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COAL FLY ASH AND DIAMOND MINING WASTES AS LIGHTWEIGHT MANUFACTURING MATERIALS

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Abstract

Various researches on coal fly ash and diamond mining wastes have been carried out to increase their economic value and reduce their negative impacts on the environment. This study was aimed at gaining the mechanical and physical properties of the lightweight brick made from mixtures of fly ash of Asam-asam vapour-based electricity power plant and diamond mining sand wastes. The study is expected to be able to provide recommendations on the utilization aspect of natural resources potential of south Kalimantan.The tests were done on mechanical (pressure strength) and physical (volume mass) properties of the lightweight brick. Mean pressure strength of the lightweight brick ranged from 23.12 to 26.46 kg/cm^2 or 2.31–2.65 MPa, and it met the the requirements of Indonesia National Standard of 03-0349-1989, 21 kg/cm^2, for quality-IV solid concrete brick. The highest pressure strength was found in the lightweight brick B with mean of 26.46 kg/cm^2 or 2.65 MPa. This brick used the composition of 50% fly ash and 50% cement, and 70 g of each foam, polymer and hardener. Mean volume mass ranged from 834–1,081 kg/m^3, and it met the requirements of Indonesia National Standard of 03-3449-1994, below 1,860 kg/m^3. The lightest was found in the lightweight brick F with mean of 834 kg/m^3. Its composition comprises 28.57% fly ash, 42.86% cement and 28.57% calcium oxide added with 70 g of each foam, polymerand hardener.

Keywords: fly ash, diamond mining waste, lightweight brick, pressure strength, volume mass.

INTRODUCTION

In Indonesia, coal is available in large amount and estimated reaching 38.9 billion tons, 67% of these are distributed in Sumatera, 32% in Kalimantan and the rest in Java, Sulawesi and New Guinea. With its good quality, high quantity and recent productivity, coal can become energy source of Indonesia for hundreds of years. According to the Directorate General of Mineral and Coal, the Ministry of Energy and Mineral Resources, national coal requirements of 2013 was 72 million tons or 20% of national production. In 2014, the national need reached 95.5 million tons or increased by 25% because of industry development and electricity necessity, with the biggest allocation for National Electricity Company, 57.4 million tons (http://www.neraca.co.id/article/31581/2014, http://ekonomi.inilah.com/read/detail/206149).

Coal is enormously used by industriesand Vapour Energy-Based Electricity Center as boiler fuels to produce steam as electricity power. There are about 5% of particulate pollutants produced from coal combustion as fly ash and bottom ash, approximately 10-20% as bottom ash and 80-90% as fly ash of total ash production (http://www.mountain-plain.org, 2006). According to the operational technical assistant of Asam-asam vapour electricity power plant (2013), coal ash piles from 2 Asam-asam power plants, Tanah Laut regency, reach 130,000 tons, and this amount is increasing up to 60 tons of ash per day from 4,400 tons of coal utilization for unit 1 and 2 power plants, especially the National Electricity Power Companies of South and Central Kalimantan have started operating the electricity power unit 3 and 4 with 130 megawatts capacity, releasing daily fly ash waste of 60 tons, andif the ash waste is not well-managed, it will result in environmental pollution problems. Major components of the coal fly ash from the electrical power plant consist of silicate (SiO_2), alumina (Al_2O_3), and ferrum oxide (Fe_2O_3), and the rests are carbon, calcium, magnesium, andsulphide.

A variety of studies on coal fly ash utilization is being done to raise its economic value and diminish its negative impact on the environment. Fly ash is largely employed in industrial companies owing to its pozzolanic features (adhesive), while bottom as his tremendously less used and onlytaken as fillers (Aziz, 2006) due to its very fine particle size so that it could function as space fills and interaggregate adhesive. As cement substitute, fly ash are recently largely needed, because cement mixture materials of coal burning ash have the superiority of strong adhesion from low lime-silica and alumina content. The fly ash applied in construction material mixtures is about 20% (Pelaihari, 2007). It is used assubstitute of Portland cement, brick, light concrete, road construction material, and land work materials (Wardani, 2008),

Lightweight brick is a concrete-like material and possesses strong, water- and fire-resistant, and durable characteristics. This brick is light enough, smooth, and has high degree of flatness. It is made to help reducing the structural burden of the building construction, accelerating the work, and minimizing the remnants in the wall construction process. The lightweight brick is made from silica sand, cement, and lime, has bigger size than batako or 60x20x10 cm, and dominant color of white or beige. Since it has light mass, the structural burden of lightweight brick is also low. Stronger structure, attractivity and particle pressure make the built space be impermeable and no moss at humid condition. It is much lighter, strong, efficient, and easily controlled in development process than other materials. It is environmental friendly and its production is not seasonally dependent as well.

