MODEL LOW ALKALI ACTIVATOR GEOPOLYMER CONCRETE MATERIAL RATIO WITH COMPRESSIVE STRENGTH

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Abstract

This paper presents the results of research on the relationship between the ratio of the composition of low alkaline activator geopolymer concrete and compressive strength. The main objective of this research is to develop a relationship model of the ratio of the constituent materials of low alkaline activator geopolymer concrete with compressive strength. The variables reviewed were the amount of alkaline activator 4% low enough, room temperature treatment and 60^{o}C ratio of alkaline activator/fly ash (AAS/FA) namely 0.35, 0.4, 0.5, 0.6. The test results show that the mole ratios of the main ingredients for geopolymer concrete are low in alkaline activators SiO_2/Al_2O_3, Na_2O/SiO_2 and H_2O/Na_2O in accordance with the mole ratio specifications for geopolymer concrete ingredients developed by Subaer Junaedi. The relationship model for the mole ratio of the constituent materials of low geopolymer concrete activator 4% and 5% curing at room temperature and 60°C with compressive strength shows a non-linear or exponential relationship with a correlation number close to 1, valid.

Keywords: material relationship model, low alkaline activator geopolymer concrete.

1. INTRODUCTION

Concrete as a building material is widely used in almost all buildings, bridges, roads, pipes, dams, reservoirs, and drainage channels. Globally, the use of portland cement is 2.8 billion tons per year, and will increase to 4 billion tons per year (Weena 2018). However, the use of cement in concrete mixes has received sharp criticism from environmentalists because it produces 0.8 tons of carbon dioxide gas for every 1 ton of cement produced (J. Peng et al 2013) or 4 billion tons of carbon dioxide per year worldwide. To reduce the negative impact of using cement, it is necessary to research the replacement of all cement with other materials that are more environmentally friendly, namely geopolymer concrete.

Lloyd and Rangan (2010) were the first to propose a mix design for fly ash geopolymer concrete. According to this method, the geopolymer concrete unit weight was set at 2400 kg/m^3 and the total fill material was fixed at 77%. The mass of fly ash and alkaline activator solution is obtained from reducing the weight of the geopolymer concrete minus the filler. The amount of fly ash is determined based on the number of comparisons with the activator solution. Furthermore, sodium silicate and sodium hydroxide are determined from the ratio of Na_2SiO_3/NaOH used.

Al Bakri et al. (2012), proposed a geopolymer mortar design by setting an activator/precursor ratio of 0.4, the ratio of sodium silicate/sodium hydroxide varied between 0.5, 11.0, 1.5, 2.0, 2.5 and 3.0, the morality of sodium hydroxide varied between 6, 8, 10, 12, 14 and 16 M, curing temperature of 700C, not using fine and coarse aggregates, the result is maximum geopolymer concrete compressive strength when the morality of sodium hydroxide is 12, the ratio of sodium silicate/sodium hydroxide is 2.5 and the ratio of activator to precursor is 0.4.

Ferdous et al. (2013) proposed the design of a geopolymer concrete mixture using a relationship model between the compressive strength of geopolymer concrete aged 28 days, the ratio of alkaline activators/Fly Ash to various amounts of Fly Ash between 320, 340, 360, 380 and 400 kg/m^3. This method first determines the compressive strength of geopolymer concrete aged 28 days, the amount of fly ash and the ratio of alkaline activator to fly ash, then determines the alkaline activator of 200 kg/m^3, the ratio of sodium silicate to sodium hydroxide is 2.5, air content is 2%. After meeting the weight of Fly As, the weight of Sodium hydroxide, Sodium silicate

Lokuge et al (2018), proposed optimizing the effect of water/solid ratio, ratio of alkaline/fly ash activators, sodium hydroxide morality, ratio of alkaline activators/fly ash on compressive strength of geopolymer concrete aged 28 days with the Multivariate Adaptive Regression method. The resulting model can be seen in figure 2.5. As proposed by Ferdous, in designing geopolymer concrete mixes this method first determines the compressive strength of geopolymer concrete aged 28 days, the amount of fly ash is 410 kg/m3, then with model or graph 2.5 it can be determined the water / solid ratio, activator / fly ash ratio, Na2SiO3/NaOH ratio and NaOH molarity. After finding the weight of fly ash, weight of sodium hydroxide, sodium silicate, after finding the weight of fly ash, weight of sodium hydroxide, sodium silicate to calculate the aggregate volume, it is obtained by the volume of concrete minus the volume of fly ash, volume of sodium silicate, volume of sodium hydroxide and volume of air. The volume of each stacking material is obtained from the weight of each stacking material divided by the specific gravity of each stacking material.

