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# A STUDY ON EFFECT OF COAL BOTTOM ASH/BOILER SLAG ON STRENGTH AND DURABILITY PROPERTIES OF CONCRETE

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**ABSTRACT**

Each year, India generates almost 30 million metric tonnes of coal bottom ash/boiler slag (CBA). Communities in the area are put at risk due to the dumping of ash from adjacent thermal power facilities. CBA disposal issues may be effectively mitigated by its productive use.

This research is being done to determine how practical it would be to use CBA as natural fine aggregate (NFA) in construction projects. The compressive strength (CS) of both Concrete 'A' and Concrete 'B' was planned to be 38N/mm2 and 34N/mm2, respectively. CBA is used to substitute NFA in the two kinds of concrete at varying percentages (20, 30, 40, 50, 75, and 100). The freshness of concrete is tested for its workability. At 90 days of age, samples were tested for acid and sulphate resistance, as well as CS and cracking split tensile strengths (TS). CBA may be successfully used as a fine aggregate substitute in both types of concrete, as shown by the test results. CBA concrete mixes exhibited reduced CS at 7 days. In comparison to the control concrete (CC) mixes' 38.20 and 34.0 N/mm2, the CS of the CBA concrete ranged from 35.0 to 37.5 N/mm2 for Mixs 'A' concrete and from 26.7 to 32.2 N/mm2 for mixes 'B' concete after 28 days. CBA concrete combinations had a greater rise in CS over time than normal concrete mixtures. After 90 days, the CS of both the CBA concrete combination and the CC mixture (mixtures 'A' and 'B') are quite close to one another.

Concrete mixture 'A' had a TS ranging from 2.72 to 2.96N/mm2 after 28 days, whereas Concrete mixture 'B' had a strength ranging from 2.16 to 2.52N/mm2. Both Concrete 'A' and 'B,' made from the control mixture, had TS of 2.67N/mm2 after 28 days. CBA concrete mixes 'A' and 'B' had TS equivalent to or greater than the corresponding CC mixtures after 90 days. Under external sulphate treatment, both grades of CBA concrete expanded more than standard concrete, although the overall stresses were far below the 0.1 percent threshold at which CS begins to decrease. CS after 28 days showed no signs of deterioration .

## I. INTRODUCTION

This section serves as a primer on the manufacturing process and chemical composition of CBA. CBA effects on the environment, its versatility, and the motivation for this study are all emphasised.

### 1.1 PREAMBLE

Many industries produce different types of solid waste materials. It's dangerous for the local ecosystem to have these solid waste products dumped there. Researching solutions to the issues of solid waste disposal is the most efficient way to put these resources to use. The potential for recycling and reusing trash in the building sector is huge. The solid waste materials may be employed as fine/coarse aggregate replacement or as extra cementitious materials in concrete, depending on their qualities. Industrial waste products, such as silica fume, metakaolin, fly ash, slag etc., have been used.

About 76% of India's energy needs are met by coal-fired thermal power plants (CEA, 2012). Annually, the nation's need for electricity grows. There is now a 6.7% nationwide energy shortfall, with the southern region experiencing a much higher

26.7 % deficit (CEA, 2012). Coal fueled thermal power stations are being built all throughout the nation in order to close the existing power deficit and satisfy growing energy demands. Large quantities of CBA are generated by thermal power plants that burn coal as fuel. Up until recently, it has been regarded as garbage and dumped on fields.

An estimated coal ash of 57.63% from coal fueled thermal power stations is utilised in cement manufacture, brick and tile industrial, building of ash dykes, and reclamation of low lying regions (Central Electricity Authority, India, 2014). Cement and bricks rely on fly ash as a key ingredient in their production. However, CBA are not used in any way. CBA are being dumped in large quantities close to where power plants are located. CBA that has been illegally deposited on open ground poses threats to the local ecology and human population. However, there is a huge demand for NFA as a building material due to an increase in infrastructure construction in the nation. When making concrete, NFA is the go-to natural NFA ingredient. There is a limited amount NFA, and it is being mined at an unsustainable pace. There is a slow but steady depletion of the natural resources. Furthermore, the ecological system becomes unbalanced as a consequence of the use of natural resources. In order to keep the country's NFA clean, several Indian states have outlawed fine aggregate mining. As a result, the cost of NFA has increased to the point that it now exceeds that of coarse aggregate. As a result, the shortage of NFA has had a significant impact on the building sector. Finding a suitable replacement for NFA in order to preserve our finite natural resource stock is, therefore, of paramount importance at the current time. The goal of this study was to look at replacing NFA with low-calcium CBA in building. CBA slag looks like NFA and has the same size particles. CBA, due to their physical qualities, may be utilised as NFA in concrete in place of NFA. CBA has been studied and used as NFA in recent years. CBA is a substance that may be used as a fine aggregate substitute in concrete, according to the study data, which is limited to strength qualities alone. Ecological worries concerning the disposal of CBA and the depletion of NFA led to the current study. The foremost objective of this investigate was to see whether low-calcium CBA could be used for anything.

