Effect Alkaline Activator Ratio on Porosity Geopolymer Binder Based Umeanyar Slate Stone Powder

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Abstract
This research focuses on the manufacture of geopolymer binder based on Umeanyar slate stone powder (USSP) with alkaline activator sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH). The effect of alkaline activator ratio on porosity was investigated in this study. USSP geopolymer binder contains SiO_2 (49%), Al_2O_3 (11%), CaO (11.2%) and uses a NaOH activator with a concentration of 14 M. The proportion of precursor and activator (P/A) are 70%: 30%; 75%: 25%; 80%: 20% and alkaline activator Na_2SiO_3: NaOH (SS/SH) were 1: 1; 1.5: 1; 2: 1, by weight. The sample of the specimen is made in the mould of a cylinder with a diameter of 25mm and height of 50 mm and tested at the age of 7 and 28 days. Porosity test according to ASTMC642-06. The porosity test results of the geopolymer binder at the age of 28 days were decreased when the P/A ratio increased and the SS/SH ratio decreased.

Index of Terms : **geopolymer, porosity, slate stone powder, umeanyar**

I. Introduction

Geopolymer is a geosynthetic binder that uses a material that does not come from cement. The term geopolymer was first introduced by Davidovits in 1978 who discovered a polymerization bond between alkaline activators and the main ingredients in the form of fly ash and rice husk ash [1–3]. Geopolymers are the synthesis of natural materials through a polymerization process where the main ingredients in the manufacture of geopolymer materials are materials containing silica and alumina elements [4–6]. Research on geopolymer continues to date because the use of this binder can be used as an alternative to using cement.

Until now, the use of cement has reached 4 billion tons per year, which means that nearly 4 billion tons of CO_2 gas are released into the atmosphere each year [7,8]. In its production, cement requires a very large amount of energy due to heating up to temperatures 1400°C-1500°C [7,9–17]. With the results of large enough CO_2 gas emissions accompanied by high temperatures in its production, mitigation measures that can be taken are reducing the use of cement in the manufacture of binders and concrete to reduce the negative impact on the environment.

Research on geopolymer continues to date. Raw materials or geopolymer precursors usually use fly ash, rice husk ash, metakaolin, white clay, or other materials that contain a lot of silica and alumina. The effect of using this precursor can affect the physical and mechanical properties of the geopolymer binder. Other factors that also influence are the activator solution, temperature, molarity concentration, and particle size. Research on the use of fly ash as a precursor that contains more than 50% silica and alumina which is activated by activator solution can produce compressive strength exceeding conventional cement [18–23]. Apart from compressive strength, physical properties also need to be considered in the manufacture of geopolymer binders. One of them is the porosity test which describes the space in a certain material.

The use of fly ash precursors and activators with SS / SH ratios increasing from 0.5 to 2.5 resulted in decreased porosity levels [24]. The effect of variations in curing temperature and activator ratio can also affect the results of the porosity of the test object. Research [25] used fly ash as a geopolymer base material and used a precursor/activator

(P/A) ratio of 0.2 and 0.4, while the SS/SH ratio was from 1 to 3. The variation of curing temperature was between 70 ° C and 100 ° C for 24 hours. The results showed that the lowest level of porosity was at a P/A ratio of 0.2 and an SS/SH ratio of 2.Other studies on porosity using fly ash precursors gave results that at the age of 7 days testing had a porosity level of 11.95%, while at 28 days it decreased to 7.65% [26]. This shows that the age factor of the test can also affect the porosity of the geopolymer binder.

II. Material And Methode

A. Material

The precursor used in this study was the Umeanyar slate stone powder (USSP). The material sample is sieve at 200µm (Figure 1). The XRF test results of the Umeanyar slate stone powder are shown in Table 1 and Figure 2. There are two types of alkaline activator used, namely sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH). Sodium hydroxide solution was prepared the day before (24 hours) with a concentration of 14 M. Geopolymer binder was made with 3 variations of precursors and activators (P/A), namely 70%: 30; 75%: 25%; 80%: 20%. While the ratio of activator sodium silicate and sodium hydroxide (SS/SH) was 1: 1; 1,5: 1; 2: 1 (Table 2).

