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# Impact on Strengthening Characteristics of Concrete Containing Pond Ash

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**Abstract-**This paper details an experiment designed to assess the qualities of concrete made with pond ash. Ash is produced when coal is burned in a thermal power station to produce electricity. The ash that settles at the boiler's bottom is diluted with water and then dumped into a nearby pond. In order to make pond ash concrete, cement was substituted with pond ash at various percentages. 25, 35, and 45 percent were the respective replacement rates. Tests were conducted on the compressive strength, split tensile strength, and flexural strength of pond ash concrete at7,28,90,180, and 365 days. Early pond ash concrete had a slower rate of gain in compressive strength than later concrete. When the proportion of pond ash in concrete rises, its split tensile strength and flexural strength drop. Microscopical examination of pond ash concrete using a scanning electron microscope reveals a small reduction in the monolithic nature of C-S-H gel as pond ash content increases. X Ray Pond ash diffraction data shows the existence of quartz crystals in various amounts. By replacing sand with pond ash in concrete production, we may save money on materials, lessen our impact on the environment, and speed up the building process.

**Keywords:***Compressive strength, Flexural strength, Pond ash, Scanning Electron Microscope, Split tensile strength, X Ray Diffraction.*

## 1. Introduction

More and more thermal power stations (TPS) are being built to keep up with the growing demand for electricity. In India, thermal power stations that use coal as their primary fuel produce the vast majority of the country's electricity. There are fourteen large TPSs in the state of Maharashtra [1]. The total amount of coal needed is 295 million tonnes, according to the Central Electricity Authority's annual report (2018) [1]. (MT). Ashes from burned coal settle to the bottom of the boiler. Typically, water is added to the ash, and the whole thing is piped away from the TPS. Ashes in liquid form collect in a large, flat area of ground called a pond. Evaporation of the water from the deposited liquid ash leaves behind only the ash particles, which are referred to as Pond ash. About 65–75 million tonnes of unused ash were dumped in ash ponds in 2007, according to a notification from the Ministry of Environment and Forests (MoEF) [2].The massive pond ash deposition causes several forms of pollution, including land, air, and water contamination, and they only worsen with time. Coal is now being used at a rate of 73.13 million tonnes per year [3], whereas the rate at which fly ash is produced is around 131.09 million tonnes per year. Getting rid of coal ash is estimated to need a thousand square kilometres of land in India, or one square metre per inhabitant [4]. The substitution of cement with pond ash in concrete is one of the most promising uses for pond ash. By recycling these materials, not only can we save space and lessen our impact on the environment, but we can also save money on building materials.

### Literature review

According to research by Singh and Siddique, (2014) [5], around 407 MT of coal is burnt each year in Indian TPS, resulting in approximately 131 MT of coal ash. Based on their studies, Jaturapitakkul and Cheerarot, (2003) [6] concluded that the ash that settles to the bottom of boilers in Thailand has a big particle size and a high porosity surface. Gupta and Singh, (2013) [7] found that just 38 percent of fly ash was put to use in India, with the remainder being deposited in a basin or landfill close to power stations, where it contributed to air, water, and soil pollution. Bhattacharjee, (2010) [8] research reveals that India is the world's second-largest user of cement, behind only China. About a tonne of carbon dioxide and other hazardous pollutants are released into the environment during the production of one tonne of cement, according to a research by Naik, (2008) [9].

According to research conducted by Bera et al. (2007) [10], the optimal moisture content of pond ash falls while the maximum dry density increases when compaction effort increases from 71.1-2370.0 kJ/cum. The size of pond ash particles is considerably coarser than fly ash particles collected from electrostatic precipitators, as shown by Arumugam et al. (2011) [11]. Bharathi et al. (2011) [12] report that silica, alumina, and a trace amount of iron oxide make up the bulk of pond ash. The early pozzolanic reaction is caused by the silica and alumina in pond ash.

