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Silica Palm Ash as An Addition to the Formation of Agropolymer Brick

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Abstract. This research was conducted to provide more value to oil palm ash and decrease the use of cement in agropolymer brick making. Oil palm industrial biomass waste contains silica (SiO_2) which can replace the silica content in cement. This study aims to determine the chemical composition of oil palm biomass ash, physical and mechanical properties and surface morphology of agropolymer bricks. Agropolymer brick made from cement: sand (1:4) with variations palm ash 0; 4.3; 8.6; 12.9; 17.2; and 21.5% which has been purified with 3% HCl and a total weight of 7500 g. Agropolymer brick making is done by utilizing palm ash to reduce cement use. XRF test results showed that the greatest composition of ash before and after acidification was SiO_2 namely 50.475% to 56.255%. The results of the water absorption test showed that the water absorption capacity of the concrete blocks increased with the addition of silica from the ash from palm biomass. The results of the average density test of concrete blocks with the addition of palm biomass silica were lower than the density of sand, namely 2.241 g/cm^3. The compressive strength test results show that formula 3 has the optimum compressive strength is 28.8235294 kg/cm^2. These results are supported by the SEM analysis of formula 3 showing that the agglomeration and grain size are not homogeneous and the surface morphology is denser. The brick produced is in accordance with SNI, SNI 03 -0348-1989 category IV the quality of solid concrete bricks B70.

Keywords : Agropolymers, Concrete brick, Palm ash

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Introduction

The problems that always arise from the development of technology in the palm oil industry is a waste problem. Industrial waste can be in the form of liquid waste and solid waste. Oil palm industrial solid waste in the form of empty bunches and shells. Palm kernel shell is a significant waste of palm oil processing, reaching 59-61% of production oil [1] and the average production of empty bunches is around 22-24% of the total weight of fresh fruit bunches processed in palm oil mills [2]. Palm oil industrial solid waste is used as boiler fuel to produce mechanical and heat energy, with a by-product in the form of biomass ash that has been not utilized [3]. In this process, the ratio of shells and fibers is 75: 254 and produces solid ash waste 15% [4].

Palm shell ash and bunches contain 68.82% silicate (SiO_2), 3.08% Alumina (Al_2O_3), 4.35% magnesite (MgO), and oxides other [5]. The silicate and alumina content in palm shell ash and bunches can be used to reduce the use of cement in concrete blocks. Cement is an adhesive that can bind solid materials such as sand and stone into an alloy. The binding properties of cement are determined by the chemical composition they contain such as lime, silicate, alumina, ferrous oxide, magnesite, and other oxides in amounts small [6]. The production of ordinary port land cement accounts for 5-7% of total greenhouse gas emissions. It is therefore important to find alternatives to cement. One of the efforts to reduce global warming is to reduce the use of cement in concrete [7].

Utilization of solid waste shell ash and palm fiber from the boiler for the manufacture of lightweight concrete bricks shows the results of compressive strength that meet the minimum limits of lightweight concrete bricks according to SNI 03-3449-2002. The water absorption capacity increases with the addition of ash [8]. Research on the utilization effect of type-b pozzolan cement on the compressive strength of concrete and on the lifespan of concrete for each object test shows a decrease [9]. Research on the use of boiler slag from burning palm oil waste as a partial substitute of sand in the manufacture of concrete presents the optimum compressive strength of concrete at a composition containing 25% boiler ash, which is 17.83 MPa [10]. Oil palm coir and shells can be used as an alternative source of silica with silica content of 59.1 and 61% respectively [3]. The utilization of palm oil fuel ash as a replacement part of cement in concrete reveals variations in the strength properties of concrete. The addition of palm ash up to 10% increased the compressive strength, flexural strength, and tensile strength of concrete compared to specimens without the addition of palm ash in its composition. The addition of oil palm ash that exceeds a certain limit causes a decrease in strength properties. Palm ash used as a cement substitute increases a large utilization of waste products [11]. Research on the substitution of pozzolan for cement on the performance of a mixture of cement and construction concrete showed an increase in both the physical properties and the performance of the mixture [12]. Another study revealed that the bricks with the addition of 25% biomass ash had the highest compressive strength with a lifespan of 28 days at 35.45 kg/cm2 and the lowest water absorption at 4.67% [13].