Development in material technology marvellously promotes the technological development of construction. In diamond mining, other wastes, such as sand and gravel, are also gained, one of which is zircon sand, and it has not been optimally exploited yet. World's zircon utilization is mostly as industrial minerals, for foundries, refractories, ceramics, glasses and others (Zulfikar *et al.*, 2008). Zircon can be used to produce fire-resistant bricks to coat smelting furnace of steel and glass. Direct use of zircon for refractories can be operated at 3,600°F or 1,968^{o}C (www.dim.esdm.go.id/, Sukandarrumidi, 2004). The presence of zircon sand as associated mineral needs to be studied to increase the economic value of the mineral resources and to have a long-term raw material source.

Lightweight bricks used for building walls have been recently done in high numbers. Several high buildings to residences and warehouses make use of the lightweight bricks for wall development, because they are weightless, stronger, better precision, and more efficient than red brick or batako. The lightweight brick production in Indonesia was motivated by fastly increased material and development service costs in the last few years. Lightweight bricks are selected as alternative material believed to be capable of responding to all the challenges and necessities. The occurrence of the lightweight brick demand and the use of zircon sand have encouraged to do research by making use of the fly ash waste and the zircon-containing diamond mining waste as mixture materials of the lightweight brick production.

In line with the development growth in South Kalimantan, the building material demand, particularly lightweight bricks, is increasing. Mean while, coal fly ash wastes disposed by the vapour-based electricity power plant of Asam-asam are potential to use as building material mixtures, and diamond mining wastes as zircon sand have not still been optimally utilized yet. High availability of these materials and lightweight brick demand have provided investigation efforts using both fly ash and diamond mining sand to produce the lightweight bricks. The objective of the study was to obtain mechanical and physical characteristics of the lightweight brick made from mixtures of fly ash of Asam-asam vapour-based electricity power plant and sand of Cempaka diamond mining wastes.

Fly ash is solid wastes of burning process in the vapor-based electricity power plant furnace released by combustion remnants and trapped using an electrostatic precipitator. This material consists of silicon-dioxide (SiO_2), aluminium-oxide (Al_2O_3) and ferrum-oxide (Fe_2O_3). From total number of ashes produced in coal combustion process, 55-85% are fly ash and the rest is bottom ash.

Fly ash has the following characteristics:

a) Based on particle size, percent passing through No. 200 sieve (0.074 mm) ranges from 60% to 90%.
b) Colors can vary from grey to black depending upon number of carbon content, the lighter the color the lower the carbon content.
c) Hydrophobic.
d) Major components comprise silicon (Si), aluminium (Al), ferrum (Fe) and calcium (Ca) with variations in carbon content.Previous study found relatively high silica (74.2% SiO_2), alumina (5.7% Al_2O_3), Fe_2O_3 (about 14.4%), alkaline metals (2.4% CaO and 2,03% MgO), and iron minerals (14.4% Fe_2O_3) (Haryanti, 2013).

Refering to Indonesian Government no. 101, 2014 as a replacement of Indonesian Government Regulation no.18, 1999 juncto no. 85, 1999, fly ash is classified as B-3 waste (hazardous and toxic materials). The use of B-3 wastes is a reuse and/or recycle and/or recovery activity intended to alter the wastes to be usable and therefore, must be environmentally secure (Living Environment Minister's Decree No. 2/2008). The use of B-3 wastes can help decreasing number of B-3 wastes, saving the natural resources and minimizing negative impacts on the environment and the human health. Reuse is done through additional physical, chemical, biological and/or thermal processes. Recycling is done by collecting usable components through additional physical, chemical, biological and/or thermal processes to produce similar or different products. Recovery is recollection of usable components through physical, chemical, biological and/or thermal processes.

The priority scale of B-3 waste utilization starts from reusage, then recycling and recovery. Entire bioassays of the coal ash samples of Asam asam Vapour-Based Electricity Power Plant on water bugs, carps, and rats found that those samples were not relatively hazardous to living organisms. (Khaerunisa, 2012). Fly ash is employed as ceramic raw material, refractories, polisher, aspalt fillers, cement raw material additive in waste treatment, and absorbant (Acosta, 2009), aluminium alloy fillers (Sulardjaka, 2010), and concrete pozzolant (Aggarwal, 2010).

