Performance of Fly Ash and Bottom Ash as Coal Combustion Product to Prevent Acid Mine Drainage Generation: Preliminary Result on a Pilot Scale

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Abstract

Coal combustion product (CCP) utilization for acid mine drainage (AMD) treatment has been studied for geochemical properties, chemical retention, and rate of salt release as well as its neutralizing capacity. Past studies have shown promising results for the application of CCP as a capping layer to minimize AMD generation in the overburden dumps. Kinetic test using column has also been carried out both in a laboratory and field to analyse its capacity to attenuate AMD from potentially acid-forming (PAF) rock, by layering CCP with NAF above PAF rock layer. The result of those kinetic test showed an increase of pH value, a decrease in dissolved metal concentrations such as Fe and Mn while oxygen concentration was appeared to decrease. However, numerous open pit mines in Indonesia are lack in NAF rock which causes inefficiency in CCP-NAF-PAF capping. Therefore, this research aims to evaluate the utilization of CCP and PAF rock blending to minimize AMD generation in overburden dump, by using test both in laboratory and field scale.

The field scale was carried out in a coal mine by constructing overburden dump test sites. The design of the overburden model consists of two compartments, compartment 1 for layering and compartment 2 for blending. The overburden test site was constructed in the size of 4 x 4 m, the height of 1.5 m from the safety berm (width of 0.5 m), and the ±45° slope. PAF with a high capacity in producing AMD was selected. The layering model was constructed with 0.3 m of PAF at the bottom of the overburden, then layered with 0.9 m of CCP and 0.3 m of topsoil at the top of the layer. Meanwhile, the blending model was constructed with 0.3 m of PAF at the bottom of the overburden then layered with a mixture of PAF:CCP (ratio 1.5:1) at 1.2 m height from the floor. Each layer was equipped with an oxygen and moisture sensor in both test sites.

Keywords: Acid Mine Drainage, Coal Combustion Product, PAF, Capping Method.

Introduction

Based on the national energy mix plan, Indonesia will build a 35,000 MW coal-fired power plant or Pembangkit Listrik Tenaga Uap (PLTU) with coal as a source of energy to meet the national electrical energy needs. Due to this development plan, it is estimated that the national coal consumption will increase in the long term by ±170 million tons/year from the current consumption of around ±70 million tons/year. The increase in the amount of coal burning will also increase the waste product of coal combustion – coal combustion products (CCP, including Fly Ash and Bottom Ash). Assuming an average burnt ash content is 15% (maximum ash content is 30%), ±36 million tons of CCP will be produced yearly. CCP in Indonesia is categorized as hazardous waste from Special Class 2 sources based on Government Regulation No. 101 of 2014 regarding the Management of Hazardous and Toxic Waste. Furthermore, based on the latest regulation, Government Regulation (PP) No. 22 of 2021 regarding the Implementation of Environmental Protection and Management, CCP from coal mines is classified as non-B3 waste. Therefore, it is essential to conduct studies on CCP utilization to prepare for the effects that occur due to the increase in CCP from these PLTUs activities.

Many of the PLTUs built are located near mining areas to reduce the cost of transportation of coal and electricity generated so that PLTUs can be used to support mining activities and distributed to the surrounding community through collaboration with the State Electricity Company, including the Asamasam PLTU. This government-operated PLTU is located ±5 km from PT Arutmin Indonesia, the Asamasam coal mine, which has been the sole coal supplier at PLTU Asamasam since 2010. Thus, PLTU Asam Asam can be categorized as a mine-mouth coal-fired power plant. Therefore, the plan to utilize CCP for re-utilization in the mining area is a reasonable reason and needs further study. Using CCP around mining areas minimizes the potential impact of exposure and reduces costs incurred due to transportation when CCP will be used for other industries. The mine-mouth coal-fired power plant area generally consists of other industrial activities that can utilize CCP, such as cement factories, which are still Indonesia's most common utilization option.

One of the potential uses of CCP in the mining area is to form a covering layer to prevent the formation of AAT from overburden dumping area, called the capping method. However, the problem is that many coal mines in Indonesia have more potentially acid-forming material (PAF) than non-acid forming material (NAF) (shortage of NAF material), so the capping process is not optimal. CCP from the mine mouth power plant can be used as a substitute for NAF due to its alkaline nature. Besides being used in the overburden dumping area, CCP can also be backfilled in voids that are ready to be rehabilitated according to the final design of the mine, making these two locations potentially take in CCP massively. The utilization of coal ash is expected to provide more value as an alternative material that can be used as a covering material and a higher amount of utilization compared to other options.

