26. Turnitin-Analysis of fly ash from PLTU Asam-Asam as a construction material in terms of its physical and mechanical properties

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Analysis of fly ash from PLTU Asam-Asam as a construction material in terms of its physical and mechanical properties

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Abstract. Nowadays, PLTU Asam-Asam produced enormous amounts of combustion waste in the form of coal ash. On the contrary, only a little effort has been made to utilize coal ash from PLTU Asam-Asam, especially from the research side. In fact, due to its siliceous material, when reacting with CH in concrete, will form CSH hence improves concrete strength. In this study, in order to analyze the physical and mechanical properties of concrete using fly ash from PLTU Asam-Asam, 54 concrete samples were prepared according to SNI-03-2834-2000. The examination of concrete samples workability was conducted based on the slump test according to SNI 1972:2008. Moreover, the compressive tests were carried out in accordance with SNI 1974:2011. The slump test results show that the pozzolanic reaction of fly ash contributes to the improvement of concrete workability. Furthermore, the variation in w/b ratio was also affecting the results of the slump test. As for the compressive strength, in general speaking, the replacement ratio of 30% of cement with fly ash in concrete could produce concrete strength up to 30 Mpa. It is also important to note that due to the pozzolanic reactions tends to delayed, it is expected that at later ages (above 28 days) concrete with fly ash will gain much more strength compared to ordinary concrete.

1 Introduction

As one of the fast-growing region in Indonesia, South Borneo increasingly needs additional electricity supply year by year. Due to this reason Asam-Asam power station (PLTU Asam-Asam), as the main power station in the South and Central Borneo, must increase its electricity generation capacity. In 2013, two electricity generation with a capacity of 130 WH each was build. In addition, in 2017, construction of another two electricity generation with a capacity of 100 WH each has been started.

The technology applied in PLTU Asam-Asam based on pulverized coal-fired boiler technology. It means that the source of electricity comes from coal. Hence, PLTU Asam-Asam generates enormous amounts of combustion waste in the form of coal ash, which is around 26,400 tons per year [1]. This causes difficulties regarding waste management. The current waste management applied by PLTU Asam-Asam is using the conventional method

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of accumulating coal ash on prepared landfills. However, this method will not solve the main problem because the amount of coal ash is increasing rapidly every year.

Nowadays, there have been many innovations in the utilization of coal ash (especially fly ash) that have been carried out both in the field of construction and agriculture. Especially in construction, the examples of coal ash utilization are such as bricks, concrete mixes, soil stability, Portland Pozzolanic Cement, etc [1]–[8]. Coal ash also used in agriculture as mixed fertilizer plants and or land reclamation [9].

Judging from the potential of the PLTU Asam-Asam coal ash and the explanation above, the utilization of coal ash (especially fly ash) become a solution that is beneficial in terms of waste management. However, due to the heavy metal contents inside coal ash, in Indonesia, Coal Ash is categorized as hazardous and toxic waste material (B3) in accordance with Government Regulation Number 101 of 2014 [10]. Although in fact, several studies have proven that coal ash relatively harmless to the environment, especially in terms of construction material [7], [11].

Until now, only a few studies have been conducted on the use of fly ash from PLTU Asam-Asam. One of it is the research by Yanuar and Umar [1]. In this study, the replacement ratio of fly ash in the concrete mix was 5%, 30% and 50% with concrete strength design (f'c) of 20 MPa, 30 MPa and 42 MPa. The results of this study indicate that with 30% fly ash replacement ratio in concrete can reach concrete's strength up to 20 MPa and 15% fly ash replacement ratio can even reach up to 30 MPa. As for 50% fly ash replacement ratio, only meets up to around 15 MPa. However, in this research, the curing time of concrete samples and the water to binder ratio (w/b) used were not stated. Thus, the characteristic of fly ash concrete from PLTU Asam-Asam fly ash is not yet complete.

In this study, in order to investigate the physical (workability) and mechanical (compressive strength) properties of PLTU Asam-Asam fly ash, concrete slump tests according to SNI 1972: 2008 and compressive tests according to SNI 1974:2011 were comparatively conducted [12][13]. It is expected that this research could give an overview of the utilization of PLTU Asam-Asam fly ash as a construction material. Consequently, this will be a waste management solution for PLTU Asam-Asam.