This study aims to make agropolymer bricks by utilizing palm ash, to determine the chemical composition of oil palm ash, to determine the physical and mechanical properties of the brick, and to determine the surface morphology.

Experimental

Equipments and materials

The equipment used to determine the composition and surface morphology of oil palm ash were X-Ray Fluorescence (XRF) and Scanning Electron Microscope (JEOL JSM-636OLA). Whereas physical and mechanical properties determined using mechanical balance, forney measure, and pycnometer.

The materials used in the study were 3% HCl (Merck), portland cement (PT. Semen Padang), biomass ash from palm oil mills, and water.

Procedure analysis

Geopolymer brick is made with a ratio of Portland cement: sand composition of 1: 4 with variations in the addition of biomass ash of 0%, 4.3%, 8.6%, 12.9%, 17.2% and 21.5% with a total weight of 7500 g and a water factor [14]. Cement (FAS) 0.4. It was dried at 60 °C and the test was carried out at the age of 14 days and the test object was prepared with a size of 30x15x10 cm [15]. Ash purification used 3% HCl and drying was carried out at a temperature of 105 °C for 4 hours. 3% HCl is obtained from 37% HCl [3]. The component formulations with variations in ash and material requirements used are calculated based on the following equation:

$$Component = \frac{factor}{conversion\ numbers} \times 7500 \quad (1)$$

Results and Discussion

X-Ray Fluorescence (XRF) analysis

Determination of the ash composition of oil palm biomass was carried out with and without acidification with 3% HCl. Table 1 shows the results of the XRF analysis of oil palm biomass ash.

Based on the table of XRF analysis results before and after purification with 3% HCl, many compounds are contained in oil palm boiler ash. Acidification with 3% HCl is a stepin refining silica. The purification process with HCl is carried out to reduce impurities such as oxides metal [3]. The greatest composition of the ash before and after acidification with 3% HCl was shown by SiO_2, namely 50.475% to 56.255%. The silica content in ash can be used to reduce the use of cement in concrete blocks because the cement's binding properties are determined by the chemical composition it contains, such as lime, silicate, alumina, ferrous oxide, and magnesium [6].

Table 1. XRF analysis before and after purification with 3% HCl

No.	Compound	Ash composition	
		Before	After
1.	MgO	6.614	4.722
2.	Ag_2O	0.292	0.152
3.	SiO_2	50.475	56.255
4.	P_2O_5	6.905	9.086
5.	SO_3	3.848	1.826
6.	K_2O	10.972	6.545
7.	CaO	17.710	10.471
8.	TiO_2	0.105	0.182
9.	Fe_2O_3	1.318	1.900
10.	Cl	1.509	6.025

Based on ASTM C618, the content of SiO_2 is below 70% and CaO of 10% indicates that this biomass ash silica is included in type F pozzolan. This is in accordance with the research which states that pozzolan has good brick [16]. Good if the content of $SiO_2 + Al_2O_3 + Fe_2O_3$ and CaO with a high percentage and high reactivity too [9]. The strength of concrete is influenced by the content of SiO_2 as a filler and as a binder. The maximum limit of SiO_2 content in sand for making concrete is around 30%, so this biomass ash is one of good aggregates and meets the standard for partial replacement of sand. Biomass ash is better than sand regarding the chemical composition, because the CaO in the ash plays a role as a binder in cement. Similarly, Al_2O_3 is very influential in accelerating the hardening of concrete. The results of research conducted by [10] show that the optimum compressive strength of concrete produced at a composition containing 25% biomass ash, is 17.83 MPa. The results of the study [11] exhibited the highest compressive strength at the addition of 10% biomass ash.

