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Physico– Chemical Characterization of Pond Ash for Use as a Replacement of Cement in Concrete

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Abstract: Concrete is the second largest consumed material for construction due to encouraged growth of infrastructure worldwide. The preparation of concrete requires large amount of concrete making materials like cement, sand and coarse aggregate. Sand and Coarse aggregate are naturally available, but cement production involves heating of limestone and other materials to high temperatures leading to release of CO_2 which in terns responsible for emission of greenhouse gases. Also, the utilization of natural resources leads to scarcity. This results in the creation of vast interest in the research area to utilize waste materials which could satisfy the criteria of strength and performance. Pond ash, a waste produced from thermal power plant, is one such material that can be used as a replacement of cement as well as fine aggregate partially or fully. To promote sustainable construction, study of physical and chemical properties of such waste material as a constituent in concrete is essential which ultimately addresses the issues related to disposal, environmental and ecological problems. Pond ash is potentially usable, but its properties depend on various factors like source of coal, type of boilers, type of coal grinding process adapted at power plant etc. This research focuses on the physical and chemical properties of pond ash like particle size distribution, specific gravity, bulk density, loss on ignition etc. to know its suitability for utilization in concrete. For this investigation, IS 3812(Part 1):2003, IS 1727, IS 2386 part -I, IS 2386 part -III are used.

Keywords: Concrete; Pond Ash; Thermal Power Plant; Sustainable Construction; Greenhouse Gases.

I. INTRODUCTION

Concrete is a construction material composed mainly of Cement, Fine Aggregate, Coarse Aggregate, Water and Admixture. The huge demand for concrete leads to overuse of natural resources. To cater to the need, alternative to concrete constituents must be develop without causing harm to environment. In India, coal fired thermal power plants produces million tons of coal ash annually. As per IS 3812 (Part 1):2003, this ash generated is classified into four major categories as Fly ash, Bottom ash, Pond ash and Mound ash. Fly ash or bottom ash or both mixed in any proportion and conveyed in the form of water slurry and deposited in pond or lagoon is called as pond ash. As compared to fly ash, pond ash, though in large amount is not use in concrete applications due to its less pozzolanic properties. Due to addition of pond ash, amount of CSH gel in the mortar increases, which may be the reason for improved performance of mortar (Lal Dhiraj Kumar et al., 2019). The results indicate that the drying shrinkage and Weight loss decreases with increase in pond ash content and fibre content. A pond ash content of 30% yielded good values of water absorption and permeable voids (Sofi A. et al., 2016). The various characteristics of pond ash as fine aggregate in concrete with its engineering properties such as its shape, gradation, texture, physical, chemical and also morphological aspects plays important role when used in concrete (Ganesh Bharathi et al., 2011). The ground bottom ash could be used as a good pozzolanic material (Jaturapitakkul Chai et al., 2011). The disposal of pond ash on large landfills is creating threat to the environment. This disposal problem can be address by utilizing pond ash in large quantity in various civil engineering construction works. However, information about use of pond ash in concrete is still insufficient. It is of prime importance to carry out research works on the feasibility of using Pond Ash and its suitability for potential utilization in concrete constructions.

The paper deals with the experimental investigation of properties of pond ash to understand its feasibility to be used in concrete.

II. SAMPLE COLLECTION

Pond ash usability depends on its characteristics, which varies according to the manner of disposal. The coarser bottom ash particles settle first and the finer fly ash remains in suspension longer because of differences in the unit weight and particle size of fly ash and bottom ash. The sampling of pond ash, hence, is difficult than that of fly ash. As compared to the ash deposited 100 m away from the point of disposal, the particle size is medium in between point of disposal and 100 m distance. Sampling of pond ash depends on the purpose of study and is to be done as per IS 6491:1972. The properties of pond ash are generally influenced by the type and source of coal, performance of generating facility, variation in collection, disposal & storage methods, temperature of coal burning, peak load demand in thermal stations and few other issues. The engineering properties of pond ash control its use as a material in construction. Hence characterizations of pond ash in terms of its physical and chemical properties play a very important role in assessing its suitability as a material in different fields of construction. In the present study pond ash samples has been collected from Rattan India Thermal Power Plant, situated in Nandgaon Peth, 13 kilometers from Amravati city, Maharashtra in India (Fig.1). The pond ash sample was collected in gunny bags from upstream sites of the ash pond (Fig.2).