2 Materials and methods

2.1 Materials

Portland composite cement (PCC), from I Co, Ltd., was used. In order to investigate the physical and mechanical properties of fly ash concrete, fly ash from PLTU Asam-Asam was used. The chemical compositions of fly ash are shown in Table 1. It shows that the percentage of $SiO_2 + Al_2O_3 + Fe_2O_3$ are more than 70%. However, the percentage of SiO_2 itself is below 50%. Based on ASTM C 618, it can be said that PLTU Asam-Asam Fly ash categorized as Class C fly ash. As for Table 2 shows the physical properties of fly ash from PLTU Asam-Asam. The fine aggregates were obtained from Matraman quarry in South Borneo, while the coarse aggregates were taken from Katunun quarry in South Borneo.

Table 1. Chemical compositions of fly ash.

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	TiO_2	MnO	SO_3	Na_2O	K_2O
Fly ash	27.07	11.69	34.73	10.80	7.24	0.35	0.23	3.68	3.98	0.23

Table 2. Physical properties of fly ash.

	Density (gr/cm^3)	Water content (%)	Specific gravity	Water Absorption (%)
Fly ash	1,21	20.2	2.55	8.23

2.2 Methods

The physical and mechanical properties of fly ash concrete were investigated through 54 samples, which are divided into two variations. The variations are ordinary concrete and 30% replacement ratio of cement with fly ash. The mixture of concrete sample is based on SNI 03-2834-2000 [14]. Every sample variations consists of three w/b ratios, which are 0.3, 0.43 and 0.5. Basically based on SNI 03-2834-2000, the w/b of concrete (with given aggregate and designed compressive strength of 25 MPa) has to be set at 0,43. However, the use of three different w/b is useful to determine the effect of differences in w/b on concrete properties.

As for the curing time for all samples were set at 3, 28 and 56 days. Furthermore, The examination of concrete samples workability were conducted based on the slump test according to SNI 1972:2008 [12]. Moreover, the compressive strength test is based on SNI 1974:2011 [13]. The complete mixture proportions of concrete samples is shown in Table 3.

Table 3. The mixture proportions of concrete samples.

NO	Sample type	Water to binder ratio	Fly ash (%)	Material requirements kg/m^3				
				Cement	Water	Coarse	Fine	Fly Ash
1	ST1	0.5	0	410	205	1135	725	0
2	ST2	0.5	30	287	205	1135	725	123
3	ST3	0.43	0	477	205	1093	700	0
4	ST4	0.43	30	334	205	1093	700	143
5	ST5	0.3	0	683	205	968	619	0
6	ST6	0.3	30	478	205	968	619	205

3 Results and discussion

3.1 Workability

Table 4 shows the slump test results. The slump tests were carried out for all sample variations, which are the ordinary concrete samples and the 30% replacement ratio of fly ash samples, with 0.3, 0.43 and 0.5 w/b ratio. From the results, it can be seen that the variation in w/b ratio was affecting the results of the slump test. The lower the w/b ratio, the concrete samples were less workable. In fact, the workability of concrete is influenced by w/b ratio [15]. However, samples with fly ash replacement ratio showed bigger slump test value compared to the ordinary concrete samples. Thus, it proves that fly ash improves concrete workability. This phenomenon could be due to the three benefits of fly ash, which are the fine particles of fly ash, spherical shape and the smooth surface of fly ash, and the “particle packing effect” of fly ash [16]. In addition, with 0.5 w/b ratio, both sample variations showed the same slump test results. It seems that higher w/b ratio already improve concrete workability. So the effect of fly ash on concrete workability become unseen.

Table 4. Slump test results.

NO	Sample type	Water to binder ratio	Fly ash (%)	Slump test results (cm)
1	ST1	0.5	0	7.6
2	ST2	0.5	30	7.6
3	ST3	0.43	0	6
4	ST4	0.43	30	6.8
5	ST5	0.3	0	2.4
6	ST6	0.3	30	2.8

3.2 Compressive Strength

The compressive strength tests were conducted according to SNI 1974:2011 [12]. As mention above, the curing time was set to 3, 28 and 56 days. Therefore, the compressive strength tests were carried out at those curing time. The average compressive strength test results for samples with w/b ratio set at 0.5 for all variation could be seen in Fig. 1. Whereas Fig. 2 shows the average test results for samples with w/b ratio set at 0.43 for all variations. In addition, Fig. 3 shows the average test results for samples with w/b ratio set at 0.3 for all variations.