Pozzolan fineness tends to have a major influence on the properties of concrete through increasing the packing effect and pozzolan activity. To make high strength bricks, silica can be used in the form of particles having active pozzolanic properties [8]. In general, pozzolanic materials contain elements of silica, alumina and iron oxide which when reacted with calcium hydroxide and alkali will form a complex component whose formation depends on the pozzolanic material activity. The higher the pozzolanic activity index of the pozzolanic material, the less the amount that can be added to the mixture. However, if the amount of pozzolanic material in the mixture is too small, this will increase the expansion power of the concrete mixture due to the alkali-silica reaction contained in the mixture. Therefore, the determination of the amount of pozzolanic material that can be used in the mixture depends on the location and specification of the mixture used. The size of the Pozzolanic activity index on the pozzolan material is determined by the amount of amorphous silica glass or known as active silica. Natural pozzolan contains a lot of crystalline silica, which is a mineral that has a little reaction or even unable to react with calcium in cement and contains only a small amount of amorphous silica glass, while the amorphous silica glass content in artificial pozzolan is larger. The pozzolanic activity index of the pozzolanic material is determined by the amount of active silica content and is also determined by the specific surface area, and chemical and mineral composition [12].

Water absorption properties of brick

Water absorption analysis is carried out by immersion for 24 hours so that it can show the ability of the test object with the water absorption value. Determination of the water absorption capacity of concrete blocks is presented in Figure 1. The water absorption capacity of formulation 1 without the addition of silica was 13.559%. This is due to the water entering through the cavities (voids) in the test object and through absorption of the constituent particles [17]. The water absorption capacity of the brick increases with the addition of silica from the ash from oil palm biomass. The smallest water absorption is shown by formula 2 where the brick with the smallest addition of silica with a value of 5.357% and the largest water absorption is shown by formulation 6 with the largest addition of silica with a value of 26.126%. This is due to the addition of too much silica so that the pozzolanic content of the biomass ash silica cannot react with the by-products of cement hydration [13]. If the water absorption in the brick is getting smaller, the brick will be more resistant (resistance) and the quality will be better [17]. The results of water absorption for all formulations meet SNI 03-0348-1989 for category II quality solid concrete bricks with a value less than 35%. The bigger the porosity of the brick, the higher the water absorption capacity [8]. The compressive strength of concrete and the pozzolanic properties (SiO_2 and Al_2O_3) of biomass ash are due to the finer grain of biomass ash. The biomass ash will react with the hydration byproduct of $Ca(OH)_2$ cement. The byproduct of the cement hydration was initially an unwanted compound, but in the presence of SiO_2 and Al_2O_3 compounds, the $Ca(OH)_2$ compound then reacted to form the desired compound, namely $C_3S_2H_3$. From the chemical process, it can be seen that the addition of excessive biomass ash resulted in a decrease in the compressive strength of the bricks because the byproduct of cement hydration, namely $Ca(OH)_2$ was exhausted so that it could no longer react with the remaining pozzolans (SiO_2 and Al_2O_3). The pozzolan content of biomass ash exceeds the maximum amount so that it can reduce cement adhesion to the mixture [13].

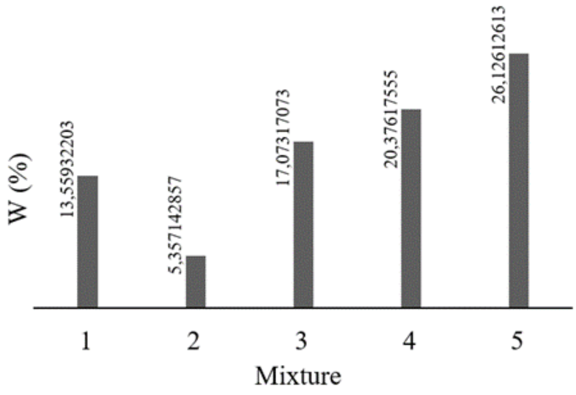

Figure 1. Water absorption after 14 days

Density properties analysis of brick

Determining the density or specific gravity of the brick is made using a pycnometer. Determination of brick density is presented in Figure 2. Lightweight brickwork can be made from quartz sandstone, lime, cement and other materials which are categorized as materials for lightweight concrete. A density of 1,850 kg m^{-3} can be considered the upper limit of true lightweight concrete, although this value is sometimes exceeded.