Methods

CCP 's physical and geochemical characterization

This research uses CCP from Asamasam coal-fired power plant, located in Asamasam Regency, South Kalimantan Province, Indonesia. Theoretically, the characterization of CCP depends on the coal source, combustion conditions, and exposure time in the air (related to oxidation level). Therefore, the evaluation of CCP 's physical and geochemical characterization at the Asamasam power plant will be carried out.

PAF's physical and geochemical characterization

In this research, PAF rock which will be used is distributed around the out pit dump and void areas. The tests to be carried out include evaluating geochemical and physical properties to determine the long-term stability of the material in the simulation to be studied. Before the kinetic test by using a column in the laboratory and field scale, PAF as the AMD-producing rock will also be evaluated.

Overburden Dumping Test

The construction of the overburden dumping test site starts with the preparation of the overburden dumping test site land, the overburden dumping model construction, drainage channel construction, material filling, and installation of moisture and oxygen sensors. The structure of the overburden dumping test site consists of 2 (two) compartments, compartment 1 for layering PAF:CCP material and compartment 2 for blending PAF:CCP material. The design of the overburden dumping model construction can be seen in Figure 1 for the top view. The overburden model was constructed in the size of 4 x 4 m, the height of 1.5 m from the safety berm (width of 0.5 m), and the ±45° slope.

At the bottom layer of layering scheme, PAF rock was added with a 0.3 m thickness. After that, CCP with 0.9 m thickness was added and followed by topsoil (0.3 m

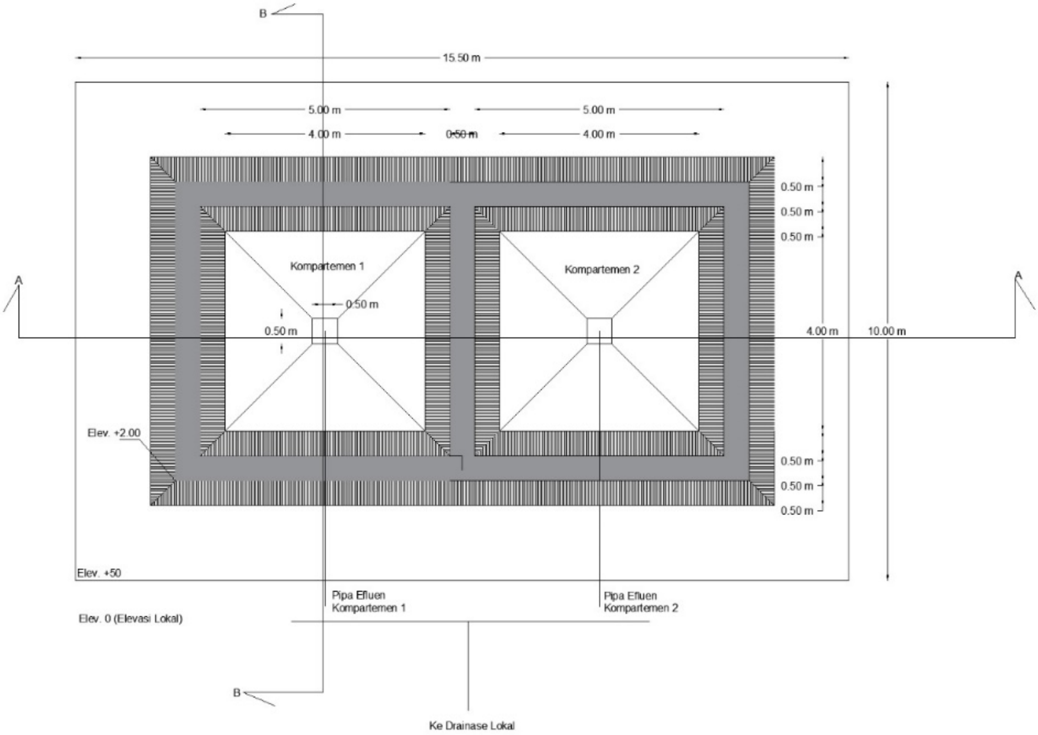

Figure 1 *The top view of overburden dumping test site*

thickness) to the top layer. In each layer of lithology, oxygen (ICT SO-421) and moisture sensors (Delta SM 150T) were installed to understand the water content and oxygen in the model.

