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Research Paper

Characteristics of The Compressive Strength On C – Type Fly Ash Based Geopolymer Mortar

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ABSTRACT

Reducing and replacing the use of cement in construction work is one way to create an environmentally friendly city. Cement production produces the effect of carbon dioxide, which creates a greenhouse effect. It is necessary to utilize renewable resources that can replace the function of cement to reduce pollution. This research aimed to determine the value of crystallization and amorphous in two types of fly ash in South Sulawesi-Indonesia. The materials used in this research are sand, fly ash, Sodium Hydroxide, and Sodium Silicate. Samples using fly ash originating from two different steam power plants, which are named fly ash A and fly ash B. Comparison of chemicals Sodium Hydroxide and Sodium Silicate in the manufacture of activators, is 1: 2. The amount of sand used is 2.75 from the amount of fly ash. There are two variations of Mortar samples, namely samples using fly ash A (FA_A) and fly ash B (FA_B). GM_FAA is the A-fly ash geopolymer mortar, and MG_FAB is the B-Fly ash geopolymer mortar. The results showed that the percentage of crystals and amorphous in A-Fly ash (FA_A) were 51.02% and 48.97%, while B-Fly ash (FA_B) was 51.28% and 48.71%, respectively. The use of FA_A material in the production of geopolymer mortars has a higher strength than mortars that use FA_B. The use of a suitable activator composition in making mortars using FA_A is 10 M Natrium Hidroksida with alkaline Modulus 2, while mortars using FA_B is 6 M Natrium Hidroksida with alkaline modulus 1.5.

1. Introduction

It is necessary to utilize eco-friendly and sustainable materials to develop an eco-friendly city. Reducing and replacing the use of cement in construction work is one way to be an environmentally friendly city. Cement production produces the effect of CO2, which results in a greenhouse effect. It is necessary to utilize renewable resources that can replace the function of cement. Concrete technology research experts have begun researching by replacing cement materials as a whole with fly ash materials that use geopolymer bonds. One of the industrial by-products in the form of fly ash waste has tremendous potential as an environmentally friendly raw material in geopolymer manufacturing. Geopolymers are materials formed from the results of polymerization and alkali-silicate aluminosilicate synthesis. Then the results form the tetrahedral framework of SiO_4 and AlO_4 [1].

The geopolymer materials use materials containing silica (Si) and alumina (Al) elements. Fly ash contains many silica and alumina elements, as previous research

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by E. Bachtiar et al. (2018) that fly ash has the aspects of silica and alumina [2]. There are four dominant elements found in fly ash, namely Aluminum Oxide (Al_2O_3), silica (SiO_2), Calcium Oxide/lime burn (CaO), and iron oxide (Fe_2O_3) [2,3,4,5]. The silica and alumina elements contained in the fly ash are melt in an alkaline solution called a chemical solution. The mixture of Na2SiO3 (Sodium Silicate), Sodium Hydroxide (NaOH), and Distilled Water (H2O) are activators widely used. All of these ingredients have an important role in synthesis. Geopolymer synthesis is very dependent on the condition of raw materials, fly ash characteristics, activator concentrations, geo-polymerization processes, and alkaline solutions [4].

Currently, geopolymers use fly ash as the primary material, which can be one of the most effective cement binding binders in the field of construction materials [5,6]. The Mortar Geopolymer is a type of mortar material for construction that does not use cement as a binder, but where mortar/concrete geopolymer formed from chemical reactions somewhat than hydration reactions such as mortar/concrete ordinary [1]. The type of activator used in the mortar/concrete geopolymer adapt to the compounds contained fly ash. The composition in making geopolymer materials must be suitable for chemical reactions to occur. Research before the use of NaOH used at 8 M - 14 M, while the ratio between Na_2SiO_3 and NaOH was between 0.4-2.5 [7]. Geopolymer products have very many advantages, especially in strength, and have a small shrinkage and creep. Besides that, geopolymers are very good to be used in aggressive environments because they have excellent acid resistance [6]. The most widely used activator in the making of geopolymers is NaOH, $NaSO_4$, and Na_2SiO_3 [8-10]. Moreover, the compound of Sodium Silicate (Na_2SiO_3) and NaOH generate the best compressive strength [11, 12].

Temuujin et all (2010) have inspected geopolymer mortar with the primary material, where the weight ratio of sand to binders varied from 1-9. The outcome of the study represents that geopolymer binders show a stable bond with sand aggregates. If the amount of fine aggregate used is higher, and the composition of the activator is fixe, it can reduce the binding capacity in the geopolymer polymerization system [3].