The results of the average density test of concrete blocks with the addition of palm oil ash silica were 2.241 g cm^{-3} lower than the density of sand. According to ASTM C128-93, a good density for the manufacture of concrete is above 2.50% so it includes coarse aggregate. The results of research by [10] produced an ash density of 2.11 g cm^{-3} according to quality standards. The addition of biomass ash replaces some parts of the sand and cement. The amount of concrete weight is inversely proportional to the amount of ash used, the more ash added, the lower the weight of the concrete. This is due to differences in the specific gravity of ash and sand, specifically 0.16 g cm^{-3} and 1.4 g cm^{-3}, where the specific gravity of ash is smaller than the specific gravity of sand.

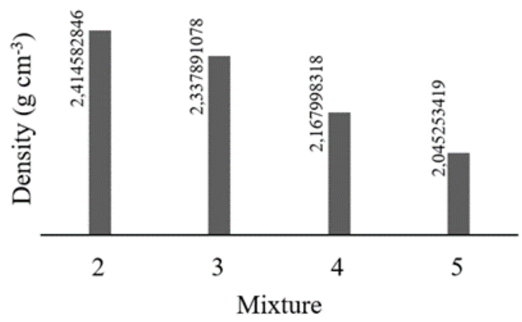

Figure 2. Brick density

Compressive strength analysis of brick

Measurement Bandwidth and load tap tap used for the calculation of the sample compressive strength of adobe. These parameters are carried out using measurements with a ruler and compressive load measurements using the Forney tool [18]. The compressive strength of the brick is an indication of the quality of a structure where the higher the compressive strength, the higher the quality of the brick produced. The compressive strength of the brick is presented in Figure 3.

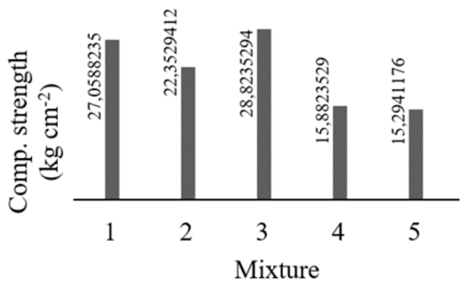

Figure 3. Brick Compression Strength

The compressive strength of bricks is determined by the composition (SiO_2), time and conditions curing and the age of the formulation is expressed as a polymer ratio. The compressive strength of agropolymer bricks is very dependent on the composition, namely the variation of the addition of silica used.

Based on the results of 5 variations of adding silica from the biomass ash used, the bricks in formulas 4 and 5 produced the lowest compressive strength of 14 days while formula 3 had the optimum compressive strength. The results of the compressive strength test of the bricks formulations 1, 2, and 3 meet the SNI 03-0348-1989 standards and fall into the category IV class with a minimum weight of 25 kg/cm^2.

One of the main performance of bricks is shown by the compressive strength. The ability of bricks to receive a compressive force per unit area represents the compressive strength. The difference in the value of the compressive strength of the brickwork is influenced by heterogeneous material, the proportion of the mixture, the shape, size, speed of loading, and environmental conditions when the brickwork is tested [18].

The addition of silica in the form of oxide (SiO_2) with high proportion is a material with dense and light particles so that it can increase the advantageous properties of aggregates such as good binding ability, lifespan resistance, strength and hardness. Silica is a filler material that can increase the density of the material, which is related to the compressive strength [8]. The fine SiO_2 particles have a high surface area and interaction. These particles interact with the constituent materials by filling the voids in the concrete. The addition of silica causes the porosity of the concrete to be smaller, thereby increasing the strength of the material [3]. Ash does not have the ability to bind like cement, but in the presence of water and its fine particle size, the silica and alumina contained in the ash will react chemically with calcium hydroxide (formed from the hydration process of cement) and produce substances that have a good binding ability [13]. The addition of biomass ash exceeds a certain limit causes a decrease in strength properties [11].

