Effect NaOH Concentration on Bagasse Ash Based Geopolymerization

Saloma[1,*], *Hanafiah*[1] , and *Kartika* Ilma Pratiwi[1]

[1]Sriwijaya University, Jl. Palembang-Prabumulih, KM.32, Inderalaya, Ogan Ilir, South Sumatra, 30662, Indonesia

Abstract. Geopolymer is a natural adhesive material which can be developed as a substitute for cement. The natural ingredients which want to use should contain silica and alumina. This paper uses bagasse ash as a basic material of mortar geopolymer. As an adhesive, the bagasse ash should be mixed with water and another activator alkali such as sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3). The NaOH's molarity variation are 8, 10, 12, 14 and 16 M with Na_2SiO_3/NaOH = 1,0 sand/bagasse ash = 2,75 and activator/bagasse ash = 0,42. This research use 50 x 50 x 50 mm cube sized specimen and conduct a compressive strength test with 3, 7, 14, 21 and 28 days. The fresh mortar test result showed that the use of NaOH's molarity variation influences the slump value and time setting. The bigger NaOH molarity variation that been used, the smaller slump value. But, the time setting is increased. While the result for density and compressive strength shown that the bigger NaOH molarity variation, the bigger density and the compressive strength. Maximum compressive strength resulted from the mixture of mortar geopolymer with 16 M concentration.

1 Introduction

Mortar geopolymer is an environmentally friendly material, which can be developed as a substitute for future construction material. While it can be used from industrial waste, the making process of geopolymer cement did not use as much energy as *Portland* cement. Portland cement needs 1.000^{o}C temperature for clinker burning process. Those burning processes produce CO_2 which pollutes the air. The geopolymer making process could reduce the greenhouse gasses emission up to only 20% left.

The main ingredient for geopolymer is a natural ingredient which contains silica (Si) and Aluminum (Al). The silica and aluminium are important for polymerization bond. These basic ingredients then reacted with alkali activator solvents such as NaOH and Na_2SiO_3, with NaOH concentration about 8-16 M [1]. The rice husk ash has a huge potential to become the main ingredient of mortar geopolymer. The research has shown that after 28 days, the maximum compressive strength was 45 MPa with NaOH concentration for about 10 M [2].

[*] Corresponding author: saloma_571@yahoo.co.id

The basic ingredient used in this geopolymer research is bagasse ash waste, which is the fuel for sugar cane mill. Sugar cane is the raw material to produce sugar. This plant only grows in a tropical territory such as Indonesia. The age of this plant, from the plantation until the harvest, is around 1 year. In Indonesia, sugar cane usually grows in Java and Sumatera island. After harvest, the sugar cane processed into 5% sugar, 5% water and 90% the bagasse (sugar cane waste). The bagasse then used in a burning process within a steam boiler. The steam boiler is the main tools to stir the sugar cane mill.

Previous research on the use of bagasse ashes as a mixture of concrete material shown a satisfying result. [3] shown that the conventional concrete with a bagasse ash mixture could bear a 30-40 MPa compressive strength. [4-5] shown that the compressive, tensile and flexural strength a concrete with bagasse ash mixture, are 10% higher than an original concrete. Besides improving mechanical characteristic, bagasse ash also could improve workability. So, it does not need to use additional superplasticizer material.

2 Material

The basic material for mortar geopolymer making should contain high silica and alumina. In this research, the basic material is bagasse ash waste, which is the main fuel for sugar-cane mill. The bagasse ash comes from PT Perkebunan Nusantara X (Persero) Surabaya, East Java. Figure 1 shows the result of bagasse ash's scanning electron microscope (SEM) test. Based on this test, the bagasse ash shape has a spherical form with ± 20 μm maximum diameter. Figure 2 is the result of XRD analysis which shown that this material contains high silica and alumina.

