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Mechanical Properties of Geopolymer Paste Containing Fly Ash Waste From Indramayu Coal Power Plant

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ABSTRACT

Cement production is one of the largest contributors of carbon dioxide gas in the world. One way to reduce the use of cement is to replace it with materials that are similar in nature, one of which is fly ash produced by coal power plants. For this reason, it is necessary to study the characteristics and utilization of fly ash waste to determine the potential use of fly ash. The research method was carried out experimentally at the laboratory of PLN Institute of Technology in Jakarta. At the characterization stage, several tests was carried out to determine physical, chemical properties of materials and pasta compressive strength for various combination of fly ash a substitute for cement by 0%, 25%, 50%, 75% and 100% (geopolymer). the results of the compressive strength age 28 days of pasta were 33,93 MPa; 36,16 MPa; 24,27 MPa; 9,67 MPa and 60,87 MPa respectively. Conclusion fly ash can substitute cement.

Keywords: fly ash, compressive strength, geopolymer, paste

1. Introduction

The Indonesian Government has set a target on providing 35,000 Mega Watts (MW) electrical energy by 2025. By this target, 60% of the electrical energy plan to be full filled with Coal Power Plant (CPP). With the increasing number of coal-fired power plants in Indonesia, the amount of Fly Ash Bottom Ash (FABA) waste will continue to increase, approaching approximately 10-15 million tons per year in the next few years [1].

FABA consists of fly ash and bottom ash. This waste is categorized as toxic and hazardous waste (Bahan Berbahaya dan Beracun B3) and classified as “dangerous” material by the Ministry of Environment and Forestry (KLHK) [2]. However FABA can be declared not as B3 waste if it has been processed into certain product such as mortar or concrete product.

Indramayu CPP is located in Sumuraden village, Sukra sub-district, Indramayu district, West Java province. This CPP has generation capacity of 3x330 MW. It has three power plants that require a supply of 12 thousand tons of coal per day so that it will produce more than 1000 tons of FABA waste per month. For the time being FABA at Indramayu CPP has not been utilized optimally and disposed outside the location of Indramayu CPP at a cost of billions of rupiah per year.

Based on several studies that have been carried out, it is known that fly ash in Indonesia has a very diverse quality depending on the origin of the coal and combustion method at the power plant. Fly ash with good quality has potential possibility to be used as geopolymer concrete that has high strength.

The purpose of this study was to determine the mechanical properties of geopolymer paste containing fly ash waste from Indramayu CPP. Fly ash was mixed to form pasta as substitute for cement in several combinatons. The pasta was tested to determine the optimum mixture of fly ash for cement substitution. With this study it is expected that fly ash from Indramayu CPP can be converted into products that are more environmentally friendly.

2. Material and Methods

2.1. Fly Ash

Fly ash is a waste material generated from coal combustion. It consists of fine grains which are generally in the form of solid and hollow balls that are carried out with the exhaust gases and captured by the air control device. In general, the main content of fly ash consists of silicate glass compounds containing silica (Si), alumina (Al), ferrum (Fe) and calcium (Ca). Small content of other compounds contained in fly ash are magnesium (Mg), sulfur (S), sodium (Na) and carbon (C).

Based on ASTM C618-17 there are two types of fly ash in Indonesia namely fly ash type F and type C. The primary difference between type C and type F fly ash is the chemical composition of the ash itself which will produce level of certain reactivity. It is known that the smoother and the more regular spherical shape of fly ash will produce higher level of reactivity. On the other hand, irregular shape of fly ash will increase the speed of setting time on fly ash mortar [4].

Figure 1. Fly ash from Indramayu CPP

Several studies on fly ash that have been conducted are aimed to replace some portion of the cement in mortar or concrete mixture. Research conducted by Mira Setiawan (2018) on fly ash as a substitute for cement in concrete concluded that the optimum compressive strength of concrete is found at 12.5% fly ash as substitution for cement. It is also found that at the beginning of concrete life, the use of fly ash increasing the strength of the concrete [5]. Research conducted by Erfan M, et al (2019) on optimizing the use of fly ash with minimum cement content in high quality concrete using variations of 30%, 35%, 40%, 45 and 50% of fly ash in cement weight, resulted that the use of 40% fly ash give the optimum compressive strength of concrete–[6]. Research by Umboh AH, et al (2014) shows that the use of fly ash from Sulawesi CPP as substitute for cement in variation of 0%, 30%, 40%, 50%, 60 and 70% resulted an optimum compressive strength at 30% substitution of fly ash for cement [7].

