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## Physical and Chemical Character of Fly Ash of Coal Fired Power Plant in Java

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**Abstract.** Quality of fly ash is varying widely in the field, it depends on the combustion process and the quality of the basic ingredients, namely coal. It will affect the physical and mechanical properties of the concrete mixtures used. This study used 12 samples of fly ash. The physical and chemical properties and finesse modulus were analyzed. The fly ash was mixed with OPC (Ordinary Portland Cement) with the proportion of 20% fly ash and 80% OPC. The specimens were form with mortar dimension of 5cm x 5 cm. The test was affected by the correlation of fly ash fineness modulus to compressive strength, correlation density of fly ash to compressive strength, and correlation of carbon content to the compressive strength.

### 1. Introduction

The potential of fly ash (FA) utilization in order to respond environmentally friendly alternative cement solution describes the positive development. This fact was supported by the data from the Ministry of Energy and Mineral Resources. About 40% of Indonesian power plants still rely on coal as a source of energy up until 2019. During this process, there were 15,027,100 tons of A was produced [1]. Power plant industry utilizes about 780 billion tons of coal and produced FA of 7.8 billion tons each year worldwide [2].

In reality, the quality of fly ash is very varied, the variation greatly affects the standard quality in the application of geopolymer concrete. Therefore, until this paper is being written, the standard for application of fly ash in geopolymer concrete technology industry was still in development phase. The main problem to map fly ash characters is the complexity of the process [3] starting from coal as its base material. Coal is a combination of biological, chemical, and physical processes that occur due to the loading effect of covering sediments, temperature, pressure, and time on the organic component. Therefore, the quality of coal can not be equated to adjust the surrounding environment that shapes it. Each location has its own character traits based on the process. Second, the process of energy utilization of coal was in accordance with the needs of industries that use it. The combination of transportation and coal usage management are sometimes considered for cost optimization. The final problem in the management of hoarding and fly ash transportation from fly ash sources is utilizing the concrete industry. One character that needs to be noted is that the quality of coal determines the chemical composition of fly ash as summarized in table 1.

Table 1 The chemical composition of fly ash by the used coal [4]

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Compounds	Bituminous Coal (%)	Sub-Bituminous Coal (%)	Lignite (%)
SiO <sub>2</sub>	20-60	40-60	15-45
Al <sub>2</sub> O <sub>3</sub>	5-35	20-30	10-25
Fe <sub>2</sub> O <sub>3</sub>	10-40	4-10	4-15
CaO	1-12	5-30	15-40
MgO	0-5	1-6	3-10
SO <sub>3</sub>	0-4	0-2	0-10
Na <sub>2</sub> O	0-4	0-2	0-6
K <sub>2</sub> O	0-3	0-4	0-4
LOI	0-15	0-3	0-5

FA character mapping has been developed by the Indonesian Geopolymer Research Consortium (KORIGI) since 2014 with the outcome of geopolymer paste [5, 6], geopolymer mortar and geopolymer concrete [7]. Hardjito [8] had utilized F class fly ash waste into geopolymer concrete. The compressive strength of the concrete can reach 80 MPa. Ekaputri [9] made geopolymer grouting material with Na<sub>2</sub>SiO<sub>3</sub> activator mass ratio to 8M NaOH of 1.5, resulting in achieving a compressive strength of 48.59 MPa within 28-day.

From the description above, it shows that the use of fly ash as a mixture of concrete material, base material of geopolymer concrete, and raw material of hybrid alkaline has double benefits. It also reduces CO<sub>2</sub> emissions, utilize waste, and reduce energy consumption for hydration cement kilns. On the other hand, the quality of fly ash is so varied that it gives impact to the nature of the concrete and the mixture that uses it. For that we need to mapping the physical, chemical and mechanical characterization of fly ash in order to facilitate the use of fly ash based on its quality. In addition, the results of this characterization also provide information on the use of fly ash especially as a geopolymer binder.

