30. Turnitin-Application of central kalimantan coal ash as a sustainable construction material

by Irfan Prasetia

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Application of central kalimantan coal ash as a sustainable construction material

I Prasetia, M Syauqi, and A S Aini

Lambung Mangkurat University, Indonesia

E-mail: iprasetia@ulm.ac.id

Abstract. The current study is related to laboratory investigations to utilize Central Kalimantan coal ash as a sustainable construction material, which is green paving blocks. For this purpose, coal ash from the Pulang Pisau coal-fired power plant, both in the form of fly ash and bottom ash, was used as an additional proportion of cement. The addition of fly ash was set at 10%, 20%, and 30%. Meanwhile, the addition of bottom ash was set at 5%. Water to binder ratio (w/b) was set at 0.45, and the curing times were set at 7, 28, and 56 days for all samples. Moreover, the sample's compressive strength test was based on BS 6717:1986 regarding the precast concrete paving block. Based on the test results, it was proven that the addition of fly ash and bottom ash could increase the compressive strength of paving blocks. The highest compressive test results were obtained from the addition of 20% fly ash and 5% bottom ash (24.62) MPa at the age of 56 days. This result is 30% higher compared to the ordinary paving blocks test result. Furthermore, according to SNI 03-0691-1996, paving blocks with a compressive strength of 20 MPa until 40 MPa can be applied as parking lots pavements.

1. Introduction

Coal ash is a byproduct of burning coal from boilers, such as burning coal for power plants. There are two forms of coal ash: light ash (fly ash) and relatively heavy ash (bottom ash). During the coal combustion process, the resulting ash is about 5%, which around 10-20% is bottom ash, and approximately 80-90% is fly ash [1]. In Indonesia, this waste is estimated to grow at least 1 million tons per year. Meanwhile, the coal-fired power plant in Kalimantan produces at least 26,400 tons of coal ash per year [2].

Based on Indonesian Government Regulation number 104 in 2014 about the management of hazardous and toxic substance waste, fly ash, and bottom ash are categorized as hazardous waste with waste code B409 for fly ash and B410 for bottom ash with hazard category 2. Based on that regulation, category 2 of hazardous waste has a delayed effect (non-acute material), has an indirect impact on humans and the environment, and has sub-chronic or chronic toxicity (long term effect). With the increasing amount of fly ash and bottom ash, optimal utilization is needed to reduce the amount and reduce the environment's impact.

Some researchers have started to study the use of fly ash and bottom ash in life. One form of utilization applied is to use fly ash and bottom ash as mixture materials such as mixture material for making concrete, bricks, etc. [3–11]. Furthermore, a considerable amount of literature has been published regarding fly ash and bottom ash as mixture materials for bricks [12–15]. However, only a few research have been conducted in terms of both ashes (fly ash and bottom ash) as a mixture for

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concrete bricks (i.e., paving block).

Based on this, it is necessary to research utilizing fly ash, and bottom ash sourced explicitly from the Central Kalimantan coal-fired power plant (PLTU Pulang Pisau) as mixture materials in making a green paving block. In this study, both ashes were used as an additional proportion of cement. This research aims to study the influence of additional fly ash and bottom ash in paving block compressive strength and categorize the coal ash paving block's quality regarding the SNI 03-0691-1996. This study's results are expected to reduce the industrial waste from PLTU Pulang Pisau and propose the mixture composition for a good quality green paving block.

2. Materials and methods

2.1. Materials

Portland composite cement (PCC), from I Co, Ltd., was used. In order to investigate the effect of Central Kalimantan Coal Ash, fly ash and bottom ash from PLTU Pulang Pisau were used. Moreover, the fine aggregates were obtained from Barito River sand in South Kalimantan. The chemical composition of fly ash and bottom ash used can be seen in **Table 1**. While the class of fly ash and bottom ash used can be seen in Table 2**2**.