Fig. 1. Processing USSP

B. Porosity Test

Porosity is a measure of the amount of free space in a particular material and this case, it is a geopolymer binder. The porosity test is defined as the weight difference between the weight of the specimen that has been immersed underwater after heating and the weight of the specimen when dry, expressed in terms of the dry weight of the specimen. To determine the value of porosity using the formula in equation 1[27].

$$P = \frac{C-A}{C-D} \times 100\% \qquad (1)$$

where :

P = porosity (%)

A = mass of oven dried sample in air (g)

C = mass of surface dry sample in the air after immersion and boiling (g)

D = apparent mass of sample in water after immersion and boiling (g)

TABLE I

XRF TEST RESULT OF THE UMEANYAR SLATE STONE POWDER

Compound	Percentage (%)
Al_2O_3	11,00
S_iO_2	49,00
K_2O	3,37
CaO	11,20
TiO_2	2,06
V_2O_5	0,03
MnO	0,55
Fe_2O_3	22,35
CuO	0,14
ZnO	0,04
Rb_2O	0,04
SrO	0,17
ZrO_2	0,12
BaO	0,20
Re_2O_7	0,04

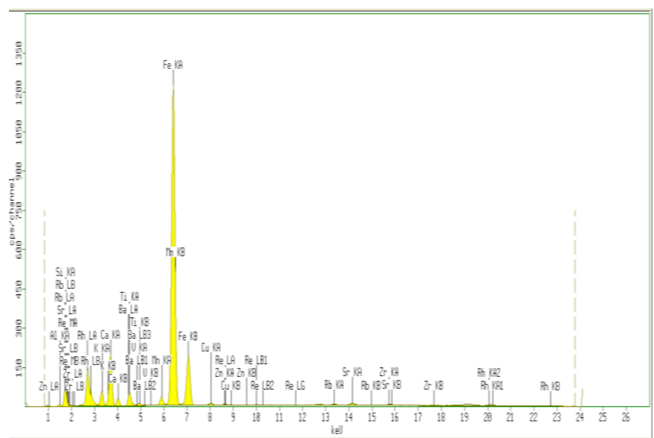

Fig. 2. XRF Result Graph of USSP

TABLE II

THE MIXING PROPORTIONS GEOPOLYMER BINDER

Group	Code	USSP (g)	Na_2SiO_3 (g)	NaOH (g)	Add water
1	Y11	455,00	97,50	97,50	11%
	Y12	455,00	78,00	117,00	11%
	Y13	455,00	65,00	130,00	11%
2	Y21	487,50	81,25	81,25	11%
	Y22	487,50	65,00	97,50	11%
	Y23	487,50	54,17	108,33	11%
3	Y31	520,00	65,00	65,00	11%
	Y32	520,00	52,00	78,00	11%
	Y33	520,00	43,33	86,67	11%

C. *Mixing geopolymer binder*

Geopolymer binder was made by mixing 14 M alkaline activator of Sodium Hydroxide with sodium silicate solution according to the ratio shown in Table 2. USSP precursor was put into a 3-liter mixer bowl with additional water equal to 11% of the weight of the precursor. Turn on low speed for 15 seconds, then put in the alkaline activator and turn the mixer back on at medium speed for 30 seconds and distribute it. After mixing evenly, prepare a cylinder mold with a diameter of 25 mm and a height of 50 mm (Figure 3). After being printed into the mold, it is tightly wrapped in airtight plastic for 24 hours. After being allowed to stand for 24 hours, the cube specimens were put in an oven with a temperature of 70°C for 24 hours. After being removed from the oven, the specimens were removed from the mold and tested at the age of 7 days and 28 days. Porosity test according to ASTM C-642 [27].

