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Submitted Abstract

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Abstract. This paper presents the results of research on geopolymer concrete using a reasonably low alkaline activator. The key objective concerning this research is to investigate whether a low alkaline activator is still qualified to produce a concrete compressive strength that fulfills the structural requirements. The experimental program is carried out by making geopolymer concrete specimens, where the variables reviewed represented the amount of alkaline activator (4% and 5%) , the ratio of alkaline activator to fly ash (AAS/FA) was 0.35, 0.4, 0.5, 0.6. The treatment temperatures of the specimens were room temperature (33^{o}C) and 60^{o}C. The experimental results of the compressive strength test have shown that the compressive strength of low alkaline geopolymer activator concrete still meets the requirements as a structural material (i.e. Indonesian Concrete Code). The weight of the resulting specimen is included in the category of normal weight concrete. The workability of geopolymer concrete with low alkaline activator tends to be better if the ratio AAS/FA also increases, but the compressive strength of concrete tends to decrease.

3.6 MA-055 The effect of asphalt emulsion type on the characteristics of cold asphalt emulsion mixtures

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Abstract. The need for road infrastructure continues to increase affecting the increase of hot asphalt mixtures. Hot asphalt requires a lot of energy to use because it goes through a heating process, so Cold Emulsion Asphalt Mixture (CAEM) is widely studied to be an eco-friendly alternative to hot asphalt mixtures. This study used a type of mixture IV Asphalt Emulsion Mixture with 4 types of emulsified asphalt, which are Cationic Slow Setting-1 hard (CSS-1h), Cationic

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The influence of low alkaline activator on the compressive strength and workability of geopolymer concrete

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Abstract. This paper presents the results of research on geopolymer concrete using a reasonably low alkaline activator. The key objective concerning this research is to investigate whether a low alkaline activator is still qualified to produce a concrete compressive strength that fulfills the structural requirements. The experimental program is carried out by making geopolymer concrete specimens, where the variables reviewed represented the amount of alkaline activator (4% and 5%) , the ratio of alkaline activator to fly ash (AAS/FA) was 0.35, 0.4, 0.5, 0.6. The treatment temperatures of the specimens were room temperature (33^{o}C) and 60^{o}C. The experimental results of the compressive strength test have shown that the compressive strength of low alkaline geopolymer activator concrete still meets the requirements as a structural material (i.e. Indonesian Concrete Code). The weight of the resulting specimen is included in the category of normal weight concrete. The workability of geopolymer concrete with low alkaline activator tends to be better if the ratio AAS/FA also increases, but the compressive strength of concrete tends to decrease.

1. Introduction

1.1. Background

Geopolymer concrete requires a suitable mix to obtain the desired strength and performance [1-3]. The application of geopolymer concrete are being developed on the structural elements [4-5]. Li [6-7] revealed there are three geopolymer concrete design methods in the world that are currently developing, namely performance-based methods, statistical modelling methods and target strength methods.

According to Diaz et al. [8], geopolymer concrete has a specific gravity of 1890 - 2371 kg/m^3 and a compressive strength of 10—80 MPa, modulus of elasticity 6812 — 42878 MPa. According to Harjito et al. [9-10], the use of alkaline activator 6% NaOH 14M molarity, fly ash with a treatment temperature of 60^{o}C, the compressive strength reaches 28–66 MPa. Alkaline activator 6.5% with NaOH 8-10 M molarity, fly ash with room temperature treatment obtained compressive strength of 7.5-45 MPa [11-14]. The use of alkaline activator of 10.8% NaOH 16M, fly ash with a treatment temperature of 60^{o}C resulted the compressive strength reached 30-60 MPa [15-18]. Pavithra [19] used an alkaline activator

8.5% NaOH 16M, fly ash with a treatment temperature of 60°C the compressive strength reached 23–53 MPa. Herwani et al. [20] used an alkaline activator 8.2% NaOH 10-14M, fly ash with room temperature resulted of 16-30 MPa for compressive strength. Reddy et al. [21] used alkaline activator of 8.5% NaOH 14M molarity, fly ash with the addition of GBBS (ground granulated blast furnace slag) and a treatment temperature of 60°C the compressive strength reaches 32–66 MPa.

