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Characterization of fly ash based on their physical and chemical properties

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Abstract: *This article represents a study for fly ash (FA) features in NTPC, India. 14 Samples of FA were gathered from some different Indian power plants. Mostly all samples are categorized as F-class FA with high-quality pozzolanic property reported by standard. All samples were studied for their physio-chemical properties. Experiment was done by making various mortars and adhesive containing FA as substitute of cement in accord with three techniques. The constricting potency results were related with control samples prepared from OPC to get strength activity index (SAI). Mortar samples were made from each FA sample as per ASTM C 311. Their potential activity was studied at 7, 28 days. The data indicated that both physio-chemical characteristic of FA control mechanical characteristic of mortars containing FA.*
Keywords*: fly ash, F-class, OPC, SAI, Mortar*

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I. Introduction

Fly ash is produced in combustion of coal at thermal power plants (TPP) in large quantity. This large quantity FA creates more problems like large area of land is needed for discarding and toxicity related with heavy metal percolated to groundwater. FA, also called as "pulverised fuel ash" in India, is a coal combustion result made-up of fine pieces that are rout out of boiler with flue gases. FA is an extremely fine substance formed after burning of pulverized coal in a TPP, and is passed by flue gas and is gathered by electrostatic cyclones. Presently, FA particles were illustrated based upon fineness since particle dimension distribution considerably affects ash's reactivity [1]. National Thermal Power Corporation (NTPC) produces approximately 60.0 million tonnes of coal ash yearly from its coal from TPP [2]. In divergence, properties of FA is not only determined by the physical properties but also source of coal, mineralogy, coal burning situation, process of collecting FA, deposit time and sampling period [3]. Consumption of FA and base ash in structure has been launched for 12 years especially in geo-polymer expertise. Geo-polymers prepared from FA yield advanced compressive power [4-7]. FA is utilized in several purposes to change naturally occurring collection and minerals, which can decrease considerably the order for normal collection (granite) and light weight collection [8]. Physical characteristics of FA are important by density, surface region and fineness, particle distribution to recognize reactivity of FA with cement. Chemical characteristics of FA are determined from its kinds of minerals, chemical composition and amorphous phases in FA. Utilization of foamed concrete (FC) by cement partly replaced by FA for town dumped underground gap backfilling was studied by [9]. Some researchers have revealed that siliceous FA improves execution of concrete. As, concretes holding siliceous FA and cement in proper fraction have visibly improved compressive power, fracture hardiness and resistance to dynamic loads [10]. Addition of FA reduces expansion of micro-fractures and makes construction more uniform and denser [11].

This work mention to ASTM C311 for examines mechanical characteristics of mortar at 7 days and 28 days. Along with standard, principal technique for determining FA for utilization as a pozzolan in concrete blend is SAI. In this work, sources of FA were taken from four power plants in U.P, India. A total of 14 FA samples were examined to obtain correlation between their mechanical and physico-chemical characteristics. Still, this paper reports the findings regarding the impact of particle size and mineralogy of FA on the SAI of mortar.

II. Material and Methods

Four power plants in U.P and industries where the FA samples were collected are NTPC Dadri, Singrauli Super Thermal Power Station, Feroze Gandhi Unchahar Thermal Power Station and Tanda Thermal Power Station. 14 ash samples were collected individually at different times in 2020. The binders were made from a mixture of cement and FA. The Ordinary Portland Cement 43 Grade used has a density of 3.2 g/cm^3 supported by As per Indian Standards. Graded river sand with a specific gravity of 2.67 g/cm^3 was used instead of silica sand.

Methods

All samples containing 14 FA were formed by three techniques. All samples were mortars as mention to ASTM C 311. All samples of mortars were healing in water after remaking until particular age for compression test. All samples of mortar were ready with a thickness of 50 mm and height 100 mm. Mix outline for mortar is exposed in Table 1. Mean of SAI of three techniques were then set on. These techniques are as:

Technique I: Non-sieved FA of every sample was utilized for preparing mortars. FA was concerned for about 20% cement substitute via weight. Compressive strength test (CST) was performed at 7 days.

Technique II: Non-sieved FA of every sample was utilized for preparing mortars. FA was concerned for about 20% cement substitute by weight. The CST was conducted at age of 28 days.

Technique III: Similar to method I, but FA was sieved to acquire particle size minor than 75 μm. The compression test (CT) for mortar sample was performed at 7 days.