According to Kim's (2015) [13] study, the compression strength of mortar made from bottom ash and fly ash is same after 3 and 28 days. Powdered bottom ash consistently improved the workability of high strength paste and mortar mix compared to mix made with only cement and fly ash. The amorphous crystalline structure of the bottom ash employed in this investigation also contributes to the high degree of hydration achieved by the mortar used in the experiment.

The mechanical qualities of concrete were found to improve when cement was replaced by bottom ash up to 10%, as reported by Kurama and Kaya (2008) [14]. Abdulmatin et al. (2018) [15] conducted experiments showing that mortar in which 20% of the cement was substituted with ground bottom ash produced higher compressive strength than control mortar. The setting period of mortar paste made with bottom ash is also somewhat slowed.

According to research by Andrade et al. (2009) [16], using bottom ash in concrete lengthens the time it takes for the mixture to cure, both initially and completely. SEM images of bottom ash concrete reveal a thick, compact C-S-H gel structure made up of crumpled sheets, as shown in a study by Aggarwal and Siddique (2014) [17].

Compressive strength of concrete with 30% washed bottom ash replacement recorded best strength at 7, 28 and 60 days i.e. 20.81 - 27.44 MPa, according to research by Sani et al. (2010) [18]. With 20% substitution of fine aggregate with bottom ash, the results of compressive test, flexural test, and split tensile test are nearly identical as those of the controlled concrete, according to the research of Sandhya and Reshma, (2013) [19].

Reviewing the published works shows that the use of pond ash in concrete is an area where very little research has been conducted. Considering the large volumes of pond ash produced, it is crucial to develop novel applications for, and secure methods of disposing of, this by-product so that it is no longer viewed as trash.

## 2. Experimental Investigation

### *3.1 Scope*

The objective of the study is to perfect pond ash-based concrete and learn its unique properties.

### *3.2 Ingredient of concrete*

The following ingredients were used in pond ash concrete.

#### *3.2.1 Cement*

The Ordinary Portland Cement (OPC) was used.

#### *3.2.2 Ash*

Chandrapur Super Thermal Power Station (CSTPS) ash that was thrown into a pond was used in the research. Disposal of Pond ash out from the power station and onto open ground is seen in Figure 1(a) and (b). To save time and effort, the ash from Pond was simply dried and put to use as is. The chemical and physical properties of Pond ash are shown in Table 1.

**Figure 1(a) Deposition of pond ash** **Figure 1(b) Ash transportation by pipe**

**Table 1: Physical and Chemical characteristic of Pond ash**

| Element | Content | IS requirement# |
|---|---|---|
| **Physical characteristic** | | |
| Fineness-passing 45 µm (%) | 61.05 | - |
| Specific gravity | 2.02 | - |
| **Chemical characteristic** | | |
| Silicon dioxide, $SiO_2$ | 60.60 | Minimum 35.00 |
| Aluminum oxide, $Al_2O_3$ + Ferric oxide, $Fe_2O_3$ | 31.29 | - |
| ($SiO_2$+$Al_2O_3$+$Fe_2O_3$) | 91.89 | Minimum 70.00 |
| Calcium Oxide, CaO | 1.86 | - |
| Magnesium Oxide, MgO | 0.58 | Maximum 5.00 |
| Sulfur Tri Oxide, $SO_3$ | 0.54 | Maximum 2.75 |
| Loss on ignition | 1.23 | Maximum 12.00 |

#IS 3812:1981 = Specification for fly ash for use as Pozzolana and admixture (Bureau of Indian Standards 1981) [20] and IS 1727:1967 = Methods of test for pozzolanic materials (Bureau of Indian Standards 1967) [21].

#### *3.2.3 Aggregate*

In this project, fine aggregate was made using the locally available sand. Before being used in the concrete production process, the contaminants were eliminated. The sand used here meets the specifications of IS 383:1970's Zone I for grading. Coarse aggregate is within the acceptable range for fineness modulus. Crushed basalt stone from a local quarry was utilised as a coarse aggregate in the construction project. This aggregate was tested in accordance with IS 2386 (Parts I & III):1963 [22]. Table 2 lists the various coarse and fine aggregate properties.