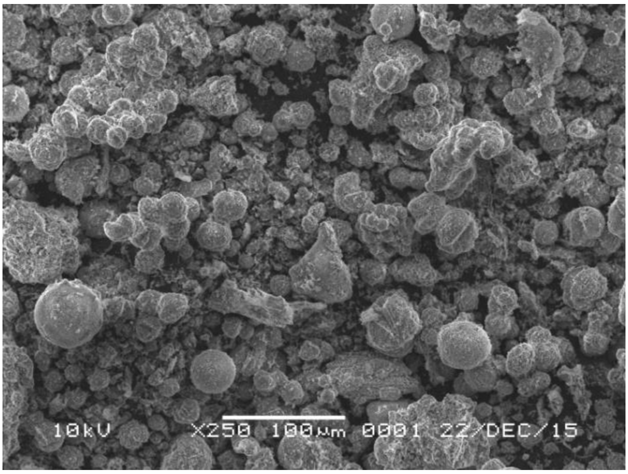

Fig. 1. SEM bagasse ash.

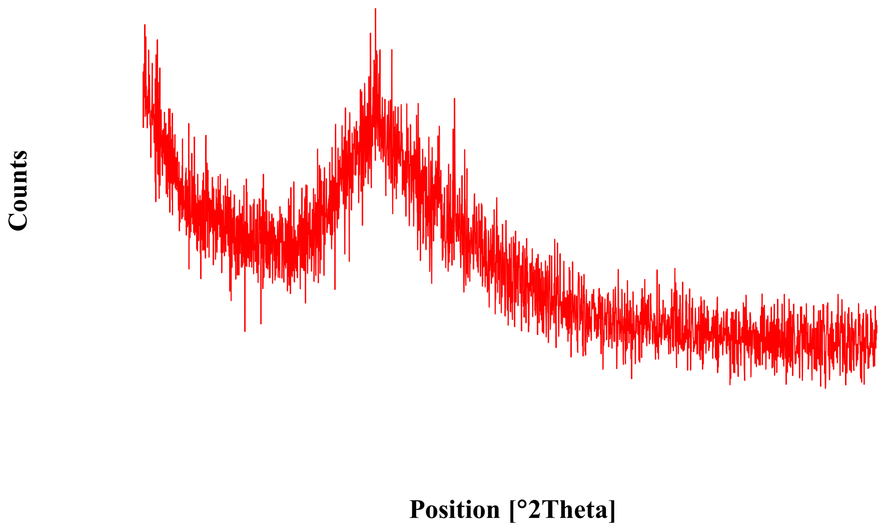

Fig. 2. XRD bagasse ash.

Activator that been used in this research is Na_2SiO_3 and NaOH. Na_2SiO_3 contain 58% gel-formed sodium silicate. Meanwhile, the powder-formed NaOH contain 98% purity level. NaOH mixed with water until it formed 8 M, 10 M, 12 M, 14 M, and 16 M concentration. This liquid then mixed with Na_2SiO_3. The comparison value between NaOH and Na_2SiO_3 is 1. Before it used to create mortar, this activator liquid bleached for about 1 day until it reaches a normal room temperature. The fine aggregate (sand) that used in this research comes from Tanjung Raja's rivers and OKI, South Sumatera. The ratio between sand/bagasse ash = 2,75 and the ratio between activator/bagasse ash = 0,42.

3 Laboratory test

This research conducted in Laboratory of Concrete and Material, Civil Engineering Faculty of Engineering, Universitas Sriwijaya. The standard for mortar mixed material refers to American Standard Testing and Material (ASTM C109). The experiment that has been conducted were workability, setting time, density and compressive strength test. The NaOH's molarity variation are 8, 10, 12, 14 and 16 M with Na_2SiO_3/NaOH = 1,0. sand/bagasse ash = 2,75 and activator/bagasse ash = 0,42. The workability test conducted by test the flow table to know the diameter distribution. While the compressive strength test conducted using a 50 x 50 x 50 mm cube-sized material for 3, 7, 14, 21 and 28 days period.

