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Research Paper

REPLACEMENT OF FINE AGGREGATE BY BOTTOM ASH IN CONCRETE

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This project presents the experimental investigations carried out to study the effect of use of bottom ash (the coarser material, which falls into furnace bottom in modern large thermal power plants and constitute about 20% of total ash content of the coal fed in the boilers) as a replacement of fine aggregates. Concrete technology can be improved based on three criteria such as durability, environmental friendliness for the future of concrete industry, cost of materials and construction. The solution for this problem is to use or utilize industrial by-products or solid wastes in producing concrete such as Bottom Ash (BA), Fly Ash (FA), slag, waste glass, silica fume, etc. The various strength properties of the concrete consists of compressive strength, flexural strength and splitting tensile strength. The strength development for various percentages (0-50%) replacement of fine aggregates with bottom ash can easily be equated to the strength development of normal concrete at various ages. Bottom ash is usually described as heterogeneous particles consisting of magnetic and paramagnetic metals, glass, synthetic and natural ceramics, minerals and unburned materials. Reduction in negative effects on economic and environmental problems of concrete industry can be achieved by the use of these concrete technologies to old conventional methods.

Keywords: Effect, Replacement, Bottomash

INTRODUCTION

Concrete is a material synonymous with strength and longevity. It has emerged as the dominant construction material for the infrastructure needs of the twenty-first century. In addition to being durable, concrete is easily prepared and fabricated from readily available constituents and is therefore widely used in all types of structural systems. The challenge for the civil engineering community in the near future is to realize projects in harmony with the concept of sustainable development and this involves the use of high performance materials and products manufactured at reasonable cost with the lowest possible environmental impact energy is the main backbone of modern civilization of the world over, and the electric power from thermal power stations is a major source of energy, in the form of electricity. In India, over 70% of electricity generated in India,

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is by combustion of fossil fuels, out of which nearly 61% is produced by coal-fired plants. This results in the production of roughly 100 ton of ash. Most of the ash has to be disposed off either dry, or wet to an open area.

OBJECTIVES OF THE PRESENT STUDY

The main objectives for this research are:

i. To determine the optimum content of bottom ash as a substitute for fine aggregate (sand) in concrete;

ii. To evaluate the mechanical properties (compressive strength) of concrete containing bottom ash from power plant as sand replacement in concrete; and

iii. To study the porosity of concrete containing bottom ash.

SCOPE OF THE PROJECT

To achieve the aim of the project, necessary and essential on cement, fine aggregate, coarse aggregate, bottom ash and concrete of different mix need to be carried out. These tests required to ascertain the variation, in the behavior of concrete when bottom ash replace sand as fine aggregate, in different proportions, while keeping the quantities of all the ingredients in the concrete mix constant, fine aggregate used for this comparative study are sand as available and bottom ash as available.

BOTTOM ASH

Bottom ash is formed when ash adheres as hot particles to the boiler walls, agglomerates and then falls to the base of the furnace at a temperature around 1200^{0}C (Kim *et al.,* 2006). Hence the term “Bottom Ash” is coarse, with grain sizes spanning from sand to gravel, granular, incombustible by-product, and solid mineral residue.

Depending on the boiler furnace types, the bottom ash collected is classified into two types: dry bottom ash and wet bottom ash (more commonly referred to as boiler slag). The incombustible mineral elements stick together until they are heavy enough causes them to remove from the bottom of the furnaces either in a wet or dry condition and is transported to handling areas by conveyor or pipe. It is angular in shape and ranges in color from a medium brown or medium grey to almost black. Bottom ash is much coarser and more highly fused than fly ash, but has a similar chemical composition to fly ash. It does not have any cementations properties due to its larger sizes.

Utilization of Bottom Ash

Disposal in landfills and surface impoundments is most commonly used coal combustion residues management option. However, there are many alternative uses, such as the use of fly ash in cement. The utilization of coal combustion residues in these productive alternatives has been increasing steadily. The cumulative coal combustion residues utilization rate increased from 24.8% in 1995 (ACAA, 1998) to 38.1% in 2003 (ACAA, 2005a) as markets for coal combustion residues increased.