**1.2 COAL BOTTOM ASH**

CBA is what's left behind after coal is burned. When coal is pulverised, the solid debris that had previously filled in the fissures is removed. Coal ash is the byproduct of coal and other non-combustible materials in a furnaces. The ash is carried by the whirling air out from the thermal region, where it cools. The boiler's flue gas removes the lighter, finer coal ash particles. Before being released into the atmosphere, boiler fuel gases are treated by electrostatic precipitators. Electrostatic precipitators filter coal ash from boiler exhaust gases. Fly ash refers to the byproduct of electrostatic precipitators that consists of coal ash. About 80% of coal ash is made up of fly ash. Clinkers are formed when tiny bits of ash coal from the combustion process stick to the furnace steam pipes and walls. CBA refers to the ash that settles to the bottom of a furnace or boiler. The majority (80%) of coal ash is fly ash, whereas the remaining 20% is CBA.

As of right now, India is the world's third-biggest user of coal. Annually, coal powered thermal power plants use around 524 million tonnes of coal (CEA, 2014). They are the primary means through which coal ash is generated. The increased ash concentration of Indian coals—up to 45 percent, depending on the coal's origin—results in substantial amounts of coal ash (CEA, 2014). Coal ash output is predicted to reach over 220 million tonnes annually with the installation of 982 GW in capacity by the end of 2021. The generation of coal ash in a coal fueled thermal power station is shown in Fig. 1.1.

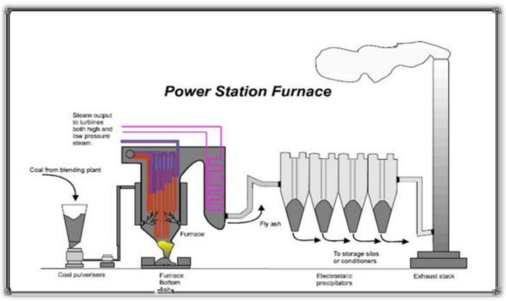


Figure 1.1 Production of coal bottom ash/boiler slag

**1.2.1 Physical Properties of Coal bottom ash**

CBA have been found in coal beds cracks with fragments of rock. CBA has different characteristics because rock debris varies from location to location. CBA characteristics are affected by the following:- Coal pulverisation level furnaces burning temperature Form of heat source

Particles of CBA are angular, uneven, porous, and rough on the surface. CBA consists of particles as small as fine aggregate or as large as fine gravel. Although particle size distribution variances from the same power plant are uncommon, CBA is often a well-graded material. CBA consists of particles with a high degree of interlocking properties. When compared to NFA, CBA is both lighter and more brittle. Bottom ash from coal may have a specific gravity anywhere from 1.2 to 2.47, based on the coal used. Low-specific-gravity CBA has a porous structure that rapidly deteriorates when compressed or loaded. CBA from high coal and low rank coal are quite impermeable and dense. CBA physical characteristics have been shown to vary widely.

**1.2.2 Chemical Properties of Coal bottom ash/boiler slag**

Calcium oxide is abundant in the ash left behind after burning lignite. In addition to its pozzolanic capabilities, this coal ash also acts as a cementitious material. Low-calcium coal ash is produced when anthracite or bituminous coals are burned; this ash has pozzolanic characteristics and a negligible amount of calcium oxide (ASTM C 618-03). Silica, alumina, and iron make up the bulk of CBA, along with trace quantities of other elements like calcium, magnesium, sulphate, etc. The coal's chemistry is determined by its origin. CBA has a wide range of chemical compositions, as shown by the data presented in the published literature.

**Mineralogy Characteristics of Coal bottom ash/boiler slag**

Pure CBA was analysed by X-ray diffraction (XRD) and found to be composed mostly of mullite, silicon oxide, and silicon phosphate. They found silica in two different crystalline forms: quartz and mullite ($SiO_2$ + alumina). Magnetite ($Fe_3O_4$) and hematite ($Fe_2O_3$) are two iron oxides that may be found in nature ($Fe_2O_3$). CBA varies in composition based on coal type and furnace operating conditions. Glass and mullite may be created when the alumino silicates like clays melt or break down ($Al_6Si_2O_{13}$). Lime, calcium ferrite, hematite, magnetite, and periclase are all byproducts of the breakdown of carbonates like calcite, dolomite, ankerite, and siderite, which emit carbon dioxide. In the process of oxidation, sulphides like pyrite ($FeS_2$) lose $SO_2$ and transform into sulphates ($SO_3$). Chlorides evaporate as NaCl and KCl, iron oxides. In most cases, quartz does not change.