Table 1. Chemical composition of fly ash. [16]

	Komposition (%)								
Materials	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	LOI
Fly Ash	40.47	12.75	21.25	14.47	6.34	1	0.34	0.69	1.36
Bottom ash	88.69	3.03	3.54	1.68	0.91	0.1	0.25	0.26	-4.82

Table 2. Classification of coal ash from PLTU Pulang Pisau

No.	Sample	$SiO_2 + Al_2O_3 + Fe_2O_3$	SiO_2	SO_3	LOI	Class
1	Fly Ash	74.47%	40.47%	1%	1.36%	Class C
2	Bottom Ash	95.26%	88.69%	0.1%	-4.82%	Class F

2.2. Methods

The coal ash paving blocks were investigated through 80 samples, which are divided into four variations. The addition of fly ash was set at 10%, 20%, and 30%. Meanwhile, the addition of bottom ash was set at 5%. Water to binder ratio (w/b) was set at 0.45, and the curing times were set at 7, 28, and 56 days for all samples. The examination of the compressive strength test is based on BS 6717-1986 about precast concrete paving blocks. The complete mixture proportions of the concrete sample are shown in **Table 3**.

Table 3. The mixture proportions of samples.

No	Sample	Sand (kg)	Cement (kg)	*Fly Ash* (kg)	*Bottom Ash* (kg)	Water (liter)
1	F0B0	45	15	0	0	6,75
2	F10B5	45	15	1,5	0,75	7,76
3	F20B5	45	15	3	0,75	8,44
4	F30B5	45	15	4,5	0,75	9,11
	Total	180	60	9	2,25	32,06

3. Results and discussion

3.1. Compressive strength

3.1.1. 7 days samples.

The compressive strength test results for 7 days samples are shown in **Figure 1**. The addition of fly ash and bottom ash in samples F20B5 and F30B5 has a strength increase of 16.11% compared to samples without the addition of fly ash and bottom ash (F0B0). It proves that the addition of fly ash and bottom ash can increase the compressive strength of paving blocks. However, it is also important to note that the compressive strength is slightly lower for the sample with 10% addition of fly ash compared to the normal sample.

Fly ash and bottom ash have pozzolanic properties. Still, at 7 days curing time, it seems no pozzolanic reaction occurred due to the hydration reaction of water and cement is still ongoing. The pozzolanic reaction requires calcium hydroxide of cement to increase compressive strength development [5][10]. At this stage, the fine fly ash grains will most likely fill the voids between the aggregates and reduce the porosity in the paving block, which causes an increase in compressive strength [17].

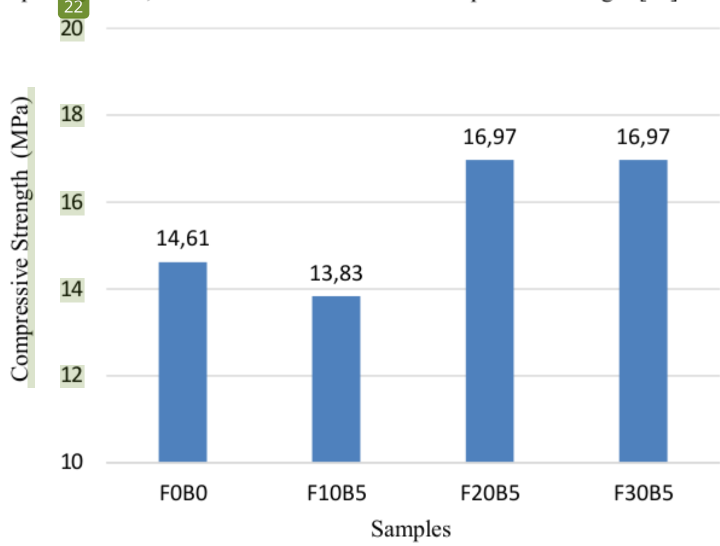

Figure 1. Average compressive strength test results for 7 days samples.

3.1.2. 28 days samples.

