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EXPERIMENTAL INVESTIGATION ON CONCRETE INCORPORTING BOTTOM ASH AS PARTIAL REPLACEMENT OF FINE AGGREGATE

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Abstract*:*

Concrete is widely used as a construction material in modern society with the growth in urbanization and industrialization and the demand for concrete is increasing day by day. Therefore, raw materials from natural resources are required in large quantities for concrete production. At the same time, a considerable quantity of industrial wastes mostly from thermal power plants is available in large quantity and the disposal of this material becomes a major issue. Fly ash generated in the power stations is consumed in the cement industry whereas the bottom ash is disposed in the open ground. Hence the bottom ash was used as a substitute for fine aggregate in concrete. This project work aims to study the performance of concrete containing bottom ash as a partial substitute for fine aggregate with different water cement ratios of 0.37, 0.38, 0.45 and 0.57. Compressive strength, Split tensile strength, flexure strength were determined compared with concrete containing 0% bottom ash were studied of bottom ash concrete.

Key words: bottom ash, compressive strength, flexural strength, split tensile strength, fly ash.

1. INTRODUCTION

Cement and concrete production consumes enormous amounts of natural resources and aggregates, thereby causing substantial energy and environmental losses. This production also contributes significantly to the emission of carbon dioxide, a naturally occurring greenhouse gas. Adjustments and improvements to the present concrete making methods are essential in order to address these environmental and economic issues. This has encouraged researchers in the area of concrete engineering and technology to investigate and identify supplementary by-product materials that can be used as substitutes for constituent materials in concrete production. The beneficial effects of some of these materials on the properties of concrete have further enhanced these efforts. Bottom ash is one of the most preferred sand replacements, especially when the engineering properties and bond strength of the hardened concrete were the primary concern. In view of this, several other pozzolanic materials are being investigated for similar applications. Bottom ash is a material that can play a similar role to sand fume as a pozzolanic material in concrete. Raw bottom ashes, which are residues from coal thermal power plant, pose an enormous disposal problem and environmental load. Bottom ash is produced from the controlled incineration of cement industry, which is then ground to the required fineness. On average, each unit weight of thermal power plant wastage would yield approximately 40–50% of bottom ash, which can be optimized positively in concrete technology. The beneficial effects of bottom ash on concrete with respect to its mechanical properties and bond strength have been widely discussed. Deduced for high-strength concrete with a compressive strength of 80 MPa can be produced by the combined utilization of bottom ash and super plasticizer from the concrete age of 28 days. Concluded for depending on the rate of addition, bottom ash enhanced the compressive strength of concrete by up to 40% at 42 days and was superior to content in this aspect. Meanwhile found that blended sand containing up to 40% bottom ash can be produced without adversely affecting the strength and bond strength properties of concrete. Addition of bottom ash into concrete also causes significant enhancement to the bond strength properties of concrete. Literature study of 30% to 40% of sand with bottom ash significantly improved the resistance of the concrete to chloride-ion penetrability.

1.1 REPLACEMENT PROCESS

At a higher proportion of replacement, it was reported that substitution of sand with up to 30% bottom ash resulted in enhanced strength and corrosion resistance, as well as a reduction in the chloride penetration and permeability of concrete. Similarly, stated that the blending of 30% bottom ash with sand resulted in approximately 35% decrease in water permeability, 28% reduction in chloride diffusion, and 75% reduction in chloride permeation of the concrete. The enhancement in the mechanical properties and bond strength of concrete due to the addition of bottom ash is caused by the reaction of sand with bottom ash during the hydration process to form additional super plasticizer. It was confirmed by the findings of bond strength. At temperature around 40ºC and in the presence of water, the amorphous silica contained in bottom ash can react with $Ca(OH)_2$ to form one kind of super plasticizer. On another note, the reduction in the available sources of natural aggregates is also affecting the construction industry. This scenario is further aggravated by the sterilization of valuable aggregate resources by the process of urbanization. Several alternative aggregates are being investigated to overcome this challenge, and some examples include manufactured aggregates, waste from quarrying activities, crushed sandstone aggregates, materials reuse from power plant waste, copper slag and bottom ash particles. In the past, residues from quarrying activities have been used for different construction applications such as in the construction of roads and highways, and in the development of building products. However, their application for concreting purposes has been very limited.