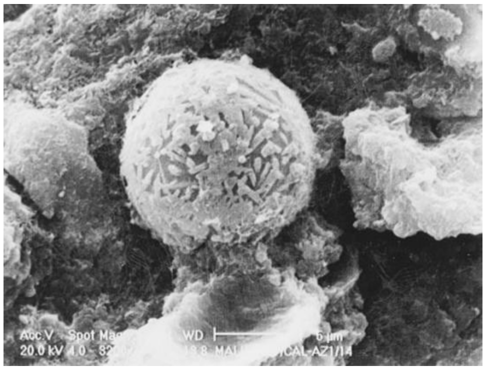

Figure 1.2 CBA particle starting to react with $Ca(OH)_2$ (Cheriaf et al1999)

**Disposal of Coal Ash**

The location for coal ash disposal is revealed in Fig. 1.3. Ash from coal-fired power stations is sluiced to ash ponds close by for decantation and drying. The slurry is roughly 80% water. FA collected in dry form at certain thermal power facilities and distributed to different customers. Ash ponds are where waste materials like FA and CBA go to be disposed of. Coal ash landfills take up huge swaths of land. Six coal-fired thermal power facilities in the Indian state of Punjab utilise large swaths of valuable farmland to dispose of their coal ash.

*Figure 1.3 Coal ash 24isposal site Andhra Pradesh slurry from NTPC ash pond*

**Environmental Impact of Coal bottom ash/boiler slag**

CBA dumped in ponds is harmful to both humans and the environment. CBA include contaminants that may seep into the ground and damage drinking water. Coal ash may leak from ash dykes and spread into the land around ash ponds in the United States (www.sourcewatch.org). There have been reports of similar dike collapses at the Rajiv Gandhi thermal power (RGTP) plant in Hissar, Haryana (India) in 2012 and at the NTPC Simhadri facility in Vishakhapatnam (India) in 2010. Crop damage occurred at Hirakud due to a rupture in the ash dykes of the Hindalco captive power plant in 2012. (India). caused thoufine aggregates of tonnes of coal ash to pour into the Satluj NFA. Ropar repeatedly broke through the GGSSTP's ash dykes.

*Figure 1.4 Coal ash dyke spill at Kingston plant, USA*

Coal ash dumps have created dunes that pose a threat to the local ecosystem. Coal ash poses serious environmental risks, therefore it's important to find useful use for it and come up with solutions to slow its buildup. The only environmentally benign answer to the challenges connected with coal ash dumping is the productive exploitation of the coal ash.

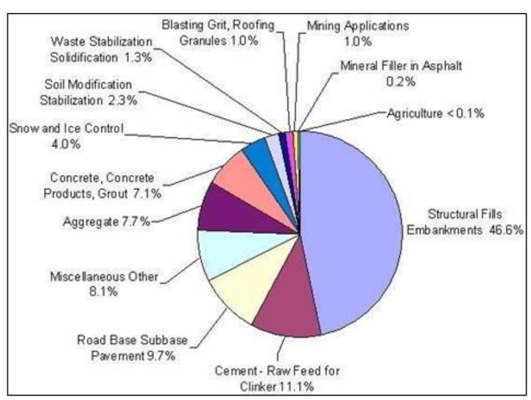


Figure 1.5 CBA applications as a percentage of toyals reused(ACAA,2006)

## II. LITERATURE REVIEW

This chapter describe a complete study of the literature concerning the use of waste materials in concrete as either an additive to cement or a replacement for aggregate. In this chapter, we take a close look at the studies completed to far on the effects of replacing some or all of the NFA in concrete with CBA.

**WASTE MATERIALS**

Numerous economic activities generate a wide variety of solid waste. The question of how to dispose of all of this trash effectively is one of the most important environmental challenges. Repurposing this trash might help ease the burden of clearing it out. The market's willingness and capacity to absorb industrial waste is crucial to the health of many industries. There is a broad variety of applications for the solid waste products that may be found depending on their composition. In the building industry, there is a huge window of opportunity to put waste materials to good use. Depending on the quality of the waste material, it may be possible to utilise it in place of or in addition to aggregate in construction materials like concrete and mortar. The government should provide financial incentives to businesses that produce high-quality byproducts in a sustainable manner.

Meat and bone meal (MBM), CBA, recycled aggregate, waste foundry fine aggregate, and copper slag are only some of the alternative aggregate sources that have been used in concrete production. The literature discusses the use of scraps such as shattered bricks. This article provides a brief overview of the studies conducted on the topic of replacing natural aggregates with solid waste in concrete.