According to Darmawan (2008), coal waste, particularly fly ash, can be used to make building materials. With coal ash mixture of vapour-based electricity power plant wastes, batako can be produced through simple manner. Priyatna (2006) stated that technical/economic benefit obtained in fly ash utilization are:

a. increased quality of building materials, stronger, more acid-resistant, and lighter than building material of cement;
b. increased cost efficiency of building material manufacture;
c. the manufacture does not use cement.

Minerals are a natural resource whose manufacturing process requires millions of years and it is non-renewable. Minerals can be employed as industrial/production raw materias, in which they are more popular as mining materials (Sukandarrumidi, 2004). In Indonesian government regulation no. 27, 1980, concerning mining material position, minerals are separated into 3 groups, strategic mining materials, vital mining materials, and non-vital and non-strategic mining materials. Zircon is categorized as vital mining material after iron and gold.

Indonesia has high diversity of natural resources, with high quality and quantity, one of which is zircon sand processible to zirconia (ZrO_2). This sand processed to pure zirconium is a basic material of semiconductor largely used in electronic industries worldwide. Nevertheless, it is, in fact, sold in sand form with much lower price than in the form of zirconia or pure zirconium, with more than 1000% of the selling price. In other words, Indonesian population only becomes consumers of itsown natural resources processed by other nations (Nurul and Mardiyati, 2006) .

Increase in added value of Indonesia mineral resources just became an actual topic beginning through implementation ofMineral and coal law by Indonesian Representativeson December 16th, 2008. The law has replaced the 40 year old-general mining law. It makes the stakeholders prepare themselves to enter the new era of metallurgic extractive industries, even though the availability of high number of Indonesia mineral resources and widely distributed has not raised the added value yet, such as associated mineral reserve. The presence of zircon minerals as associated minerals needs to be considered. It could result from that zircon minerals have sufficiently significant potential to being a long-term raw material source.

Building material technology is increasingly developing, one of which is lightweight brick development. Brick is classified as normal brick and lightweight brick. The former has a density of about 2,200–2,400kg/m^3 and its strength is dependent upon mixture design. Lightweight brick is also called Aerated Lightweight Concrete (ALC) or Autoclaved Aerated Concrete (AAC). Other names are Autoclaved Concrete Cellular Concrete (cement with air bladder-producing chemical liquid), Porous Concrete, and in England, Aircrete and Thermalite. Dissimilar to common concrete, lightweight concrete can be set as desired. In general, lightweight concrete density ranges from 600 to 1,600 kg/m^3. Hence, major superiority of the concrete is the mass, so that its usage on the high building project will be able to significantly reduce the mass of the building itself.

Genowefa Zapotoczna et. al (2011) studied on the lightweight concrete characteristics of Autoclaved Aerated Concrete in Poland covering density, pressure strength, heat transfer, and resistance to fire. Their findings indicated that the density ranged fom 300 to 750 kg/m^3 with pressure strength of about 1.5 to 5 Mpa, had good resistance to fire and good sound insulation due to its large porosity**,** it could be soundproof**.**

Yothin Ungkoon, et. Al (2007) analyzed the microstructural materials of autoclaved aerated concrete in wall construction using optical microscope and scanning electron microscope (SEM). The testing was done by comparing the AAC wall and common wall and found that the former had higher pressure strength and better resistance to heat.

Haryanti (2014) who studied the fly ash of Asam-asam vopour power plant coal as mixture material of lightweight brick found that the pressure strength still met the requirement of 03-0349-1989 INS, 21 kg/cm^2 for quality-IV solid concrete brick.

METHOD

This study was quantitative and through experimental approach to material testing. Parameters measured were mechanical (pressure strength) and physical (volume mass) characteristics of the brick. The standard used followed the requirements of Indonesia National Standard of 03-3449-1994 and 03-0349-1989 for volume weight and pressure strength, respectively.

The study was carried out in Asam-asam Vapour-Based Electricity Power Plant and Structural and Civil Engineering Material Laboratory, Faculty of Technique, Lambung Mangkurat University, South Kalimantan. Materials used were fly ash of Vapour-Based Electricity Power Plant of Asam asam, silica sand, Cempaka diamond mining wastes, Pc cement, water, foam, polymers, and hardener. Equipment used were foam producer, concrete framer, Universal Testing Machine (UTM), balance and sieves.