2. LITERATURE REVIEW

S.L.Tighe-2008 The strength of all specimens with added pozzolanic materials was higher than that of the control at 28 days. This is a preliminary study on the effect of the chemical composition change of the additives using bottom ashes on the improvement of interfacial zone based on the bond strength point of view. In addition, the application to a normal aggregate-paste interface should also be investigated.

N.P. Rajamane-2009 Quarry dust is a by-product from the granite crushing process in quarrying activities. Experimental studies was undertaken to evaluate the compressive strength development and other mechanical properties of HSC, such as modulus of rupture, dynamic modulus of elasticity it can be compensated by a good mix design and by the use of super plasticizer.

J. Annie Peter-2005 Experiments have been carried out to evaluate the utilization of bottom ash by-product of power plant as fine and coarse aggregates in high-strength concrete with compressive strength of 60–80MPa. The effect of fine and coarse bottom ash on the flow characteristics and density of concrete mixture was investigated in the aspect of particle shapes and paste absorption of bottom ash. The flow characteristics of fresh concrete were slightly reduced by the use of coarse bottom ash, whereas the effect of fine bottom ash can is neglected.

P.S. Ambily -2003 The effects of coal bottom ash as fine aggregates in place of sand was used and compressive strength, bond strength are studied. The results shows that the compressive strength, split tensile strength and flexural strength decreased as the percentage of replacement coal bottom ash increased as compared to controlled concrete.. The split tensile strength was increased at 7, 28, 56 and 112 days for 10% to 30% replacement and after that it was decreased for remaining replacement.

Huanzi Wang -1997 Effects of three types of curing on coconut shell aggregate concrete has been studied for long term performances. The water absorbed by the coconut shell during the coarse of soaking is stored and the pore structures in the coconut shell behave like a reservoir. Biological decay was not evident as the cubes gained strength even after 365 days. In coconut shell aggregate concrete no bond failure even at the later ages and maintained good quality for the long-term performance.

Veerle Boel-2009 Test results indicate significant improvement in the strength properties of plain concrete by the inclusion of bottom ash as partial replacement of fine aggregate, and can be effectively used in structural concrete. This study explores the possibility of replacing part of fine aggregate with bottom ash as a means of incorporating significant amounts of bottom ash.

Wouter De Corte-2001 The purpose of this study was to investigate the influence that replacing natural coarse aggregate with recycled concrete aggregate as on concrete bond strength with reinforcing steel. On average, natural aggregate concrete specimens had bond strengths that were 9 to 19% higher than the equivalent RCA specimens. Bond strength and the aggregate crushing value seemed to correlate well for all concrete types. The natural aggregates mainly due to the higher porosity of the adhered mortar. These findings agree closely with the published literature.

Geert De Schutter-2009 Bottom ash acts as a partial replacement material for both Portland cement and fine aggregate. The published information on FA as sand replacement material is limited and rational guidelines to estimate the compressive strength of concrete are not available. The prediction formula suggested can be used to modify any basic cement concrete mix so that the concretes with and without sand replacement by FA have similar strength.

3. EXPERIMENTAL DETAILS

A. Properties of material

The materials used in this experiment were ordinary Portland cement(OPC), bottom ash as fine aggregate, for casting specimens

Cement*:* As per IS code 1727(1967) Pozzolanic Portland cement has a number of properties that are beneficial in concrete application. The most important properties of cement concrete type are dependent on the user and applications. By varying ratio of cement, the characteristics of cement adapted to specific applications. The physical properties of pozzolanic Portland cement are listed in table I below.