## 2. Methodology

The research method used to answer fly ash characterization mapping: the literature studies about materials and coal processing and stage interviews. The first phase was the coal-burning process interviews, the regulations used in the production process, quality control, quantity data produced by power plant, the spread of consumers, the management of waste handling and transport procedures to the consumer. Then the second phase was interviews to consumers include fly ash sources and quality control. The field data collection was conducted to obtain data related to sample tests that had been done by the PLTU (steam power plant) in processing fly ash and supporting data as stated in the above questionnaire. The data group was divided into 2 sources i.e. fly ash SB power plant (77 data) and fly ash PLTU-P power plant (12 data).

Each data group will be calculated based on the amount of data that pass ASTM C-618 standard, then divided by the amount of data contained in each data group and multiplied by 100%. To obtain the fineness impact graph with concrete compressive strength (cubed mortar size 5x5x5 cm<sup>3</sup>), the field data obtained were sorted by fineness (ASTM C430) from the smallest value to the largest one, while density test use the ASTM C188 standard. There were two parts of discussion on following chemical properties in this study, namely data on the oxide levels in fly ash obtained through XRF test and data on minerals in fly ash obtained through the XRD test. The data on fly ash physical properties were obtained from fly ash sieve analysis, fly ash weight analysis, mortar making, and pasta making.

**3. Result and Discussion**

*3.1 Fineness*

The Data collection of 89 data from SB power plant and PLTU-P power plant can be summarized in Table 2. The standard used for categorization is ASTM C618. Figure 1 illustrates the fineness effects of fly ash on strength

Table 2 Confirmation of field data with ASTM C618

No	Origin	Auto Clave	Fineness + 325 mesh	Strength Activity Index	Water Requirement		Total Data
					max 105%(Class F or C)	max 115% (Class N)	
1	SB	100%	84.40%	98.70%	100%	100%	77
2	PLTU-P	100%	100%	100%	100%	100%	12

From the data above, it can be concluded that the sample variance obtained from PLTU-P is better than the SB power plant in relation to ASTM C-618 comparison.

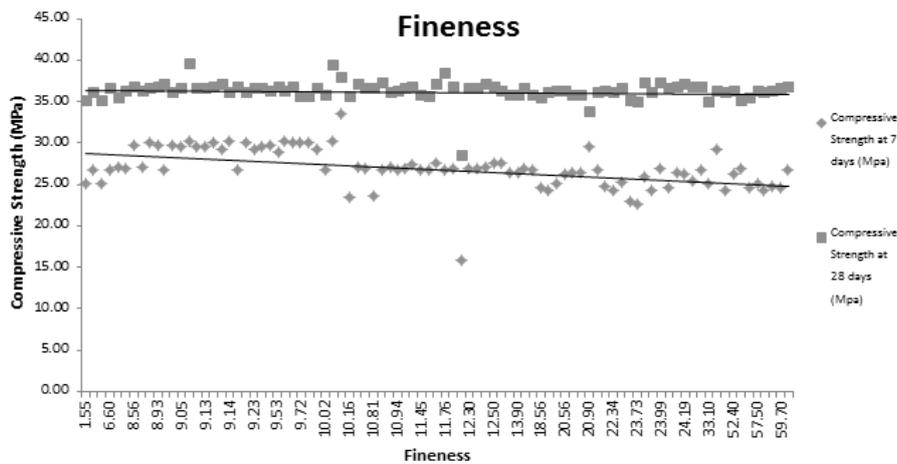


Figure 1. Fineness

The graph above shows the decrease of mortar compressive strength at the age of 7 days which followed by the increasing of fineness. Thus, it can be concluded that the rougher fly ash the less ability it has as a filler, causing a decrease in compressive strength and vice versa. However, the graph does not show a drastic decline rate at 28 days. This was attributed to the fly ash fineness value which still within the range allowed by ASTM that was 34% maximum stuck in filter no.325 in most data.

*3.2 Density*

Figure 2 shows the increased compressive strength at 7 days as density increases. In accordance with the function of fly ash as filler or cavity filler in concrete, it can be concluded that the denser fly ash, the more solid concrete. Thus, it can increase the strength of concrete.