Based on the problems and previous research, the author finds the potential of fly ash that can use as a friendly material for the environment. For this reason, the author interest in examining the characteristics of fly ash in South Sulawesi as a base material instead of cement. As a primary material, fly ash will replace all cement as a binding material in concrete using the polymerization method.

2. Experimental Methods

2.1 Materials

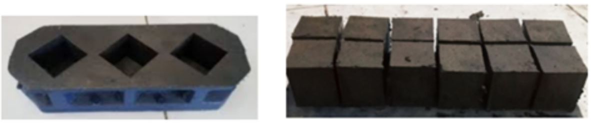
The research uses local material. This work used the equipment in the making of geopolymer mortar samples. They are fly ash, Sodium Silicate (Na_2SiO_3), and Sodium Hydroxide (NaOH), sand, and water.

There are two types of fly ash used in this study. They are from two power plants in South Sulawesi. The name Fly Ash A is FA_A, and Fly Ash B is FA_B. This research is part of a previous study by Bachtiar.E. et al., 2018, which using the same fly ash [2]. The fly ash composition used as described by Erniati B et al. (2018) in the previous paper that there are four highest chemical compositions, they are; silicate, Aluminium Oxide, Iron oxide, and Calcium Oxide/burnt lime [2].

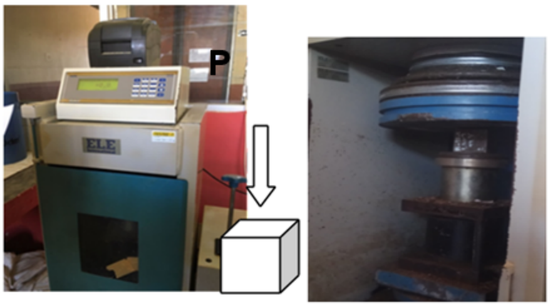
The sand/fine aggregate used is local sand. It is a natural aggregate in Takalar district. This sand is one of the filling materials for geopolymer mortar samples. The fines-aggregate of a surface dry weight is 2.76. Fines aggregate testing based on the Indonesian National Standard. The results of the fines aggregate examination, sand included in zone 1 (one) gradation: coarse sand. Making mortar samples using chemical activators, namely Sodium Hydroxide (NaOH) and Sodium Silicate (Na_2SiO_3). The material obtained from existing local stores

2.2 *Experimental design and sample*

This study uses an innovative method, i.e., experimental approach. This research uses SNI 03-6825-2002 standard in the making and testing of samples. Mixed design is after knowing all the characterization of the material used. The composition of the activator used in this study is the same as previous research [1]. The composition NaOH use at 10 M. Comparison of sodium hydroxide and Sodium silicate is 1: 2. The ratio of fly ash and sand is 1:2.75. For fines aggregate characterization, there are several types of tests based on SNI, namely sludge, specific gravity and absorption, organic content, volume weight, moisture content, and filter analysis. Fly ash chemical tests were carried out by using X-Ray Diffraction analysis. X-ray diffraction (XRD) performs on a Shimadzu 7000 X-ray diffractometer. The test specimens of the mortar used are in the form of cubes with a size of 5x5x5 cm can see **Fig. 1**. The compressive strength test of the mortar sample was carried out at 7, 14, 28, and 56 days using a UTM (Unit Testing Machine). Weighing the mortar in mortar testing. The test results in the compressive strength of mortar in MPa. Sample photos and trial sets can see **Fig.1**.



(a) Molding. **(b) Sample geopolymer Mortar.**



(c) The Compression Testing Machine (UTM)

Fig. 1. A photo of the experimental set-up.

There are several sample variations in this study, namely the curing method, age, and fly ash. Two curing methods are done using room temperature (±25^{o}C) and heated in an oven at 85^{o}C. The compressive strength test of the mortar sample was carried out at 14, 28, and 56 days. The fly ash used comes from two steam power plants named fly ash A and fly ash B. Samples GM_FAA is A fly Ash based-geopolymer mortar, and MG_FAB is B fly ash based-geopolymer mortar.

3. Result and Discussion

3.1. Characterization of Fly Ash

Generally, the width of the X-ray diffraction occurs due to dislocation due to instrumental amplification, increase in crystal size, and strain. The helpful breadth and specimen broadening are factors that contribute to the dilation of diffraction peaks. Regardless of the expansion of the instrument, widening a diffraction peak from the widening of the sample can come from the result of crystal size and microstrain (lattice strain due to the displacement of cell units around its normal position [12,13].