4 Result and discussion

4.1 Test result of slump flow

The test result for slump flow showed in Figure 3. Based on Figure 3, the higher NaOH concentration, the lower slump flow value. This happens due to the bigger NaOH concentration that been used, the bigger its density in a 1-liter liquid water. So, it makes the

NaOH liquid become thicker. Therefore, the use of small NaOH concentration makes the mortar mixed become flow and produced a broader diameter.

The decreasing percentage of slump flow mortar geopolymer value shown in Table 1 which shows that the slump flow percentage decreasing congruent with the increasing of NaOH concentration. The decreasing percentage are 10.93%, 33.72%, 40.82%, and 46.81%. This shown that the increasing concentration of NaOH can decrease mortar geopolymer workability.

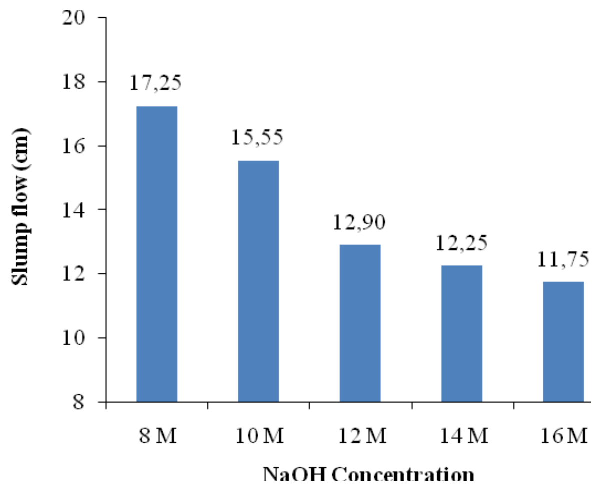

Fig. 3. Slump flow.

Table 1. Difference percentage of mortar geopolymer's slump flow.

NaOH concentration	Slump flow (cm)	Increasing percentage (%)
8 M	17.25	0
10 M	15.55	10.93
12 M	12.90	33.72
14 M	12.25	40.82
16 M	11.75	46.81

4.2 Setting time

The result of setting time test can be shown in Figure 4. The result showed that the fastest bonding-time happens in the mortar with 16 M NaOH concentration, with 105 minutes time and 165 minutes latest bonding-time. Meanwhile, the longest initial setting time happens in a mortar with 8 M NaOH concentration for 161,25 minutes and 225 minutes final time. Based on this research, it can be concluded that the bigger NaOH concentration, the faster the setting time.

 DOI: 10.1051/matecconf/20167801025

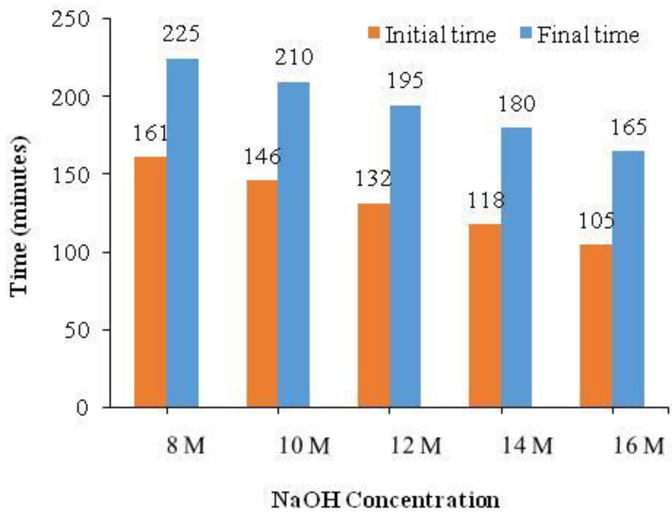

Fig. 4. Setting time.

