Feasibility of using slacked lime in producing high calcium fly ash based geopolymer mortar

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Abstract. Many efforts have been made to decrease ordinary Portland cement (OPC) consumption in the construction world. One of which is developing research on geopolymer material. A type of base material to produce geopolymers is fly ash that rich silica and alumina. This paper aims to the study possibility of using hydrated lime in producing high calcium fly ash based geopolymer mortar. The test material is then given curing treatment for 3 and 7 days before being tested for compressive strength. The test results of material characteristics indicate that the compressive strength at 7 days can be used as a concrete brick for class IV wall pairs for the level of quality of hollow concrete brick of 20 kg / cm^2 based on SNI 03-0349-1989.

Introduction

The combustion of raw coal in thermal power plants generates fly ash as a waste material. The disposal of fly ash occupies a considerable amount of land and this waste presents serious problems of storing and environmental pollution. Therefore, there are many continuous works have been conducted to develop more efficient methods used fly ash which decrease the impact of fly ash dumping.

Concrete is one of the mostly used construction materials all over the world and the prominent binder to produce concrete is ordinary portlad cement (OPC). However, production of ordinary Portland cement is a natural resources deplety and releases large amounts of CO_2 gas which responsibles for about 7% of the green house gas produced annually [1]. In this concern many effort have been made to decrease ordinary Portland cement. Replacing the amount of Portland cement on mortar with by-product materials such as fly ash can be one of the alternatives to produce more environmentally friendly material construction.

The development of inorganic alumina-silica polymer defined as geopolymer is another method to produce environmentally friendly construction material. Geological origin or by product materials, that rich in silicon and alumunium such as fly ash can be synthesized to produce geopolymer [2]. Curing at elevated temperatures is needed to improve the process of geopolymer synthesis. Almost all geopolymer manufacturing processes use curing at elevated temperatures around 40-110°C with a variable curing duration from 1 hour to 48 hours.

This study is a series of investigations that try to reduce the use of curing ovens. This study does not use an oven to simulate high temperatures in specimens. This study uses fly ash containing high levels of CaO along with slacked lime to help the geopolymer process containing Na(OH) solution.

Geopolymer mortar specimens made of Fly ash and slacked lime activated by Na(OH) compressive strength tested at the age of 3 days and 7 days.

2. Material and Methods

2.1. Material

Fly ash was obtained from dumping area nearby the power plant of cement factory in South Sulawesi, Indonesia. The physical properties is shown in table 1 and chemical composition of this is shown in Table 2. The fly ash contains a large amount of calcium hydroxide it conforms to the requirements of a class F mineral admixture as defined by ASTM [3] specifications for fly ash and raw calcined natural pozzolan for use as a mineral admixture in Portland cement concrete. Local river sand with specific gravity of 2.606 and fineness modulus of 2.628 in saturated surface dry condition was used for making mortar.

Table 1. Physical characteristic of fly ash and calcium hydroxide.

No	Material Characteristic	Fly Ash	Slacked Lime ($CaOH_2$)
1	Specific gravity (kg/m^3)	2.65	2.25
2	Particle size	100% finer than 75μm	100% finer than 150 μm

Table 2. Chemical content of fly ash.

	MgO	Al_2O_3	SiO_2	SO_3	K_2O	CaO	Fe_2O_3
Tonasa (%)	5.36	10.91	34.98	2.15	0.88	20.47	12.41

2.2. Design a mixture of geopolymer mortar

Geopolymer mortars, was made with sand to binder ratio of 3:1. Fly ash and calcium hydroxide Ratio as binder is 1:1. The NaOH as alkali activator concentration viz 7 m. For all specimens, the mass ratio of water to binder was 0.5. After 24 hours the specimens were ini water curing and air curing. The composition design can be seen in Table 3.

Table 3. Geopolymer mortar mixture composition (1m^3).

Curing type	Fly ash (kg)	Slacked Lime (kg)	Sand (kg)	Water (kg)	NaOH 7 molar (kg)	Foam agent (ml)	Catalyst (ml)
Water curing	262	223	1438.8	262.2	71.7	-	-
Air curing	262	223	1438.8	262.2	71.7	-	-

2.3. Method for making specimen

The research plan was designed to determine the effect of fly ash and lime out on the compressive strength of geopolymer mortar with cylindrical molds measuring 10 cm x 20 cm. The mixing method used in this study:

- Fine agregate + fly ash + calcium hydroxide, mixing in dry conditions for 2 minutes (slow speed).
- Enter an alkali activator (NaOH) and water, mix for 1 minute.