Corrected instrumental widening which corresponds to crystal peaks or amorphous diffraction, is estimated using Equations 1 [13]. The Scherrer formula prepares only the lower limit of crystallite size. Calculation of crystal size using XRD characterization data andScherrer eq.1 and eq.2 [12].

$$\beta hkl = [(\beta hkl)^2 measured - \beta^2 instrumental\ ]^{1/2} \quad (1)$$

$$D = \frac{K\lambda}{\cos\theta} \quad (2)$$

Where D is the volume-weighted crystallite size (nm). K is a constant whose magnitude depends on the crystal form factor, diffraction plane (hkl), and definition of the amount used, whether as Full Width at Half Maximum (FWHM) or Integral Breadth from the peak. Amount λ is the X-ray wavelength (Å), θ is the diffraction angle of diffraction, while β is the expanded diffraction peak measured (in radians). The microstrain contribution to the widening of FWHM and Integral Breadth at the diffraction peak expresse in the form of eq.3 [15,16].

$$\beta(2\theta) = C\varepsilon\frac{\sin\theta}{\cos\theta} \quad (3)$$

Microstructure properties of fly ash A and B showed in **Table 1**. There are three microstructure properties analyzed, namely crystallite size, strain, and Relative texture Coefficient.

Table 1. Crystallite Size and Strain

Type of Fly Ash	2θ	D Scherrer (nm)	Strain (unit)
Fly Ash A (FA_A)	33,735	11,332	0,011
	43,335	14,1896	0,007
	26,963	14,169	0,011
Fly Ash B (FA_B)	26,928	19.620	0.008
	35,924	13.700	0.009
	24,337	18.080	0.010

The percentage of minerals found in fly ash A and fly ash B obtain from X-Ray Diffraction analysis and then observed diffraction peaks and then matched with JCPDS Card from the Joint Committee on powder diffraction standard (JCPDS). There are 4 (Four) minerals in A and B fly ash, namely Quarts, Zeolit, Mullite, and Ca_2SiO_4. The composition of mineral fly ash shown in **Table 2.**

Table 2. Mineral of Fly Ash A and Fly Ash B

Mineral	Fly Ash A (%)	Fly Ash B (%)
Quartz	12,534	27,703
Zeolite	12,911	24,937
Mullite	13,688	16,922
Ca_2SiO_4	14,110	18,671

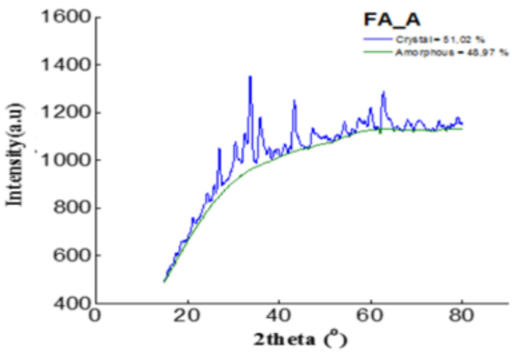


Fig 2. Xray Diffraction (XRD) of the A – Fly Ash

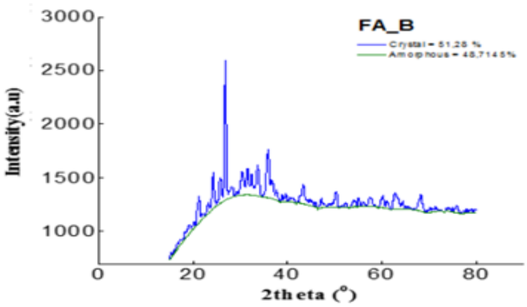


Fig 3. Xray Diffraction (XRD) of thr B – Fly Ash

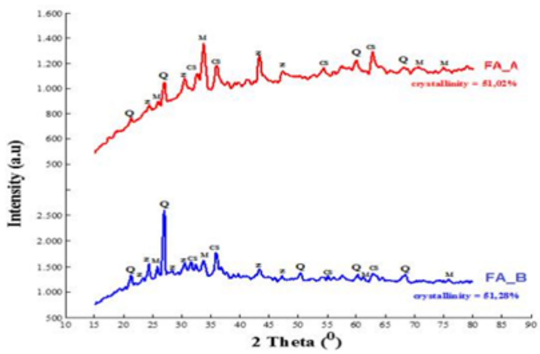


Fig 4. Xray Diffraction (XRD) of fly ash minerals

The results of X-ray diffraction (XRD) analysis, fly ash A (FA_A) have apercentage of cristal of 51.02% and an amorphous of 48.97%. Fly ash B (FA_B) has a rate of cristal of 51.28%(2) and an amorphous of 48.71%. The cristal and amorphous compositions on the two fly ash used were not very different. The intensity of the fly ash A show in **Fig.2** while the strength of the fly ash B shown in **Fig. 3.**

