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Differences in the Quality of Bottom Ash and Fly Ash for the Cement Industry as an Alternative Fuel (AF)

Nurul Faizah Setiaji, Ariyanti Sarwono*, I Wayan Koko Suryawan
Faculty of Infrastructure Planning, Department of Environmental Engineering, Universitas Pertamina, Jakarta 12220, Indonesia
*e-mail: ariyanti.sarwono@universitaspertamina.ac.id

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Abstract
Cement is a prominent Indonesian industry. Industrial fuel needs are growing. In Indonesia, biomass is an essential natural resource with a variety of primary products such as fiber, wood, oil, food, and others that are utilized domestically and exported to generate foreign cash. This study compares fly ash and bottom ash as alternative fuel feedstock materials from the cement industry. This study uses cement industry data from East Java. As, Cd, Cr, Pb, Hg, TI, Sb, Co, Ni, Cu, V, Zn, Se, and Sn for bottom ash and fly ash quality data are employed. The investigation followed a paired t-test to compare ash types based on metal characteristics, then an ANOVA post-test to establish the significance of bottom ash and fly ash values. The paired t-test on two types of ash showed a 0.103 difference. ANOVA shows that ash kinds differ significantly. Bottom ash and fly ash have different qualities. Hence their management requires various approaches. This treatment utilizes bottom ash. For fly ash, the quality-related parameters must be lowered.

1. Introduction

The cement industry is one of the major industrial sectors in various regions of Indonesia [1]. The cement industry is a strategic industry that is much needed as the primary supporting industry for infrastructure development, such as bridges, ports, buildings, and others [2], [3]. The increasing demand and domestic consumption of cement in Indonesia provide opportunities for national and foreign companies to build the cement industry in Indonesia. Various foreign cement industries have now entered the territory of Indonesia by building cement factories directly in multiple regions.

The need for fuel for industrial cement purposes is increasing yearly [4], [5]. Meanwhile, the availability of fuel oil and gas and the price continue to grow, and production and distribution are often constrained. Renewable energy has become a significant need for the community to drive the nation's economy [6]–[8]. In addition to daily needs for households, fuel is also a source of energy to drive production machines for small and medium industries. Fuel is a must-have production raw material in the industry, small and medium enterprises, and households. The increase in fuel will be economic pressure on them. The ash formed, mainly bottom ash, still has a calorie content of 3000-3600 kcal/kg [9]. Ash and bottom ash from the cement industry as an alternative fuel raw material.

Coal is widely regarded as one of the most valuable natural resources [10]. For the better part of the last century and a half, it has been put to use all over the world as a source of fuel for generating electricity and steam. Both developing and developed countries have seen a significant increase in their demand for coal to be used in the production of energy [11]. The predominant element that makes up coal is carbon, which gives it its characteristic black color and makes it primarily composed of carbon [12]. When coal is burned in coal-fired boilers, it produces several different types of ashes, including fly ash, coal bottom ash, boiler slag, flue gas desulfurization materials, and other fluidized bed combustion ash, cenospheres, and scrubber residues, amongst other things [13], [14].

Table 1. Bottom Ash and Fly Ash Quality

Parameters	Bottom Ash	Fly Ash	Standard
As	13	39	≤ 15
Cd	0	0	≤ 5
Cr	25	232	≤ 25
Pb	0	0	≤ 300
Hg	0	0	≤ 1.2
TI	0	0	≤ 2
Sb	0	0	≤ 120
Co	0	0	≤ 12
Ni	43	46	≤ 100
Cu	57	52	≤ 100
V	24	176	≤ 25
Zn	54	100	≤ 500
Se	0	0	≤ 10
Sn	0	0	-

Fly ash, also known as pulverized fuel ash, is a byproduct of the combustion process that occurs in the furnaces of coal thermal power plants [15]. Electrostatic precipitators, which were installed to reduce levels of air pollution [16], are responsible for collecting them. Its primary components are silica, alumina, and ferric oxides, as well as magnesium oxide, sulfuric acid, and sodium oxide. Fly ash is the remnants of burning coal generally produced by factories and power plants. Therefore, fly ash is a material with good pozzolanic properties. The fly ash content primarily consists of oxides of silica (SiO_2), aluminum (Al2O_3), iron (Fe2O_3), and calcium (CaO), as well as small amounts of potassium, sodium, titanium, and sulfur [17]. Coal bottom ash is one of the most significant sources of industrial waste produced from coal-based thermal power plants [10], [18].

Bottom ash, as well as fly ash, is the result of coal combustion in the power plant's boiler [19], [20]. The size of bottom ash is more significant than fly ash, so bottom ash falls to the bottom of the kiln. The physical appearance of bottom ash is similar to that of natural river sand, and its gradation varies as fine sand and coarse sand. The grain size of bottom ash makes researchers interested in using it as a substitute material in concrete production [21]. However, the larger particle size of fly ash causes the workability of the bottom ash to be worse than the mixture using cement and fly ash. In general, coal ash pozzolanic reactions are related to particle fineness; in this case, bottom ash has a coarser and larger particle size than fly ash which is believed to cause an ineffective pozzolanic reaction [22].This study aims to determine the differences in the quality of fly.