**Table 2: Characteristic of coarse and fine aggregate**

| Property | Coarse Aggregate (crushed basalt) | Fine Aggregate (natural sand) |
|---|---|---|
| Fineness Modulus | 7.06 | 2.84 |
| Specific gravity | 2.88 | 2.66 |
| Bulk density | 1765.05 kg/cum | 1984.37 kg/cum |
| Water absorption | 1.67 % | - |

## 4. Mix Proportions and Mix Design

Concrete mix design refers to the procedure of determining the optimal proportions of individual constituents to achieve the desired qualities while keeping production costs to a minimum. Concrete mix design was informed by the Bureau of Indian Standards' BIS 456:2000 [23] and BIS 10262:2009 [24]. The concrete mix was designed for an M25 grade with a desired strength of 31.6 MPa. For the purpose of creating the concrete mixtures, pond ash was used in place of cement at varying percentages. Control concrete testing mixes helped settle on a water-cement ratio of 0.49. Cement was used to replace the pond ash at three different percentages: 25%, 35%, and 45%. The proportions of the concrete mixes employed in the current endeavour are shown in Table 3.

**Table 3. Concrete Mix proportions**

| Mix | *w/b | Water | Cement | Pond ash | | FA | CA |
|---|---|---|---|---|---|---|---|
| | | | | Percentage | Quantity | | |
| CC | 0.49 | 181 | 368 | - | - | 645 | 1271 |
| M1 (25%) | 0.49 | 181 | 276 | 25 | 92 | 645 | 1271 |
| M2 (35%) | 0.49 | 181 | 239 | 35 | 129 | 645 | 1271 |
| M3 (45%) | 0.49 | 181 | 202 | 45 | 166 | 645 | 1271 |

Abbreviations: CC= Control Concrete, *w/b = water/binder ratio, i.e. water/(cement + pond ash), FA = Fine Aggregate, CA = Coarse Aggregate

We used to IS 516:1959, which was reaffirmed in 1999 [25] to determine the compressive strength of the cubes we tested. The average compressive strength was calculated using a concrete cube mould with 15 cm side lengths. Concrete has a low tensile strength and is a brittle substance. The flexural strength (IS 516:2004) and split tensile strength (IS 5816: 1999) [26] tests were performed to learn about the concrete's behaviour under strain. Concrete's manageability was evaluated using the slump cone test.

The microstructure of the elements in the sample may be examined by using a scanning electron microscope (SEM). SEM creates pictures of a sample by scanning and focusing a beam of electrons on it. The X-Ray Diffraction (XRD) test involves firing a focussed ray beam at the sample at a very precise incidence angle. The X-rays deflect or diffract in different directions because of the crystal structure of the sample. Each chemical has a different diffraction pattern in an XRD analysis.

## 5. Results and Discussions

### *5.1 Properties of concrete in fresh state*

Table 4 shows the results of observing the slump and density of pond ash concrete, two factors that contribute to its workability.

### *5.2 Properties of concrete in hardened state*

Compressive strength, split tensile strength, and flexural strength were some of the qualities of concrete tested.

#### *5.2.1 Compressive strength of concrete*

The compressive strength of pond ash concrete at different age were tested and recorded in Table 4.

**Table 4. Compressive strength of pond ash concrete**

| S N | Mix | Slump (mm) | Density (kg/cum) | Compressive strength in MPa at different age (days) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 7 | 28 | 90 | 180 | 365 |
| 1 | CC | 117 | 2460 | 27.6 | 34.1 | 44.0 | 46.0 | 48.5 |
| 2 | M1 (25%) | 114 | 2380 | 17.8 | 28.5 | 38.0 | 40.0 | 42.0 |
| 3 | M2 (35%) | 114 | 2375 | 14.3 | 23.5 | 36.6 | 37.3 | 40.8 |
| 4 | M3 (45%) | 112 | 2360 | 11.6 | 22.8 | 32.8 | 36.4 | 37.1 |

Compressive strength increased by a percentage of 28 days in Figure 2. The strength for pond ash concrete (PAC) at 28 days is assessed as 100%. It is known from graph that with the advancement of age, the percentage rise in compressive strength of PAC mixture grew at a quicker pace owing to pozzolanic reaction.