The lightweight brick was box-shaped of 15 cm x 15 cm x 15 cm, with brick mixture design of 900 kg/m^3. Mixture composition consisted of PCC Indocement cement, fly ash, silica sand, tohor lime, and diamond mining sand to produce A, B, C, D, E, F, G, H, I, J lightweight bricks as follows:

Sample A : 57.14% fly ash and 42.86% cement

Sample B : 50.00% fly ash and 50.00% cement

Sample C : 37.50% fly ash, 50.00% cement and 12.50% silica sand

Sample D : 37.50% fly ash, 37.50% cement and 25.00% of calcium oxide

Sample E : 42.86% fly ash, 42.86% cement and 14.28% sand

Sample F : 28.57% fly ash, 42.86% cement and 28.57% of calcium oxide.

Sample G : 28.57% fly ash, 42.86% cement and 28.57% of diamond mining sand.

Sample H : 35.00% fly ash, 50.00% cement and 15.00% of diamond mining sand.

Sample I : 37.50% fly ash, 50.00% cement and 12.50% of diamond mining sand.

Sample J : 40.00% fly ash, 50.00% cement and 10.00% of diamond mining sand.

Foam, harderner, and polymer were also added, each of which was 70 g, to the mixture of cement, fly ash and sand. Five lightweight bricks were produced for each**.** The whole lightweight brick composition is given in the following Table.

Table 1.Mixture composition of lightweight brick materials

Mixture Composition of Lightweight Brick	Major Materials (%)					Additive (g)		
	Fly Ash	PCC cement	Sand		Calcium Oxide	Foam	Hardener	Polimer
			Silica	diamond Mining Wastes				
A	57.14	42.86	-	-	-	70	70	70
B	50.00	50.00	-	-	-	70	70	70
C	37.50	50.00	12.50	-	-	70	70	70
D	37.50	37.50	-	-	25.00	70	70	70
E	42.86	42.86	14.28	-	-	70	70	70
F	28.57	42.86	-	-	28.57	70	70	70
G	28.57	42.86	28.57	-	-	70	70	70
H	35.00	50.00	-	15.00	-	70	70	70
I	37.50	50.00	-	12.50	-	70	70	70
J	40.00	50.00	-	10.00	-	70	70	70

RESULTS AND DISCUSSION

The lightweight bricks of fly ash and diamond mining waste sand produced in the vapour-based electricity power plant of Asam-asam and then tested in the Material and Construction Laboratory of Faculty of Techniques, Lambung Mangkurat University, were aimed to maximally utilize those wastes under premitted limit. The use of silica sand of AlurJorong (Asam-asam) and calcium oxide is expected to produce nearly white-colored bricks as those in the market using economic consideration-based local materials. Lime could be classified into several types,calcium oxide (CaO), calcium hydroxide $Ca(OH)_2$,air lime and hydrolic lime. These could be applied as concrete adhesion material with Portland cement, since it is better and could reduce cement need, used as whitening material. In addition, the zircon-containing diamond mining waste sand as associated material of Cempaka diamond mining, Banjarbaru, was also employed.

Figure 1 Lightweight brick under study

Mechanical Feature of the Lightweight Brick

Pressure strength test of lightweight brick A, B, C, D, E, F, G, H, I, and J used 5 testing objects as presented in Figure 1.

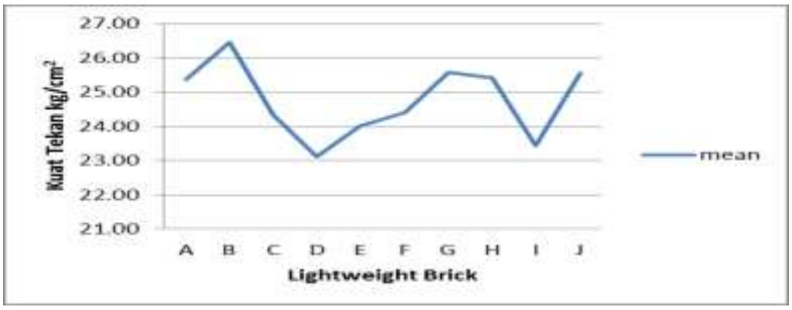

Figure1. Lightweight pressure strength graph (kg/cm^2)

Fig. 1 shows that mean pressure strength of the lightweight produced ranged from 23.12 to 25.46 kg/cm^2 or 2.31 to 2.65 Mpa. These findings indicated that these pressure strengths met the requirements of 03-0349-1989 Indonesia National Standard, 21 kg/cm^2, for quality IV-soild concrete brick. The lightweight brick of B consisted of 50% cement and 50% fly ash, and added with 70 grams of each foam, polymer and hardener.

