].

III. MIX DESIGNATIONS

This study consisting of 13 mixes of concrete with different proportion of bottom ash or washed bottom ash which are 0%, 5%, 10%, 15%, 20%, 25% and 30% replacement of fine aggregate on which the experimental investigations were carried out. Mixes were designated as MB 0, MB5, MB10, MB15, MB20, MB25, MB30, MW5, MW10, MW15, MW20, MW25, MW30.

Quantities of materials for 1 m^{3}of each mixes are as given in the Table VI and Table VII.

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TABLE VI. PROPORTIONS OF BOTTOM ASH MIXES

Mix	Cement (kg)	Fine aggregate (kg)	Bottom Ash (kg)	Water (litres)	Coarse aggregate (kg)
MB0	350.22	850.04	0	157.6	1103.63
MB5	350.22	807.54	34.76	184.45	1103.63
MB10	350.22	765.04	69.52	189.73	1103.63
MB15	350.22	722.53	104.28	194.99	1103.63
MB20	350.22	680.03	139.04	200.27	1103.63
MB25	350.22	637.53	173.8	205.54	1103.63
MB30	350.22	595.03	208.56	210.82	1103.63

TABLE VII. PROPORTIONS OF WASHED BOTTOM ASH

Mix	Cement (kg)	Fine aggregate (kg)	Washed Bottom Ash (kg)	Water (litres)	Coarse aggregate (kg)
MW5	350.22	807.54	34.76	184.80	1103.63
MW10	350.22	765.04	69.52	187.85	1103.63
MW15	350.22	722.53	104.28	196.04	1103.63
MW20	350.22	680.03	139.04	201.66	1103.63
MW25	350.22	637.53	173.8	206.10	1103.63
MW30	350.22	595.03	208.56	212.90	1103.63

MIXES

IV. RESULTS

A. Results of Compressive strength

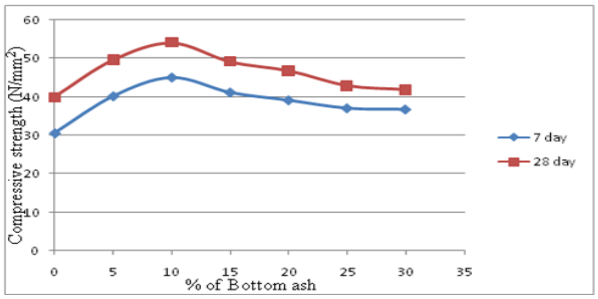

Fig.1 Variation of 7thday and 28th day compressive strength of Bottom ash concrete

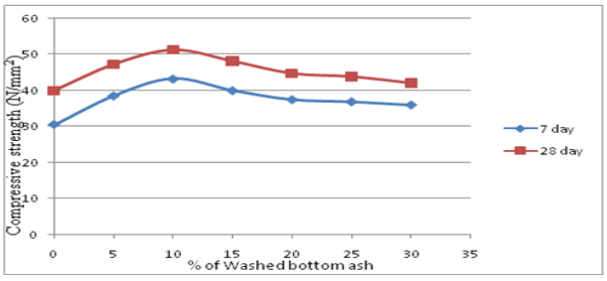

Fig.2 Variation of 7thday and 28thday compressive strength of Washed Bottom ash concrete

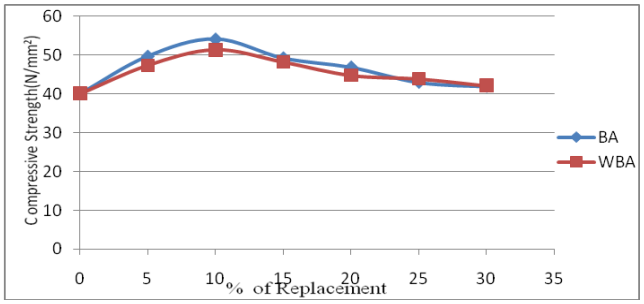

Fig.3 Variation of 28thday compressive strength of Bottom Ash and Washed Bottom Ash concrete

Addition of bottom ash and washed bottom ash in concrete positively affects its strength under compression. There is a significant increase in the compressive strength of concrete both in 7 days and 28 days testing. Compressive strength gets increased with the addition of bottom ash and washed bottom ash. But the maximum enhancement is obtained at 10% of bottom ash and washed bottom ash replacement. Beyond that there is no significant change in the compressive strength. Among bottom ash concrete and washed bottom ash Concrete the bottom ash concrete has greater compressive strength than washed bottom ash concrete.