Fig. 1 Location of pond ash collection

Fig. 2 Pond ash collection

III. EXPERIMENTAL INVESTIGATION

Pond ash sample collected from Rattan India Thermal Power Plant, have been tested in the laboratory to investigate its physical and chemical properties, and engineering behaviour. The physical properties of the pond ash like particle size distribution, specific gravity have been determined.

A. Chemical Composition

Based on chemical analysis the pond ash is classified as class "F" (ASTM C [1]). Table 1 shows chemical composition of the pond ash.

Table 1 Chemical Composition of Pond ash

S.No.	Test Parameter	Result (%)	Permissible limits as per IS:3812-2013 RA: 2017
1	Silicon dioxide (SiO_2) + Aluminium Oxide (Al_2O_3) + Ferric Oxide (Fe_2O_3)	87.10	Minimum 70 %
2	Silicon dioxide (SiO_2)	55.28	Minimum 25%
3	Calcium Oxide (CaO)	2.59	Not Specified
4	Magnesium Oxide (MgO)	2.14	Maximum 5%
5	Total Sulphur as Sulphur Trioxide (SO_3)	0.88	Maximum 3%
6	Total Soluble salts	0.48	Maximum 1.5%
7	Total Chloride	0.017	Maximum 0.05%

B. Loss on Ignition

Loss on Ignition of pond ash is calculated as per the procedure mentioned in IS:1727-1967.
An oven dried sample of pond ash approximately 1 g (m1) is heated for 15 min by placing it in a muffle furnace at a temperature between 9000C to 10000C. Cool and Weigh. Then again heated for 5 min. and reweigh (m2). The loss on Ignition is given by

$$\text{Percent Loss on Ignition} = ((m1 - m2) / m1) \times 100 = ((1-0.984) /1) \times 100 = 1.16\%$$

C. Specific Gravity

Specific gravity of pond ash is calculated as per the procedure mentioned in IS:1727- 1967.
Le Chatelier flask is filled with kerosine to a point on the stem between zero and the 1 ml mark and then immerse in the temperature-controlled water bath, maintained at about room temperature for sufficient interval of time. Then the reading of the liquid in the flask is taken. A weighed quantity of pond ash is placed in a Le Chatelier flask, taking care that no portion of the it adhere to the inside of the flask above the liquid, by slightly vibrating the flask. Then to remove any air bubble, incline and roll the flask. The reading is taken after the flask immersed in the water bath. The difference between the first and final readings represents the volume of liquid displaced by the weight of pond ash. The specific gravity is calculated as

$$\text{Specific Gravity} = \text{Weight of pond ash in g.} / \text{Displaced volume of liquid in ml.} = 46 / 22 = 2.09$$

D. Particle Size Distribution

Particle size distribution is done according to procedure mentioned in the IS:2386 (Part I)-1963.
The minimum weight approximately 400 g each of the pond ash, fly ash and bottom ash is taken for the sieve analysis as per Table IV of IS 2386(Part I)-1963. The sample is brought to air-dry condition by heating at a temperature of 1000C to 1100C before weighing and sieving. The air-dry sample is weighed and sieved successively on the appropriate sieves starting with the largest. The sieves are shaken for 10 minutes. The shaking is done with a varied motion, forwards and backwards, left to right, circular clockwise and anticlockwise. On completion of sieving, the material retained on each sieve is weighed. The results obtain are reported in Table 2 and the graph plotted as in Fig.3.