Figure 2 shows the compressive strength test results for 28 days samples. Compressive strength result for 28 days samples shows that the addition of fly ash and bottom ash in samples F10B5, F20B5, and F30B5 has a strength increase of 6.90%, 21.84%, and 38.51%, respectively compared to samples without the addition of fly ash and bottom ash (F0B0). At this stage, the hydration reaction of cement and water has produced calcium hydroxide and the pozzolanic reaction began to occur. With the production of calcium hydroxide (a byproduct of cement hydration), the pozzolan (fly ash and bottom ash) begins to react and produce calcium silicate hydrate gel (C-S-H) through the pozzolanic reaction, which is responsible for the enhancement of strength [5,18].

In contrast to the cement hydration with water that is fast, the pozzolanic reaction takes place slowly but will gain more strength at the latter curing time. The hydration heat produced is also lower than the portland cement, so it is useful for casting concrete in hot weather or making massive concrete [19].

However, because of the slow pozzolanic reaction, construction material products with pozzolan need longer curing time [19–21].

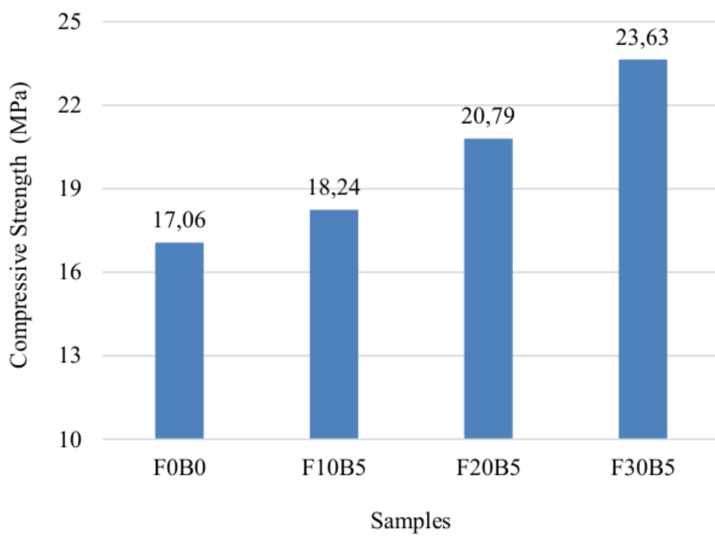

Figure 2. Average compressive strength test results for 28 days samples.

3.1.3. 42 days samples.

The compressive strength test result at 42 days shows the same pattern compared to the 28 days result. Samples F10B5, F20B5, and F30B5 has a strength increase of 2.30%, 28.74%, and 43.68% respectively compared to F0B0 samples. A significant increase in strength could be observed from samples with higher addition of fly ash. However, the strength development for F10B5 samples is considered insignificant. One explanation for this phenomenon is that the amount of pozzolan available affects the yield of C-S-H gel produced, leading to a significant influence on sample strength development [10].

Furthermore, at 42 days curing time, it can be seen that for samples using portland cement increase in strength did not occur. The cement hydration process takes place quickly for 28 days and will slow down after that. Thus, after 28 days, only a little or even no increase in strength could be observed. The average compressive strength test results for 42 days samples could be seen in **Figure 3**.

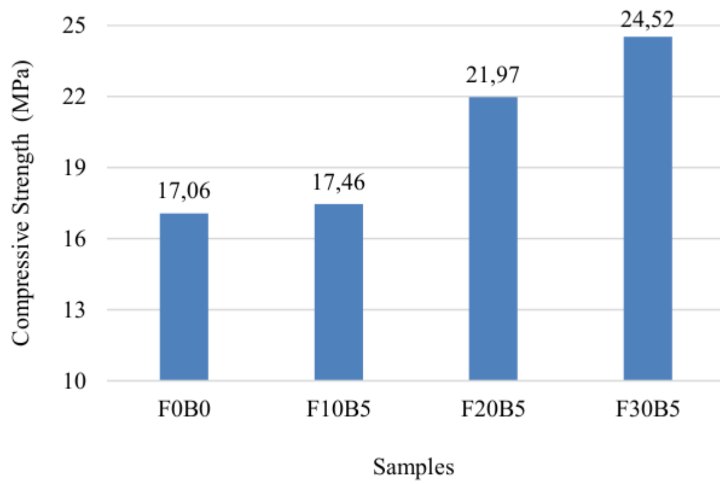

Figure 3. Average compressive strength test results for 42 days samples.