Tabel no 1: Mix Design of Mortar

Method	Water - Binder ratio	Sand (g)	Binder (500 g)		Water (ml)
			OPC (g)	Fly Ash (g)	
Technique I	48%	1350	390	110	240
Technique II	48%	1350	390	110	240
Technique III	45%	1350	425	75	225

Physical and Chemical Characterization:

Testing to determine specific gravity, particle size division and particular surface region of each FA were conducted for physical characterization. Few characteristic procedures were performed to determine fine quality and Loss of Ignition (LOI) to find quantity of ash containing particles surplus to 45 μm. Oxide substance in FA was examined with XRF technique. XRD and wet method were used for mineralogy and chemical characteristics. Global amorphous of FA was analyzed based on mineral components like mullite, hematite, magnetite, etc.

Strength Activity Index:

Each FA was coded from samples S1 to S14. Control mixture was made of non-FA mortar (OPC samples). SAI was calculated as per ASTM C311 in Eq (1).

$$\text{SAI} = \frac{X}{Y} \times 100$$

Where: X= mean compressive potential of samples containing FA (MPa)

Y = mean compressive potential of control sample (MPa)

III. Results and Discussions

Strength Activity Index:

SAI of each technique was examined for each mortar. The average of SAI and rank of samples were listed in Table 2. The mean of SAI range between 0.87 and 1.18. It is well known that incorporating FA in mortar dissuade a significant increase in compressive strength up to 28 days due to slow pozzolanic doings [12]. In general, sieved FA used in the technique III increases the compressive strength of mortar. Denser pore structures to create mortar potential at early age are granted by finer particles [13]. Fig. 1 stand for results of SAI and rank of samples according to mean of SAI.

Table no 2: SAI of Samples

Sample Code	Technique I		Technique II		Technique III		SAI (Average)	SAI Rank
	fc' (1)	SAI	fc' (2)	SAI	fc' (3)	SAI		
S1	22.6	0.82	27.6	0.76	30.64	0.99	0.85	14
S2	27.2	0.97	27.4	0.74	37.70	1.17	0.96	9
S3	30.5	1.10	35.2	0.96	34.02	1.18	1.08	8
S4	34.2	1.24	34.2	0.94	39.22	1.32	1.16	3
S5	31.4	1.14	36.2	0.98	32.95	1.19	1.10	7
S6	30.8	1.14	35.5	0.99	35.44	1.24	1.12	6
S7	24.2	0.88	46.2	1.30	38.02	1.28	1.15	4
S8	24.2	0.86	36.2	1.00	25.72	0.98	0.94	10
S9	25.4	0.91	33.0	0.90	26.60	0.98	0.93	11
S10	28.6	1.02	48.2	1.30	30.28	1.20	1.17	2
S11	24.4	0.88	29.4	0.84	26.44	0.96	0.89	12
S12	34.0	1.22	38.6	1.08	33.68	1.26	1.18	1
S13	25.2	0.86	29.2	0.82	26.38	0.92	0.86	13
S14	33.0	1.18	38.2	1.04	33.60	1.22	1.14	5