Simatupang (2015) found a relationship between the compressive strength of geopolymeer concrete and the molarity ratio H 2O]/[Na2O + SiO2+ Al2O3] and Bondar (2018), found a relationship between the compressive strength of geopolymer concrete and the percentage of Na2O, SiO2/Na2O molarity ratio and water/binder ratio Sodium Silicate. So far, the manufacture of geopolymer concrete uses more than 6% alkaline activator, how does it affect if you use as little as 4% alkaline activator. In this study an attempt has been made to propose a Relational Model of Low Alkaline Activator Geopolymer Concrete Material Ratio with compressive strength which has not been carried out by other researchers.

2. SIGNIFICANCE OF RESEARCH

Research on the ratio of geopolymer concrete materials to low alkaline activators and compressive strength has been carried out so far using alkaline activators (6 – 15%). Alkali activators are the most expensive materials in the manufacture of geopolymer concrete. 4% alkaline activator

3. METHODOLOGY AND MATERIALS

The research was conducted in a laboratory according to SNI and ASTM testing standards. Fly ash comes from PLTU Lontar Banten, including type F with levels of SiO2, Al2O3 and Fe2O3 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 gray gel. Based on the level of ease of application, in this study the target strength design method was chosen with 4% and 5% alkaline activators. The molarity of 14M Sodium hydroxide and the ratio of Sodium silicate/Sodium hydroxide is 2.5.

Alkali solution fly ash activator ratio varies by 0.35, 0.4, 0.5 0.6. The composition of the ratio of alkaline activator/fly ash (AAS/FA), fly ash, sodium hydroxide (NaOH), sodium silicate (Na2SiO3) fine and coarse aggregate is presented in Tables 1 and 2.

Table 1 Composition of 4% alkaline activator geopolymer concrete for 1 cubic meter

AAS/FA	0.35	0.4	0.5	0.6
FA (kg/m3)	286	250	200	167
W NaOH (kg/m3)	29	29	29	29
W Na2SiO3 (kg/m3)	71	71	71	71
W fine agg (kg)	728	744	766	782
W coarse Agg (kg)	1,246	1,274	1,313	1,339
water (liter)	35	35	35	35

Table 1 Composition of 5 Table 1 Composition of 4% alkaline activator geopolymer concrete for 1 cubic meter
% alkaline activator geopolymer concrete for 1 cubic meter

AAS/FA	0.35	0.4	0.5	0.6
FA (kg/m3)	343	300	240	200
W NaOH (kg/m3)	34	34	34	34
W Na2SiO3 (kg/m3)	86	86	86	86
W fine agg (kg)	690	709	736	755
W coarse Agg (kg)	1,182	1,215	1,261	1,292
water (liter)	34	30	30	26

4. RESULTS AND DISCUSSION

4.1 Geopolymer Concrete Compression Test Results Low Alkaline Activator 4%

The results of the compressive strength of 4% alkaline activator geopolymer concrete aged 28 days with curing temperatures of 33oC and 60oC were 12 specimens respectively. The unit weight and compressive strength of concrete at each AAS/FA ratio are presented in table 3. Geopolymer concrete specimens and tests are shown in Figure 1.

Figure 1 Test object and 4% alkaline activator

geopolymer concrete test

Table 3. Test results of 4% alkaline activator geopolymer concrete aged 28 day of treatment temperature 33^{o}C and 66^{o}C

AAS/FA	f'_c (MPa)			
	treatment temperature 33^{o}C	average	treatment temperature 66^{o}C	average
0.6	19.1	21.7	23.2	24.1
0.6	21.7		23.1	
0.6	24.2		25.9	
0.5	21.1	23.6	32.9	30.6
0.5	27.0		25.9	
0.5	22.8		32.9	
0.4	32.7	30.8	32.6	35.0
0.4	32.9		40.0	
0.4	26.9		32.5	
0.35	32.5	34.7	41.2	36.8
0.35	36.8		35.4	
0.35	30.8		34.0	

4.2 Geopolymer Concrete Compression Test Results Low Alkaline Activator 5%

The results of the compressive strength of 5% alkaline activator geopolymer concrete aged 28 days curing at room temperature 33oC and 60oC for 12 specimens respectively, are shown in table 4. The test objects and the compressive strength testing process of geopolymer concrete with 5% alkaline activator are shown in Figure 2.

