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Bond Strength of Concrete Incorporating Bottom Ash as Partial Replacement of Fine Aggregate- A Review

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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.This study reviews 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 and bond strength etc. Different research papers are reviewed. The practical use of Bottom ash shows a great contribution to waste minimization as well as resources conservation.**

Keywords: **Bottom Ash, Compressive Strength, Flexural Strength, Splitting Tensile Strength, Workability, bond strength**

I. 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.

A. Need for the Use of fly Ash in Construction

Coal is the product of million of years of decomposing vegetable matter under pressure, and its chemical composition is erratic. In addition electric companies optimize power production from coal using additives such as flue gas conditioners, sodium sulfate, oil and other additives to control corrosion, emission and fouling. The resulting fly ash can have a variable composition and contain several additives as well as products from incomplete combustion. Properly selected fly ash reacts with lime to form CSH-the same cementing product as in Portland cement. This reaction of fly s=ash with lime in concrete improves strength. Special care must be taken in selecting fly ash to ensure improved properties in concrete**.**

B. Bottom Ash

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 utilization of coal ash in normal strength concrete is a new scope in concrete mix design and if put to use on large scale would ameliorate the construction industry, by minimizing the construction cost and abating the ash content. This paper presents the review of various experimental investigations carried out by many the effect of use of replacement for sand, since the use of bottom ash has been limited.

C. Use of Bottom Ash

In comparison to sand, an elementary raw material, the black sandy material obtained is a subsidiary raw material. Using this material is more endurable and environmentally amicable and eludes the use of natural resources such as sand and gravel. Bottom ash is used in following activities

- Road construction

D. Foundation material

- Noise barriers
- Aggregate
- Art Supplies

Fig.1: Fly ash and Bottom ash

I. LITERATURE REVIEW

A. Workability

After P. Aggarwal et al. [1] studied various strength properties for various percentages of replacement of sand with bottom ash, results indicated that workability of concrete decreased with the increase in bottom ash content.

Abdulhameed Umar Abubakar et al.

[3] found that the workability of the concrete in fresh state decreased as the percentage of Coal Bottom Ash increases. P. Tang et al. [5] used Municipal solid waste incarnation Bottom Ash Fines (0-0.2 cm) as aggregate in HPC. Results showed a gradual decrease in workability with the increased replacement bottom ash fines with sand. Remya Raju et al. [9] observed decreased slump values of mixtures with the increase in level of replacement of sand by bottom ash. K.N. Virendra Kumar et al. [10] indicated a decrease in workability by surrogating bottom ash content.

A. Density

According to P. Aggarwal et al. [1] the density of concrete decreased with the increase in bottom ash content due to the low specific gravity of bottom ash as compared to fine aggregates. Experimental investigations from Abdulhameed Umar Abubakar et al. [3] revealed that the air- dried density of the concrete showed a marked decline due to low specific gravity of Coal Bottom Ash. M.P. Kadam et al. [7] detected from his investigation that the density of concrete in hardened state was decreased linearly with increase in ratio of bottom. Tests unveiled that the density of 10

% replacement was increased by 0.04 % for

7 days, and then it was progressively decreased from 2.31% to 13.53%, 1.32% to 16.32%, 2.67% to 14.89% and 1.46% to 18.37% for cube specimen when fine aggregate was replaced from 10 % to 100 % by bottom ash at 7, 28, 56, and 112 days.

K.N. Virendra Kumar et al.[10] spotted the density of concrete is decreased with the increase in % replacement of bottom ash from 0% to 30%, due to the low specific gravity of bottom ash as compared to fine aggregate.

B. Compressive Strength

P. Aggarwal et al. [1] discovered Compressive strength, of fine aggregates replaced bottom ash concrete specimens were lower than control concrete specimens at all the ages. The strength difference between bottom ash concrete specimens and control concrete specimens became less discrete after 28 days. Compressive strength of fine aggregate replaced bottom ash concrete continues to aggrandize with age for all the bottom ash contents. Mix containing 30% and 40% bottom ash, at 90 days, attains the compressive strength equivalent to 108% and 105% of compressive strength of normal concrete at 28 days. The span required to attain the required strength is more for bottom ash concrete.

Corresponding to the research of Mohd Syahrul Hisyam bin Mohd Sani et al.

[2] the compressive strength of concrete mixes made with various % of Washed Bottom Ash as fine aggregate replacement comprehensive of control sample (fully natural sand) was determined at 3, 7, 28, and 60 days of curing. It can be seen that the compressive strength of concrete mixes of sand replacement is much lower than control sample at all tested day.

According to M. Purushothaman et al. [4] Bottom Ash added Concrete mixes showed enhanced compressive strength than the conventional concrete and shows 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. [5] found that 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. [7] 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. [8] 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 38.25kN/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. [9] observed that Compressive strength reduced marginally on the inclusion of bottom ash in concrete.

A. Splitting Tensile Strength

Pursuant to P. Aggarwal et al. [1], Splitting tensile strength of fine aggregates replaced bottom ash concrete specimens were inferior than control concrete specimens at all the ages. Bottom ash concrete procures splitting tensile strength in the range of 121-126% at 90 days of splitting tensile strength of normal concrete at 28 days.