S.NO	PROPERTIES	RESULT
1	Normal consistency	30%
2	Initial setting time	30min
3	Final setting time	600min
4	Specific gravity	3.15

Table 1: physical properties of cement

Fine aggregate*:* Sand was used as fine aggregate. Sieve analysis was carried out and found to be sand in zone II fineness modulus has found to be bags and kept ready for casting. The properties of fine aggregate are listed in table II below

S. NO	PROPERTY	SAND

1	Finesses modulus	3.48
2	Specific gravity	2.60
3	Bulk density	1.53-1.58
4	Water absorption	0.71

Table 2: Properties of Fine Aggregate

Coarse aggregate*:* The coarse aggregate used was broken granite-crushed stone and it was free from clay, weeds, and any other organic matters, they are nonporous. 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 III

S. No	Property	Value
1	Type	Crushed
2	Maximum size	20 mm
3	Specific gravity	2.62
4	Finesses modulus	3.24
5	Impact value	91.8%
6	Water absorption	0.73%

Table 3: Properties of coarse aggregate

Bottom ash: Bottom ash is collected at the bottom of the combustion chamber in a water-filled hopper, is removed by means of high-pressure water jets and conveyed by sluiceways to a decanting basin for dewatering followed by stockpiling and possibly crushing (Steam, 1978). The specific gravity (SG) of bottom ash is around 2 – 3 and shows the higher carbon content that ensuing in lower specific gravity. The total composition of silica(sio2),alumina(al2o3) and iron oxide(fe2o3) in bottom ash exceeded 70%, indicating that it can be classified as class F ash as specified in ASTM C 618[8]. The partical size distribution for natural sand and bottom ash is presented in fig 1. Almost more than 50% of bottom ash particle have a dimension less than 250µ,which makes greater amount fine particles available in concrete.the specific gravity of fine and coarse aggregate are found to be 2.60 and 2.62 respectively. Physical properties and chemical compostition of bottom ash are presented in table IV.

S.NO	PHYSICAL PROPERTIES	VALUES	CHEMICAL	VALUES
1	Particle size	10^{-1}-10^{1}	SiO_2	20-60
2	Mean particle dia, mm	500-700	Al_2O_3	10-35
3	Saturated hydraulic	10^{-3}-10^{-1}	Fe_2O_3	5-35
4	Specific gravity	2.17-2.78	CaO	1-20
5	Dry bulk density	0.74-1.6	MgO	0.3-4
6	Surface area	0.4	SO_3	0.1-12

Table 4: properties of bottom ash

Fig 1: Sieve Analysis

4. RESULTS AND DISCUSSIONS

***A. Compressive strength*:** As per IS code 519 (1959) Compressive strength test was done in order to evaluate the strength characteristics of mortar. The compression test was done on standard cube specimens of size 100 mm, 150mm for each mix. The compressive load was applied at 5.3 kN/sec using a compression testing machine of 2500 KN capacity.In each type, 3 cubes were tested at the age of 7 days; 28 days and the average strength of these cubes were reported for each age in table V

Mix	W/C Ratio	0% BA		40% BA	
		7 days	28 days	7 days	28 days
1	0.37	35.09	44.9	38.9	44.08
2	0.38	33.45	43.23	36.9	42.40
3	0.45	32.09	42.70	35.83	40.25
4	0.57	34.05	39.09	33.3	39.58

