Fly ash fineness – Comparing residue on 45 micron sieve with Blaine's surface area

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This paper compares the residue on 45 micron test sieve with Blaine's air permeability results and shows that the latter is sensitive to loss on ignition (LOI). The 45 micron sieve test for ascertaining the fineness of fly is an optional test in the Indian Code IS 3812:2003 part I and II.[1,2] With the help of laboratory data the paper proposes to make the test a mandatory quality control tool for using fly ash as a pozzolona.

The quality of fly ash generated by coal fired Thermal Power Station shows a wide range of variation in both chemical and physical properties because both the quality of coal and the combustion condition of boilers vary. While supplying fly ash quantities, matching user's specification is important; past investigations show that the pozzolanic properties of fly ash are not so much governed by the chemistry as by the mineralogy and particle size. Regardless of the fly ash type, particles under 10 micron are the ones that contribute to the 7 and 28 days strengths. Particles between 10 and 45 micron contribute to strength from 28 days and up to about one year. Particle above 45 microns are considered inert. They behave like sand particles. It has been reported that the particles below 10 microns govern the fly ash reactivity.[3] Therefore fineness of fly ash correlates with concrete strength. This paper focuses on the importance of 45 micron wet sieve test analysis over Blaine's test. Like the former, the latter also gives measurement of the particle size of fly ash. However, the former is simple to use, less prone to variations and does not require specialised instrument and laboratory conditions.

Material and method

Fly ash samples were collected from unit 7 of Koradi thermal power station (210 MW) and unit 1 and 2 of Dahanu thermal power station (250 MW) from the electrostatic precipitators (ESP) hoppers. The ESPs at Koradi and Dahanu thermal power stations were commissioned in 1983-84 and 1993-94 respectively.

Six Samples from Koradi thermal power station Unit 7 and 4 composite samples from Dahanu thermal power station Unit 1 and Unit 2 collected on different dates, made a set of 10 samples for analysis.

The specimens' fineness was determined by wet sieving through a 45 micron sieve following IS 460:1962. In addition, their Blaine's air permeability was measured following IS 1727:1967.[4] Tables 1 and 2 shows the results.

To find out if a relationship existed between Loss on ignition, Residue on sieve (ROS) and Blaine's value additional samples were prepared in the laboratory. Addition of coal dust of fineness below 75 micron (200 mesh sieve) to fly ash samples of known LOI gave specimens with different LOI.

Table 1. Residue on 45 (μm) sieve and corresponding specific surface area by Blaine's permeability method (m^2/kg) of Unit-7 Koradi ESP rows

EPS field#	1		2		3		4		5	
Specimen number	Blaine's value, m^2/Kg	ROS 45 (μm) %	Blaine's value, m^2/kg	ROS 45 (μm) %	Blaine's value, m^2/Kg	ROS 45 (μm) %	Blaine's value, m^2/Kg	ROS 45 (μm) %	Blaine's value, m^2/Kg	ROS 45 (μm) %
1	202	50.7	294	24.2	325	17.5	389	11.6	430	4.2
2	210	51.2	296	24.1	320	18	390	11.5	440	4.8
3	203	50.8	290	24.2	289	18	395	11	440	5.3
4	215	50.1	298	24.1	302	17.8	400	10.5	425	5.2
5	214	50.5	299	24.5	330	17.3	390	11.2	430	4.7
6	195	50.3	293	25.1	319	17.2	410	10.3	422	5.8
Mean	206.5	50.6	295	24.36	314.16	17.63	395.66	11.01	431.16	5.0
Standard deviation (±)	7.82	0.38	3.34	0.38	15.53	0.35	8.16	0.52	7.49	0.55

320 m^2/kg Blaine's value is mandatory as per Indian standard IS 3812 part I guidelines and 200 m^2/kg as per Indian standard IS 3812 part II guidelines.

Table 2. Residue on 45 (μm) sieve and corresponding specific surface area by Blaine's permeability method (m^2/kg) of Unit 1 and 2 of Dahanu ESP rows

EPS field#	1		2		3		4		5		6	
Specimen number	Blaine's value	ROS 45 (μm)	Blaine's value	ROS 45 (μm)	Blaine's value	ROS 45 (μm)	Blaine's value	ROS 45 (μm)	Blaine's value	ROS 45 (μm)	Blaine's value	ROS 45 (μm)
	m^2/kg	%	m^2/kg	%	m^2/kg	%	m^2/kg	%	m^2/kg	%	m^2/kg	%
1	230.2	48.66	395.3	13.19	462.21	4.75	520.79	0.5	570.29	0.12	550.95	0.46
2	195.32	61.15	444.83	6.78	487.32	2.12	545.32	0.3	580.32	0.16	590.12	0.02
3	207.36	53.83	368.52	14.6	501.25	2.2	580.45	0.1	590.25	0.25	575.3	0.2
4	189.94	62.6	408.36	10.49	503.21	2.38	582.6	0.5	540.2	0.6	589.69	0.01
Mean	205.70	56.56	404.25	11.27	488.49	2.86	557.29	0.35	570.26	0.28	576.51	0.17
Standard deviation (±)	17.88	6.51	31.73	3.44	18.89	1.26	29.70	0.19	21.64	0.21	18.38	0.21