Problem Of Coal Ash

The value of coal is absolutely opposite by the environmental issues. The negative aspects of mining operation can lead to confirmations among citizen group, government agencies and the mining industry. The conflicts tend to be centered on the following issue:

i. Destruction of landscape

ii. Destruction of agriculture and forest lands

iii. Dust

iv. Sedimentation erosion

PROPERTIES OF BOTTOM ASH

Information regarding the physical, chemical, and engineering properties of coal combustion residues is required before these materials can be safely effectively utilized. The physical and engineering properties, in particular, are important parameters affecting the behavior of coal combustion residues in various engineering applications. Information concerning the chemical composition is important for addressing the potential environmental impacts associated with coal combustion residues utilization and disposal. Most of the researchers has accentuated that bottom ash has quite alterable physical, chemical, and engineering characteristics. It is not only varying from one plant to another, but also from day to day production within a single plant over time.

Therefore, these characteristics reported by researchers just can be taken as references and not absolutes. Power plant's operating parameters play an important role in the validation on the characteristics of bottom ash from a given source. As long as it remains constant, laboratory data tested on these bottom ashes can be recognized as valid. It is important to insure that the samples obtained are representative of the entire supply (National Research Council, 2006). There are two different types of bottom ash: dry bottom ash and wet bottom ash (boiler slag). Basically, wet bottom ash tends to have more regular characteristics than dry bottom ash because of wet bottom ash is solidified from the molten slag while dry bottom ash is the straightforward product of flaming process.

MATERIALS AND METHODS

Cement

Portland cement concrete is foremost among the construction materials used in civil engineering projects around the world. The reasons for its often use are varied, but among the more important are the economic and widespread availability of its constituents, its versatility and adaptability, as evidenced by the many types of construction in which it is used, and the minimal maintenance requirements during service (Mindess et al., 2003). Concrete is unique Among major construction materials in that it is generally designed specifically for a particular, project using locally available materials (Lay, 1990).

Fineness Test

This experiment is carried out to check the proper grinding of cement. The cement which is produced by an industry is checked for its quality, that either it is good for certain type of construction or it doesn't possess that much strength. For example, for RCC and other heavy load bearing structures such as bridges it is essential that the cement which is being used in the concrete should have the ability to provide the required strength, while in the PCC structures it is not so much critical.

The ability to provide strength of a certain type of cement is checked by finding the fineness of that cement, because the fineness of cement is responsible for the rate of hydration and hence the rate of gain of strength and also the rate of evolution of heat.

If the cement is fine then greater is its cohesiveness, which is the property, required in the concrete because it gives compactness to the concrete. Usually cement loses 10% of its strength within one month of its manufacturing.

Sieving Method

This method serves only to demonstrate the presence of coarse cement particles. This method is primarily suited to checking and controlling production process. The fineness of cement is measured by sieving it on standard sieves. The proportion of cement of which the grain sizes are larger than the specified mesh size is thus determined

Standard Consistency Test

Mix about 25% water by weight of dry cement thoroughly to get a cement paste. Total time Take 400 g of cement and place it in the enameled tray taken to obtain thoroughly mixed water cement paste, i.e., “Gauging time” should not be more than 3 to 5 min. Fill the vicatmould, resting upon a glass plate, with this cement paste. After filling the mould completely, smoothen the surface of the paste, making it level with top of the mould. Place the whole assembly (i.e., mould + cement paste + glass plate) under the rod bearing plunger. Lower the plunger gently so as to touch the surface of the test block and quickly release the plunger allowing it to sink into the paste. Measure the depth of penetration and record it.

Prepare trial paste with varying percentages of water content and follow the steps as described above, until the depth of penetration becomes 33 to 35 mm.

Normal consistency of cement = 33%

Setting Time Test

We need to calculate the initial and final setting time as per IS: 4031 (Part 5) – 1988. To do so, we need Vicat apparatus conforming to IS: 5513 – 1976, Balance, whose permissible variation at a load of 1000 g should be +1.0 g, Gauging trowel conforming to IS: 10086 – 1982.

i) Prepare a cement paste by gauging the cement with 0.85 times the water required to give a paste of standard consistency.

ii) Start a stop-watch, the moment water is added to the cement.

iii) Fill the Vicatmould completely with the cement paste gauged as above, the mould resting on a nonporous plate and smooth off the surface of the paste making it level with the top of the mould. The cement block thus prepared in the mould is the test block.

Initial Setting Time

Place the test block under the rod bearing the needle. Lower the needle gently in order to make contact with the surface of the cement paste and release quickly, allowing it to penetrate the test block. Repeat the procedure till the needle fails to pierce the test block to a point 5.0 ± 0.5 mm measured from the bottom of the mould. The time period elapsing between the time, water is added to the cement and the time, the needle fails to pierce the test block by 5.0 ± 0.5 mm measured from the bottom of the mould, is the initial setting time.