Table 2: Particle Size Distribution of Pond ash, Fly ash, Bottom ash

IS Sieve Size (mm)	Percent Passing		
	Pond Ash	Fly Ash	Bottom Ash
10	99.998	100	100
4.75	90.748	100	100
2.36	80.248	99.75	98
1.18	7.848	99.5	94.5
0.6	0.698	99	90.25
0.3	0.298	98	79.5
0.15	0.003	55.5	31.75
0.075	0.0005	10.75	14.75
PAN	0	0	2.5
Grading Zones	Zone-II	Zone-IV	Zone-IV

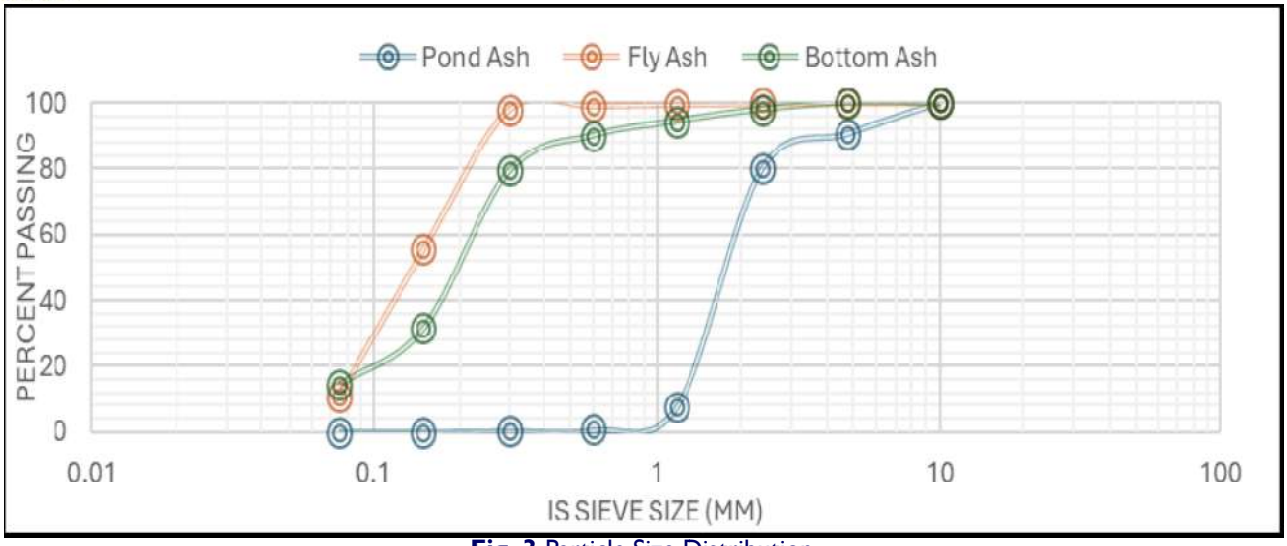

Fig. 3 Particle Size Distribution

IV. CONCLUSION

A variety of tests were conducted on pond ash samples collected Rattan India thermal power station to study the physical, chemical and engineering behaviour. Based on the experimental investigations, following are the main conclusions.

1. The specific gravity value of 2.09, indicates that pond ash has a potential to be use as replacement of cement in concrete.
2. The particle size distribution curve shows that pond ash is categorized in zone- II whereas fly ash and bottom ash are categorized in zone-IV as per IS: 383 -2016. Major portion of pond ash are finer particles i.e. sand size fraction with some silt size fraction which can be used for fill material.
3. Loss on ignition is only 1.16% which is within permissible limits of maximum 5 % as per IS:3812(Part 1)-2013 RA: 2017.
4. Chemical analysis clears that it is class F fly ash (Siliceous fly ash) as per ASTM (C1) standards.
5. Calcium content is low which confirms that its low calcium fly ash.

From the results it can be concluded that the pond ash has good potential for use as a material for various applications like partial replacement of fine aggregate or cement in concrete, backfill material, filter material etc... The use of pond ash in this way helps to utilize huge amount of waste material generating from power plants which ultimately useful to decrease environment pollution, greenhouse gases and come out as a sustainable eco-friendly material in construction industry.

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