Loss on ignition was determined at 1000± 25°C following IS 1727:1967.[4] The samples analysis took place at 60% ± 2% relative humidity and 35°C± 1°C. A standard cement sample calibrated the Blaine's apparatus. The known LOI of Koradi and Dahanu samples were 1% and 0.5% respectively. The Dahanu thermal power station being a new plant had better coal quality and combustion efficiency than Koradi thermal power station. Table 3 shows the variation in Blaine's with LOI.

Result and discussion

Indian code IS 3812:2003 part-I specifies that fly ash fineness by Blaine's permeability method should be more than 320 m^2/kg, which corresponds to a maximum of 34% residue on 45 micron sieve and IS 3812:2003 part II specifies 200 m^2/kg fineness corresponding to the residue on 45 micron sieve of maximum 50%. Table 4 summarises the Indian standards. Koradi specimen

Table 3. Variation in Blaine's value with Loss on ignition percentage

	Sample with different loss on ignition (LOI)	% Residue on 45 micron sieve	Blaine's value m^2/kg
Koradi TPS	1.00%	18%	324
	1.25%	18%	316
	1.85%	18%	357
	2.08%	18%	370
	2.50%	18%	378
	3.10%	18%	382
	3.57%	18%	390
Dahanu TPS	0.49%	10%	390
	0.75%	10%	390
	0.85%	10%	410
	1.00%	10%	410
	1.50%	10%	419
	1.75%	10%	422
	2.50%	10%	445
	3.07%	10%	450
	3.52%	10%	458

Table 4. Indian code for the siliceous pulverised fuel ash

No.	Component / characteristics	Unit	IS 3812 (part I) 2003	S 3812 (part II) 2003
	Chemical requirement			
1.	$SiO_2 + Al_2O_3 + Fe_2O_3$, min	%	70	70
2.	SiO_2, min	%	35	35
3.	MgO, max	%	5.0	5.0
4.	Total sulphur as SO_3, max.	%	3.0	5.0
5.	Alkali as Na_2O, max.	%	1.5	1.5
6.	Loss on Ignition	%	5.0	5.0
7.	Moisture content, max.	%	-	-
	Physical requirement			
1.	Specific surface (Blaine's), min.	m^2/kg	320*	200
2.	Sieve residue on 45 micron sieve, max	%	34 (optional test)	50 (optional test)

from field# 3 and Dahanu specimen from field#2 onwards satisfy IS 3812:2003 part-I in terms of Blaine's fineness. From Table1, it is observed that Blaine fineness value of 320 m^2/kg corresponds to about 18% residue on 45 micron sieve and not 34 % as specified in the IS 3812:2003 part-I; however Blaine fineness value of 200 m^2/kg corresponds to 50% residue on 45 micron sieve, which matches with the Indian code, IS 3812:2003 part-II (Tables 1&2).

Brink and Halstead postulated that the particles of unburnt carbon being highly porous, influence the results of air permeability method because of both external and internal surface of particles of carbon.[5]

An increase in carbon content is accompanied by an increase in total surface area even though the external surface area and actual fineness decrease, introducing an error in the fineness as determined by Blaine's method.

To verify this, an exercise was undertaken by blending fine coal of known LOI with fly ash and wet sieving the specimen through a 45 micron sieve and comparing the results with Blaine's surface area (Table 3). This table shows that by increasing LOI, the Blaine's surface increased even though the residue on 45 micron had not changed. Indeed the LOI increase introduces an error in the fineness measurement in the surface area.

While every effort was made to achieve precision, performing Blaine's measurement was prone to error due to failure to sufficiently compress the sample and control the humidity. Indian standard recommends that the apparatus shall be calibrated periodically to check for possible wear on plunger or permeability cell, loss in manometer fluid and the quality of filter paper used for the test.[4] The most important precaution is that the apparatus calibration should be made by the same operator who does the fineness determination. Blaine's value is based on air permeability; hence porosity is directly related to the uniformity of the sample.

Conclusion

Blaine's value apparatus operation needs utmost care because with this equipment the probability of variation is high even when the same operator uses the equipment. Therefore for fly ash samples, the Blaine's surface area is at best a supplementary measurement. The most significant physical performance characteristic is the particle size. This determination with wet sieve method is robust and low cost giving a good reproducibility. Therefore the relevant Indian code should give more importance to the sieve analysis by making it mandatory rather than keeping it an optional test.

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