Table 2. Bottom Ash and Fly Ash T-Value Pair Test Value

	Parameters	Value
	Mean	-30.6429
	Std. Deviation	65.41772
	Std. Error Mean	17.48362
95% Confidence Interval of the Difference	Lower	-68.4139
	Upper	7.12821
	t	-1.753
	df	13
	Sig. (2-tailed)	0.103

Table 3. Bottom Ash and Fly Ash ANOVA Test Value

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	6051.429	6	1008.571	1.75E+31	0.000
Intercept	7617.306	1	7617.306	1.32E+32	0.000
Ash	6051.429	6	1008.571	1.75E+31	0.000
Error	4.04E-28	7	5.77E-29		
Total	9384	14			
Corrected Total	6051.429	13			

3. Research Methods
This study uses secondary data from the cement industry in East Java. The data used is the quality data of metal parameters consisting of As, Cd, Cr, Pb, Hg, TI, Sb, Co, Ni, Cu, V, Zn, Se, and Sn. The measurement of these parameters was carried out by the AAS method. The data analysis carried out was a parametric test preceded by descriptive analysis. The investigation was continued with a paired t-test to determine the comparison of ash types based on metal parameters. Then an ANOVA test was performed on the post-test to assess the significance of the difference in bottom ash and fly ash values. This statistical analysis was carried out with SPSS software.

4. Results and Discussions
In utilizing external hazardous waste, PT Semen X Tuban Factory has its material content standards. Therefore, where external hazardous waste enters PT Semen Indonesia (Persero), the Tuban Factory must be tested in a laboratory first and adjusted to the standards of the Ministry of Environment as stated in the Material Safety Data Sheet (MSDS). MSDS is information or knowledge that chemical laboratory implementers must know in handling chemicals [23]. Table 1 is data of an external hazardous waste material MSDS that is used as a reference for the composition of hazardous waste materials that are allowed to be processed by PT Semen X.

The results of the paired t-test on the two types of ash showed that there was a significant difference in values of 0.103 (Table 3). This indicates that the two data sets do not have the same value or cannot be matched. So, the quality of bottom ash and fly ash is unrelated. The results of the ANOVA are summarized in Table 3. The results of the ANOVA test show that there are significant differences in ash types. Because there are differences in the quality of bottom ash and fly ash, the ash management must be carried out with different treatments. This treatment can use bottom ash optimally. Meanwhile, it is necessary to decrease the parameters that still do not meet the quality standards for fly ash. The utilization of external hazardous waste as an alternative fuel (AF) has several stages, as shown in Figure 1.

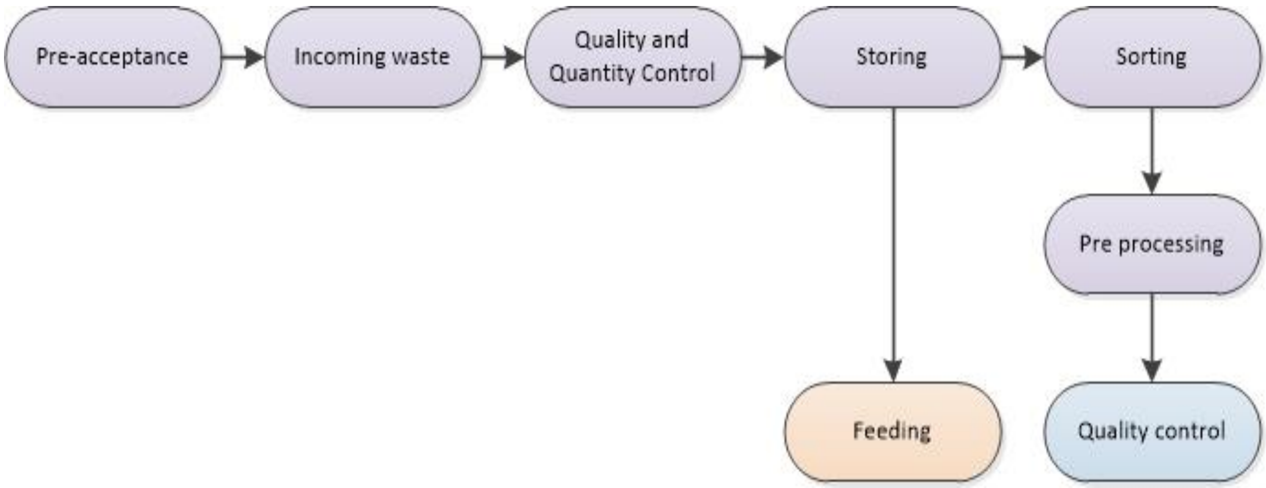

Figure 1. Utilization of external hazardous waste as an alternative fuel (AF) diagram process

4.1 Pre-Acceptance (Legals and technical screening)
Pre-acceptance is the stage of controlling waste input/input, related to determining the type of waste that can be accepted based on physical and chemical characteristics that follow the criteria/specifications and factory operations, occupational health and safety, and the Environment, as well as related to the legality aspect of the permit. Applicable, covering the type of waste received and transportation permits from the waste producer to PT Semen X Factory.