4.3 Density

The result for density test can be shown in Figure 5. The maximum density which resulted from the mixture of 16 M NaOH is 1,79 gram/cm. The minimum density resulted from the mixture of 8M NaOH is 1,69 gram/cm. Based on this result, the more vary the NaOH, the higher its density. In a long period, the density will decrease until it reached the constant number. This happens because the water that contained in the mortar becomes evaporated. The increasing density percentage of mortar geopolymer can be shown in Table 2. Based on the data in Table 2, the density increaseds along with the increasing of NaOH concentration. The increasing density percentage on 10 M, 12 M, 14 M and 16 M in a row is 1.74%, 2.87%, 4.51% and 5.58%

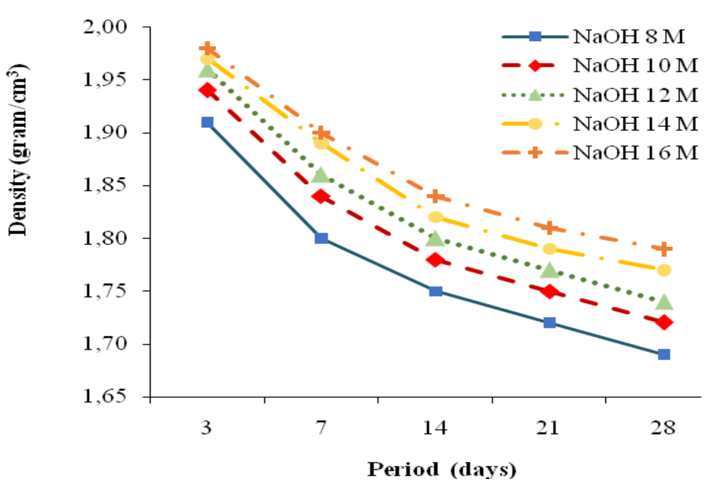

Fig. 5. Density.

Tabel 2. Difference percentage of mortar geopolymer's density.

NaOH concentration	Density (cm)	Increasing percentage (%)
8 M	1.69	0
10 M	1.72	1.74
12 M	1.74	2.87
14 M	1.77	4.51
16 M	1.79	5.58

4.4 Compressive strength

Figure 6 shown the development of compressive strength for 3–28 days period with NaOH concentration including 8 M, 10 M, 12 M, 14 M. In the age of 3 to 7 days, all mortar have the same Compressive strength development. Furthermore, from the age of 14 days, mortar with 14 M and 16 M NaOH concentration experienced a faster development of compressive strength compare to mortar with 8 M, 10 M and 12 M NaOH concentration. The fast improvement of compressive strength in 14 M and 16 M concentration NaOH happens due to the role of NaOH in the creation of zeolite formation. Na_2SiO_3 in an activator liquid also plays a role in the fast improvement of compressive strength. This is due to Na_2SiO_3 accelerating reaction in the polymerization process. Table 3 indicates the increasing number of Compressive strength, along with the improvement of NaOH concentration. The increasing Compressive strength percentage in a 10 M, 12 M, 14 M and 16 M mortar concentration in a row are 30.18%, 48.97%, 42.49% and 66.19%.

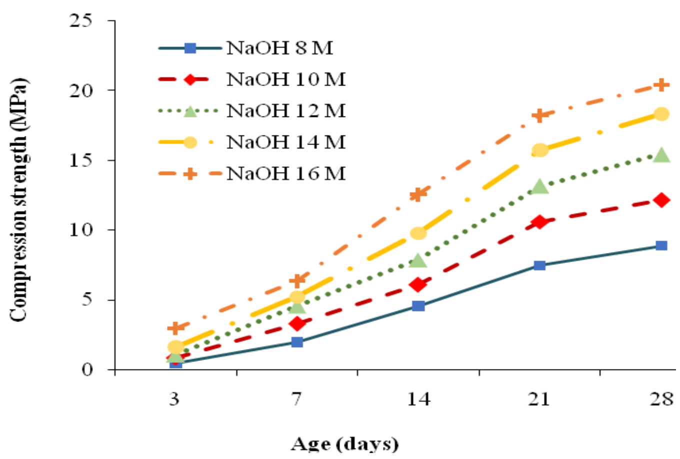

Fig. 6. Compressive strength.

Table 3. Percentage of mortar geopolymer's increasing compressive strength.