- The ready mixture is then tested for flow table test according SNI 03-6825-2002 [4] with minimum requirement 110 mm [5][6].
- After mixing, casting the specimens into 10 x 20 cm steel clylinder mould then compacted with vibration.
- After 1 x 24 hours, the specimens removed from the mold.
- Water curing and air curing were applied, Figure 1 shows the process of mixing for making geopolymer mortar.

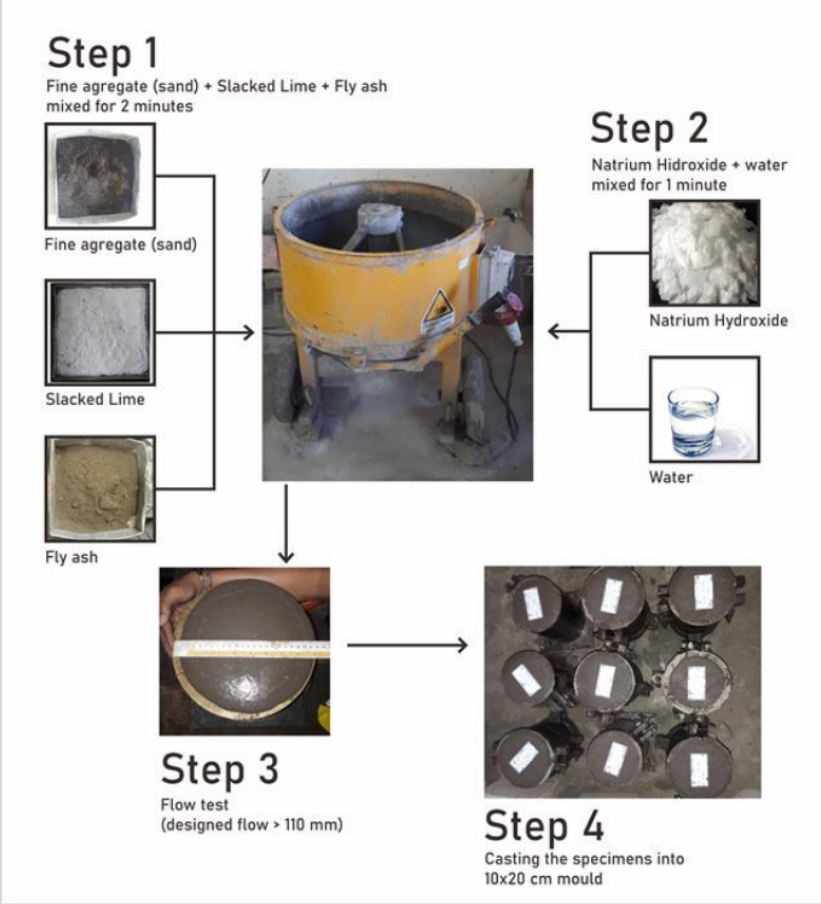

Figure 1. The process of making geopolymer mortar

3. Experimental Procedure

3.1. Compressive strength

The compressive strength of geopolymer mortar was evaluated after 3 and 7 days with 10 x 20 cm standard cylinders based on SNI-03-6825-2002 at the loading displacement rate of 0.2 mm/s. Figure 2 displays the test method of compressive strength geopolymer mortar.

Figure 2. Compressive strength test method.

4. Result and Discussion

4.1. Volume Weight

Figure 3 displays the volume weight of geopolymer mortar. The volume weight for 3 days geopolymer mortar is 1.894 kg for water curing and 1.898 kg and for air curing. Anthe volume weight for 7 days geopolymer mortar is 1.879 kg for water curing and 1.888 kg for air curing. It can be concluded that the volume weight of geopolymer mortar decreases with increasing age.

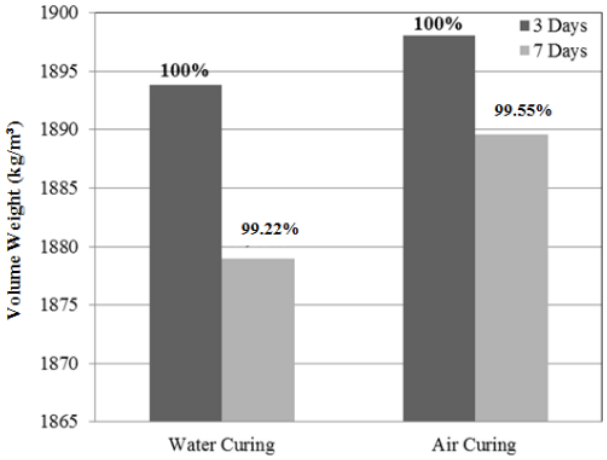

Figure 3. Volume weight of geopolymer mortar.