4.2 Acceptance and inspection
At this stage, the activity begins by scheduling the arrival to ensure that the appearance of the waste contained in the factory is truly following the technical aspects and applicable legalities. Then the manifest, physical examination, and waste sampling were conducted to be tested in the laboratory. After that, it was weighed using a weight feeder.

4.3 Processing
The initial handling of waste includes storage, grinding, mixing, and homogenization processes at the processing or pre-processing stage. This stage is well planned so that the waste can meet the specifications of cement production and ensure that it meets the applicable environmental standards to the maximum.

4.4 Feeding
The feeding stage is where the process of feeding waste into the cement production process is adjusted to the characteristics of the waste and the cement production process [24]. This process requires a warehouse (storage) to store incoming waste and waste to be fed. Things that need to be considered in the application of the Co-processing method as an alternative fuel (AF) are the composition, shape, size of the waste, and the water content of the type of waste so as not to affect the stability of the operation and the quality of the cement product produced. Some conditions must be met based on the Decree of the Ministry of the Environment No. 308 of 2017 types of hazardous waste that can be used as a substitute for alternative fuel (AF) in kiln facilities are,

1) Minimum calorific value 2,500 kcal/kg
2) The moisture content is at most 15%
3) Total organic halide (TOX) content as fluoride (F) and chloride (Cl) is at most 2%
4) The content of polychlorinated biphenyls (PCBs) for liquid phase hazardous waste is at most 2 ppm
5) The lowest flash point value is 100^{o}F.
6) The highest total content of heavy metal arsenic (As) is 5 ppm.
7) The highest total content of heavy metal Cadmium (Cd) is 2 ppm.
8) The highest total content of heavy metal Chromium (Cr) is 10 ppm.
9) The total heavy metal content of lead (Pb) is at most 100 ppm.

There are several stages of activities for the use of hazardous waste as a substitute for alternative fuel (AF) in the kiln facility as follows:
a. Solid phase hazardous waste that meets the criteria is enumerated using a shredder machine.
b. Carry out a compatibility test for solid phase hazardous waste.
c. Each solid phase of hazardous waste is in harmony with the process of mixing and stirring in a batch system.
d. Furthermore, the results of the mixing that have been homogeneous are fed to the kiln.
e. For the liquid phase, hazardous waste that meets the criteria will be fed to the preheater kiln.
f. The composition of hazardous waste as fuel substitution with a maximum provision of 50% of the main fuel requirement.

In Indonesia, biomass is an essential natural resource with a variety of primary products [25]–[27], which are not only used to meet domestic needs but are also exported and become the backbone of the country's foreign exchange-earners. Therefore, waste handling is highly recommended using the 3R technique (Reuse, Reduce, Recycle) [28], [29]. The briquettes developed in this study are the composition between bottom ash and biomass of coconut shells, coffee shells, and kapok shells[29]–[33]. The waste to energy process is a process that undergoes grinding treatment, mixing of raw materials, molding, and drying under certain conditions that have particular shapes, physical sizes, and chemical properties [29]–[34].

One potential weakness of the study is its limited scope. The investigation only compares fly ash and bottom ash from the cement industry in East Java, Indonesia. As a result, the study's conclusions may not be generalizable to other regions or industries. The sample size used in the study is not provided in the passage, making it difficult to assess whether the sample size was sufficient to accurately represent the population. Another weakness of the study is the lack of detail about the statistical analysis used to analyze the data. While the passage mentions that a paired t-test and ANOVA post-test were used, it does not provide details about the specific statistical methods used or the assumptions made. Additionally, the passage does not provide information on the methods used to collect the data or the quality assurance and quality control procedures implemented to ensure the accuracy and reliability of the data. Finally, the lack of information about the authors and their affiliations makes it difficult to assess the credibility and potential biases of the study.

To improve this study for future research, there are several steps that can be taken. Firstly, future studies can consider expanding the scope of the research to cover other regions and industries. This will provide more comprehensive information and allow for more generalizable results. Additionally, future studies should use a larger sample size to ensure that the results accurately represent the population. This will increase the statistical power of the analysis and reduce the likelihood of biased results.

Moreover, future studies should provide more detail about the specific statistical methods used and the assumptions made during the analysis. This will help readers better understand the results and assess the credibility of the study. Furthermore, it is important for future studies to provide detailed information on the methods used to collect the data and the quality assurance and quality control procedures implemented to ensure the accuracy and reliability of the data. This will increase the validity of the study and improve its credibility.

5. Conclusion

The investigation was followed with a paired t-test to determine the comparison of ash types based on metal parameters. Following that, an analysis of variance (ANOVA) test was done on the post-test to assess the significance of the difference in the values of bottom ash and fly ash. A significant difference in values of 0.103 was found between the two ash types when subjected to a paired t-test. The findings of the ANOVA test indicate that there are discernible differences between the various ash forms. Therefore, the ash management must be carried out using multiple treatments, given that the quality of bottom ash and fly ash is distinct. This process makes the most efficient use of bottom ash. Meanwhile, to achieve quality standards for fly ash, it is important to reduce the parameters that are now too high.

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