Specific Gravity of Cement

1. Determine and record the weight of the empty clean and dry pycnometer, wp.
2. Place 10 g of a dry soil sample (passed through the sieve no. 10) in the pycnometer. Determine and record the weight of the pycnometer containing the dry soil, wps.
3. Add distilled water to fill about half to three-fourth of the pycnometer. Soak the sample for 10 min.
4. Apply a partial vacuum to the contents for 10 min, to remove the entrapped air.
5. Stop the vacuum and carefully remove the vacuum line from pycnometer.
6. Fill the pycnometer with distilled (water to the mark), clean the exterior surface of the pycnometer with a clean, dry cloth. Determine the weight of the pycnometer and contents, wb.
7. Empty the pycnometer and clean it. Then fill it with distilled water only (to the mark). Clean the exterior surface of the pycnometer with a clean, dry cloth. Determine the weight of the pycnometer and distilled water, wa.
8. Empty the pycnometer and clean it.

Specific gravity of cement = 3.15.

Fine Aggregate

The composition of sand is highly variable, depending on the local rock sources and conditions, but the most common constituent of sand in inland continental settings and non-tropical coastal settings is silica (silicon dioxide, or SiO_2), usually in the form of quartz.

The second most common type of sand is calcium carbonate, for example aragonite, which has mostly been created, over the past half billion years, by various forms of life, like coraland shellfish. It is, for example, the primary form of sand apparent in areas where reefs have dominated the ecosystem for millions of years like the Caribbean.

In terms of particle size as used by geologists, sand particles range in diameter from 0.0625 mm (or 1D16 mm) to 2 mm. An individual particle in this range size is termed a sand grain. Sand grains are between gravel (with particles ranging from 2 mm up to 64 mm) and silt (particles smaller than 0.0625 mm down to 0.004 mm). The size specification between sand and gravel has remained constant for more than a century, but particle diameters as small as 0.02 mm were considered sand under the Albert Atterberg standard in use during the early 20th century. A 1953 engineering standard published by the American Association of State Highway and Transportation Officials set the minimum sand size at 0.074 mm. A 1938 specification of the United States Department of Agriculture was 0.05 mm. Sand feels gritty when rubbed between the fingers (silt, by comparison, feels like flour).

Bottom Ash

Bottom ash obtained from thermal power plant at Neyveliin India was used in the investigation. The specific gravity of bottom ash was 1.68.

Physical Properties

Bottom ashes have angular particles with a very porous surface texture. Bottom ash particles range in size from a fine gravel to a fine sand with very low percentages of silt-clay sized particles. The ash is usually a well-graded material, although variations in particle size distribution may be encountered in ash samples taken from the same power plant at different times. Bottom ash is predominantly sand-sized, usually with 50 to 90% passing a 4.75 mm (No. 4) sieve, 10 to 60% passing a 0.42 mm (No. 40) sieve, 0 to 10% passing a 0.075 mm (No. 200) sieve, and a top size usually ranging from 19 mm (3/4 in) to 38.1 mm (1-1/2 in). Table 1 compares the typical gradations of bottom ash and boiler slag.

Table 1: Physical Property of Bottom Ash

S. No	Characteristics	Test Result
1	Colour	Grey to black in colour
2	Specific gravity	1.68
3	Bulk density	1120kg/m3
4	Fineness modulus	2.73

Chemical Properties

Bottom ash and boiler slag are composed principally of silica, alumina, and iron, with smaller percentages of calcium, magnesium, sulfates, and other compounds. The composition of the bottom ash or boiler slag particles is controlled primarily by the source of the coal and not by the type of furnace presents a chemical analysis of selected samples of bottom ash and boiler slag from different coal types and different regions.

Bottom ash or boiler slag derived from lignite or sub-bituminous coals has a higher percentage of calcium than the bottom ash or boiler slag from anthracite or bituminous coals. Although sulfate is usually very low (less than 1.0%), unless pyrites have not been removed from the bottom ash or boiler slag.

Due to the salt content and, in some cases, the low pH of bottom ash and boiler slag, these materials could exhibit corrosive properties. When using bottom ash or boiler slag in an embankment, backfill, sub base, or even possibly in a base course, the potential for corrosion of metal structures that may come in contact with the material is of concern and should be investigated prior to use.