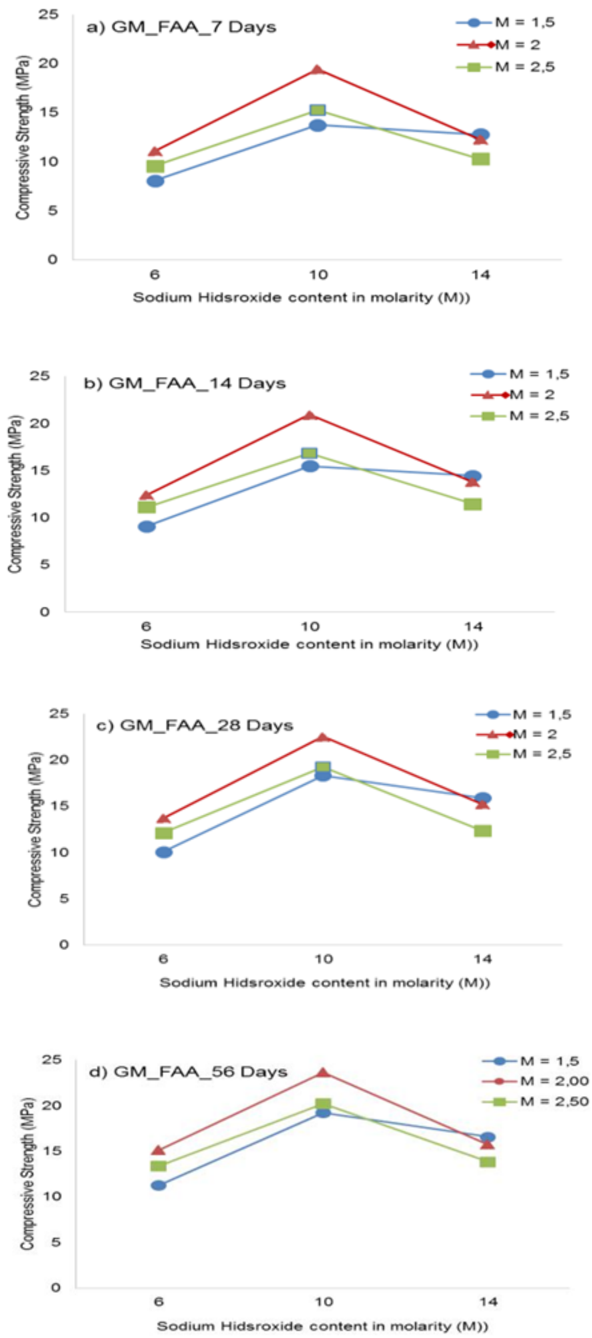
3.2 The Compressive Strength of Mortar Geopolymer

The research results of the effect of the composition of activators on the compressive strength on the fly ash A geopolymer mortar shown in **Fig. 5**. In **Fig. 5**, there are 4 (four) figure, namely 1) Mortar Geopolymer that uses FA_A at the age of 7 days (GM_FAA_7 Days), 2) Mortar Geopolymer that uses FA_A at the period of 14 days (GM_FAA_14 Days), 3) Mortar Geopolymer that uses FA_A at the age of 28 days (GM_FAA_28 Days), 4) Mortar Geopolymer that uses FA_A at 56 days (GM_FAA_56 Days). **Fig.5** shows that the highest compressive strength is in geopolymer mortar, which uses a composition of 10 Molar NaOH and alkaline modulus 2. The compressive strength of the four variations of ages 7, 14, 28, and 56 days is in the composition of 10 NaOH molars and modulus alkali 2.

The effect of activators composition on the compressive strength on the geopolymer mortar used fly ash B shown in **Fig 6**. In **Fig 6,** there are 4 (four) figure, namely 1) Geopolymer mortar that uses FA_B at the age of 7 days: MG_FAB_7 Days, 2) Geopolymer mortar that uses FA_B at the period of 14 days: MG_FAB_14 Days, Geopolymer mortar that uses FA_B at the age of 28 days: MG_FAB_28 Days, 4) Geopolymer mortar that uses FA_B at 56 days: MG_FAB_56 Days.