NaOH percentage	Compressive strength (MPa)	Increasing percentage (%)
Mortar type N	6,2	0
8 M	8.88	30.18
10 M	12.15	48.97
12 M	15.44	42.49
14 M	18.34	66.19
16 M	20.44	69.67

4.5 Compressive strength vs density

Graphic for analysis of mortar geopolymer's compressive strength and density can be shown in Figure 7. The result for analysis of mortar geopolymer's compressive strength and density with 8 M, 10 M, 12 M, 14 M and 16 M NaOH concentration shown that the coefficient determination value (R^2) is 0.9936 with Equation 1:

$$f_c' = 116.99\,\gamma - 188.75 \quad (1)$$

where:
f_c' = compressive strength (MPa)
γ = density (gram/cm^3)

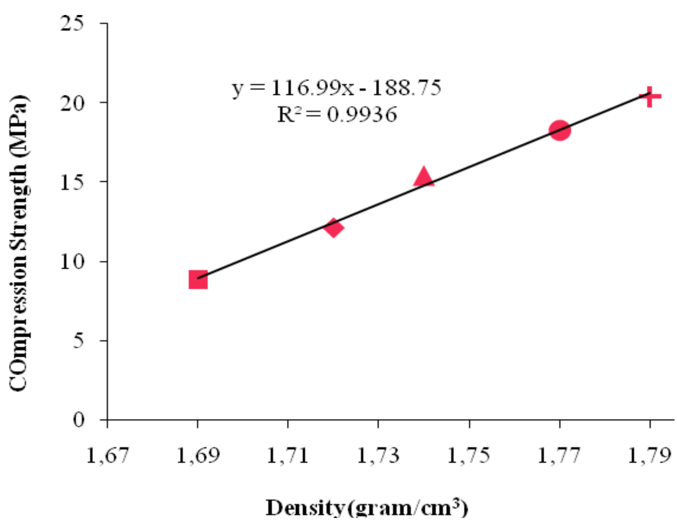

Fig. 7. Compressive strength vs density in 28th day.

4.6 Compressive strength vs NaOH concentration

Analysis of compressive strength regression and NaOH concentration can be shown in Figure 8. The analysis found that coefficient determination value (R^2) is 0.9962 with Equation 2:

$$f_c' = 8.7174\ M^{0.526} \tag{2}$$

where:
f_c' = compressive strength (MPa)
M = molarity (M)

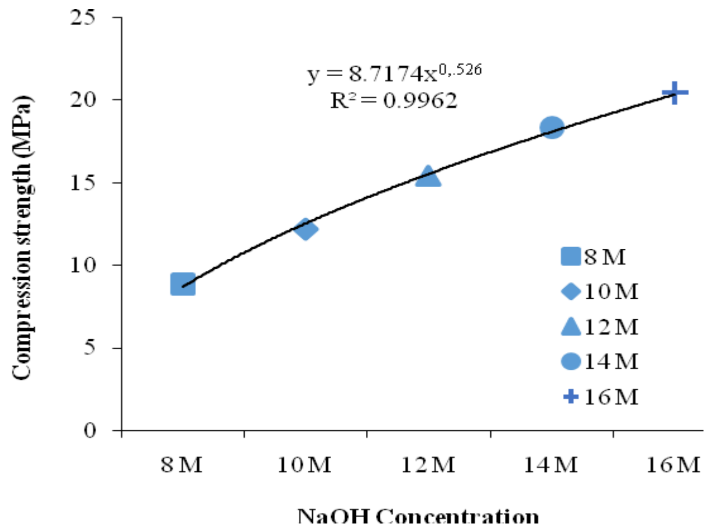

Fig. 8. Compressive strength vs NaOH concentration in 28th day.