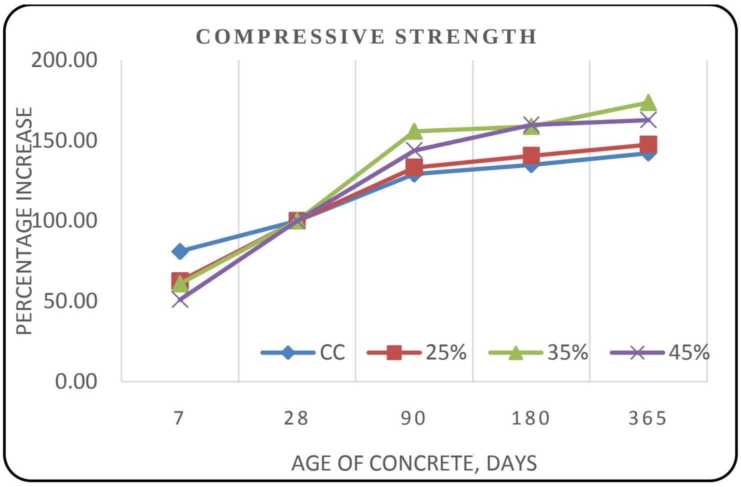


**Figure 2 Percentage increase in compressive strength**

***5.2.2 Split tensile strength of concrete***

In order to measure the split tensile strength of PAC, a cylinder of 30 cm in length and 15 cm in diameter was cast. Experiments were run at both the 28-day and 90-day marks. Different percentages of replacement at 28 and 90 days are shown in Figure 3 as causing a shift in the split tensile strength.

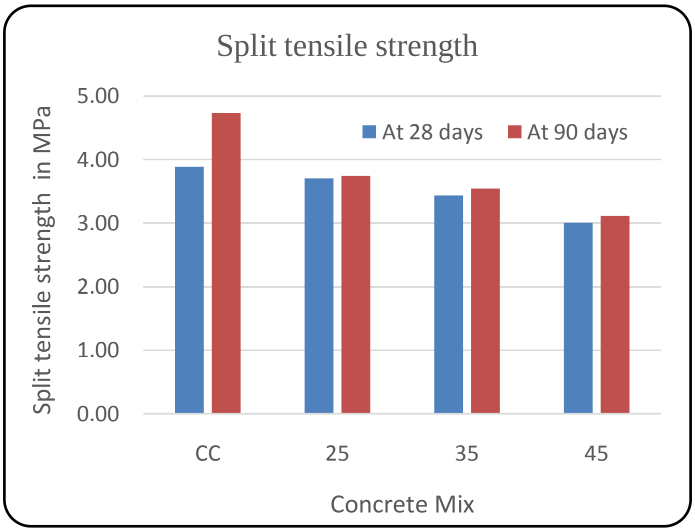


**Figure 3 Split tensile strength variation of PAC**

The data in the graph clearly show that the split tensile strength of concrete declines as the proportion of replacement rises and that it improves as the concrete ages. Regardless of proportion and age, the strength is lower than that of control concrete.

***5.2.3 Flexural strength of concrete***

The flexural strength of PAC was measured after the beams were cut to dimensions of 15 by 15 by 60 centimetres. After 28 and 90 days, the flexural strength of the concrete was measured. Figure 4 shows PAC flexural strength at 28 and 90 days with various percentages of replacement.