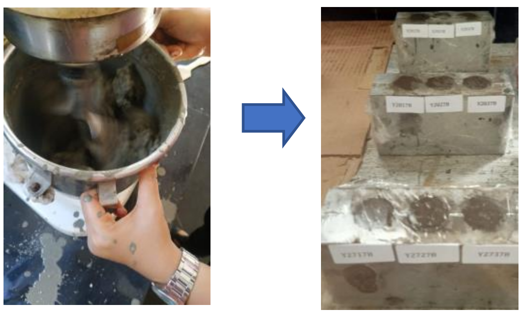

Fig. 3. Mixing geopolymer binder USSP

Fig. 4. Curing geopolymer binder USSP

III. Result And Discussion

The porosity test was carried out at the age of 7 days and 28 days. The results of the porosity test of the geopolymer binder sample are shown in Table III and Figure 7-9.

Table III shows the results of the porosity test for each group of geopolymer binders made from Umeanyar slate stone powder. In group 1 shown in Figure 7, the lowest percentage of porosity was found in the Y13 (7 days) specimen sample of 5.91% and 4.24% at the age of 28 days. This shows that the age of the test and the ratio of the activator alkaline can affect the porosity value of each specimen. Likewise with group 2 and group 3. In group 2 at the age of 7 days had the lowest porosity value of 8.70% and at the age of 28 days was 5.78%. Whereas in group 3, the lowest porosity value was found in the Y33 test object, which was 10.94% at 7 days and 8.88% at 28 days.

TABLE III
POROSITY TEST RESULT

Group	Code	USSP (g)	Na_2SiO_3 (g)	NaOH (g)	Porosity (%) 7days	Porosity (%) 28 days
1	Y11	455,00	97,50	97,50	8,04	5,74
	Y12	455,00	78,00	117,00	7,76	4,48
	Y13	455,00	65,00	130,00	5,91	4,24
2	Y21	487,50	81,25	81,25	10,49	6,57
	Y22	487,50	65,00	97,50	9,31	6,14
	Y23	487,50	54,17	108,33	8,70	5,78
3	Y31	520,00	65,00	65,00	13,11	10,69
	Y32	520,00	52,00	78,00	11,99	9,96
	Y33	520,00	43,33	86,67	10,94	8,88

Figure 5 shows the results of the porosity test in group 1. The average decrease in porosity was 31% when the test object was 28 days old. This shows that the geopolymer binder experiences a reduction in the number of pores along with the increasing age of the specimen. The test object with code Y13 has the lowest level of porosity with a value of 5.91% at the age of 7 days and 4.24% at the age of 28 days. Y13 specimen contains the highest sodium silicate activator which can accelerate the polymerization bond. So that when the specimen is 28 days old, the pore size is getting smaller and can reduce the number of pores in the research sample.

The graph of the porosity test results in group 2 is shown in Figure 6. At the age of 28 days, the average decrease in porosity was 35%. The lowest percentage of porosity occurred at the highest SS/SH ratio, namely the Y23 specimen. This shows that the percentage of the number of pores decreases with the increasing age of the specimen and the SS/SH ratio. When the specimen was 7 days old, the porosity test result was 8.70% and decreased to 5.78% at the age of 28 days. While the test object code Y21 has the highest porosity level of 6.57% with the lowest SS/SH activator ratio. This shows that the activator ratio is increasing, which can reduce the porosity value of the geopolymer binder.

A decrease in the value of porosity also occurred in group 3 (Figure 7). At the age of 7 days, the highest porosity value was 13.11% and decreased to 10.69% at the age of 28 days. Whereas the Y33 test object had the lowest porosity value of 10.94% at the age of 7 days and decreased to 8.88% at the age of 28 days. The porosity value decreased with the increasing age of the specimen and the activator ratio. The high content of sodium silicate in the solution can accelerate the polymerization bond. The addition of water to the mixture can also affect increasing the porosity value, this has also been proven in previous studies [28].

