Utilization of FABA Waste from coal combustion at the PLTU Air Anyir as an alternative to local construction materials

D Yofianti and H A Yukho

1Civil Engineering Department, Engineering Faculty, Bangka Belitung University, Kampus Terpadu UBB Balunijuk, Merawang, Bangka Regency, Bangka Belitung Province, 33172, Indonesia
2Maintenance Division, Electric Steam Power Plant Air Anyir, Jalan Lintas Timur, Air Anyir, Merawang, Bangka Regency, Bangka Belitung Province, 33172, Indonesia

E-mail: desyyofianti@gmail.com

Abstract. FABA (fly ash and bottom ash) is a by-product of coal combustion at the Air Anyir steam power plant (PLTU), in the Province of the Bangka-Belitung Islands. The waste generated from this PLTU always increases every year, but its utilization is not getting the attention of the related parties. In connection with these reasons, the aim of this study was to analyse the advantages and disadvantages of FABA utilization and to identify barriers in applying the use of FABA as an alternative to local construction materials. The in-depth interview method was selected in this study to obtain detailed information regarding FABA issues. The interviewees were derived from the internal and external parties of the PLTU Air Anyir. The interview results were analysed using the narrative method. The results of this study are expected to encourage relevant parties to use FABA as an alternative substitute for construction materials.

1. Introduction

The PLTU Air Anyir is one of the steam power plants with a capacity of 2x30 MW which is under the control of PLN Bangka Belitung. The PLTU Air Anyir uses a CFB (Circulating Fluid Boiler) system to run the generator. This CFB system uses bio-diesel fuel for starting-up, then after stabilizing, the fuel is replaced with 4200 heat-type coal. The use of coal as fuel to heat boilers from the generator engine, of course will produce a by-product as a result of burning the coal. The by-product is in the form of solid waste, namely fly ash and bottom ash (FABA). FABA waste from the PLTU Air Anyir has not been fully utilized by the PLTU itself or related parties (government, private and the public). This has resulted in an increase in the accumulation of FABA waste from year to year. Based on interviews conducted by the researcher of one of interviewees, mentioning that until the beginning of 2019, there has been a build-up of FABA waste at the PLTU Air Anyir of 35,000 tons. This, of course, needs serious attention from related parties for further handling.

The by-products of coal combustion at a power plant centre have become an environment issue and to be trending topics, which are discussed among the researchers. Research related to the utilization of FABA waste to reduce the impact on environmental problems has been carried out both domestically [1],[2] and internationally [3],[4]. In addition, there is also research conducted to minimize or neutralize the harmful mineral content of the coal combustion process [5].
Based on the aforementioned background, this study aimed to analyse the advantages and disadvantages of FABA utilization and to identify barriers in applying the use of FABA as an alternative to local construction materials.

2. Research Method
The choice of the type of research method that is suitable for this study was carried out at the early step, before starting the data collection. The next step was to interview the selected participants who have determined in advance. The final step analysed interview results so that the outcome could be used as recommendations to the parties concerned.

2.1. Data collection
Data collection in this study used the in-depth interview method to seek detailed information regarding FABA issues faced by PLTU Air Anyir. The interview process was done in person with a duration between 30 minutes and one hour. The interviews were conducted by the researcher by asking their approval at the first in terms of time and place. The interviews were conducted on five participants who were experts in their field related to the by-product of coal combustion.

2.2. Data analysis
The interview results were analysed using the narrative method [6],[7]. The results of this study are expected to encourage relevant parties to use FABA as an alternative substitute for construction materials.

3. By-product of coal combustion
Each steam power plant that uses coal as fuel to heat its boiler, definitely produces a by-product of combustion [8],[9]. The by-products can be in the form of fly ash [3],[10], and bottom ash [1],[2]. A similar thing also happened to the PLTU Air Anyir, where coal combustion produced ash waste in the form of fly ash and bottom ash (FABA). However, besides the two types of waste, the PLTU Air Anyir also produces liquid waste. This was stated by the interviewee 1 that the PLTU Air Anyir produces three types of waste from the coal combustion process, namely fly ash, bottom ash, and waste water. Regarding with fly ash and bottom ash, this plant is still dealing with problems in handling them. However, this plant already has its own equipment to process the waste water so it is safe to return it to nature. From the statement conveyed by the interviewee 1, it was revealed that the by-product of coal combustion in the form of ash was still an obstacle in its handling. However, this problem can actually be overcome by coordinating and actively approaching the PLTU Air Anyir to several interrelated government institutions, such as local governments, environmental agencies, urban planning services, public works agencies, academics, and communities around the site.