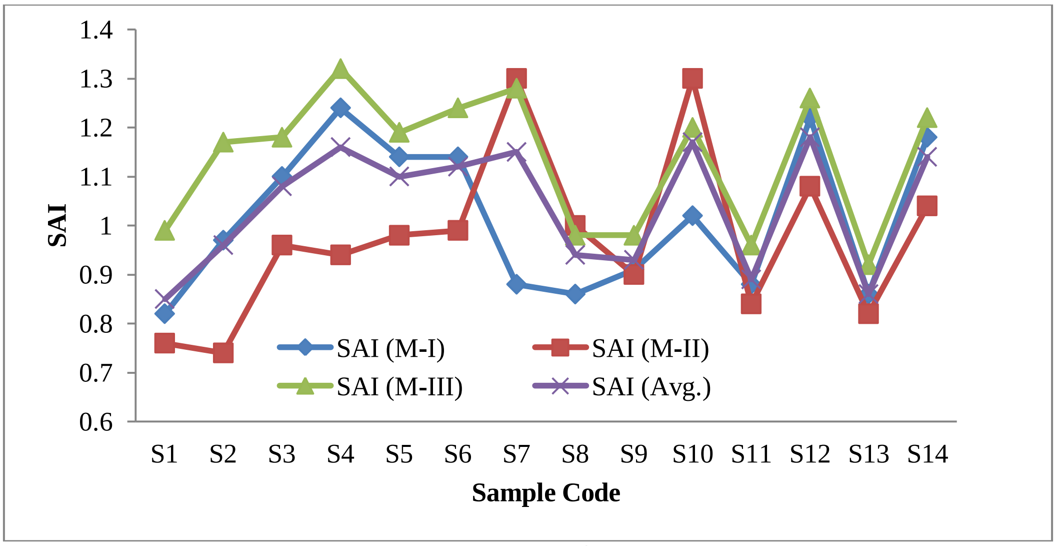

Figure no 1: SAI of Samples

The Effect of Physical Properties on SAI:
The Effect of Physical Properties

Physical characteristic of ashes are planned in Table no 3, represents outcome of physical characteristic of FA on SAI. This is given that reducing LOI of FA increased these SAI, where LOI signified stages of carbon substance in FA after combustion. This can be explained that the dimension of FA particles that is exposed by weight of ashes containing dimension lesser than 45 µm improves value of every SAI. Enhancing degree of fine quality of FA used in mixture would decrease porousness of concrete resultant in enhancing the compressive potential [14].

Table no 3: Physical properties of FA samples

Sample Code	Sieve no.325 (% weight)	Specific gravity (g/cm^3)	Specific Surface Area (m^2/g)	LOI (%)	Percent retained on 45 µm sieve
S1	51.8	2.28	0.242	0.82	17.0
S2	67.8	2.60	0.526	1.43	15.6
S3	85.8	2.58	0.681	0.80	19.2
S4	71.0	2.52	0.425	1.86	16.6
S5	76.8	2.69	0.462	1.56	19.0
S6	74.6	2.68	0.554	2.28	28.3
S7	80.2	2.60	0.542	2.59	19.3
S8	81.2	2.10	0.510	0.46	17.2
S9	82.2	2.36	0.436	0.28	10.4
S10	66.6	2.44	0.414	2.74	9.2
S11	83.3	2.37	0.448	2.95	13.4
S12	71.6	2.26	0.488	2.88	12.6
S13	52.8	2.37	0.255	2.93	12.5
S14	54.8	2.28	0.282	2.97	23.4

Specific gravity of all samples varies from 2.10 to 2.69 g/cm^3. With regard to the fineness determination of FA, two approaches were used: (a) Amount of particles smaller than 45 µm and (b) specific surface are determination. The first one was analyzed with the amount of the FA sample passed when wet-sieved on a no 325 sieve (45µm). S1 is the thickest as compared to others. It is verified that smaller particles of the ashes contribute higher surface area (Figure 2 & 3). Moreover, specific gravity increased as the particle size decreased.

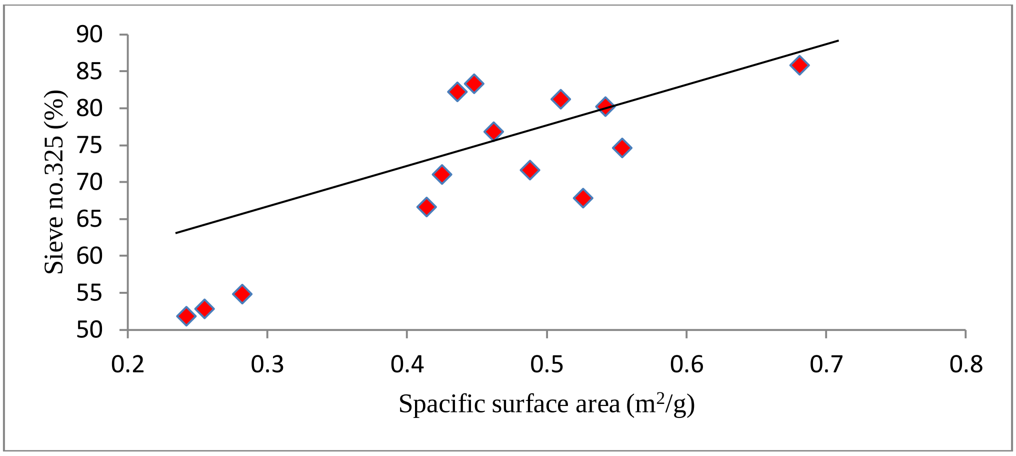

Figure no 2: Relation of surface area and particle size less than 45μm

The physical characterization consisted fundamentally particle size distribution was conducted with laser diffraction method. The range of granulometrical analysis was between 3 μm and 100 μm although coarser particles may exist. The distribution of particle dimension plays the significant role in reactivity of FA. Except S1, majority of particle dimension (75%) was distributed smaller than 45μm with 20% of particles at less than 5 μm. In general, diameter at 90% distribution is less than 100 μm. According to these results, S1 presents the greatest particles while smallest particles for the most part were contained in S3.