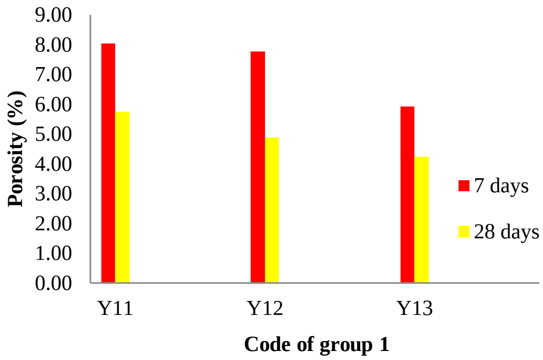

Fig. 5. Porosity test result of group 1

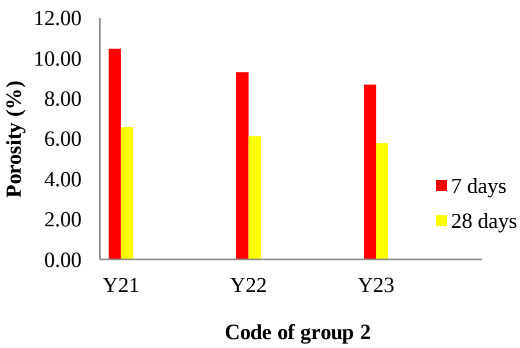

Fig. 6. Porosity test result of group 2

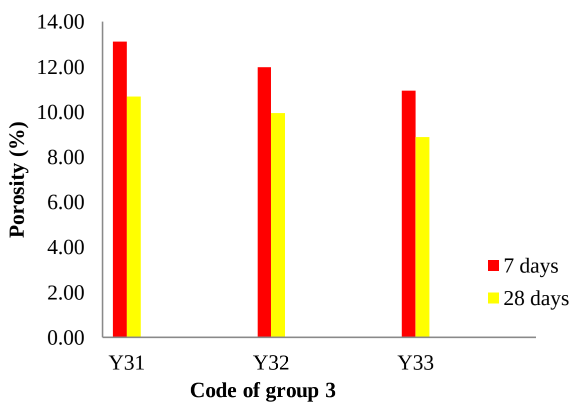

Fig. 7. Porosity test result of group 3

From the results of the porosity test that was carried out at the age of 7 and 28 days, the porosity tended to decrease. The porosity value in each group also decreased if the SS/SH ratio increased and the P/A ratio decreased. Several factors influence the porosity value of the geopolymer binder. In this study, there was a factor of the ratio of the precursor to activator (P/A), the ratio of the alkaline activator (SS/SH). In addition, there was an additional 11% of water in each group based on the weight of the precursors. The highest P/A ratio was 80% / 20% and the addition of water by 11% (57.2 g) gave the lowest porosity values at the age of 7 and 28 days. Meanwhile, the lowest P/A ratio is 70% / 30% and the highest SS/SH ratio has the lowest porosity value. The addition of water in group 1 was also given at 11% (50.05 g) by the weight of the binder. The porosity that occurs is caused by the water released in the polymerization process which can affect the physical properties of the binder. The number of hydroxyl ions supplied by additional water (H_2O) and alkali metal ions, namely Na in the activator solution, can accelerate the activation of the alkali. The impact of this situation is that it can form more gel so that it can create a matrix with strong bonds between particles and can reduce porosity [29,30]. So the higher the SS/SH activator ratio, the lower the porosity value of the USSP geopolymer binder.

IV. CONCLUSION

The composition of the precursor and activator (P/A) and the ratio of the alkaline activator (SS/SH) can affect the percentage of porosity in the geopolymer binder. In this study, there were several results, namely a decrease in porosity in each of the P/A and SS/SH groups. Each group with the highest SS/SH ratio had the lowest level of porosity. This shows that the geopolymer binder with a high sodium silicate solution has a role in accelerating the polymerization reaction, thereby reducing the percentage of pores in each of the specimens. Meanwhile, the group with the highest P/A ratio had a large porosity value as well, due to the incomplete polymerization process of the USSP geopolymer binder.

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