For compartment 2 (blending scheme), the bottom of the overburden dumping test site is layered with 0.3 m thick PAF material, followed by PAF and CCP blending material (weight ratio of 1.5:1) until it reaches a height of 1.2 m. The top soil layer is added with a thickness of 0.3 m. Oxygen and moisture sensors are installed on PAF material and a mixture of PAF and CCP. Leachate water from this overburden dumping test site was also collected to be further analyzed.

Data and Analysis

Table 1 shows the geochemical properties of CCP, soil and PAF. The CCP and top soil is categorized as NAF, while PAF is high in producing acid.

Table 1 *Static test result for CCP, Soil and PAF*

Code	Lithology	pH Paste	TS (%)	MPA	ANC kg H_2SO_4/ton	NAPP	NAG pH (s.u.)	NAG pH = 4.50	NAG pH = 7.00
CCP	CCP	9.92	0.37	11.33	337.8	-326	6.39	9.4	0
Top Soil	Soil/Sub Soil	4.90	0.40	12.25	0,00	12.25	5.05	0	2.33
PAF	Claystone	4.02	103.82	0.00	103.8	0.00	2.6	54.8	76.2

Table 2 Physical Properties

Code	Tipe Material	Spesific Gravity, Gs	Bulk Density, γm kN/m³	Dry Density, γd kN/m³	Porositas, n	Degree of Saturation, Sr %	Water Content, Wn
PAF	Disturbed	2.7	15.2	13.57	0.5	33	12.04
Top Soil	Disturbed	2.73	19.7	15.81	0.42	92	24.58
CCP	Disturbed	2.85	16	12.36	0.57	65	29

The test results show that the PAF and FABA materials have the same specific gravity with similar porosity (SG > 2.50; n > 0.45). Moreover, CCP has a higher saturation than PAF. In addition, the PAF material is smaller in size than the CCP, which is possible because the CCP is taken in an open heap, so cementation occurs. The CCP material is bonded/agglomerated to each other.

From XRF result, CCP can be classified based on its elemental oxide content. CCP were classified as Type-C (pozzolanic cementitious) based on ASTM; Type Cl based on CSA; and FCS/Fericalsiatic type (chemical content of (SiO_2 + Al_2O_3 + Fe_2O_3) at least 70% and CaO content at least 10%). In addition, fly ash generally has high CaO and low SO3 values, which can be classified as Aluminosilicate CCP to Basic CCP / alkaline CCP. CCP have pozzolanic-cementitious properties and can neutralize acids derived from calcium oxide.

FTIR test results show PAF is mainly associated with aluminosilicate minerals, minerals with OH-bonds (such as kaolinite), and pyrite minerals (Fe-S bonds). Meanwhile, the CCP consists of aluminosilicates associated with amorphous material (glass) and carbonates (associated with portlandite/calcite/lime) which can neutralize acid mine drainage.

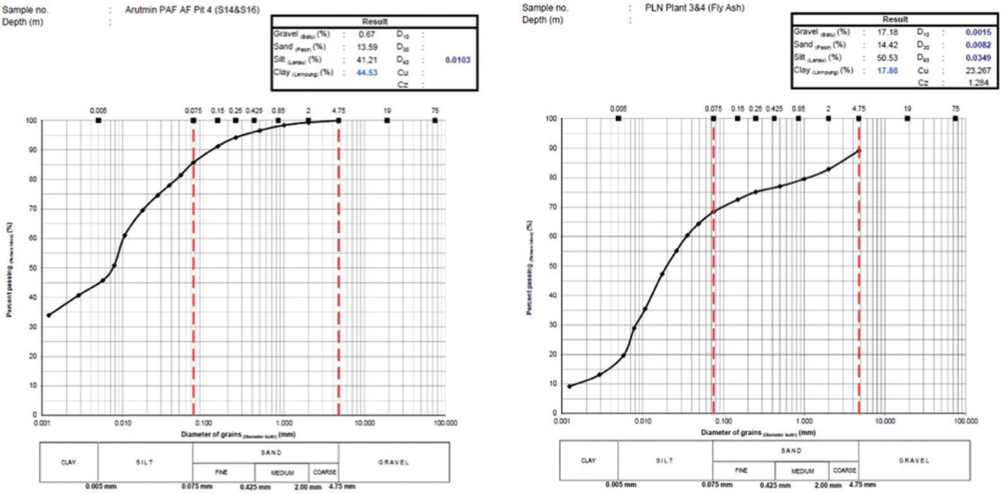

Figure 2 Size Distribution of CCP (left) and PAF (right)

