Utilization of bauxite residue (red mud) in the manufacture of geopolymer concrete bricks

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Abstract. The environmental problems associated with bauxite residue are a large amount of waste and the high pH value. The solution that can be done to reduce pollution is to utilize bauxite residue. In this study, bauxite residue was used as a raw material for making concrete bricks without using cement. The methods used are casting, curing, and testing. The x-ray diffraction test results found 4.6% Bayer sodalite and the x-ray fluorescence test results found 11.30% Na2O, indicating the amount of NaOH in the bauxite residue. In addition, the percentage of SiO_2, Al_2O_3, and Fe_2O_3 67.27% indicates that the bauxite residue has pozzolanic properties so that it can be used as a binder. However, the compressive strength test results only yielded an average value of 1.25 MPa, and a water absorption value of 6%, so further research is needed to design a mixture with optimal compressive strength.

Keywords: Bauxite; Waste; geopolymer and concrete

1 Introduction

West Kalimantan, Indonesia has the largest bauxite reserves in Indonesia and there are two companies that process bauxite into alumina with a production capacity of 300,000 tons/year and 1,000,000 tons/year. The two companies process bauxite ore into alumina through the bayer process. The Bayer process is a process in which bauxite is extracted using high concentrations of sodium hydroxide (NaOH) to dissolve alumina at specific temperatures and pressures depending on the type of bauxite being processed. In this process, an alumina-rich solution is produced and a reddish-brown residue or waste is known as bauxite residue (red mud). There are two environmental issues related to bauxite residue: large amounts of waste and high alkalinity with a pH range of 10-13. Of the 100% bauxite that is processed, more than 50% will become bauxite residue which is a burden on the environment and has the risk of causing contamination of soil, surface water, and groundwater. The high alkalinity of bauxite residue is difficult to exploit, but based on the results of previous studies it gives good results when used in the construction sector. On the other hand, Portland cement is widely used in the construction sector as a mixed ingredient in the manufacture of concrete bricks, whereas 1 ton of Portland cement produced produces 1 ton of CO_2 which is released into the air. Concrete production contributes 5% of CO_2 production in the world each year, so an alternative material is needed that can be used to replace or substitute Portland cement with environmentally friendly concrete bricks. The results of previous studies show that the bauxite residue contains SiO_2 and Al_2O_3 > 50%, so it is classified as a pozzolanic material that has cement-like properties besides having high alkalinity which indicates the presence of NaOH content in the bauxite. residues that can become additional base activators. So from these two problems, innovation is needed to utilize bauxite processing waste into alumina while reducing the use of cement which is the

JICOMS 2022, November 16, Jakarta, Indonesia

DOI 10.4108/eai.16-11-2022.2326118

cause of carbon emissions into a product that has added value, namely geopolymer concrete brick [1]

Geopolymer concrete brick is a mixture consisting of geopolymer paste, coarse aggregate, and fine aggregate (as filler). Generally, the manufacture of geopolymer concrete bricks combines pozzolan materials and alkaline activator solutions. Bauxite residue is one of the pozzolanic materials because it has high Al and Si content. Another advantage is that it contains an alkaline solution and sodium silicate due to the addition of sodium hydroxide in the process of processing bauxite into alumina so that it can also be used as an alkali activator. However, the use of bauxite residue in the manufacture of geopolymer concrete bricks has not been widely studied, especially in Indonesia, so the purpose of this study is to determine the composition of the bauxite residue using X-Ray Diffraction (XRD) and X-Ray Fluorescence (XRF) and determine the compressive strength and absorption values. water from bauxite residue-based geopolymer concrete bricks.

Geopolymer concrete brick made from bauxite residue is one of the innovations in replacing the use of portland cement. This can be an alternative solution for using bauxite residue, which is getting bigger every year in West Kalimantan, Indonesia's two alumina processing industries.