Table 5: Compressive Strength of Concrete with Bottom Ash

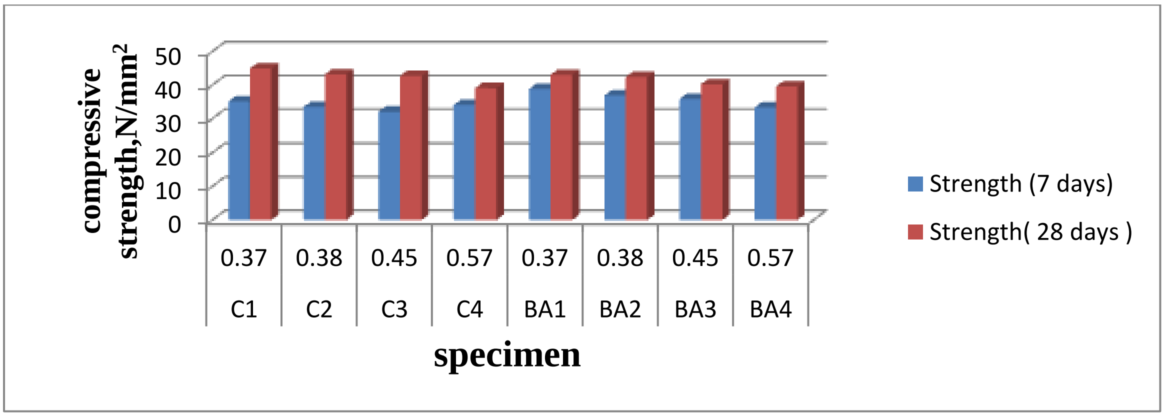

Fig 2. Compressive Strength of Concrete

B. ***Flexural strength:*** The modulus of rupture was determined in accordance with Standard Test Method for Flexural Strength of Concrete Using Simple Beam Third-Point Loading. The test consists of subjecting a (100 mm x 100 mm x 500 mm) concrete beam to a four-point load until failure. The Flexural strength test on bottom ash concrete cubes was conducted and the comparisons of results with controlled concrete were as shown in table VI. Figure III shows the flexural strength Vs Days relationship of controlled concrete using the prisms with different water cement ratio.

Mix	w/c ratio	0% BA		40% BA	
		7 days	28 days	7 days	28 days
1	0.37	5.98	6.55	4.55	5.55
2	0.38	4.93	5.75	4.08	4.55
3	0.45	3.25	4.98	4.3	4.98
4	0.57	2.95	3.75	3.05	3.45

Table 6: Flexural Strength of bottom ash concrete

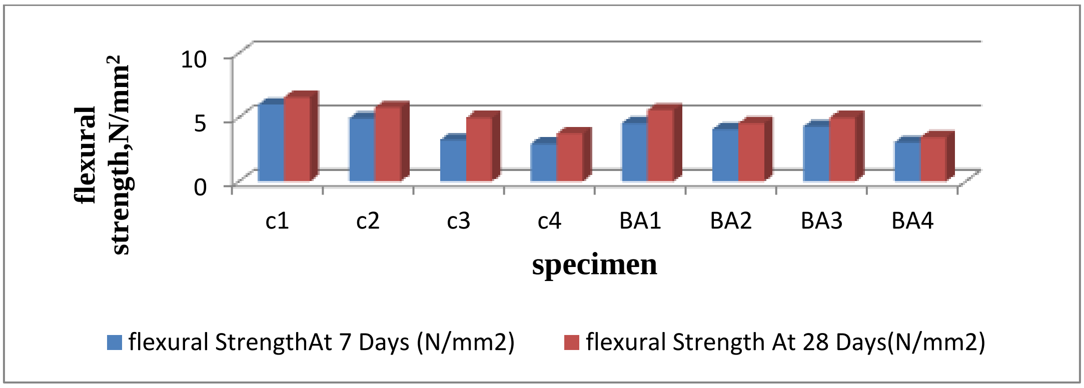

Fig 3: Flexural Strength of CC& BAC concrete

C. ***Split Tensile Strength*****:** The splitting tensile strength was determined in accordance with Standard test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens. The specimens consisted of 75 mm diameter, 100 mm tall cylinders for each mix design, which were tested upon reaching the appropriate concrete compressive strength. Equation was used to determine the splitting tensile strength of each cylinder test result. The splitting tensile strength test on bottom ash concrete cubes was conducted and the comparisons of results with controlled concrete were as shown in table VII. Figure IV shows the split tensile strength Vs Days relationship of controlled concrete with different water cement ratio.