Figure 2 Test object and 5% alkaline activator geopolymer concrete test

Table 3. Test results of 5% alkaline activator geopolymer concrete aged 28 day of treatment temperature 33oC and 66oC

AAS/FA	f'_c (MPa)			
	treatment temperature 33^{o}C	average	treatment temperature 66^{o}C	average
0.6	17.4	23.1	29.0	30.9
0.6	28.8		29.3	
0.6	21.1		34.6	
0.5	33.2	33.0	33.5	32.9
0.5	33.8		31.9	
0.5	32.0		33.5	
0.4	35.5	33.9	28.5	36.6
0.4	27.9		38.4	
0.4	38.2		44.7	
0.35	35.8	36.3	38.9	42.6
0.35	33.0		37.7	
0.35	40.1		46.3	

4.3 Calculation of the ratio of stacking materials for geopolymer concrete

Calculation of the ratio of silicate, alumina and sodium oxide can be calculated in the following steps:

1) Knowing the data on the percentage of reactive SiO2, Al2O3, Na2O and SiO2
2) compounds from Fly ash
3) Calculating the need for Fly ash in the mixture
4) Calculating the weight of each compound with the formula of percentage content x
5) weight of Fly ash
6) Calculate the moles of each compound using the weight formula divided by the
7) relative molarity of each compound
8) Calculating the need for sodium silicate in the mixture
9) Calculating the weight of each compound using the percentage formula x weight of
10) Sodium Silicate
11) Calculate the moles of each compound

using the weight formula divided by the

12) relative molarity of each compound
13) Calculating the need for sodium hydroxide in the mixture
14) Calculating the weight of each compound with the formula of percentage content x
15) weight of sodium hydroxide
16) Calculate the moles of each compound using the weight formula divided by the
17) relative molarity of each compound
18) Count the amount of each compound contained in Fly ash, Sodium silicate and
19) Sodium hydroxide
20) Calculate the molarity ratio of the compound

4.4 Relationship Model of Compressive Strength with the Ratio of Concrete Ingredients Low Alkaline Activator Geopolymer 4%

The compressive test results of 4% alkaline activator geopolymer concrete aged 28 days, curing at room temperature 33oC, curing temperature at 60oC with the ratio Na2O/SiO2 and ratio SiO2/Al2O3 are shown in Tables 5 and 6.

Table 5 Average compressive strength of 4% alkaline activator geopolymer concrete aged 28 day of treatment temperature 33oC with ratio Na2O/SiO2

No	Rasio Na2O/SiO2	compressive strength of AAS 4% temperature 33 fc' (MPa)	compressive strength of AAS 4% temperature 60 fc' (MPa)
1	0,21	34,7	36,8
2	0,23	30,8	35,0
3	0,26	23,6	30,6
4	0,28	21,7	24,1

Table 5 Average compressive strength of 4% alkaline activator geopolymer concrete aged 28 day of treatment temperature 33oC with ratio SiO2/Al2O3

No	Rasio SiO2/Al2O3	compressive strength of AAS 4% temperature 33 fc' (MPa)	compressive strength of AAS 4% temperature 60 fc' (MPa)
1	3,09	34,7	36,8
2	3,19	30,8	35,0
3	3,44	23,6	30,6
4	3,69	21,7	24,1

4.5 Relationship Model of Compressive Strength with the Ratio of Concrete Ingredients Low Alkaline Activator Geopolymer 5%

The compressive test results of 5% alkali activator geopolymer concrete age 28 days, curing at room temperature 33oC, curing temperature at 60oC with the ratio Na2O/SiO2 and ratio SiO2/Al2O3 are shown in Tables 7 and 8.

Table 7. Average compressive strength of 5% alkaline activator geopolymer concrete aged 28 day of treatment temperature 33oC with ratio Na2O/SiO2

No	Rasio Na2O/SiO2	compressive strength of AAS 5% temperature 33 fc' (MPa)	compressive strength of AAS 5% temperature 60 fc' (MPa)
1	0,20	36,3	40,8
2	0,22	33,9	37,0
3	0,25	32,9	33,0
4	0,28	22,2	31,0

Table 8. Average compressive strength of 5% alkaline activator geopolymer concrete aged 28 day of treatment temperature 33oC with ratio SiO2/Al2O3

No	Rasio SiO2/Al2O3	compressive strength of AAS 5% temperature 33 fc' (MPa)	compressive strength of AAS 5% temperature 60 fc' (MPa)
1	3,07	36,3	40,8
2	3,20	33,9	37,0
3	3,45	32,9	33,0
4	3,71	22,2	31,0

4.6 Model relationship between the ratio of stacking materials Geopolymer concrete is low in activator alkaline 4% room temperature treatment 33oC and 60oC.

According to Davidovits (1999), Geopolymers are materials produced from a chemical reaction of polymeric aluminosilicate and alkali-silicate which produces tetrahedral bonded SiO4 and AlO4 polymer frameworks consisting of 3 types, namely: Poly(sialate) tipe (-Si-O-Al-O), poly (sialate-siloxo) type (-Si-O-Al-O-Si-O) and poly (sialate-disiloxo) type (- Si-O-Al-O-Si-O-Si-O).