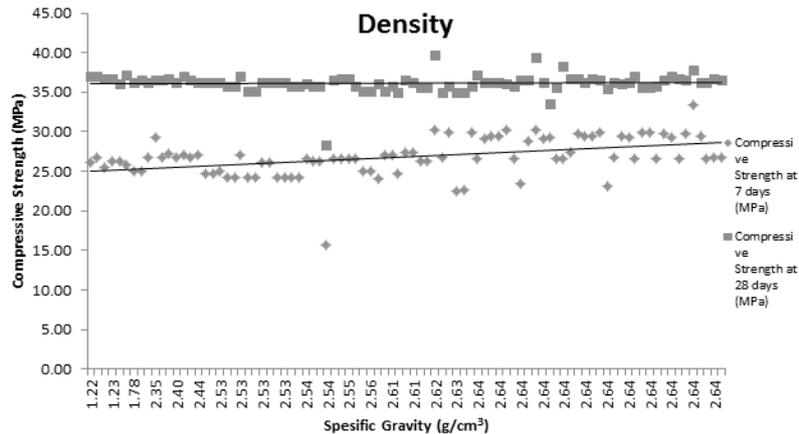


Figure 2. Density

3.3 Data of Oxide Compounds

The data on the chemical properties of fly ash are obtained from PLTU-P as the producer and SB as consumers.

Table 3 Confirmation of field chemical data with ASTM and CSA

No	COMPANY	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	SO <sub>3</sub>	SiO <sub>2</sub> + Al <sub>2</sub> O <sub>3</sub> + Fe <sub>2</sub> O <sub>3</sub>	CaO	ASTM		CSA	
								Class	Index	Class	Index
1	PLTU-P	34.97	14.23	20.05	7.49	69.25	13.92	F	0.7	CI	0.5
2	PLTU-P	68.05	10.98	6.39	6.1	85.42	5	F	0.9	F	1
3	PLTU-P	47.55	20.28	10.34	5.23	78.17	9.37	F	0.8	CI	0.5
4	PLTU-P	48.01	19.19	9.38	6.7	76.58	9.96	F	0.8	CI	0.5
5	PLTU-P	61.12	15.63	15.32	2.36	92.07	2.11	F	1	F	1
6	PLTU-P	60.47	16.51	15.19	2.26	92.17	2.12	F	1	F	1
7	SB	50.18	28.11	9.06	0.46	87.81	3.66	F	0.9	F	1
8	SB	50.54	31.2	8.21	1.41	91.36	5.34	F	1	F	1

Information :

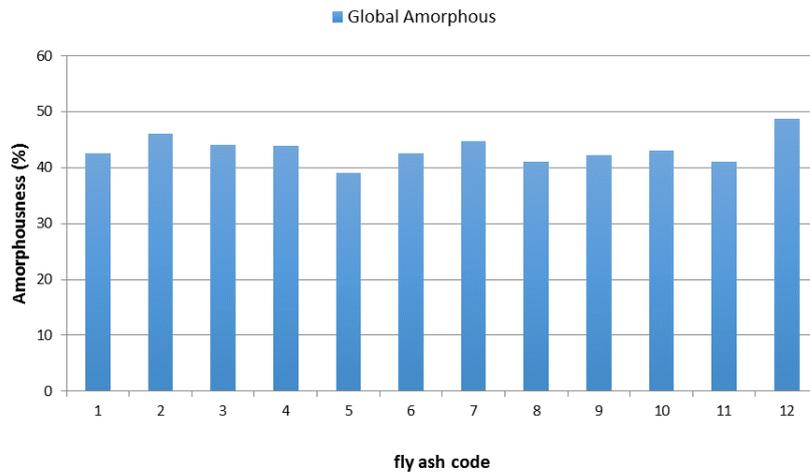
Not linear with ASTM C-618 (SO<sub>3</sub>> 5%)

From the table above, it can be concluded that fly ash derived from PLTU-P in general can be classified as F class fly ash according to ASTM C-618 and class F / CI according to CSA. However, 4 of 8 data indicate that fly ash at PLTU-P Power Plant contains a relatively high SO<sub>3</sub> (> 5%) Based on Table 3.3 on the chemical composition of fly ash, it can generally be said that fly ash which produced by PLTU-P power plant has a tendency to derive from coal of Bituminous Coal type because it has high Al<sub>2</sub>O<sub>3</sub> content (> 10%) and has qualified range of allowed oxide.