2 Research Methods

The method of making geopolymer concrete bricks from bauxite residue consists of casting, curing, and testing. The ratio of bauxite residue, fine aggregate, and coarse aggregate used is 1:2:3. The mixture of alkaline solution used is 12 M and Na2SiO3 in liquid form. In the first stage, all the constituent materials are dried first, the bauxite residue is sieved with a size 16 chicken, fine aggregate with a size of 10, and coarse aggregate with a size of ¾ then these three constituent materials, are mixed manually until homogeneous. Then the mixture is poured into a 8 x 8 x 8 cm mold and compacted. The mold is smeared with oil first to make it easier to take samples from the mold. Curing was carried out at room temperature from day 1 to day 7, the samples were covered with plastic to reduce evaporation. While the compressive strength test was carried out on days 7, 14, 21, and 28 days followed by a water absorption test. In addition, X-Ray Diffraction (XRD) and X-Ray Fluorescence (XRF) tests were also carried out to determine the mineralogy and chemical composition of the bauxite residue. The following is a research flowchart.

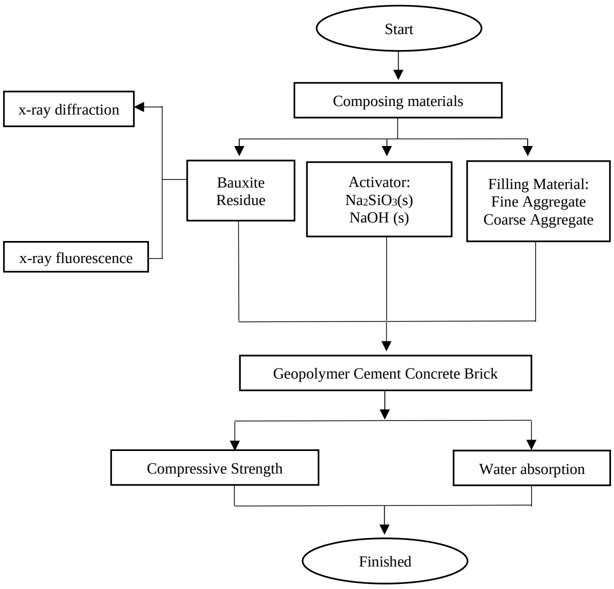

Fig 1. Research Flowchart

3. Result and Discussion

Bauxite residue is a by-product or waste from processing bauxite into alumina through the Bayer process. More than 95% of the world's bauxite-to-alumina processing industry uses the Bayer process [2]. The Bayer process was developed by Karl Josef Bayer, in which bauxite is extracted using sodium hydroxide (NaOH) to dissolve alumina. The Bayer process consists of four main stages, namely digestion, clarification, precipitation, and calcination. The processing of bauxite into alumina is currently carried out through the Bayer process. The Bayer process begins by separating fine-sized impurities by grinding and washing processes, then the washed bauxite is added to the digester where it is reacted with sodium hydroxide (NaOH) solution at a certain temperature and pressure depending on the type of bauxite being processed.

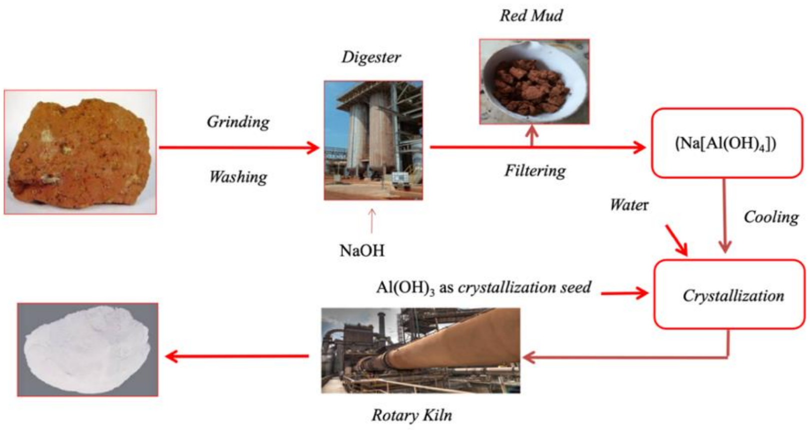

Fig 3. Bayer Process

In the digestion process, the gibbsite is dissolved with NaOH to obtain a solution rich in alumina, namely sodium aluminate ($NaAl(OH)_4$).