The quality of the by-products of coal combustion is also likely to be influenced by two factors, namely the combustion temperature and the type of coal used as fuel. However, it is still a premature presumption of the researcher due to the lack of research regarding this matter. These factors are in line with what was revealed by the interviewee 2 and also reinforced by the interview 3. Both said that sometimes if the coal combustion temperature exceeds normal temperatures, the bottom ash produced will look visually different. However, unfortunately they did not explain further differences. They said that the combustion temperature under normal conditions ranged from 750°C to 900°C.

In terms of the relationship between the combustion temperature and the by-product produced, the interviewee 5 said that he heard the story of his friend that there had been studies using bottom ash material for testing in the laboratory. The bottom ash taken is the result of burning coal at normal temperatures. However, at different times, the friend took the bottom ash back in the same place, but after inspecting carefully, it turned out that the difference in shape and colour. Next, he asked the technician at the combustion division regarding the use of temperature. However, unfortunately the interview could not provide further explanation, since only that information was obtained. The interviewee 5 was objection to give his opinion about this matter, since he himself was not sure and did
not see it in person. Therefore, it could be concluded that the relationship between the factor, combustion temperature and the by-product results is still a presumption. To prove it, further research needs to be done. The waste collection facility from coal combustion at the PLTU Air Anyir is already available at a designated location, and is far from the location of the residential area. The process of burning coal and handling waste ash as a by-product can more or less be illustrated as in Figure 1 below.

![Coal combustion process and handling of ash waste](image1)

**Figure 1.** Coal combustion process and handling of ash waste [11]

Ash handling plant (AHP) is a tool that is needed in a coal-fired power plant, where this tool serves as a reservoir of residual ash from coal combustion, then distributed to the ash valley [11]. This AHP system is divided into two types, namely fly ash and bottom ash.

3.1. *Fly ash (FA)*

According to the explanation from interviewee 4, the process of handling fly ash occurs in the ESP (Electrostatic Precipitator) system [11], where this system is one of the technologies for controlling fly ash pollution from boilers. The working principle of ESP is to provide an electric charge to fly ash by using a discharge electrode [12]. In general, interviewee 4 says that there are four stages of the process that occur in ESP so that fly ash can be collected, i.e. charging, collecting, rapping, and hopper. Next, the fly ash is taken to a larger shelter. Based on information provided by interviewee 4, it is known that the PLTU Air Anyir produces 12,000 tons of fly ash and bottom ash per year. However, as of early January 2019, 35,000 tons of FABA waste has been accumulated in available shelters. From this explanation, it can be analysed that there has not been special handling of the waste build-up that has occurred at the PLTU Air Anyir. This condition needs to be found a solution jointly between related parties so that the matters of waste accumulation can be overcome and reduce environmental issues [9]. If this condition is neglected, it is contrary to the applicable provisions, where it is stated that the FABA waste storage limit is only one year (356 days).

3.2. *Bottom Ash (BA)*

Explanation obtained by a researcher from interviewee 4 that bottom ash (BA) is ash produced from combustion from the furnace, which is accommodated in a reservoir under the combustion chamber.
The BA container is known as SSC (Submerged Scrapper Conveyor). Furthermore, the SSC system is equipped with pumps that function as water circulation. The SSC system is also equipped with equipment, such as crusher, conveyor, silo, pump and slurry mixer.

4. Discussion
From the results of interviews that have been conducted, there are three things that will be discussed in this section, such as the mineral content found in FABA, the utilization of FABA to improve the quality of the environment, and the implementation barriers to using FABA as construction material.