**Use of Cement Slag and Other Waste Products as Filler**

The first country like Romans have waste materials like volcanic ash into concrete as a pozzolanic element. In 1937, studies on the usefulness of fly ash as a pozzolanic ingredient were published. At the Didcot Power Station in the United States, fly ash was initially utilised in the construction of admittance roads and the RCC oil tank in 1981 and 1982. (Dustan, 1983). Cement made from fly ash wasn't mass-produced in India until the early 1990s. In place of cement, materials like metakaolin (MK), GGBS, and silica fume may be used to make mortar and concrete (SF).

Using waste components such GGBS, FA, and SF in concrete decreased chloride permeability, according to studies by Mishra et al. (1994). Utilizing FA and SF as cement supplementary materials, Khan and Lynsdale (2002) created high performance concrete with excellent strength and permeability characteristics while using 8-12 percent SF as cement replacement. They discovered that the CS of concrete dropped when using fly ash alone, but that the strength of high- performance concrete rose when utilising fly ash in combination with 10 percent silica fume. Over a 10% silica fume addition, CS did not improve.

Younsi et al. discovered that the hydration time of concrete was lengthened when FA or GGBS was used in place of cement (2013). When FA or GGBS was added to concrete, the content of portlandite decreased. Water-cured concrete with mineral additions had a finer pore structure and less resistance to fast carbonation associated to the concrete standard.

A mix design for the manufacture of self-compacting concrete (SCC) with FA and SF was proposed by Hemalatha et al. (2014a) after they accounted for the delayed strength increase of SCC with these additives after 28 days of curing age. The increased particle concentration in SCC causes the interfacial transitional zone in concrete to shrink with time, as discovered by Hemalatha et al. (2014b). Significant changes in micro and macro features were seen in SCC containing FA and SF after curing, but SCC devoid of FA and SF saw no such changes.

Khatib et al. (2014) discovered that replacing 10% of the cement with MK provided the greatest boost to the CS of mortar. More than a 20% material replacement did not increase CS. CS of mortar with 20% MK may improve by as much as 50% when compared to mortar without MK. Khatib, et al. (2012). CS falls at younger ages if GGBFS is substituted for cement in concrete. To compensate for early age CS reduction after curing, 10% metakaolin was used (Khatib and Hibbert, 2005). With the addition of MK, the strength of concrete is improved significantly after just 14 days of hydration.

According to Figueiredo et al., using metakaolin as a cement replacement has shown good results in shielding concrete against chloride attack (2014). Paiva et al. studied how metakaolin dispersion affected fresh and cured concrete properties (2012). Using metakaolin as a cement substitute led to an increase in concrete porosity and water use. The metakaolin's pozzolanic action prevented the agglomeration from lowering the concrete's CS. When water-reducing agents were utilised, the CS increased by 30 percent, and the porosity decreased by 30 percent, when metakaolin was substituted for 30 percent of the cement.

According to Tripathy and Barai, autoclave cured mortars with up to 40% cement substitution with crusher stone dust had CS that were equal to or higher than those of the reference normal cured mortar (2006).

**Waste Materials as Aggregate**

Research conducted by Siddique (2003a, b) found that increasing the ratio of flyash to fine aggregate increased the concrete's CS but lowered its abrasion resistance when used as a NFA substitute in concrete. Cyr et al. found that MBM CBA may be utilised as a fine aggregate substitute in mortars (2005). Substituting up to 17 percent MBM CBA for fine aggregate in mortar may provide comparable CS.

Cyr et al. (2006) found that the addition of rubber fine aggregate to concrete increased strain by 25percent of the total but decreased CS. Cachim et al. (2014) suggest that in the manufacturing of concrete from C&D garbage, ceramic debris, copper slag, and plastic debris, recycled aggregate may be utilised to partially replace aggregate. Up to a 15% replacement rate for natural aggregate, Cachim (2009) found that concrete constructed using crushed bricks had almost the same strength and stiffness attributes as conventional concrete. The performance of the concrete decreased when natural aggregates were used to replace 30 percent of the cement. The mechanical characteristics of concrete were investigated by Khatib (2005), who looked at how using recycled material as NFA. He found that recycledaggregate concrete generated strength at a faster pace than CC after 28 days of curing. Evangelista and Brito (2007) found that including up to 30 percent of fine recycled material into concrete did not detract from the material's mechanical properties.

Khatib and Ellis investigated the possibility of utilising foundry fine aggregate as NFA in concrete (2001). Researchers noted a decrease in CS and drying shrinkage while using foundry fine aggregate as NFA in concrete. CS, TS, EM, and flexural strength (FS) of prism were all found to be somewhat improved when foundry fine aggregate was used as NFA, according to research by Siddique et al (2009).

Both the CS and TS of concrete were shown to decrease with increasing concentrations of foundry fine aggregate, as proven by Guney et al (2010). Ten percent foundry fine aggregate as NFA does not meaningly alter the CS of concretecompared to regular concrete.