1.2. Objective
Alkaline activator is one of the building blocks on geopolymer concrete which is relatively expensive compared to other building materials, so it is necessary to reduce the use of alkaline activator to be more economical. Until now, the design of low-alkaline activator geopolymer concrete mixes has been undeveloped yet. Based on the description above, this research was conducted on geopolymer concrete using low amounts of alkaline activator, namely 4% and 5%, with the primary objective of recognizing to what extent the compressive strength of concrete can be achieved.

1.3. Research significance
Research on the compressive strength of concrete and workability of geopolymer concrete has been recently performed by using an alkaline activator (6–15%). Alkaline activator is identified to be the most expensive material in geopolymer concrete, therefore it is necessary to maximize efficiency with the use of a minimum of alkaline activator, but the strength of concrete is however maintained as a structural concrete material. Research on geopolymer concrete with low alkaline activator (4% and 5%) including its design is undeveloped at present.

2. Experimental program
2.1. Materials and test variables
This research is an experimental research conducted in a laboratory. The standard of the specimens for testing follows Indonesian National Standard or SNI [22] and ASTM [23]. Fly ash typically obtain from water-powered plant of Lontar Banten (PLTU) including type of F with SiO_2, Al_2O_3 and Fe_2O_3 levels of 79.56%, all of which are more than 70%. NaOH in the form of white flakes and Sodium silicate in the form of a clear grey gel. Based on the level of ease of application, in this study, the target strength design method was chosen with 4% and 5% alkaline activator. The molarity of the 14M Sodium hydroxide and the Sodium silicate or Sodium hydroxide ratio is 2.5.

Alkaline solution fly ash ratio activator varies by 0.35, 0.4, 0.5 0.6. The composition of the ratio of alkaline activator or fly ash (AAS/FA), Fly ash, Sodium Hydroxide (NaOH), Sodium Silicate (Na_2SiO_3) fine and coarse aggregates are presented in Tables 1 and 2.

2.2. Procedure for making test objects.
This study begins by calculating the weight of the geopolymer concrete stacking material according to the compositions set out in Tables 1 and 2. Next, the manufacture of sodium hydroxide solution according to the molarity of 14M by adding 560 grams of sodium hydroxide into 1,000 grams of water, until the temperature drops to the same as the room's temperature and then stored in a bottle and tightly closed to prevent carbonization.

Table 1. Composition of 4% alkaline activator geopolymer concrete.

AAS/FA	0.35	0.4	0.5	0.6
FA (kg/m^3)	286	250	200	167
NaOH (kg/m^3)	29	29	29	29
Na_2SiO_3 (kg/m^3)	71	71	71	71
Fine aggregate (kg)	728	744	766	782
Coarse aggregate (kg)	1,246	1,274	1,313	1,339
Water (liter)	35	35	35	35

Table 2. Composition of 5% alkaline activator geopolymer concrete.

AAS/FA	**0.35**	**0.4**	**0.5**	**0.6**
FA (kg/m^3)	343	300	240	200
NaOH (kg/m^3)	34	34	34	34
Na_2SiO_3 (kg/m^3)	86	86	86	86
Fine aggregate (kg)	690	709	736	755
Coarse aggregate (kg)	1,182	1,215	1,261	1,292
Water (liter)	34	30	30	26

The next step is to produce alkaline activator by mixing the sodium silicate and sodium hydroxide in a ratio of 2.5 which was made the day before the manufacture of the test object. Then the mixture of fly ash, fine aggregate and coarse aggregate is stirred until evenly mixed and put into a cement mixer. Subsequently added with alkaline activator solution. After completely smooth, the mixture is taken and a slump test was performed.

Finally, the mixture from the cement mixer is put into a cube mold with a size of 100x100x100 mm, after the test object is opened from the cube mold, it is packaged in plastic so that there is no excessive evaporation. The specimens were treated for 28 days at room temperature. In calculating the compressive strength, the results of the compressive test from the cube specimen above are converted to produce a compressive strength equivalent to the results of the compressive test of a cylinder specimen with a diameter of 150 mm and a height of 300 mm at the age about 28 days (f_c').

3. Experimental Results and Discussion

3.1. Geopolymer Concrete contains of 4% of alkaline activator

The test specimens and geopolymer concrete tests are shown in Figure 1. Figure 2 shows an example of slump test. The results of the compressive strength and slump value of 4% alkaline activator geopolymer concrete aged 28 days with maintenance temperatures (T) of 33^{o}C and 60^{o}C in common were 12 specimens each. The unit weight and compressive strength of concrete for each AAS/FA ratio are properly presented in Table 3.