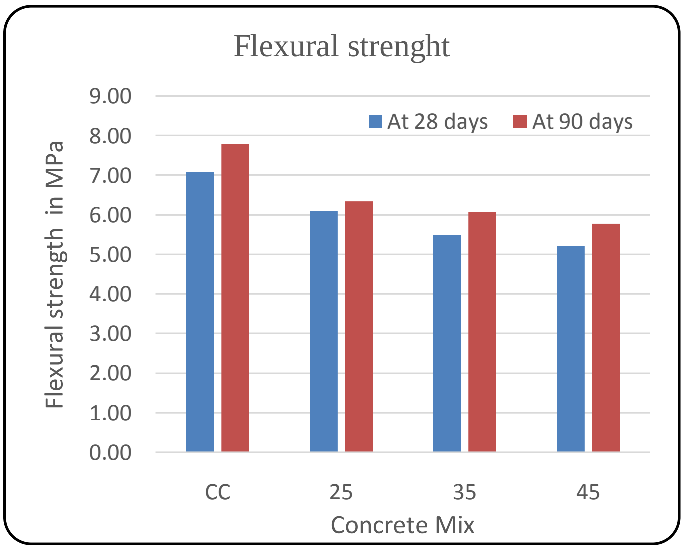


**Figure 4 Flexural strength variation of PAC**

PAC's flexural strength grows slowly with age, although it's still less than that of control concrete.

***5.3 Scanning Electron Microscope (SEM) analysis***

As the electron beam interacts with the sample's atoms, it gives out signals that can be analysed microscopic examination. Figure 5 (a) and (b) display the results of the SEM analysis of 15% and 45% PAC, respectively (b).

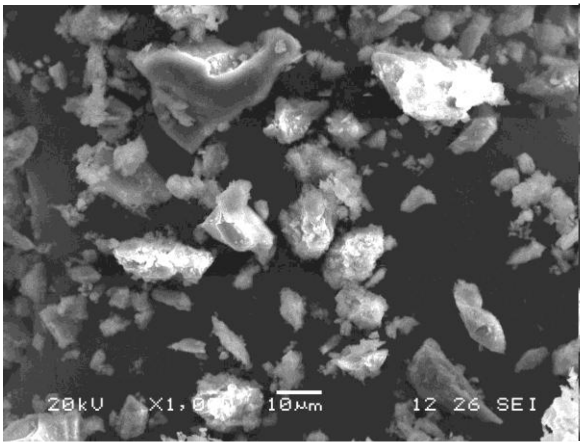


**Figure 5 (a) Micrographs of 15% PAC**

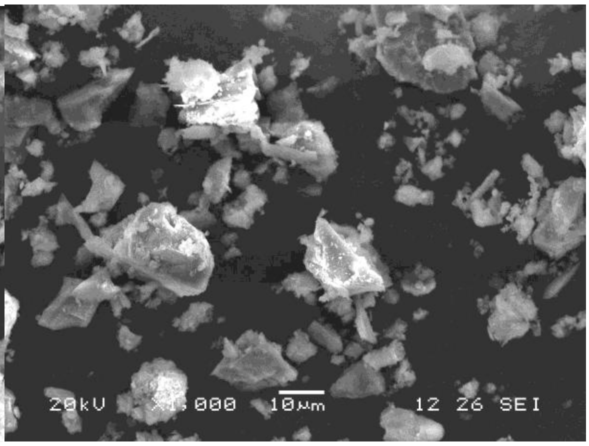


**Figure 5 (b) Micrographs of 45% PAC**

SEM photos with a lot of contrast show C-S-H gel. Particles of pond ash are round, black, and medium in size. A decrease in void size is visible in micrographs of a 15% PAC blend. CSH gel is applied to the aggregate and acts as a binder. The micrographs of 45% PAC show that the loss in strength is caused by the insufficient development of C-S-H gel.

***5.4 X-Ray Diffraction (XRD) analysis***

When x-rays hit a crystalline solid, they produce a pattern known as diffraction (Phase). Images of X-ray diffraction patterns from PAC samples are shown in Figure 6 (a) and (b).