4.1. The content of FABA mineral
The main component of bottom ash has silica oxide content [1],[13], where the silica is 41.73% and the oxide content is almost the same as clay [1]. The content of silica oxide includes: silicon oxide (SiO₂) [1],[13], aluminium oxide (Al₂O₃) [2],[13], iron oxide (Fe₂O₃) [2],[14], lime (CaO) [2], and magnesium oxide (MgO) [1],[2]. Almost all fly ash contains pozzolan elements, meaning that fly ash has properties similar to cement [12]. Based on the mineral content, FABA can be classified in two categories, i.e. Class F and Class C [15],[16].

4.2. The utilization of FABA to improve the quality of environment
FABA can be used for several things so that it can reduce its impact on the environment [14],[17]. FABA can be utilized in construction industry [8],[10],[14],[18], soil amelioration, ceramic industry, catalysis, depth separation, zeolite, and synthesis [10]. For the construction industry, FABA can be a building material [14], such as concrete [12],[14],[15],[18], which is known as geopolymer concrete [14], and a mixture of bricks [1]. In addition, FABA can also be used as a substitution of filler and fine aggregate in hot-mix asphalt mixture.

Concrete mixtures that use certain proportions of fly ash (25%–50%) [14],[15] have advantages because they can increase the strength of concrete [12],[14], durability [12], and also can reduce costs and energy in construction [14]. Although it can be used as a concrete mix material, FABA still included in the category of hazardous waste since it contains heavy metals [9],[14] like arsenic, lead and selenium, which can cause health issues [14]. In addition, FABA is also one of the causes of air pollution and carbon dioxide emission [8],[14]. Therefore, to reducing environmental problems [9], the use of FABA as an alternative construction material needs to be regulated with separate policies and regulations so that not to create new problems. For example, the US government has made a policy regarding the use of fly ash as a green building material. The policy is contained in the leadership in energy and environmental design (LEED) which regulates the percentage of fly ash in concrete mixtures [14]. Perhaps, the actions taken by the American government could be adopted as a reference by the Indonesian government to make a policy of using FABA a construction material.

If viewed as a whole from the explanation above, it can be seen that the use of FABA is more profitable than the loss. FABA is more widely used in the construction industry than in the other fields. However, another advantage of using fly ash is reduced permeability to water and aggressive chemicals [12].

4.3. The implementation barriers to using FABA as construction material
According to by interviewee 5, the PLTU Air Anyir has collaborated with Indonesian Geopolymer (KORIGI) for research into the utilization of FABA waste. The results indicate that FABA waste can be used as a mixture of cement, ready mix concrete, paving, and brick making. The percentage of FABA used in concrete mixes ranges from 20% - 50%. To make a concrete mix in one m³, fly ash as much as 57 kg and bottom ash as much as 149 kg. The cost of making ready mix concrete using 20% FABA and 50% FABA respectively is Rp.547,643 and Rp.425,499. This value is cheaper than without using FABA (Rp.633,724). The example given is only for use in one m³, so that it can be imagined if the use of FABA is done on a larger scale, then the problem of accumulation of FABA can be solved. In addition, the use
of FABA as an ingredient in making bricks also provides high economic value and reduces the accumulation of FABA waste. Therefore, it can be concluded that if the government and related institutions support the use of FABA waste as a local construction material more seriously, the FABA build-up can be avoided and can also increase the economic value of the FABA.

In section 4.2, it has been explained that FABA is broadly used as a construction material, both for building construction and infrastructure. However, consideration of the use of FABA from its positive and negative aspects should not be ignored. Therefore, there are several barriers encountered in implementing FABA usage as follow: (i) lack of policies that specify the FABA classification; (ii) lack of regulation especially the use of FABA as a construction material; (iii) lack of technical instruction regarding the percentage of use of FABA which is permitted as a concrete mixture; (iv) lack of coordination and commitment between steam power plant and government agencies for handling FABA waste; and (v) lack of funding to implementing the utilization of FABA waste. Therefore, it is inevitable that to apply the use of FABA as an alternative construction material still requires a long process both in terms of policies and regulations as a guideline in its implementation.

5. Conclusion
Overall, it can be concluded that:

- The use of FABA has more advantages compared to its disadvantages, especially in the construction industry. In addition, using FABA can reduce the accumulation of FABA in the shelter location so that it can decrease environmental problems;
- There are three factors that hinder the implementation of FABA as a local construction material, i.e. policy and regulation, coordination and commitment, and funding availability.