The use of optimal number of mixture as many as 50% gave higher pressure strength. It could result from:

- Fine particle size that enables to fill the empty spaces of the brick, so that it becomes denser.
- The compounds contained in the fly ash are reactive with other compounds in the cement that causes better adhesion.

Moreover, the use of maximum number of diamond mining waste sand as many as 10% will give the lightweight brick higher pressure strength.

Physical feature of the lightweight brick

The physical feature of the lightweight brick A, B, C, D, E, F, G, H, I, J is presented in Figure 2.

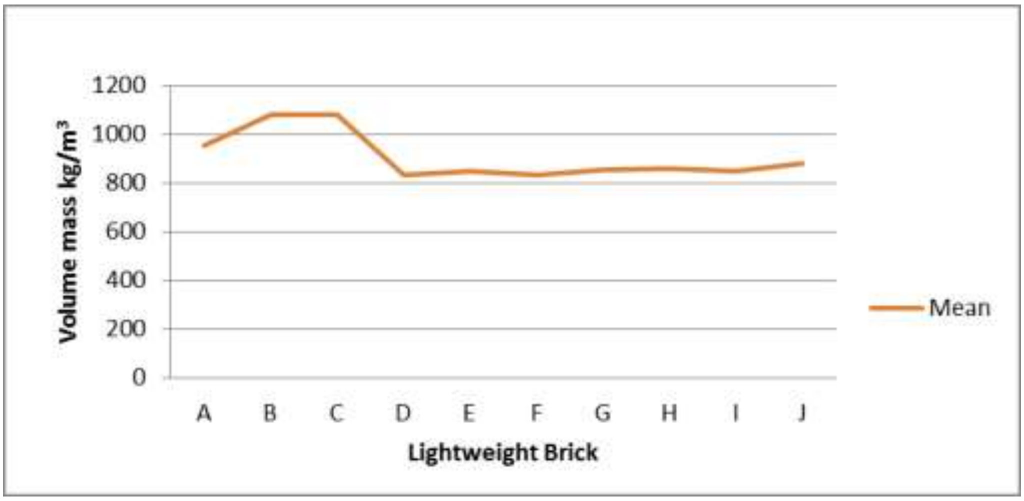

Figure 2 Volume mass of the lightweight brick

The volume mass of the lightweight brick under study still met the requirements as lightweight brick, sample F had the lightest mass with mean of 834 kg/m^3. According to Tjokrodimuljo (2007), a concrete called light has a mass less than 1,800 kg/m^3, and it is under 1,860 kg/m^3 according to Indonesian National Standard of 03-3449-1994. The composisition of sample F consisted of fly ash of 28.57%, cement of 42.86%, and calcium oxide of 28,57%, added with 70 g of each foam, polimer, and hardener.

CONCLUSION

This study concluded that the mechanical characteristics (pressure strength) and the physical characteristics (volume mass) of the lightweight brick were the following:

1). Mean pressure strength was 23.12-26.46 kg/cm^2 or 2.31–2.65 MPa.

It still met the Indonesia National Standard of 03-0349-1989, 21 kg/cm^2, for quality IV-solid concrete brick. The biggest pressure strength was recorded in the lightweight brick B, with mean strength of 26.46 kg/cm^2 or 2.65 MPa. and a composition of 50% cement and 50% fly ash and 70 g of each foam, polymerand hardener.

The use of optimal mixture of 50% of fly ash material resulted in higher pressure strength.

The use of maximum number of diamond mining waste sand of 10% would produce higher pressure strength**.**

2). Mean volume mass ranged from 834–1081 kg/m^3. It still met the Indonesia National Standard of 03-3449-1994, under 1,860 kg/m^3. The lightest was recorded in the lightweight brick F with mean volume mass of 834 kg/m^3 and a composition of 28.57% fly ash, 42.86% cement, 28.57% calcium oxide, and 70 g of each foam, polymer, and harderner.

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