Mix	w/c ratio	0% BA		40% BA	
		7 days	28 days	7 days	28 days
1	0.37	2.7	5.75	4.55	5.45
2	0.38	2.33	5.45	3.89	4.75
3	0.45	2.04	4.55	2.45	4.07
4	0.57	2.04	3.85	2.09	3.98

Table 7: Split Tensile Strength of bottom ash concrete

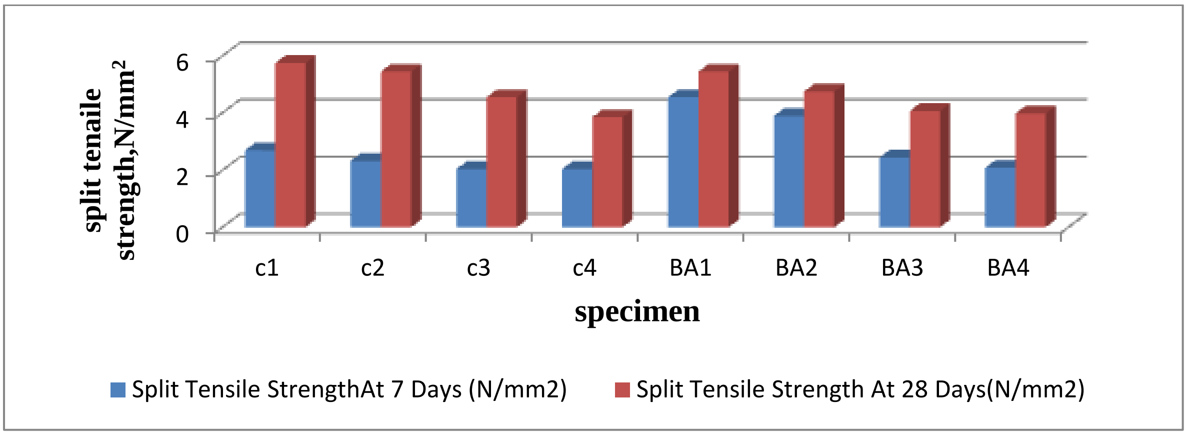

Fig 4: Split Tensile Strength CC& BAC concrete

CONCLUSION

In the above investigation, the test was conducted for 1:1.7:3 mix ratio containing 40% bottom ash as replacement of sand with different water cement ratio of 0.37, 0.38, 0.45 and 0.57. The slump was measured using slump cone apparatus and the slump was found to vary from 135 to 145 mm for controlled concrete and 125 to 140 mm for bottom ash concrete. Hence the workability of bottom ash concrete is almost same as that of controlled concrete.Compressive strength test on bottom ash concrete cubes was conducted and the comparisons of results with controlled concrete were plotted in graph. Compressive strength of controlled concrete M1 is 44.90 N/mm^2, where as for bottom ash concrete the compressive strength is 41.09 N/mm^2. Similarly for M2, M3 & M4 mixes the compressive strength of bottom ash concrete is almost same as mix of controlled concrete. Split tensile test was conducted on bottom ash concrete and controlled concrete. 28 days split tensile strength of controlled concrete mix M1 is 5.75 N/mm^2, where as the split tensile strength of bottom ash concrete is 5.45 N/mm^2. Hence Similarly for M2, M3 & M4 mixes the Split tensile strength of bottom ash concrete is almost same as mix of controlled concrete. Flexural strength test was conducted on specimens, 28 days flexural strength of controlled concrete mix M1 is 4.55 N/mm^2, where as the flexural strength of bottom ash concrete is 5.55 N/mm^2. Hence Similarly for M2, M3 & M4 mixes the Flexural strength of bottom ash concrete is almost same as mix of controlled In the 40 MPa direct replacement mixtures, both bottom ash concretes had higher compressive strength values than the controlled concrete. This is likely due to the stronger bond between the concrete and the steel. In the 40 MPa direct replacement mixtures, bottom ash concrete had slightly higher compressive strength values and controlled concrete had lower compressive strength values.

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