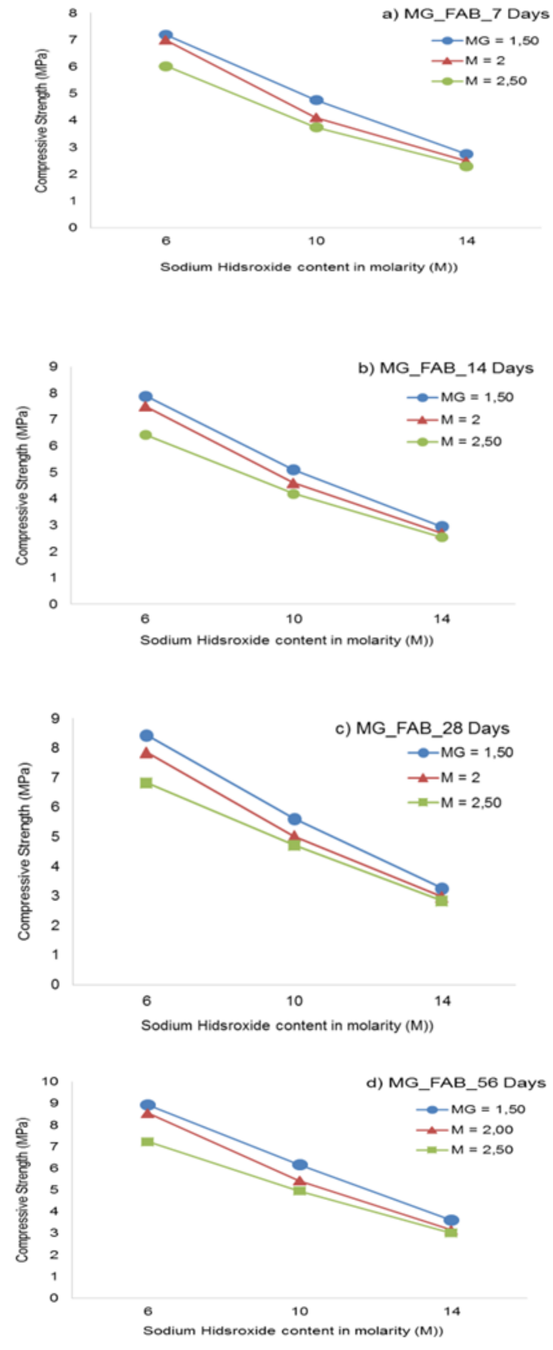
Fig. 6 illustrates the effects of activators used on geopolymer mortar compressive strength using fly ash B as a base material. **Fig.5** (a, b, c, d) it can be seen that the best composition of various variations of the activator composition is a composition of 6 Molar with 1.5 alkaline modulus. Then 6 Molar with an alkaline modulus of 2 and 2.5.

From **Fig. 5** and **Fig. 6** is a clear picture of the compressive strength of geopolymer mortars. The compressive strength of the GM_A sample is higher than that of the GM_B sample. This difference can occur due to the chemical content and the different crystal sizes produced. So the coal waste PLTU has different characteristics. M.T. Muhammad Faheem et al. (2013) that the strength of geopolymer mortar depends on the nature and cause of the material [17]. In addition, geopolymer mortars that use fly ash as a base material can be used as construction materials if in areas exposed to high temperatures [18].



M : is The modulus alkaline is a ratio of Na2SiO3/ NAOH

Fig 5. Effects of NaOH in Molarity on the compressive strength of the sample GM_FA_A for 7 days (a), 14 days (b), 28 days (c) and 56 days (d).



The modulus (M) of the activator is the ratio of Na2SiO3/NaOH.

Fig 6. Fig 6. Effects of NaOH and modulus alkali on the compressive strength of the sample MG_FA_B for 7 days (a), 14 days (b), 28 days (c) and 56 days (d).

4. Conclusions

Based on the results and discussion, the results of the interim study concluded that the material used as the primary material in Geopolymer Mortar has a crystallization composition that is not much different. Fly ash A (FA_A) has 51.02% crystals and 48.97% amorphous. Fly ash B (FA_B) has 51.28% crystals and 48.71% amorphous. Secondly, Fly ash used is a mineral, namely Quarts, Zeolite, Mullite, and Ca_2SiO_4. The compressive Strength on Mortar Geopolymers that use fly ash A (GM_FAA) is higher than Geopolymer Mortar using fly ash B (MG_FAB). The composition of the optimum activator of fly ash in Mortar Geopolymer, which uses a form of NaOH 10 M with a ratio of Na_2SiO_3/NaOH, equals 2. The highest compressive strength value in Geopolymer Mortar using B-fly ash (GM_FAA) occurs in Geopolymer Mortar, which uses A (MG_FA_B) composition of NaOH 6 M with Na2SiO3 ratio / NaOH is 1.5. In especially of mortar geopolymers that use B fly ash, the higher the form of NaOH molarity, the lower the compressive strength.

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