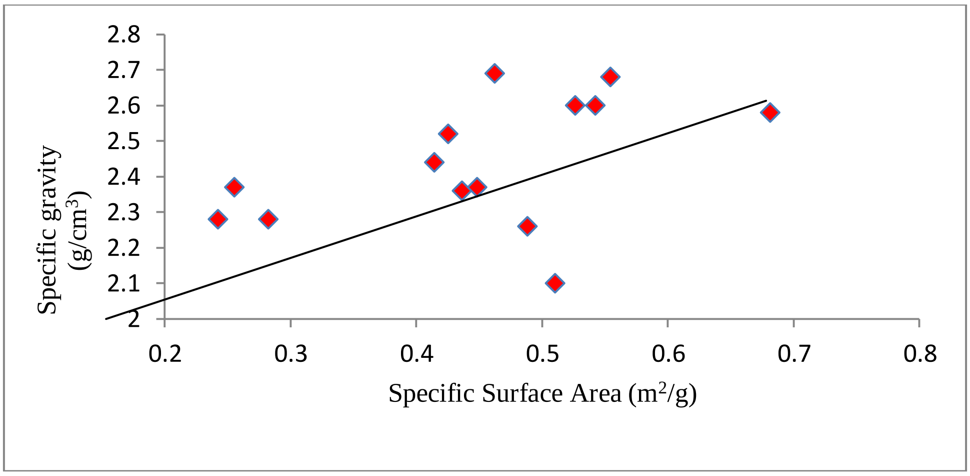

Figure no 3: Relation of surface area and specific gravity

The Effect of Chemical Composition:

Chemical formation and global amorphous of FA samples were planned in Table no 4. Every sample is intimated as class F-fly ash along with ASTM C618. Chemical formation is facilitated for FA classification based on substance of oxides was studied by [15]. The class of FA is associated to amorphous of mineral formation. In general, low carbon FA are required and limited up to 6% or allowable up to 12% for certain circumstances. About this research, carbon content was determined in size fraction less than 75 μm (mesh no. 200). FA having particle size at 75-100 μm contains 4% of carbon; it is reported by [16]. Smaller size fractions have lesser carbon content. Lesser carbon substance in FA increases SAI of mortar. It is shown in table no 3 that carbon content in FA and global amorphous of mineral in FA influence the strength of mortar. SAI is rather independent on calcium and silica content. The minimum of 70% by FA weight containing the total quantity of SiO_2, $Al2O_3$ and Fe_2O_3 is requirement of class F-fly ash as pozzolan. However, representation of FA reactivity is more affect by amorphous mineral than oxides content. Silica content refers to crystalline and amorphous stage. Silica presents in amorphous form may increase the mechanical characteristics of mortar.

Table no 4: Chemical compositions of fly ashes

Sample Code	Al_2O_3	Fe_2O_3	SiO_2	Al_2O_3+Fe_2O_3 +SiO_2	SO_3	CaO	Carbon	Global amorphous
S1	28.32	12.34	48.10	88.76	0.62	4.42	9.40	42.6
S2	26.14	11.12	50.20	87.46	0.55	4.68	11.10	46.1

S3	16.73	22.18	48.34	87.25	0.54	5.86	3.22	44.1
S4	24.64	11.60	51.64	87.88	0.49	5.12	5.12	43.9
S5	26.52	14.90	43.54	84.96	0.26	7.92	3.10	39.0
S6	20.16	9.36	38.60	68.12	1.26	11.42	3.02	42.5
S7	22.20	15.10	49.64	86.94	0.52	5.68	7.18	44.8
S8	22.10	16.82	47.72	86.64	0.62	7.10	4.28	41.0
S9	16.84	17.32	38.54	72.70	0.91	18.20	3.92	42.3
S10	27.12	11.42	52.66	91.20	0.02	3.92	4.88	43.0
S11	33.62	8.82	48.16	90.60	0.40	6.66	7.12	41.0
S12	24.88	11.62	37.26	73.76	0.38	16.64	3.10	48.8
S13	27.12	11.40	52.66	91.18	0.01	3.96	4.92	43.0
S14	32.60	9.20	47.10	88.90	0.44	6.63	7.14	41.0

IV. Conclusions

The physico-chemical properties of fourteen FA sample have been studied. The SAI of mortars having 20% FA as cement substitution has been determined. These results evidenced that SAI is affected by surface area, carbon substance and amorphous nature of mineral substance in FA. SAI is independent of oxides content in FA. From this, it is concluded that particle size affected compressive potential of samples when ash holds particles size less than 45 μm.

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