The use of fly ash as substitution for cement also has been analyzed on mortar mixture. Research conducted by Kabir D, et al (2018) on the use of fly ash as an additive in mortar with composition of 0%, 10%, 20%, 30%, 40% and 50% show that the greater portion of fly ash added, the higher compressive strength resulted [8].

Based on those previous research, this research was expected to show strength characteristic of Indramayu CPP fly ash as a substitution for cement in mortar mixture. The result was expected to increase the use of Indramayu CPP fly ash on substitution of cement either in mortar mixture or in concrete.

2.2. Methodology

The research was conducted experimentally at PLN Institute of Technology laboratory. The stages of the research are as follows:

1. Literature Study
   Literature obtained from various written sources, either in the form of books, articles, and journals, or documents relevant to the problems was studied to collect information that can be used as ~~a~~ references to strengthen the existing arguments.
2. Preparation Stage
   Preparation stage in the form of providing materials required for implementation of experimental research were fly ash waste, cement and water. For 100% fly ash substitution for cement, alkali activactor is

required as replaced for water. This stage is also included preparing tools to be used to mix and test the pasta

3. Material Test
   Materials for paste mixture were tested to find specific gravity for cement; gradation, specific gravity and chemical elements (XRF) for fly ash.
4. Making Test Items
   pasta specimens with Combination of fly ash with ratio of 0%, 25%, 50% and 75% were made to determine the impact of fly ash substitution for cement. The last paste mixture was with 100% fly ash without cemen. For this mixture, water was replaced by alkali activactor to generate chemical reaction of the mixture.
5. Initial Setting Time Test
   Initial setting test were carried out for each variation of the test object.
6. Compressive Strength Testing
   Compressive strength test was carried out at the age of 7 days, 14 days and 28 days.
7. Analysis of results and discussion
   Analysis and discussion were carried out to compare the compressive strength of each variation.
8. Conclusion
   Analysis on the test result was conducted to resume the research.

2.1.1. Research Material

The materials used for this research are:
1. Gresik Portland cement Type I
2. Fly ash waste from Indramayu CPP.
3. Water from groundwater at the Concrete Laboratory of the PLN Institute of Technology.
4. Alkali Activactor.

2.1.2. Research Eqiupment

Equipment used for this research are as follows:
1. Scales to weigh the test object. The scales used is Ohauss GT-2100 with 0.001 grams accuracy.
2. Sieves no. 200 used to determine the gradation fly ash waste.
3. Vicat test equipment for testing specific gravity of cement.
4. The wykehan farrance pressure test machine has a capacity of 2000 kN.
5. Mixer for stirring
6. Pasta Mold.

2.1.3. Test Sample and Compression Test

The dimension of test sample is 5 cm x 5 cm x 5 cm based on Indonesia National Standard SNI 03-6825-2002 [9] as shown in Figure 2. Variation of cement pasta with 0%, 25%, 50%, 75% and 100% (geopolymer) of fly ash were produced. The total number of test samples were 45 pieces, with 9 pieces of samples in each variation.

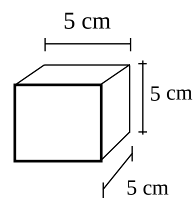

Figure 2. The shape of the specimen of the test sample

Figure 3. The making of the test sample

Compression test was carried out at the age of 7, 14 and 28 days. The test was carried out statically using Compression Testing Machine based on SNI 03 6825 2002 [9] which is presented in Figure 4. The test was carried out on each test sample with variations of fly ash waste from the weight of cement according to the design age. In addition to the strength of the pasta test, a test was also conducted to determine the setting time of the pasta.

Figure 4. Instrument for paste testing

3. Results and Discussions

The results of the preliminary testing of the material are presented in Table 2.