*3.4 Mineral in Fly Ash*

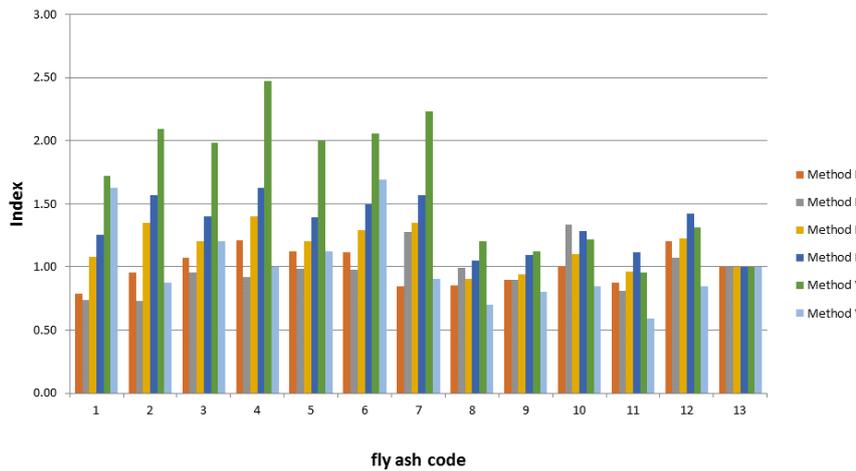
From the result of graph comparison between amorphous global and mortar / pasta mortar strength index showed similar pattern. Therefore, it can be concluded that the level of amorphous fly ash greatly affects the strength of mortar / pasta. Here are the results of pure fly ash XRD according to the code: Perbandingan global amorphous terhadap index fly ash