Figure 1. Test object and 4% alkaline activator geopolymer concrete.

(a) Slump test of specimen with alkaline activator 4%, (AAS/FA=0.40)

(a) Slump test of specimen with alkaline activator 4%, (AAS/FA=0.35)

Figure 2. Slump test.

Table 3 shows that the lowest concrete compressive strength is 18.1 MPa and the highest compressive strength is 30.6 MPa. The minimum value of the concrete compressive strength shows that geopolymer concrete with 4% alkaline activator still meets the requirements as structural concrete as required by SNI-2847-2019 [24], which represents a minimum of 17 MPa. As seen on Table 3, the the compressive strength specimens with AAS/FA ratio of 0.4 and 0.35 above 22 MPa. This results meets the requirements as an earthquake-resistant structural material based on Indonesian concrete code (minimum of 21 MPa). Other results from Table 3 above also show that the weight of the specimen is in the range of 2100 to 2400 kg/m^3, therefore it remains in the category of normal weight concrete. In addition, the resulting slump value shows higher workability if the AAS/FA ratio is higher. The higher the slump value, the average compressive strength of concrete tends to decrease.

Table 3. Test results of 4% alkaline activator geopolymer concrete aged 28 day- treatment temperature 33°C and 66°C.

AAS/FA	Slump (mm)	Unit weight (kg/m^3)		f'_c (MPa)			
		Treatment of T=33°C	Treatment of T=66°C	Treatment of T= 33°C	Average	Treatment of T=66°C	Average
0.6	120	2,188	2,177	15.9	18.1	19.3	20.0
0.6		2,234	2,207	18.1		19.2	
0.6		2,259	2,203	20.1		21.5	
0.5	100	2,303	2,207	17.5	19.6	27.3	25.4
0.5		2,308	2,325	22.4		21.5	
0.5		2,414	2,237	18.9		27.3	
0.4	40	2,394	2,310	27.2	25.6	27.1	29.1
0.4		2,367	2,310	27.3		33.2	
0.4		2,345	2,325	22.3		27.0	
0.35	20	2,341	2,252	27.0	28.8	34.2	30.6
0.35		2,409	2,402	30.5		29.4	
0.35		2,363	2,379	25.6		28.2	

3.2. Geopolymer concrete contains of 5% alkaline activator

The test object and the process of testing the compressive strength of geopolymer concrete with 5% alkaline activator are shown in Figure 3. The results of the compressive test of 5% alkaline activator geopolymer concrete aged 28 days at room temperature (T) of 33°C and 60°C obtain 12 specimens, respectively, are shown in Table 4.

Figure 3. Compressive test of 5% alkaline activator geopolymer concrete aged 28 days.

Table 4: Test results of 5% alkaline activator geopolymer concrete aged 28 days with treatment at 33°C and 60°C.

AAS/FA	Slump (mm)	Unit weight (kg/m^3)		f'_c (MPa)			
		Treatment of *T*=33°C	Treatment of *T*=66°C	Treatment of *T*=33°C	Average	Treatment of *T*=66°C	Average
0.6	125	2,350	2,286	14.5	18.6	24.1	25.5
0.6		2,352	2,378	23.9		24.3	
0.6		2,415	2,291	17.5		28.7	
0.5	90	2,330	2,341	27.6	27.4	27.8	27.3
0.5		2,384	2,265	28.1		26.5	
0.5		2,402	2,317	26.6		27.8	
0.4	40	2,394	2,362	29.5	28.1	23.7	30.4
0.4		2,426	2,390	23.2		31.9	
0.4		2,366	2,414	31.7		37.1	
0.35	25	2,387	2,350	30.8	30.1	32.3	34.0
0.35		2,363	2,370	27.4		31.3	
0.35		2,415	2,401	33.3		38.4	

Similar to the results of the compressive strength test of 4% alkaline activator geopolymer concrete, the compressive strength of geopolymer concrete with 5% alkaline activator shown in Table 4 provides a compressive strength of a minimum of 18.6 MPa, and a maximum of 38.4 MPa. These results indicate the resulting geopolymer concrete still meets the requirements when implemented as a structural material. Except specimens with AAS/FA ratio of 0.6, the average compressive strength of other specimens is higher than 21 MPa, therefore it meets the requirements as an earthquake-resistant structural material. The unit weight of the specimens produced is additionally included in the normal weight category (2200-2400 kg/m^3).