References
[1] Suseno H, Prastum, Susanti L and Setyowulan D 2012 Pengaruh penggunaan bottom ash sebagai pengganti tanah liat pada campuran bata terhadap kuat tekan bata Jurnal Rekayasa Sipil 6 272-281
[2] Hartanto D, Widiastuti N and Ulfin I 2010 Pemanfaatan limbah abu dasar (bottom ash) sebagai bahan penyepap multifungsi untuk ammonia dan organic pada air tambak udang serta penyerapan logam berat dari limbah industry pelapisan logam Research Institutions and Community Service (Surabaya: ITS)
[3] Yao Z T, Xia M S, Sarker P K and Chen T 2014 A review of the alumina recovery from coal fly ash, with a focus in China Fuel 120 74-85
[4] Elsageer M A, Millard S G and Barnett S J 2009 Strength development of concrete containing coal fly ash under different curing temperature conditions World of Coal Ash (WOCA) [Internet]. Available from: http://www.flyash.info/2009/145-elsageer2009.pdf
[5] Is I and Gani A 2015 Pengaruh penambahan kaolin terhadap reduksi logam Pb pada proses pembakaran batubara Jurnal Rekayasa Kimia dan Lingkungan 10 106-111
[6] Gilbert N (ed) 2008 Researching Social Life, 3rd Edition (London: Sage)
[7] Jovchelovitch S and Bauer M W 2000 Narrative interviewing [online]. London: LSE Research Online Available at: http://eprints.lse.ac.uk/2633 Available in LSE Research Online: August 2007
[8] Ahmaruzzaman M 2010 A review on the utilization of fly ash Progress in Energy and Combustion Science 36 327-363 https://doi.org/10.1016/j.pecs.2009.11.003
[9] Tiwari M K, Bajpai S, Dewangan U K and Tamrakar, R K 2015 Suitability of leaching test methods for fly ash and slag: A review Journal of Radiation Research and Applied Science 8 https://doi.org/10.1016/j.jrras.2015.06.003
[10] Yao Z T, Ji X S, Sarker P K, Tang J H, Ge L Q, Xia M S, and Xi Y Q 2015 A comprehensive review on the applications of coal fly ash Earth-Science Reviews 141 105-121 https://doi.org/10.1016/j.earscirev.2014.11.016
[11] Ash handling system PLTU (sistem penanganan abu pada pembangkit listrik tenaga uap) [Internet]. Power Plant; 2018 September 2 [cited 2019 May 21]. Available from: https://www.bronanda.com/2018/09/sistem-penanganan-abu-ash-handling-system-pltu.html

[12] Rosenberg A 2010 Using fly ash in concrete [Internet]. National Precast Concrete Association. Available from: https://precast.org/2010/05/using-fly-ash-in-concrete/

[13] Toniolo N and Boccacini A R 2017 Fly ash-based geopolymers containing added silicate waste A review Ceramics International 43 14545–14551

[14] Boyer M How fly ash concrete works [Internet]. Home & Garden [cited 2019 May 21] Available from: https://home.howstuffworks.com/home-improvement/construction/materials/fly-ash-concrete.htm

[15] Hemalatha T and Ramaswamy A 2017 A review on fly ash characteristics-towards promoting high volume utilization in developing sustainable concrete Journal of Cleaner Production 147 546-559 https://doi.org/10.1016/j.jclepro.2017.01.114

[16] Flyash concrete [Internet] Sustainable Sources; 2019 [cited 2019 May 21] Available from: http://flyash.sustainablesources.com/

[17] Zhuang X Y, Chen L, Komarneni S, Zhou C H, Tong D S, Yang H M, Yu W H and Wang H 2016 Fly ash-based geopolymer: clean production, properties and applications Journal of Cleaner Production 125 253-267 https://doi.org/10.1016/j.jclepro.2016.03.019

[18] Xu G and Shi X 2018 Characteristics and applications of fly ash as a sustainable construction material: A state-of-the art review Resources, Conservation and Recycling 136 95-109 https://doi.org/10.1016/j.resconrec.2018.04.010

Acknowledgment
We gratefully acknowledge the funding from USAID through the SHERA programme – Centre for Development of Sustainable Region (CDSR). In year 2017-2021 CDSR is led by Centre for Energy Studies – UGM.