$$Al_2O_3.3H_2O\ (s) + 2NaOH(aq) \longrightarrow 2NaAl(OH)_4 \quad (1)$$

At a temperature of 150ºC and a pressure of 800 kPa, not only does the gibbsite dissolve in NaOH, but reactive silica in the form of kaolinite also dissolves and forms sodium silicate which dissolves in sodium aluminate solution. The reaction is as follows:

$$3Al_2Si_2O_5(OH)_4 + 18NaOH \longrightarrow 6Na_2SiO_3 + 6Na[Al(OH)_4] + 3H_2O \quad (2)$$

This dissolved reactive silica then reacts further with sodium aluminate to form a precipitate of Desilication Products (DsPs) with the main form of Bayer Sodalite [1]

$$6Na_2SiO_3 + 6Na[Al(OH)_4] + Na_2X \longrightarrow Na_6[Al_6Si_6O_{24}].Na_2X + 12NaOH + 3H_2O \quad (3)$$

Insoluble minerals and precipitates that form Desilication Products (DsPs) with the main form of bayer sodalite are considered as impurities known as bauxite residue (red mud).

Two things are still a world environmental issue, about bauxite residue, first in terms of the amount produced and second its basicity. This is due to the not optimal washing which results in a sodium hydroxide (NaOH), sodium carbonate (Na_2CO_3) and sodium aluminate ($NaAl(OH)_4$) remaining in the liquid phase [3] , besides Bayer sodalite which is still left in the red mud in the solid phase is also a source of basicity. The higher the Bayer sodalite is formed, the more NaOH is consumed. From the results of the X-Ray Diffraction (XRD) test on the red mud research sample, it was found that 4.6% Bayer sodalite was shown in the following figure:

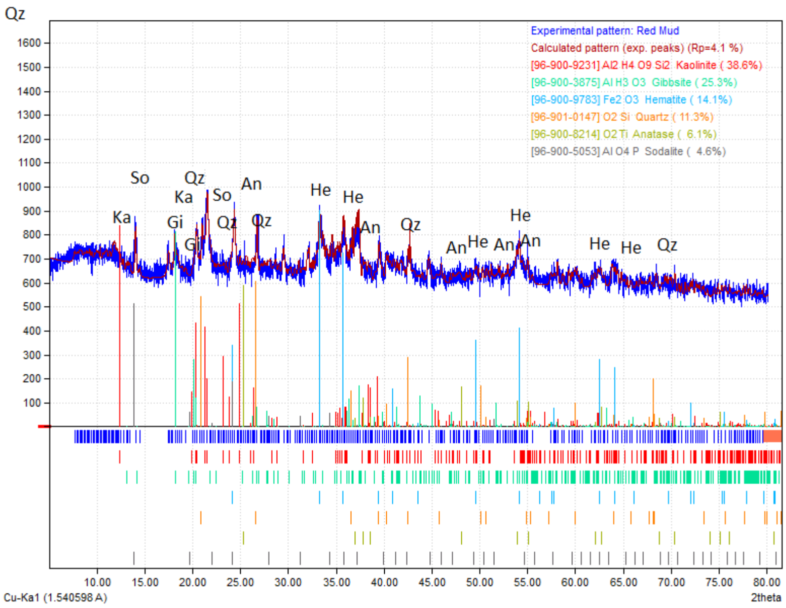

Fig 4. X-Ray Diffraction (XRD) test results on bauxite residue

Pozzolan is a material that contains silica and alumina in a fine state that passes through a 0.21 mm sieve. Pozzolan does not have properties like cement but in a smooth state reacts with free lime and water into a solid mass that is insoluble in water [4]. The reaction of cement compounds with water forms CSH and $Ca(OH)_2$ compounds which are then $Ca(OH)_2$ compounds will react with a pozzolan to form CSH and CAH. The reaction of cement compounds with water is as follows:

$$C_3S + H_2O \longrightarrow CSH + Ca(OH)_2 \quad (4)$$
$$C_2S + H_2O \longrightarrow CSH + Ca(OH)_2 \quad (5)$$