Tests for Bottom Ash

Sieve Analysis

Sieve analysis (or gradation test) is a practice or procedure used (commonly used in civil engineering) to assess the particle size distribution (also called gradation) of a granular material.

Mix Proportions

Five mixture proportions were made. First was control mix (without bottom ash), and the other four mixes contained bottom ash. Fine aggregate (sand) was replaced with bottom ash by weight. The proportions of fine aggregate replaced ranged from 20% to 50%. Mix proportions are given in Table . The controls mix without bottom ash was proportioned as per Indian standard Specifications IS: 10262-1982 to obtain a 28-days cube compressive strength of 33.3 MPa. Hand mixing was done for the concrete mixes.

Preparation and Casting of Test Specimens

The 150 mm concrete cubes were cast for compressive strength, 150 × 300 mm cylinders for splitting tensile strength and 101.4 × 101.4 × 508 mm beams for flexural strength. After casting, all the test specimens were finished with a steel trowel. All the test specimens were stored at temperature of about 30^{o}C in the casting room. They were demolded after 24 h, and were put into a water-curing tank.

RESULTS AND DISCUSSION

The various aspects studied include (i) the effect of bottom ash on workability (Compaction Factor) of fresh concrete; (ii) the effect on compressive, flexural and splitting tensile strength using bottom ash in varying percentages as a partial replacement of fine aggregates.

Compressive Strength

Compressive strength of concrete mixes made with and without bottom ash was determined at 7, 28, 56, 90 days. The test results are given in Table 1 and Figures 1a and 1b. The gain of compressive strength by different types of bottom ash concrete with respect to their compressive strength at the age of 90 days varies from 56-65% at 7 days 75-85% at 28 days and varies between 86-90% at 56 days. The bottom ash concrete gains strength at a slower rate in the initial period and acquires strength at Splitting Tensile Strength of the Concrete with age.

Figure 1: Compressive Strength of Concrete Mixes Mad with Bottom Ash

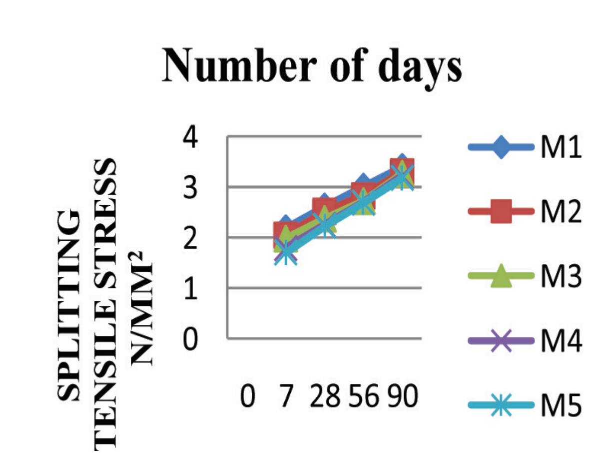
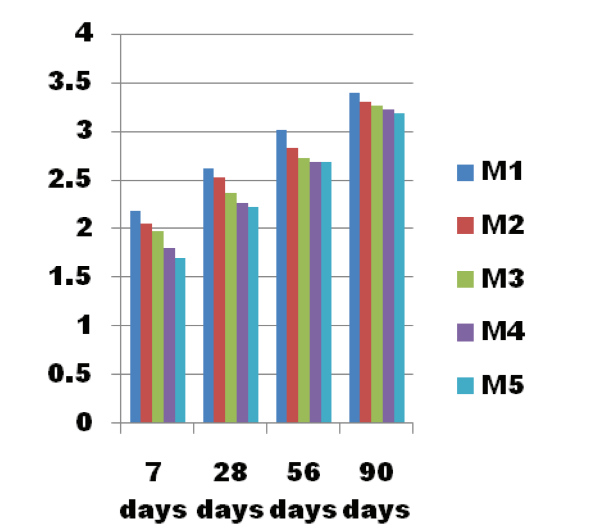


Figure 2: Compressive Strength of Concrete Mixes Mad without Bottom Ash



CONCLUSION

The workability of concrete decreased with the increase in bottom ash content due to the increase in water demand, which is incorporated by increasing the content of superplasticizer. 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.

Compressive strength, Splitting tensile strength and Flexural 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 distinct after 28 days.

Compressive strength, Splitting tensile strength and Flexural strength of fine aggregate replaced bottom ash concrete continue to increase 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 and attains flexural strength in the range of 113-118% at 90 days of flexural strength of normal concrete at 28 days. The time required to attain the required strength is more for bottom ash concrete.

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