Menadi et al. (2009) discovered that using 15% CaO dust as NFA in concrete decreased CS while increasing gas permeability and chloride ion penetration. Lime stone dust at 15% reduced water permeability in concrete but had no effect on capillary water absorption.

Sahu et al. (2003) reported that the CS, TS, and EM of concrete were all improved by utilising up to 40 percent stone dust as NFA.

The CS and water absorption properties of concrete made with 25% SSA as NFA were both determined to be comparable to those of the reference concrete (Kosior- Kazberuk, 2011).

The strength and durability of concrete, say Yuksel et al. (2006), are determined by the GGBFS/fine aggregate ratio. Although GGBFS decreased concrete's strength, itgreatly improved its durability.

## III. OBJECTIVES AND SCOPE OF WORK

### 3.1 SIGNIFICANCE OF WORK

The major causes of environmental degradation are I the buildup of industrial waste products and (ii) the overexploitation of finite natural resources. Coal ash is becoming an environmental issue in India and other developing nations as vast quantities collect around coal-fired power station facilities. Across the globe, there has been a rising pattern of recycling and reusing unwanted items. Cement and concrete factories have been using fly ash for a long time. Therefore, research into the potential use of CBA and boiler slag in concrete is essential. High-calcium CBA has been the focus of certain studies as a potential NFA for use in construction materials like concrete. However, there has been little to no progressin this area in India. There is not enough information in the literature to make effective use of CBA. As a result, boiler slag and CBA are not used in any way. CBA and boiler slag may be recycled and reused as building material while also helping to reduce waste and conserve scarce natural resources. Whether or not a manufactured good is used may have a significant impact on a country's economy and ecology. This is especially true in the building sector.

### 3.2 GAP IN THE WORK AREA

Publication on the use of low-calcium CBA as NFA in concrete is few, and what does exist focuses mostly on the material's impact on concrete's strength. When compared to CBA investigated in other countries, that generated in India lacks cementitious property, has low- calcium oxide level, and has a low specific gravity. NFA in concrete made from Indian CBA has not been the subject of any prior research. Before it can be generally recognised as a raw construction material to be utilised in the manufacturing of structural concrete, research into the strength and durability features of concrete using low-calcium CBA as NFA is necessary.

### 3.3 OBJECTIVES AND SCOPE OF WORK

- The following are the primary aims of this work:
- Test how using CBA in lieu of NFA affects the qualities of newly pouredconcrete.
- Determine how the strength parameters of cured concrete change when CBA is used as a partial or complete substitute for NFA.

The following are all within the purview of this paper:

- Materials description
- Mixture layout for regular concrete construction
- A variety of concretes with variable amounts of fine aggregate

replacement areprepared.

- CBA and boiler slag concrete mixture qualities were compared to those of freshly mixed CC.
- CBA concrete combinations and CC samples were cast.
- Strength characteristics of hardened CC and concrete mixes made from CBA and boiler slag were tested.

## IV. EXPERIMENTAL PROGRAM

In the following sections, we will discuss the testing procedures that were utilised in this investigation to provide an accurate portrayal of the components that go into the production of concrete. The potential impact of substituting CBA with NFA is briefly discussed.

### 4.1 INTRODUCTION

The experimental programmer chosen for this investigation is shown schematically in Figure 4.1; it begins with a battery of laboratory tests to evaluate the materials' qualities, then moves on to casting and curing of specimens. The impact of using CBA in place of fine aggregate is investigated by testing cured specimens in accordance with statutory requirements. The procedure to begin this research is laid out in full.

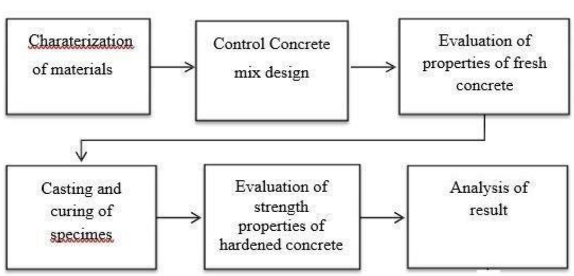


Figure 4.1: Schematic diagram of experimental program

### 4.2 CHARACTERIZATION OF MATERIALS

**Cement**

The cement used in this research of Grade 43 that meets the requirements of BIS: 8112-1989. This binding material's physical qualities are measured in accordance with BIS: 4031-1988, including its consistency, CS, and setting times.

**a) Consistency**

The standard consistency of any given cement paste is that produced by inserting a vicat plunger. The method used to do this is in line with BIS: 4031 (Part-4)-1988. To conduct the test, just mix 300 grammes of dry cement with enough water to produce a paste. After gently shaking the mould to release any trapped air, the top surface was levelled using a trowel. The vicat apparatus has the mould and non-porous plate inserted in it. The Vicat machine's plunger is affixed to a rod bearing. In order to puncture the cement paste, the plunger was gently lowered until it touched the surface, and then abruptly released. The proportion of water used in Steps 1 through 3 should be adjusted until the paste reaches the desired consistency.