Here it can be seen that the levels or ratios of silicate, alumina and sodium oxide have a very important role in the polymerization of geopolymer concrete. Geopolymer concrete which has good compressive strength with metakaolin precursor material according to Davidovits has the following ratio:

1) SiO_2/Al_2O_3 : 2,50 – 5,0
2) Na_2O/SiO_2 : 0,17 – 0,50
3) H_2O/Na_2O : 5,00 – 15,00

and according to Junaedi with fly ash material has a ratio of:

1) SiO_2/Al_2O_3 : 3,00 – 5,00
2) Na_2O/SiO_2 : 0,20 – 0,50
3) H_2O/Na_2O : 5,00 – 15,00

The specifications for the mole ratio of the main ingredients for low geopolymer concrete as alkaline activators SiO2/Al2O3, Na2O/SiO2 and H2O/Na2O are in accordance with the specifications for the mole ratio for the ingredients for geopolymer concrete developed by Subaer Junaedi using fly ash and slightly different from the specifications developed by Davidovit using metakaolin. Comparison of specifications for the mole ratios of geopolymer concrete ingredients is presented in table 9. The relationship between the compressive strength of low geopolymer concrete with alkaline activator 4% and 5% curing at room temperature and 60° C with the mole ratio of geopolymer concrete ingredients shows a non-linear or exponential relationship. The smaller the mole ratio of the geopolymer concrete, the greater the compressive strength of the concrete. The relationship model for the compressive strength of low geopolymer concrete with alkaline activator 4% and 5% curing at room temperature and 60° C with the mole ratio of geopolymer concrete ingredients is presented in table 10.

Table 9 Comparison of mole ratios of geopolymer concrete ingredients

Rasio	Mole ratio of geopolymer concrete with low alkaline activator	Upper and lower limits of mole ratio of geopolymer concrete with metakaolin material from Davidovit	Upper and lower limits of mole ratio of geopolymer concrete with fly ash material from Subaer Junaedi
SiO2/Al2O3	3,06	3,5 - 4,5	3,0 - 5,0
Na2O/SiO2	0,21	0,2 - 0,28	0,2 - 0,5
H2O/Na2O	7,08	15 -17,5	5,0 - 15,0

Table 10. Compressive strength relationship model of low geopolymer activator concrete alkaline to the mole ratio of geopolymer concrete constituents

No	Relationship Models	Models	correlation number	validity
1	Model relationship of low geopolymer concrete compressive strength 4% alkaline activator curing temperature 33oC with Na2O/SiO2 ratio	*fc'* = 3,0107 (Na2O/SiO2)^-1,55,	R² = 0,9805	valid
2	Model relationship of low geopolymer concrete compressive strength 4% alkaline activator curing temperature 33oC with SiO2/Al2O3	*fc'* = 714,38 (SiO2/Al2O3)^ -2,707,	R² = 0,956	valid
3	Model relationship of low geopolymer concrete compressive strength 4% alkaline activator curing temperature 60oC with Na2O/SiO2 ratio	*fc'* = 4, 9473(Na2O/SiO2)^ -1,298,	R² = 0,9284	valid
4	Model relationship of low geopolymer concrete compressive strength 4% alkaline activator curing temperature 60oC with SiO2/Al2O3 rasio	*fc'* = 528,277 (SiO2/Al2O3)^-2,344,	R² = 0,9583	valid
5	Model relationship of low geopolymer concrete compressive strength 5% alkaline activator curing temperature 33oC with Na2O/SiO2 ratio	*fc'* = 5,379(Na2O/SiO2)^-1,1214,	R² = 0,7802	valid
6	Model relationship of low geopolymer concrete compressive strength 5% alkaline activator curing temperature 33oC with SiO2/Al2O3	*fc'* = 435,83(SiO2/Al2O3)^-2,184,	R² = 0,8068	valid
7	Model relationship of low geopolymer concrete compressive strength 5% alkaline activator curing temperature 60oC with Na2O/SiO2 ratio	*fc'* = 9,2919 (Na2O/SiO2)^-0,927	, R² = 0,9494	valid
8	Model relationship of low geopolymer concrete compressive strength 5% alkaline activator curing temperature 60oC with SiO2/Al2O3 rasio	*fc'* = 246,99(SiO2/Al2O3)^-1,605,	R² = 0,9141	Valid

5. CONCLUSION

The mole ratios of the main ingredients making up geopolymer concrete are low in alkaline activators SiO2/Al2O3, Na2O/SiO2 and H2O/Na2O in accordance with the mole ratio specifications for making up geopolymer concrete developed by Subaer Junaedi. The relationship model for the mole ratio of the constituent materials for geopolymer concrete with low alkaline activator 4% and 5% curing at room temperature and 60° C with compressive strength shows a non-linear or exponential relationship with a correlation number close to 1, valid

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