Table 1. Material Test Results

Test	Result
Cement Specific Gravity	3025 kg/m^3
Specific Gravity of Fly Ash Waste	2940 kg/m^3
Fly Ash Waste Gradation	Pass Sieve no 200
Fly Ash Chemical Test (XRF test)	Fly Ash Type F

The setting time test is carried out after the sample test is made. Based on the test, the result of initial setting time for all variations of fly ash to cement with proportion of 0%, 25%, 50%, 75% and 100% (geopolymer) are as follows:

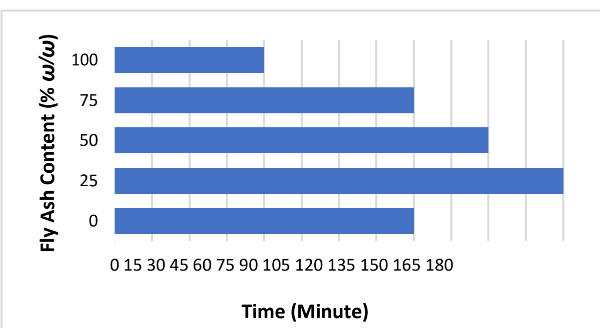

Figure 4. Geopolymer Initial Setting Time of Pasta

The compressive strength test was carried out for 7 days, 14 days and 28 days. The results of the compressive strength test pasta for all variations of fly ash to cement with proportion of 0%, 25%, 50%, 75% and 100% (geopolymer) as follows:

Table 2. Mortar Compressive Strength Test Results

Fly ash content (% ω/ω)	Age	Size (cm)			Cross-sectional area (mm^2)	Average compressive strength (MPa)
		l	w	h		
0%	7	5	5	5	2500	24,40
	14	5	5	5	2500	30,20
	28	5	5	5	2500	33,93
25%	7	5	5	5	2500	24,68
	14	5	5	5	2500	31,12
	28	5	5	5	2500	36,16
50%	7	5	5	5	2500	14,73
	14	5	5	5	2500	23,10
	28	5	5	5	2500	24,27
75%	7	5	5	5	2500	3,30
	14	5	5	5	2500	8,33
	28	5	5	5	2500	9,67
100%	7	5	5	5	2500	31,26
	14	5	5	5	2500	50,47
	28	5	5	5	2500	60,87

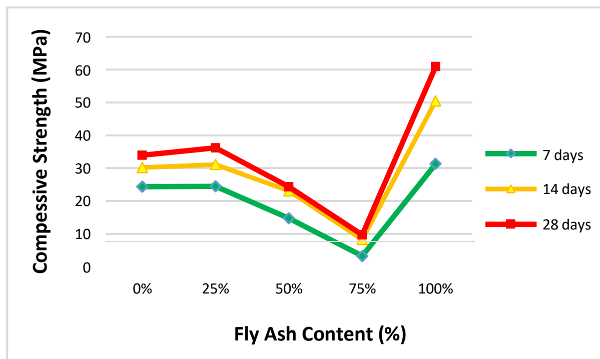

Figure 5. Mortar Compressive strength

Based on the results presented in Table 2 and Figure 5, it is known that as the higher use of fly ash portion in geopolymer paste as substitute for cement in creases, the compressive strength of pasta decreases. However at 100% fly ash substitution of cement and the use of alkali activactor to replaced water, increased the compressive strength to a maximum of 60,87 Mpa after 28 days explain of the standard compressive strength for paste.

4. Conclusion

The following conclusions can be drawn from this study The results of chemical tests using XRF analysis show that fly ash from Indramayu CPP meets the classification of class F fly ash based on American Society for Testing and Materials (ASTM) C618 with optimum setting time 180 minutes. The compression strength of geopolymer paste decreases at 50% to 75% cement substitution by fly ash. Substitution of 100% cement by fly ash with alkali activator gave the optimum value of paste compressive strength as 60.87 Mpa this figure meets the standard of paste.

Further researches on the use of alkali activator in various portion of fly ash substitution for cement in paste and in concrete to show geopolymer characteristics are suggested. It is necessary to pay attention to the density of the test materials since it will significantly affect the results of the compressive strength of the paste.

Acknowledgement

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