**b) Setting times**

The initial and ultimate setting times of cement are measured using tests that adhere to BIS: 4031 (Part-5)-1988. Per the statute, tidy cement paste was made by measuring the cement with 0.85 times the amount of water called for to get the typical consistency. To do this particular evaluation, vicat equipment is used. Having created a cement paste, it was poured into the mould and any excess was smoothed off with a trowel. Both the mould and the non-porous plate are installed in the vicat machine. The cement paste was pierced by gently lowering the plunger until it just touched the surface, and then rapidly releasing it. The foregoing procedures were repeated until the needle could no longer enter the block at a depth of at least 5.0 0.5 mm, as measured from the base of the mould.

For accurate final-setting time monitoring, you'll need to swap out the needle's annular attachment. After leaving the test block for final setup, sometimes the annular collar attachment is dropped softly to the surface of the test block but does not leave an imprint. Time from when water is applied to the cement until the collar arrangement does not leave an imprint is the cement's ultimate setting time.

**c) Compression strength**

Cubes of 69.5 mm, 69.5 mm, and 69.5 mm in accordance with BIS:4031 (Part-6)- 1988 are used in the test. Fine aggregate meets or exceeds BIS: 650-1966 specifications. A dry mix of 300 kilos of cement and 600 grammes of fine aggregate is required to produce the specimens. The ratio of ingredients used is 1:3. The proportion of water to fine aggregate and cement mass should be (P/4+3.0). After the moulds were filled, table vibrators were used to crush the material for two minutes, yielding the final specimens. After 24 hours, the cubes were unmolded and placed in a water bath to cure. The specimens are compressed under a continuous pressure of 35 N/ mm2/ min in a compression testing equipment.

Natural fine aggregate (NFA) and Coal bottom ash/boiler slag

This research makes use of NFA derived from two different sources: NFA and rock that falls into zones III and II, respectively, of the BIS 383-1960 classification system. CBA and NFA were both sieved using a 4.75 mm mesh. These materials were subjected to the preliminary tests outlined in BIS: 2386 (Part I and II)-1963, including particle size distribution, specific gravity, and water absorption.

**Coarse Aggregate**

Important tests were performed to evaluate the physical qualities of 20-millimeter- or smaller Crushed stone coarse aggregate utilised in this research. The physical properties of coarse aggregate is evaluated as per BIS: 2386 Part III- 1963 compliant coarse aggregate were measured and analysed. Roughly three thoufine aggregate kilos of coarse aggregate were immersed in water for a whole day. After that, the samples are left out until there is no longer any detectable moisture on the surface at room temperature.

**MIX DESIGN**

Concrete 'A' and Concrete 'B' were used as controls; they were both formulated to attain a 28-day CS of 38.0 and 34.0 N/mm2, respectively, in accordance with the specifications outlined in BIS 10262-2019. The NFA used to make the Concrete 'A' had a fineness modulus of 1.97 and fell within Zone III of the BIS: 383-1970 classification system. Quarry fine aggregate meeting the requirements of Zone II of BIS: 383-1970 and with a fineness modulus of 2.58 was used in the production of concrete 'B.

Concrete A

CS at 28 days = 30 N/mm2

The Quality Control Level Is AcceptableCoarse Aggregate Size Limit Set at 20mm Compactibility Factor = 0.9, or very workable. Exposure Level = Low

CS goal on day 28 = 38 N/mm2

Concrete B

CS at 28 days = 25 N/mm2

The Quality Control Level Is Acceptable Coarse Aggregate Size Limit Set at 20mm Compactibility Factor = 0.9, or very workable. Exposure Level = Low

Goal CS in 28 days = 34 N/mm2

Table 4.1 Mix Proportions of control concrete.

| Mix | Fine aggregate Conforms to grading zone as perIS 383-1970 | Water Cement Ratio | Cement (kg/m³) | Fine aggregate (kg/m³) | Aggregate (kg/m³) | Water | Super Plasticizer (kg/m³) |
|---|---|---|---|---|---|---|---|
| Concrete A | III | 0.45 | 479 | 479 | 1175 | 215.5 | - |
| Concrete B | II | 0.5 | 400 | 520 | 1200 | 200 | 2.0 |