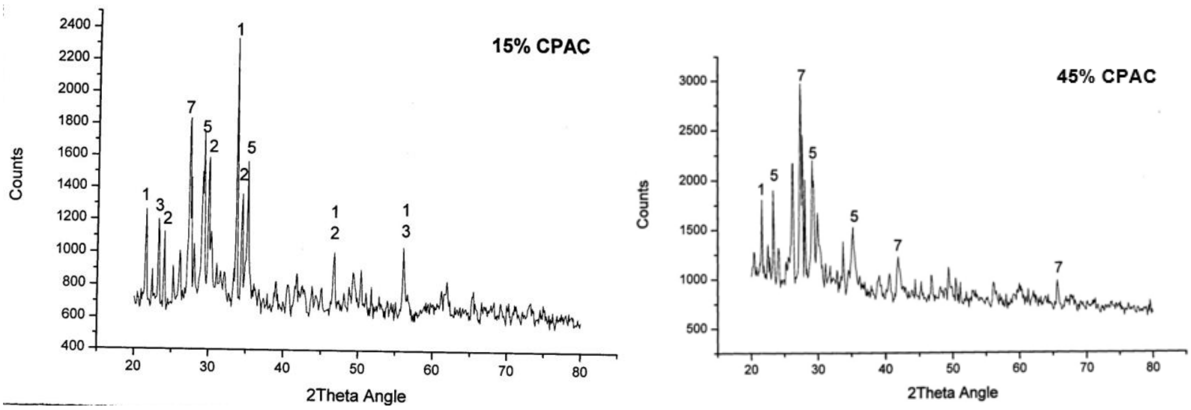


**Figure 6 (a) X-ray Diffraction of 15% PACFigure 6 (b) X-ray Diffraction of 45% PAC**

[Notations – 1: CASH-Calcium Aluminium Sulphate Hydroxyte, 2: CASHH-Calcium Aluminium Sulphate Hydroxyte Hydrate, 3: CS-Calcium Silicate, 4: CSH-Calcium Silicate Hydrate, 5: $CaCO_3$-Calcium Carbonate, 6: $Fe_2O_3$-Iron oxide, 7: Q-Quartz]

Pond ash has a wide range of quartz crystalline phases, as revealed by XRD. Samples with 15% PAC had the highest concentration of calcium silicate (3), whereas those with 45% replacement Calcium Aluminium Sulphate Hydroxyte Hydrate(2, CASH H) have very little calcium silicate (3) left, suggesting that it may have been totally eaten.

**6. Conclusions**

The research reveals the following, all of which are indicative of the efficiency of using pond ash in concrete.

- Concrete's binding element, cement, is reduced as pond ash percentage rises, while ash's unburnt carbon content rises. As a result, pond ash loses some of its compressive strength. Figure 2 displays the rate of growth of compressive strength of pond ash concrete, showing that it was relatively low in the early stages (mostly at 7 and 28 days) (after 90 days).
- The chemical reaction of pond ash in first phase is gradual but later on it interacts swiftly with calcium hydroxide generated during hydration process. The chemical interaction of pond ash with calcium hydroxide enhances strength of concrete.
- The density of pond ash concrete drops as the percentage of pond ash rises because pond ash has a lower specific gravity than cement and more pores.
- As the percentage of pond ash in the concrete mixes grows, the concrete becomes less workable. This is mostly due to the pond ash's increasingly high carbon content, harsh texture, and coarse size.
- Figures 3 and 4 illustrate the results of a test that separated the tensile and flexural strengths of PAC, respectively, and show that the strength of PAC gradually declines with increasing percentage of pond ash. All of the strengths are lower than the control concrete.
- Carbon and C-S-H gel formation are seen by scanning electron microscopy in PAC at 15% and 45%. C-S-H gel was somewhat less solid as the proportion of pond ash rose. Ca(OH)2 was used to encase the pond ash particles before they were placed in the matrix.
- When it comes to characterising crystalline materials, X-ray diffraction (XRD) is one of the most effective non-destructive methods available. In 15% PAC, Calcium Aluminium Sulphate Hydroxyte (CASH) and Calcium Aluminium Sulphate Hydrate (CASH H) make up the bulk of the peak, whereas Quartz predominated in 45% PAC.

Taking into account the aforementioned factors, it is believed that Pond ash has considerable potential for application in the production of concrete. Durability, permeability, and shrinking are just a few of the additional PAC qualities that need investigation.

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**Conflicts of Interest**

The authors declare no conflict of interest.

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