Conforming to P. Bhuvaneshwari et al. [6] 50% replacement of bottom ash with 0.3% glass fibre showed the maximum 7 day and 28 day split tensile strength indicating that concrete mix with 50% bottom is the most optimum. The augmentation of fibres reduces the workability of concrete which was subdued by the addition of bottom ash as replacement of fine aggregate M.P. Kadam et al. [7] found that 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. According to K. Soman at al. [8] there was an increase of split tensile strength by 0.7%, 5.70% and 12.16% at 7 days curing are noted for 10%, 20% and 30 % replacement. For 50% replacement there is a slack of 15.20 % at 7 days curing. At 28 days curing there was an increase in splitting tensile strength for 20% and 30% replacement and only slightly less in 10 % replacement and 20.6% reduction when replacement was 50%.

Remya Raju et al. [9] observed that on the addition of micro silica to Coal bottom Ash (CBA) concrete, there was an improvement in splitting tensile strength of concrete. According to K.N. Virendra Kumar et al. [10] the split tensile strength of concrete for 0%, 5%, 10%, 15%, 20%, 25%, and 30% replacements by bottom ash decreases from 3.5 N/mm² to 2 N/mm² at 7 days, and 5 N/mm² to 2.5 N/mm² at 28 days. For 0% to 15% of replacements, split tensile strength as nearly increased by 75-100% from 7days to 28 days. The split tensile strength gain was decreased slightly as the replacement % increases from 0% to 30%. The decrease in 28 days split tensile strength up to 15% replacement was laggard and behind which it is decreased significantly.

B. Flexural Strength

According to P. Aggarwal et al. [1] flexural strength of sand replaced bottom ash concrete specimens were lower than control concrete specimens at all the ages. The strength difference between bottom ash concrete specimens and control concrete specimens became less distinct after 28 days. Flexural strength of fine aggregate replaced bottom ash concrete continues to increase with age for all the bottom ash contents. M. Purushothaman et al. [4] revealed that the incorporation of 10% silica fume and 40% bottom ash in concrete results in significant improvements in its flexural strength. According to P. Bhuvaneshwari et al. [6], Concrete with 30% replacement of bottom ash with sand showed high flexural strength normal specimen. M.P. Kadam et al. [7] observed that the flexural strength was increased for upto 30 % substitution of bottom ash and after that it was decreased. K. Soman at al.

[8] observed that 30 % replacement of fine aggregate by bottom ash gives equivalent flexural strength at the age of 28 days. There is only a marginal decrease in flexural strength at 10, 20 and 30% replacement levels.

Remya Raju et al. [9] found that the flexural strength of concrete almost linearly decreased as the replacement level of bottom ash was increased.

C. Water Absorption

Investigations from Remya Raju et al. [9] showed that the water absorption of concrete incorporated with bottom ash at 28 days curing age approximately increased linearly with the increase in bottom ash levels in concrete.

D. Bond strength

According to P. Aggarwal et al. [1] Pullout tests were performed to develop an empirical model for the ultimate bond strength by evaluating bond strengths in two different concrete mixes, Pull-out tests on corroded high-strength concrete specimens showed more brittle behavior (sharp decrease in bond strength-slip curve occurred at the peak bond strength. Although this study was based on pullout tests with prepared specimens and may therefore not reflect the actual behavior of reinforced concrete sections under the influence of bending, where both concrete and the reinforcement are in tension, the results and findings of this study are general and may be used directly and as a guide for further studies. L. Butler et al. revealed that the bond strength of the tested specimens was significantly affected not only by the value of hydrostatic pressure acting on the repair material, but also by the way of application of the load to the entire repair system. In the case of horizontal substrates, hydrostatic pressure acts on the concrete surface and press the concrete to the contact surface, causing, generally, growth of bond strength of the repair concrete to the substrate.

P.S. Kumar et al. observed the jackets increase the bond strength and ductile behavior due to the transfer of splitting bonding failure to pull-out bonding failure. For a continuous reinforcement column, the jacket did not contribute to the increase in the flexural strength because the flexural strength depended on the slip and yield of reinforcing bars. Based on the above findings, the thickness of the steel wrapping jacket should be determined from the bonding and confining actions.

II. CONCLUSIONS

The workability of Bottom ash concrete reduces with the increase in bottom ash content due to the increase in water demand.The density of Bottom Ash concrete decreases with the increase in bottom ash content due to the low specific gravity of bottom ash as compared to fine aggregates.Compressive strength of sand replaced bottom ash concrete will be lower than normal concrete specimens at all the ages.Splitting Tensile strength of sand replaced bottom ash concrete will be lower than normal concrete specimens at all the ages.Flexural strength of fine aggregate replaced bottom ash concrete will be lesser than normal concrete specimens at all the ages.Effective splitting tensile strength can be achieved after 90 days compared to normal concrete.Replacing natural fine aggregate with bottom ash, can have a significant effect on bond strength with steel even for similar concrete strength. The strength difference between bottom ash concrete and normal concrete will become less distinct after 28 days.By replacing sand with bottom ash in the range of 30% to 50% bottom ash, at 90 days, attains a higher compressive strength and flexural strength compared to the strength of conventional concrete at 28 days.Water absorption is more Bottom Ash Concrete compared to conventional concreteStrength characteristics of Bottom Ash Concrete can be improved by adding suitable fibers and incorporating other materialsBond strength of concrete can be obtained from stress strain behavior of concretre using bottom ash.The ultimate bond strength by evaluating bond strengths in two different concrete mixes, three concrete cover depths and different mass losses of reinforcement bars after corrosion

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