B. *Results of Splitting Tensile Strength*

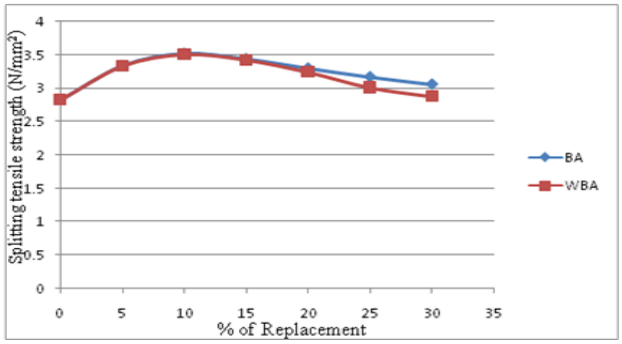

Fig.4 Variation of Splitting tensile strength of Bottom ash and Washed bottom ash concrete

Test results indicate that inclusion of bottom ash and washed bottom ash in concrete improved the splitting tensile strength of concrete. Bottom ash and washed bottom ash due to its pozzolanic nature give an improved paste characteristics and good transition zone. Splitting tensile strength depends on the quality of paste and the transition zone of the concrete. Spitting tensile strength is greater in Bottom ash and washed bottom ash concrete when comparing to control mix. Maximum value of splitting tensile strength obtained for bottom ash concrete is about 3.54 N/mm^2 and maximum value of splitting tensile strength obtained for washed bottom ash concrete is about 3.50N/mm^2 which are greater than splitting tensile strength of control mix. It is due to the dense pore structure which may obtained by better packing effect of bottom ash and washed bottom ash.

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C. Results of Flexural strength

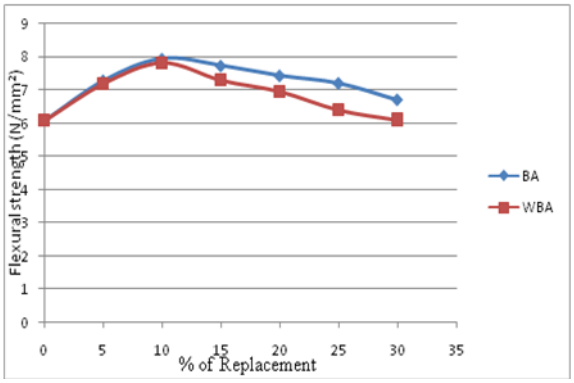

Fig.5 Variation of Flexural strength of Bottom ash and Washed bottom ash concrete

Flexural strength of concrete also increases due to the addition of bottom ash and washed bottom ash in to the concrete. Presence of bottom ash and washed bottom ash improves the hydrated structure of concrete and provides better particle packing. Maximum value of flexural strength obtained is for bottom ash concrete is 7.94 N/mm^2 and for washed bottom ash concrete maximum value of flexural strength is 7.83 N/mm^2 which is greater than control mix flexural strength.

V. CONCLUSIONS

The present experimental investigations had presented results of bottom ash and washed bottom ash concrete on strength properties of concrete. The study was carried out using M30 grade concrete. Firstly, the chemical and physical characteristics of materials used such as bottom ash, washed bottom ash, cement and aggregates were investigated. Further experiments were conducted by replacing fine aggregate in varying percentages 0%, 5%, 10%, 15%, 20%, 25% and 30%. Mechanical properties such as compressive strength, splitting tensile strength, flexural strength with bottom ash and washed bottom ash concrete were evaluated. Test results indicate that both bottom ash and washed bottom ash are suitable for improving the properties of concrete. Following are the conclusions obtained.

- There is significant increase in the strength of concrete due to incorporation of bottom ash and washed bottom ash as compared with concrete without bottom ash and washed bottom ash.
- Workability of concrete mix found to be greater than control mix but among bottom ash and washed bottom ash concrete workability of washed bottom ash mix is less than bottom ash concrete mix.
- Compressive strength of bottom ash and washed bottom ash concrete is higher than control mix. Among bottom ash and washed bottom ash concrete mix, bottom ash concrete mix has greater compressive strength than washed bottom ash concrete mix at 10% replacement of fine aggregate.
- Optimum percentage of bottom ash and washed bottom ash was obtained as 10%, since in that range maximum results were observed. Beyond 10 %, there is no significant change in the values of strength.
- Splitting tensile strength and flexural strength of concrete improved on use of coal bottom ash and washed bottom ash as fine aggregate in partial replacement of M-sand up to the optimum percentages.

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