4.2. Geopolymer mortar compressive strength

Based on visual observation, the result of compressive strength of geopolymer mortar is shown in figure 4. Effect of curing method and curing age are the two crucial variables affecting the compressive strength of geopolymer mortar in this research. The compressive strength increased with an increase in age, the strength development in 7 days specimen was higher than 3 days specimen. The compressive strength of geopolymer mortar at 3 days is obtained 2.12 MPa for water curing specimen

and 1.89 MPa for air curing specimen, And then compressive strength of geopolymer mortar at 7 days is obtained 2.73 MPa for water curing specimen and 2.63 MPa for air curing specimen.

These results indicate the reaction between NaOH solution with Fly ash and slacked lime takes place over time.

There was no cracking in the specimen at 3 days and 7 days in the air curing and water curing, this shows no shrinkage in the test object. Figure 3 shows the hardened geopolymer mortar specimen. Water mixed with Na(OH) solution does not evaporate excessively so that the binding process goes well.

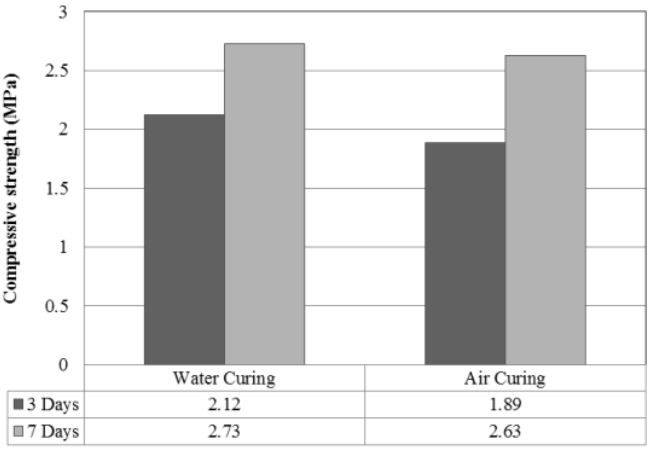

Figure 4. Compressive strength of geopolymer mortar.

Crack Pattern

Figure 5 displays the crack pattern of 3 day geopolymer mortar specimen, each with a water curing and air curing specimens. There is a similarity in the pattern of cracks in the specimen, crack patterns that occur parallel to the direction of the load so that the columnar [8][9] crack pattern is categorized. Figure 6 displays the crack pattern of 7 day geopolymer mortar specimen, each with a water curing and air curing specimens. There is a similarity in the pattern of cracks in the specimen, crack patterns that occur parallel to the direction of the load so that the columnar crack pattern is categorized.

Figure 5. Crack pattern of 3 days geopolymer mortar.

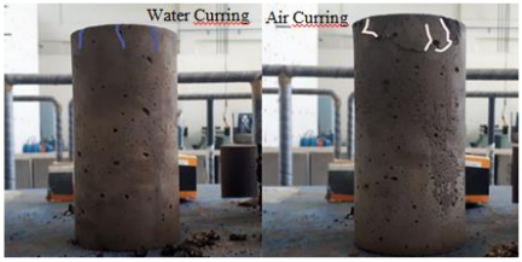

Figure 6. Crack pattern of 7 days geopolymer mortar

Geopolymer mortar have almost the same crack pattern variation, the crack pattern is in the direction of the load so that no spalling occurs on the specimen. The length and width of the crack pattern that occurs decreases with increasing age, explaining that the strength of the geopolymer mortar increases with increasing age.

Concluding Remarks

Based on the obtained data, fly ash and calcium hydroxide as binder activated by natrium hydroxide can be produced with reasonable strength. The volume weight of geopolymer mortar decrease with curing time. From the results of the 7 day compressive strength obtained foamed geopolymer mortar can be used as a brick concrete hole of 20 kg / cm2 based on SNI 03-0349-1989 [7]. At the initial age of the specimen, it can be assumed that the specimen can be transported to the construction area. Further research is needed regarding geopolymer mortar resistance to aggressive environments. Therefore, fly ash and calcium hydroxide as binder can be used by material geopolymer mortar.

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