Additional materials in cement production can use natural pozzolan to reduce production costs and increase the strength and durability of concrete or cement mixtures, this is also stated by Waani [12] which states that the substitution of cement is 10-20% by pozzolan. Artificial fly ash and 10% oil palm biomass ash showed an increase in bending strength and strain, bending toughness, and water absorption of themixture glass fiber-reinforced concrete. According to Sooraj [19] this palm ash is recommended to be used as a commercial product in concrete construction, namely as a cement substitution material up to 20% of the weight of the mixture. Palm oil ash silica can be used as an alternative to cement and utilize large amounts of waste.

Scanning Electron Microscope (SEM)

SEM analysis was carried out at 500 × magnification to see the distribution, agglomeration and holes on the surface of the bricks. Surface morphology using SEM is shown in Figure 4.

Surface morphology analysis using SEM was carried out in formula 1 (without the addition of biomass ash) and formula 3 with the addition of biomass ash with optimum mechanical strength. The SEM image of formula 1 shows voids and agglomerations which are distributed in all parts, while the SEM image of formula 3 shows agglomeration and inhomogeneous grain size due to the addition of silica ash biomass samples in an amorphous state. Compounds other than silica still exist before and after the purification process. However, the dominating compound was silica (SiO_2) with a mass of 50.475% for the sample before

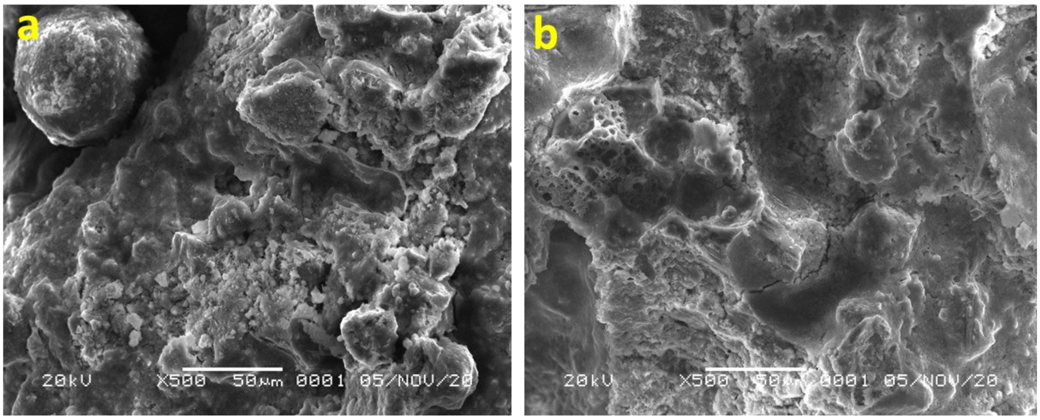

Figure 4. Surface morphology analysis using 500 × magnification SEM (a) formula 1, (b) formula 3

purification and increased in mass to 56.255% after the purification process was carried out [20]. The surface morphology of formulation 3 is denser than that of formula 1 without the addition of silica. This is caused by changes in the pore structure of the cement paste which shows an increase in hydration and is pozzolanic, resulting in higher compressive strength [21].

Conclusion

The manufacture of agropolymer bricks is carried out by utilizing oil palm ash to reduce the use of cement. The results of the XRF test showed that the largest composition of ash before and after acidification was SiO_2, which was 50.475% to 56.255%. The results of the water absorption test showed that the water absorption capacity of the bricks increased with the increase in the amount of silica added from the oil palm biomass ash. The test results of the average density of bricks with the addition of palm oil silica ash are lower than the density of sand, which is 2.241 g/cm^3. The results of the compressive strength test show that formula 3 has an optimum compressive strength of 28.8235294 kg/cm^2. This result is supported by the results of the SEM analysis of formula 3 which shows agglomeration and inhomogeneous grain size and a denser surface morphology. The bricks produced are in accordance with SNI SNI 03-0348-1989 Category IV B70 solid concrete brick quality.

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