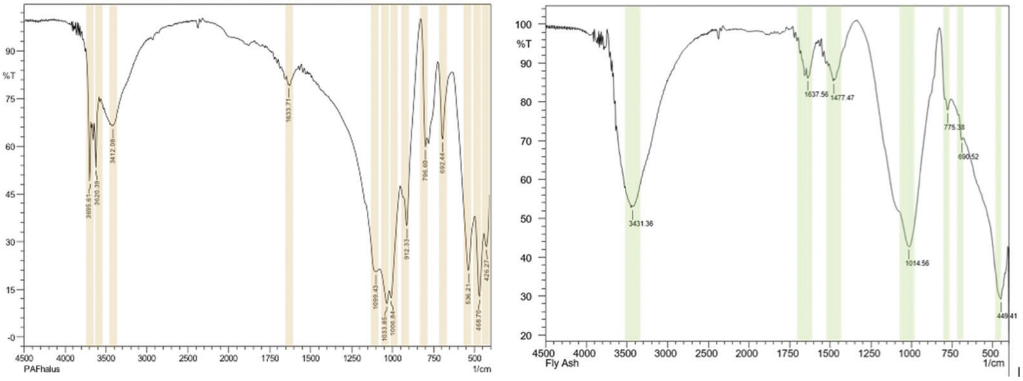

Figure 3 Transmittance graph from FITR : CCP (left) and PAF (right

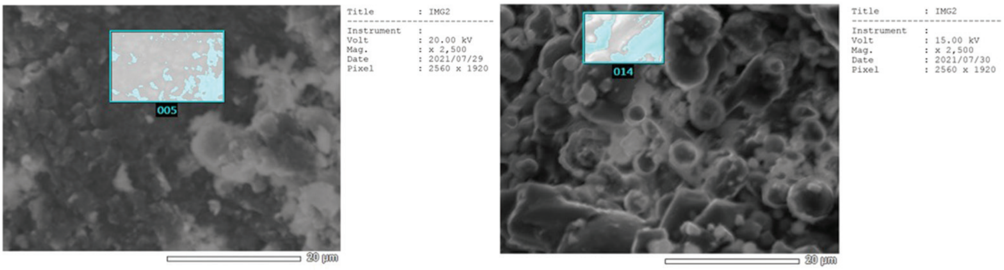

Figure 4 SEM EDS 2500x for PAF (left) and CCP (right)

SEM-EDS results show that PAF has a layered/flaky morphology like materials with the main composition of clay minerals. There are also unevenly distributed euhedral pyrite crystals. The EDS results show confirmation of XRF and XRD, where the material is composed of aluminosilicate material with an increase in Fe and S at the location where FeS2 (pyrite) is located. Meanwhile, the CCP sample was granular with several amorphous forms, and cementation was seen between the individual grains. CCP mainly consists of aluminosilicates with trace elements iron and increased calcium (presumably from calcite/lime/portlandite) and magnesium (magnesite, dolomite), which can neutralize AMD.

Discussion

Overburden dumping test site results show that the layering scenario in AMD formation's neutralization is better than the mixing scenario. The layering scenario shows that the trend of pH varies between 7 – 9 (except at one monitoring point where the pH drops to 4).. For the mixing scenario, the pH value is around 2.50. The results of the chemical quality test in the blending scenario show a higher increase in dissolved metal when compared to the results of the water chemical quality test in the layering scenario. The pH and ORP values of the leachate affect the solubility of metals especially Fe and Mn. Higher concentrations of Fe and Mn occur in the mixing scenario compared to the layering scenario.

***Table 3** Statistics of Measurement Results of Leachate in Blending Scenarios*

	pH	ORP	Eh (mV)	EC (µs/cm)	TDS (mg/L)	Temp (^{0}C)
Max	5.91	236.30	506.30	10030.00	6270.00	30.60
Min	2.37	75.00	345.00	1661.03	1095.00	23.70
Average		201.48	471.48	4023.40	2466.50	26.80

Table 4 Statistics of Measurement Results of Leachate in Layering Scenarios

	pH	ORP	Eh (mV)	EC (µs/cm)	TDS (mg/L)	Temp (°C)
Max	8.90	151.70	421.70	9640.00	6620.00	30.10
Min	4.25	-442.00	-172.00	707.00	464.00	24.20
Average		-77.60	192.40	4564.49	3162.44	27.07