3.1.4. 56 days samples.
For compressive strength test result at 56 days curing time, the addition of fly ash and bottom ash samples still show an increase in the development of strength, especially for F10B5 and F20B5 samples. However, a slight reduction in strength could be observed for 56 days F30B5 compared to 42 days F30B5. It seems that the amount of pozzolan has far exceeded the amount of CH available. Thus, the pozzolanic reaction no longer occurs and development in strength is stopped. It is also important to note that there is a high possibility that after 56 days, the compressive strength of sample F20B5 still increases. **Figure 4** shows the average compressive strength test results for 56 days samples.

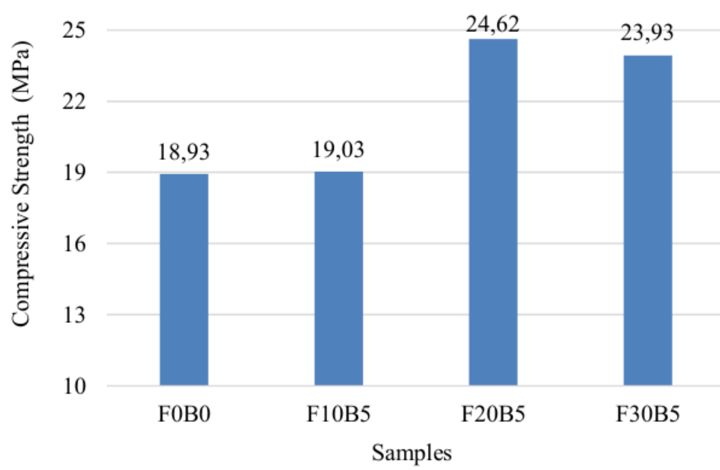

Figure 4. Average compressive strength test results for 56 days samples.

3.2. Application recommendations

Based on SNI 03-0691-1996, the 7 days compressive strength test for F0B0 and F10B5 samples is categorized as the D quality. The application for paving block with D quality classification is for garden paving. Whereas for samples F20B5 and F30B5 are classified as C quality. For its application, quality C is used for pedestrian paving.

As for the 28 days compressive strength test results, F0B0 and F10B5 samples are equal to the C quality. Furthermore, the F20B5 and F30B5 samples are considered as the B quality. Quality B paving block is used for parking lot paving. Besides, the compressive strength test results of paving block at the age of 42 days and 56 days for F0B0 and F10B5 samples are classified as C quality and for F20B5 and F30B5 samples are categorized as B quality.

In general, the addition of 20% of fly ash and 5% bottom ash on paving block mixtures could give the highest compressive strength results. Thus, this mixture is being proposed as the ideal green paving block mixture. Furthermore, if it is desired to make maximum use of the waste, then the addition of 30% of fly ash and 5% bottom ash is the best green paving block mixture to ensure a cleaner environment.

4. CONCLUSIONS

A series of laboratory studies have been conducted to investigate the influence of fly ash and bottom ash on paving block strength. The recommendation of green paving block mixtures and its application also being proposed based on the results obtained. Here are some important points to conclude:

1. The addition of fly ash and bottom ash on the paving block mixture increased paving blocks' compressive strength. Especially for samples with the addition of 20% fly ash and 5% bottom ash at 56 days can reach up to 24.62 MPa.
2. In terms of producing the highest strength, the addition of 20% fly ash and 5% bottom ash in the paving block mixture is being proposed. In addition, as for the ecological reason, the addition of 30% fly ash and 5% bottom ash is being proposed for more environmentally friendly paving blocks.
3. The suggestions that can be made for further research are as follows:
   a. Further research is needed on the 20-30% fly ash with a 2.5% addition difference.
   b. Further research is needed for sample F20B5 at the age of more than 56 days to see the fly ash pozzolanic reaction's development.

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