**Global Amorphous**



**Figure 3.** Global Amorphous comparison of fly ash.

**Fly Ash Index**



**Figure 4.** Fly ash index comparison of fly ash.

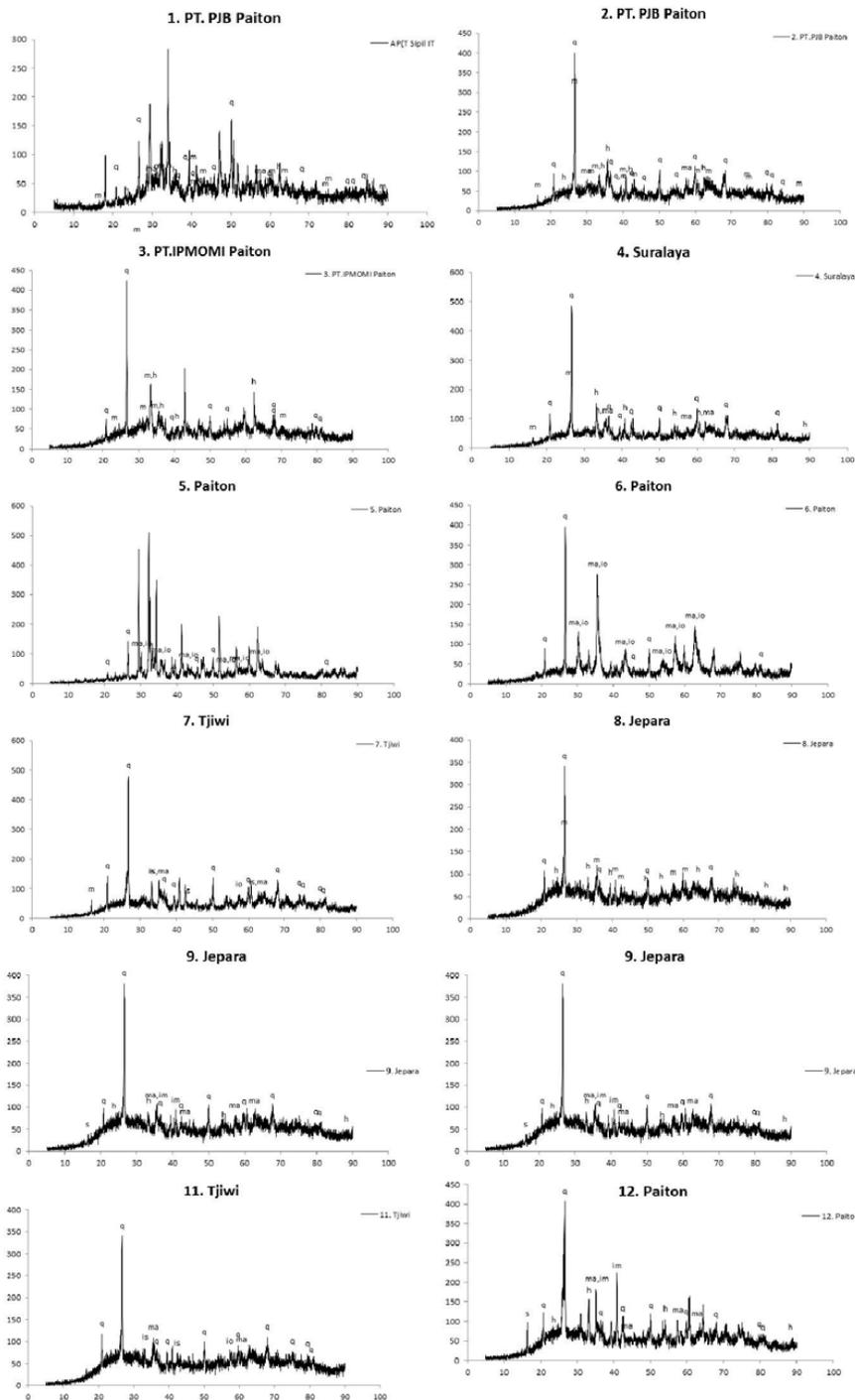


Figure 5. Results of XRD fly ash test



There are 3 main mineral compositions in fly ash which are minerals formed from  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ , and  $\text{Fe}_2\text{O}_3$ . Formation of the percentage of mineral composition is generally proportional to the percentage of oxide composition that is formed. These minerals have different shapes. Generally, the main constituent minerals in fly ash are Quartz ( $\text{SiO}_2$ ), Mullite ( $\text{Al}_6\text{Si}_2\text{O}_3$ ), and Hematite ( $\text{Fe}_2\text{O}_3$ ). In the pattern of fly ash minerals usually Quartz has the highest peak and followed by other minerals. The strength of mortar and paste is not only influenced by the peaks alone, but also influenced by the number of peaks that arise (Global Amorphous).

In general, the minerals in OPC type I paste are portlandite ( $\text{Ca}(\text{OH})_2$ ), calcium carbonate, and calcium silicate. The above graph shows that with the addition of fly ash to the paste mixture, it will reduce the intensity of the portlandite minerals in certain peaks and will increase the mineral intensity of calcium silicate. This is related with the reaction of fly ash in a paste utilizing  $\text{Ca}(\text{OH})_2$  formed from the cement hydration process to form calcium silicate. Fly ash can be said to have high reactivity rates if fly ash can react with many portlandite marked by significant Portland peak decline.

#### 4. Conclusion

The secondary field data of fly ash shows the variation of physical properties of the best samples are derived from PLTU-P power plant in relation to comparison with ASTM C-618 and chemically classified under class F / CI according to CSA. In general, fly ash from PLTU-P Power Plant contains high  $\text{Al}_2\text{O}_3$  (> 10%) and has fulfilled the required oxide range requirement. In laboratory tests (primary data), the physical properties of sieved fly ash proven to obtain better compressive strength result because most of the carbon will be retained on filter number 200 and reduce the cement water factor. The higher amorphous level of a fly ash will give a good impact on the strength of the concrete chemically, and vice versa. The strength of mortar and paste under review is not only influenced by the highest peak, but also influenced by the number of peaks that arise (Global Amorphous).

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