## CASTING AND CURING OF SPECIMENS

To make concrete, we utilised a mixer with a 0.06m3 capacity. Cement, fine aggregate, and CBA were measured out and dry mixed until a consistent colour and texture were attained, with no cement lumps visible. The mixture is then evenly mixed following the addition of coarse aggregate. The water is split in half based on the proportions specified by the design. The super plasticizer was diluted in some of the water, and then the two liquids were combined in a blender. In order to get a consistent blend, a gauging time of at least 5 minutes is recommended. Select and properly grease all 150 mm x 150 mm x 150 mm cube examples over which concrete will be poured. CS will be measured using these samples, both submerged and unsubmerged in sulphate solution. In addition, concrete's modulus of elasticity was calculated by casting cylinders of 150 mm and 300 mm in diameter. The sorptivity, chloride ion penetration, and water loss from air drying were all estimated by casting a second set of cylindrical specimens (100 mm x 200 mm). A 100 mm 100 mm 100 mm specimen was cast to measure the effects of an external acid assault. Prism specimens measuring 75 mm x 285 mm were then constructed to determine the length change caused by air drying and subsequent immersion in a sulphate solution. Tiles measuring 300 mm × 300 mm were produced from concrete to test its abrasion resistance. After adding water to the concrete mixture for 24 hours, these samples are starting to take shape in themould. After being removed from their moulds, the specimens were cured at room temperature in water. The specimens are shown in Figs. 3.2.

Figure 4.2 Casting of concrete cubes for CS

## TEST PROCEDURE FOR EVALUATION OF PROPERTIES OFCONCRETE

This section provides a summary of the processes used to evaluate the various characteristics of concrete, both in their uncured and cured states, as part of this research.

### Workability

The Indian standard BIS: 1199-1959 specifies a process for determining the new concrete's workability through the slump test and the compaction factor test.

**a) Slump Test**

After thoroughly cleaning the interior of the mould, fill it with concrete in four separate levels. Each layer should be compacted with 25 strikes from a tamping bar with a diameter of 16 mm. The blows must be distributed evenly over the mold's cross area. After the top layer of concrete has been tamped down, the surplus loose filled mass should be knocked off using a trowel. see Fig. 3.4 for an illustration of this process.

Figure 4.3 Slump of fresh concrete

## V. RESULTS AND DISCUSSION

### 5.1 INTRODUCTION

Anastylosis CBA as a partial or entire replacement of NFA is discussed in this chapter, along with the characterisation of materials, test results, and qualities of new concrete, and the strength of hardened concrete mixes.

### 5.2 CHARACTERIZATION OF MATERIALS

**Cement**

The properties of cement tested results are tabulated in Table 5.1. The Cement usedin present work has is satisfied as per BIS 8112- 1989.

| Physical properties | | |
|---|---|---|
| Property | Test result | BIS value |
| Fineness ( $m^2/kg$) | 278.6 | > 225 |
| Initial setting time (min) | 125 | > 30 |
| Final setting time (min) | 175 | < 600 |
| CS ($N/mm^2$) | | |
| Consistency (%) | 28 | |

Table 5.1 Physical Properties of Cement

**NATURAL FINE AGGREGATE AND COARSE AGGREGATE**

The physical properties of the aggregate are presented in table 5.2

Table 5.2 Physical properties of fine aggregate, CBA and coarse aggregate.

| Property | Natural fine aggregate | Quarry fine aggregate | Coal bottom Ash | Coarse aggregate |
|---|---|---|---|---|
| Specific gravity | 2.60 | 2.59 | 1.39 | 2.68 |
| Water absorption by Mass (%) | 2.46 | 2.06 | 31.58 | 0.38 |
| Fineness modulus | 1.97 | 2.76 | 1.37 | 6.28 |

### 5.1 PROPERTIES OF CONCRETE MADE WITH FINE AGGREGATE (Concrete 'A')

#### 5.1.1 Mix Proportions

The CC mixture was fallowed as per BIS: 10262-1982 to obtaine strength of 38.0N/mm2 at 28 days o f curing .Zone III fine aggregate is used in CC as per BIS 383-1960.The mix is represented as concrete 'A' and its details are shown in Table 5.3. Both NFA and CBA oven dried at 1000 C and cooled at room temperature for 24+1 hr respectively before use in concrete mixtures. As CBA has lesser waterretention capacity it is composed in wet state from thermal power plant and dried in oven. The measurement of actual absorption of water is difficult by CBA in mixing process. So that the amount of water supplied to each mixture was constant and the unit water content did not change. The NFA was substitute with CBA in concrete by mass at 20%, 30%,40%,50%,75% and 100% level.