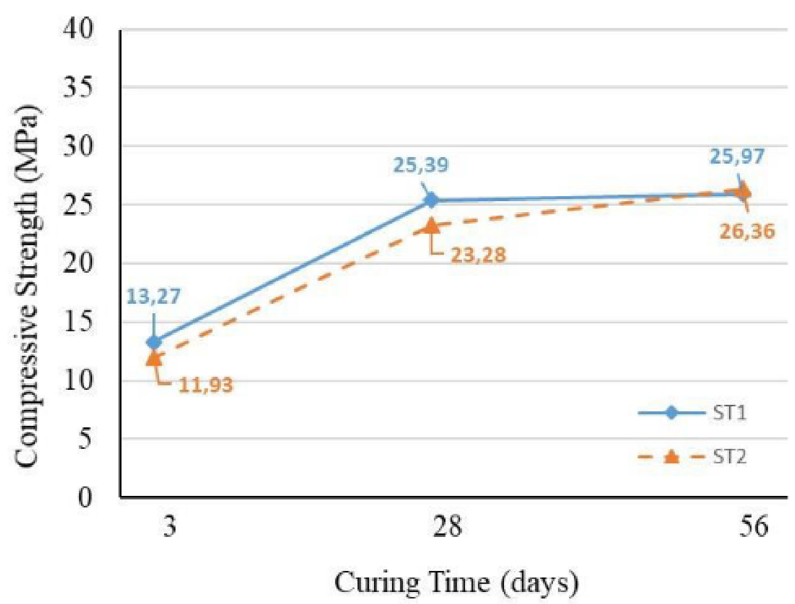

Fig. 1. Average compressive strength test results for samples with 0,5 w/b ratio.

From Fig. 1, it could be seen that the highest compressive strength is 26,36 MPa from sample with 30% replacement ratio of fly ash (ST2) at 56 days curing time. It means that fly ash will improve the compressive strength of concrete, even though naturally a higher w/b ratio will reduce the compressive strength of concrete [15]. Another interesting fact is that the compressive strength of ordinary concrete sample (ST1) at 28 and 56 days curing time were almost the same, tends to be flat, at around 25 MPa. Conversely, the different results could be found in ST2 sample.

As for ordinary concrete, it is known that the final compressive strength could be achieved at 28 days, especially for concrete with high w/b ratio, and only a slight increase in strength will occur afterward. In contrary, as for concrete with fly ash, the pozzolanic reaction between fly ash and Portland cement can produce more CSH gel which plays a role in increasing the strength of concrete [3]. Nonetheless, the pozzolanic reaction is delayed and occurs after the hydration reaction between cement and water. Hence, after 28 days curing time, the strength of concrete with fly ash is still increasing significantly.

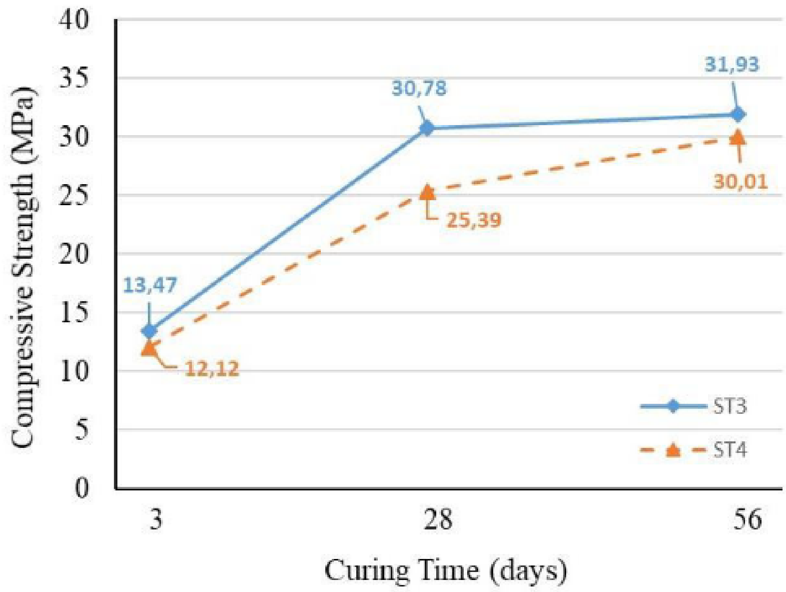

Fig. 2. Average compressive strength test results for samples with 0,43 w/b ratio.