4.7 NaOH concentration vs density

Analysis of NaOH concentration regression and density is shown in Figure 9. On the 28th day, the test found that the coefficient determination value (R^2) is 0.9962 with Equation 3:

$$\gamma = 0.025\ M + 1.667 \tag{3}$$

where the:
γ = density (gram/cm^3)
M = molarity (M)

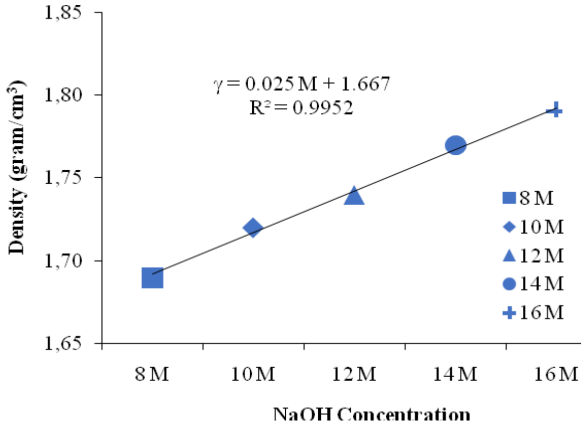

Fig. 9. Density vs NaOH concentration in 28th day.

4.8 Slump flow vs NaOH concentration

Analysis for slump flow regression and NaOH concentration is seen in Figure 10.

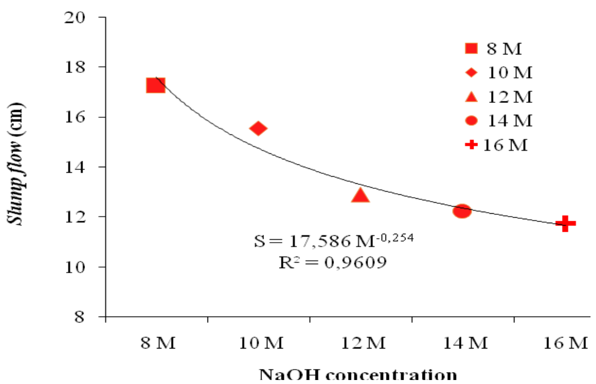

Fig. 10. Slump flow vs NaOH concentration in 28th day.

The analysis found that the coefficient determination value (R^2) is 0.9609, with Equation 4:

$$S = 17.586\ M^{-0.254} \tag{4}$$

where the:
S = *slump flow* (cm)
M = molarity (M)

5 Conclusion

Conclusions of this research are:

- The test result for slump flow mortar geopolymer shows that NaOH concentration influences the workability of the mixture. This happens due to the bigger NaOH concentration, the bigger density in a 1 Litre mortar geopolymer liquid. So, the more viscous the NaOH liquid.

- The test result for setting time mortar geopolymer show that the fastest bonding time resulted from 16 M NaOH concentration's which need 105 minutes. And for the last bonding, it need165 minutes. Based on this result, it can be concluded that the bigger NaOH concentration, the faster the bonding time.
- The result of density test shown that in each variant of NaOH concentration, the density for bagasse ash's mortar geopolymer is 1.69-1.79 gram/cm^3.
- The result of Compressive strength test showed that the maximum compressive strength for the 28th day mortar is 20.44MPa, with 16M NaOH concentration. The minimum compressive strength resulted from 8 M NaOH concentration, which is 8.88 MPa. It can be concluded that the bigger NaOH variant concentration, the bigger compressive strength that resulted.

This work was financially supported by the DIPA Sriwijaya University 2015.

References

1. A. Motorwala, V. Shah, R. Kammula, P. Nannapaneni, D. Raijiwala, International Journal of Emerging Technology and Advanced Engineering, **3**, 159 (2013)
2. Y, Kim, B.J. Lee, V. Saraswathy, S. Kwon, Scientific World Journal, **2014**, 1 (2014)
3. U.R. Kawade, V.R. Rathi, V.D. Girge, Int. J. Innov. Res. Sci. Eng. Technol., **2(7)**, 2997 (2013)
4. R. Srinivasan, K. Sathiya, International Journal for Service Learning in Engineering, **5(2)**, 60 (2010)
5. R. Srinivasan, and Sivakumar, J. Eng. Appl. Sci. (Asian Res. Publ. Netw.), **7(11)**, 1436 (2012)