Furthermore, Figures 4 and 5 show the comparison of the average compressive strength of geopolymer concrete with 4% and 5% alkaline activator between the specimens treated at 33°C and 60°C. In general, from the two figures, it can be seen that the compressive strength of geopolymer concrete with a temperature treatment of 60°C has tends higher compressive strength.

4. Conclusion

Geopolymer concrete that adequately fulfills the compressive strength requirements for concrete structures remains capable of being produced despite the use of low alkaline activator (4% and 5%). Likewise, the weight of the geopolymer concrete produced still meets the criteria of normal weight concrete. The workability of geopolymer concrete tends to be better if the AAS/FA ratio also increases but the compressive strength tends to decrease. The manufacture of geopolymer concrete with a treatment temperature of 60°C will reliably produce a higher and more optimal compressive strength when compared to the manufacture of specimens with a treatment temperature of 33°C. From the results of this study, it is recommended that further research on geoplopymer concrete with low alkali activator, namely its mechanical behavior comprehensively be carried out.

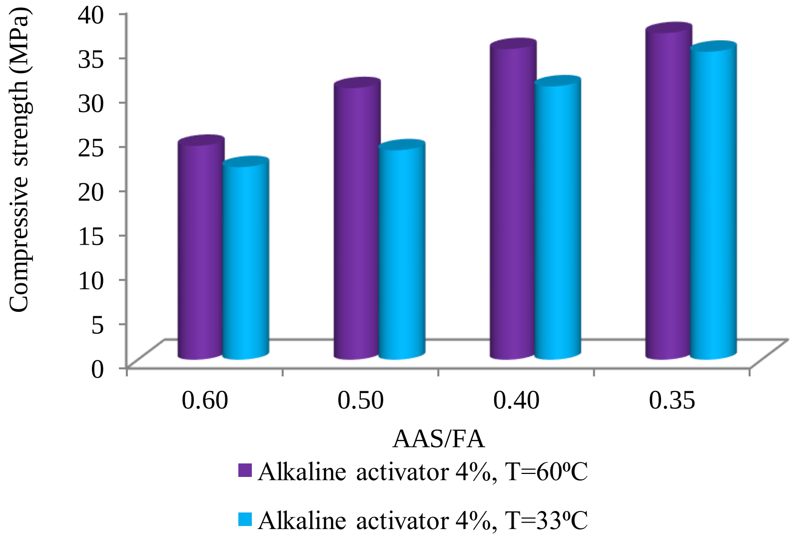

Figure 4. Comparison of the average compressive strength of 4% alkaline activator geopolymer concrete aged 28 days at room temperature 33°C and 60°C.

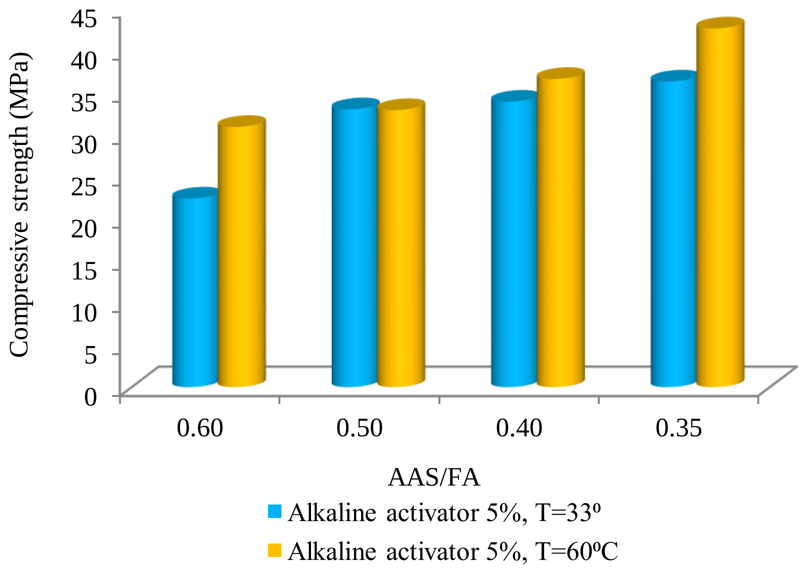

Figure 5. Comparison of the average compressive strength of 5% alkaline activator geopolymer concrete aged 28 days, room temperature 33°C and 60°C.

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