Table 5.3 Mix proportions of concrete (concrete 'A').

| Mix | Ceme nt (kg/m³) | w/c ratio | FA (kg/ m³) | FA replacement level(%) | Coal bottom ash (kg/m³) | Coarse aggregate (kg/m³) | Water (kg/m³) |
|---|---|---|---|---|---|---|---|
| Control concrete | 479 | 0.45 | 479 | 0 | 0 | 1175 | 215.55 |
| A20 | 479 | 0.45 | 383.2 | 20 | 51.22 | 1175 | 215.55 |
| A30 | 479 | 0.45 | 334.6 | 30 | 76.82 | 1175 | 215.55 |
| A40 | 479 | 0.45 | 287.4 | 40 | 102.43 | 1175 | 215.55 |
| A50 | 479 | 0.45 | 239.5 | 50 | 128.04 | 1175 | 215.55 |
| A75 | 479 | 0.45 | 119.75 | 75 | 192.06 | 1175 | 215.55 |
| A100 | 479 | 0.45 | 0 | 100 | 256.08 | 1175 | 215.55 |

**Properties of Fresh Concrete**

**Workability**

Concrete's workability refers to how well and consistently it can be mixed, poured, compacted, and finished once it has been mixed. With enough force, it may overcome resistance and lead to complete consolidation. The new concrete mixture's consistency is the determining factor here. Concrete slump is a quality control indicator. No universally accepted test exists for homogeneity. Slump test and compaction test are used to determine the workability.

**Slump test**

According to the findings of the tests (Fig. 5.1), the slump values of concrete mixes comprised of CBA and boiler slag decrease as the proportions of each component increase. According to Table 5.3, CBA has a greater water absorption rate than NFA. When compared to NFA, the porous particles of CBA absorb water much more quickly during the mixing process. When NFA is replaced by CBA, the specific area of the aggregate is enhanced. This was caused by factors such as the coarse texture and angular shape of CBA particles. Slump value has been shown to rise with increasing statured surface area by many researchers, including Aramraks(2006), Andrade(2009), and Chun(2008). The amount of water absorbed is 29%. In contrast, the CBA employed here has particles that are angular in form, rough in texture, and porous; 17.2 percent of these particles are finer than 150 m.

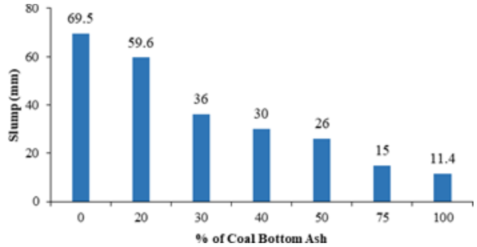


Figure 5.1: Effect of CBA on slump values of concrete (Concrete 'A')

## VI. CONCLUSSIONS

This research looks at how replacing some or all of the fine particles in freshly mixed concrete with low-calcium CBA and boiler slag affects the material's strength and other qualities. Workability, CS, TS, and acid resistance are some of the concrete qualities investigated. According to the findings of the tests conducted, low-calcium CBA may be utilised as a NFA in the manufacture of concrete. The following inferences may be made from the analysed test data.

**PROPERTIES OF FRESH CONCRETE**

Properties like as workability in new concrete made with low- calcium CBA are shown here, as well as others that have not before been described.

**Workability**

When used as a fine aggregate substitute in concrete, CBA and boiler slag reduced the material's workability. CBA and boiler slag tend to absorb more water than is initially available during mixing, reducing the amount of free water available to lubricate the mixture's individual particles. Slump values and compaction factors of concrete, held constant at the same water-cement ratio, declined linearly with increasing amounts of CBA.

The impact was magnified when the

material was used to substitute a larger percentage of fine aggregate in concrete.

**Compression strength**

The CS of concrete made with CBA and boiler slag increased significantly in comparison to that of the standard CC. Concrete with this material added as NFA has reduced strength at 7 days of age compared to CC. CBA reinforced concrete mixes had greater CS than CC after 28 days.

CS of CBA concrete mixes was greatly improved after 28 days of curing age, when pozzolanic activity of the CBA was initiated.

Splitting Split tensile strength

Up to 50% CBA concrete combinations attained TS as compared to CC after 28 days. After 90 days, the TS of the concrete mixes that were divided was the same as or greater than that of the CC mixtures.

It has a considerable impact on both ratios when used as NFA in concrete, even at the young curing age of 7 days. Substituting CBA for fine aggregate in concrete had less of an impact as time went on. As with fine aggregate concrete, the mixture's CS increased more rapidly than its TS with age.

**Acid Resistance**

Under external sulphuric acid attack in terms of mass loss and loss in CS was almost same of CBA concrete and CC mixture.

**Sulphate Resistance**

As subjected to external sulphate attack, CBA concrete mixtures showed somewhat larger expansion strains. After 90 days of immersion, the expansion stresses of all concrete compositions were substantially lower than 0.1%. Except for concrete mixture A100, the CS of CBA concrete mixtures after 90 days of submersion in suphate solutions was identical to the corresponding CC.

Further Work

The early age of CS of concrete is reduced by the addition of CBA as NFA. Therefore, more research is needed to determine how to increase the strength of CBA concrete at an early age.

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