A similar pattern could be found in Fig. 2. Only a slight increase of strength could be seen for ordinary concrete sample (ST3) from 28 days to 56 days curing time. On the contrary, in terms of strength, sample with fly ash (ST4) shows a sharp increase from 28 days to 56 days curing time. Although, from this results the compressive strength of ST3 sample is slightly higher compared to the ST4 sample. In addition, it also can be noted that due to the lower w/b ratio, ST3 and ST4 samples are show higher compressive strength compared to ST1 and ST2 samples, especially at later ages. Thus, it can be seen that w/b affects the compressive strength of the concrete.

A sharp increase in terms of strength from 28 days to 56 days curing time for ST4 sample could confirm the effect of pozzolanic reaction from fly ash. In the early stage, until 28 days, concrete strength is obtained from the hydration reaction between cement and water. Consequently, the strength of ST4 at 28 days curing time is very low compared to ST3 sample, due to ST4 sample has less cement compared to ST3 sample. After the hydration reaction end, the pozzolanic reaction of fly ash is increasing. One of the reason is due to the hydration reaction produces Calcium Hydroxide (CH), which is beneficial in the pozzolanic reaction of fly in concrete [17]. The more CH is produced, the higher strength can be achieved due to the pozzolanic reaction effects. As a result, after 28 days, the ST4 sample gained significant strength.

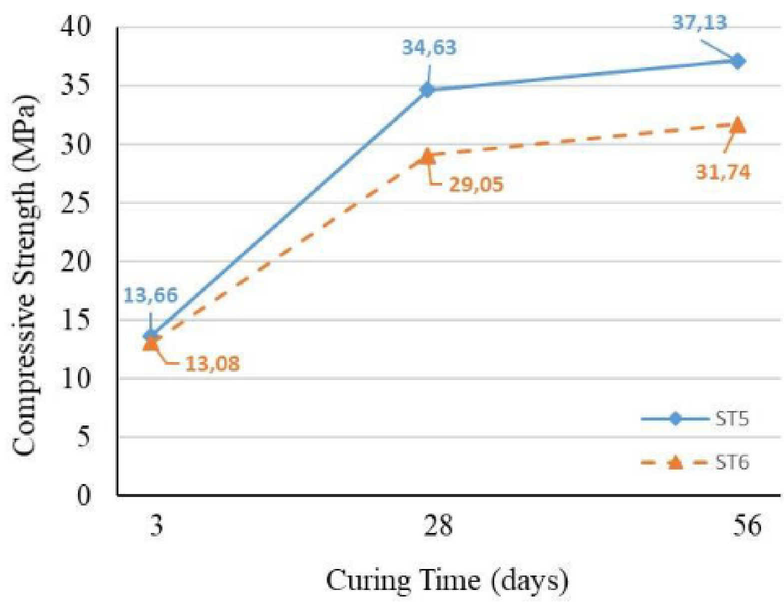

Fig. 3. Average compressive strength test results for samples with 0,3 w/b ratio.

As for compressive strength test results for samples with 0,3 w/b ratio (Fig. 3), the pattern rather different if compared to the others results. The increase in strength for both samples (ST5 and ST6) from 28 days to 56 days could be seen. In contrast, if we compare with the previous results, the improvement of strength for ordinary concrete (ST1 and ST3) is very small. However, in terms of w/b influence, it still could be noticed that the lower w/b will further increase the strength of the concrete.

This finding is in agreement with previous investigations. Concrete with low w/b ratio yields a higher compressive strength with increase in curing time (28 days until around 90 days) compared to concrete with higher w/b ratio [15] [18]. It is also important to note that although sample with fly ash (ST6) has a lower strength compared to ordinary concrete sample (ST5), yet at later ages, the strength of fly ash concrete might increase significantly [19].

4 Conclusions

The purpose of this research was to analyze the fly ash from PLTU Asam-Asam as a construction material in terms of its physical and mechanical properties. The pozzolanic reaction of fly ash has mainly been pointed out as well as the possibility to use this material as a cement replacement in concrete. In terms of physical property (workability), its known that the variation in w/b ratio was affecting the results of the slump test. In addition, as for the effect of fly ash in workability of concrete, the test results can ensure that fly ash could increase the workability of concrete.

In terms of mechanical property (compressive strength), the pozzolanic reaction of PLTU Asam-Asam fly ash could give contribution to the strength improvement. Furthermore, with a decrease in w/b, there is an increase in the strength of the concrete. In general speaking, the replacement ratio of 30% of cement with fly ash in concrete could produce concrete strength up to 30 Mpa. Moreover, if using high w/b ratio, the fly ash concrete could be used as structural concrete with strength up to 25 MPa.

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