The result of $Ca(OH)_2$ from equations 4 and 5 which is a by-product of the hydration reaction, reacts again with the elements SiO_2 and Al_2O_3 in the pozzolanic material to get more CSH and CAH. The reaction of the pozzolan to $Ca(OH)_2$ can be seen in equations 6 and 7 below:

$$Ca(OH)_2 + H_2O + SiO_2 \longrightarrow CSH \quad (6)$$
$$Ca(OH)_2 + H_2O + Al_2O_3 \longrightarrow CAH \quad (7)$$

Bauxite residue is a material that has pozzolanic properties, as can be seen from table 1 below, where the levels of SiO_2, Al_2O_3, and Fe_2O_3 are > 50% while CaO levels are > 5%.

Table 1. Bauxite residue XRF test results

(oxides)	(unit)	(amount)	(elements)	(unit)	(amount)	sd
SiO_2	%	13.57	Si	%	6.34	0.08
TiO_2	%	2.14	Ti	%	1.28	0.04

Al_2O_3	%	21.77	Al	%	11.52	0.11
Fe_2O_3	%	31.93	Fe	%	22.33	0.16
CaO	%	4.91	Ca	%	3.51	0.08
Na_2O	%	11.30	Na	%	8.39	0.12

In addition, due to the addition of NaOH during the Bayer process, red mud has a Na_2O content of 11.30 so it can be used in the manufacture of geopolymer concrete bricks without cement. In this study, geopolymer concrete bricks were made according to the predetermined mix design, and the average compressive strength values were obtained as shown in table 2 as follows:

Table 2. Average compressive strength values

Sample Code	Compressive Strength Value (MPa)
BR 7	2
BR 14	1
BR 21	1
BR 28	1

The average compressive strength value from day 7 to day 28 produces a compressive strength value that is still far from the SNI value of the paving block required, which is at least 8.5 MPa so the mix design mix that has been planned does not meet the requirements. Meanwhile, the water absorption value obtained a value of 6% which indicates that it has met SNI. from paving blocks.

The results of the research above show that the bauxite residue has a relatively good water absorption value because it has a large surface area and porosity [. However, the magnitude of this porosity makes the average compressive strength value of the bauxite residue low, namely 1.25 MPa. Apart from porosity, this is also caused by the presence of Na_2O which does not react so that it turns into Na_2CO_3 at room temperature, this is evidenced by the appearance of white spots on the samples made after being left for several days. When compared with the research results of geopolymer concrete bricks with fly ash the resulting compressive strength is much greater [5]. So further research is needed on the composition proportions in the manufacture of geopolymer concrete bricks using this bauxite residue.

4. Conclusion

The bauxite residue has 4.6% Bayer sodalite and 11.30% Na_2O, indicating the amount of NaOH contained in the bauxite residue. In addition, the percentage of SiO_2, Al_2O_3 and Fe_2O_3 >50% and CaO>5%. showed that the bauxite residue has pozzolanic properties so that it can be used as a binder in the manufacture of geopolymer concrete bricks. However, from the compressive strength test results, only an average value of 1.25 MPa was produced, and a water absorption value of 6%, so further research is needed to design a mixture with optimal compressive strength.

Acknowledgments

This research work is supported by the Ketapang State Polytechnic and sponsored by the Directorate General of Vocational Education, Ministry of Education, Culture, Research, and Technology.

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