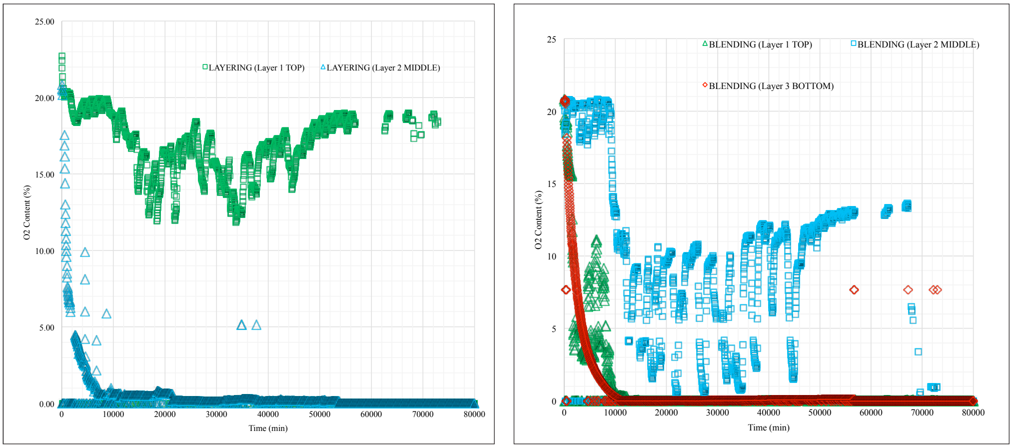

***Figure 5** Oxygen measurement result in layering and blending scheme*

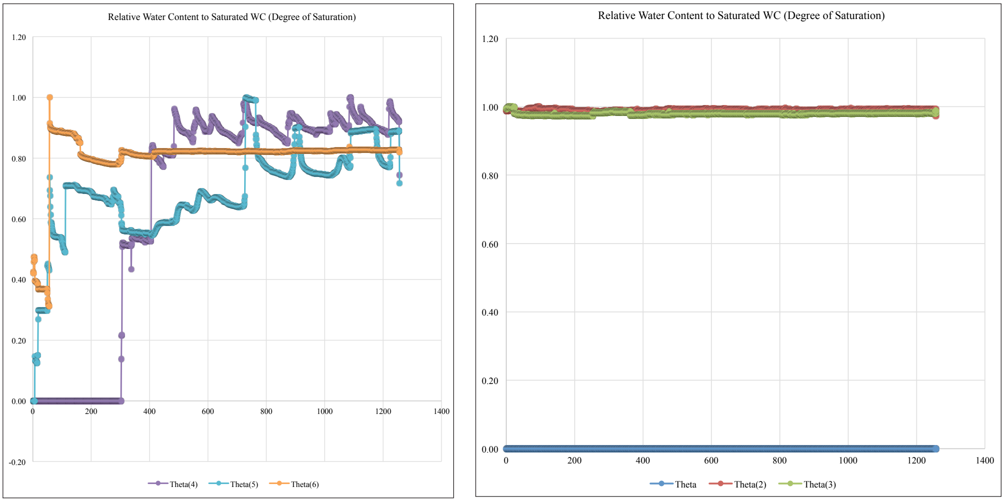

***Figure 6** Relative water content measurement result in layering and blending scheme*

From the results of monitoring the oxygen concentration, it can be seen that the top soil layer has O_2 variability concentration value, suggesting that oxygen diffusion still occurs at the top of the test site. In the middle layer, in the blending scenario, the variability of O_2 is still significant, which means that O_2 occurrs. Meanwhile, the O_2 value is decreased significantly for the layering scenario, suggesting that O_2 diffusion is retained in the FA layer in layering scenario. In the lowest layer (PAF), the O_2 value in both scenarios is generally low. Based on O_2 conditions and O_2 diffusivity, the layering scenario is more likely to decrease the oxygen diffusion rate in overburden dumping.

In the test with of PAF and CCP blending, it is possible that the CCP material will tend to “stick” and agglomerate to the claystone/PAF material to form particles with a larger size so that preferential flow of water/oxygen occurs and a mechanism to prevent diffusion. The pH of the pore water is low, and acid mine water is still formed (as seen from the O2 profile, which is more limited/inhibited in the layer pile)

Conclusions

The overburden dumping test site shows that the layering scenario of PAF and CCP has better prevention/neutralization of AMD formation compared to blending scenario, due to its preferential flow of water and oxygen.

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