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Effect of hydrated lime on compressive strength mortar of fly ash laterite soil geopolymer mortar

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Abstract. This paper explored the suitability of fly ash, hydrated lime, and laterite soil with several activator (sodium hydroxide and sodium tiosulfate) to produce geopolymer mortar. Furthermore, the heat that released by hydrated lime was used instead of oven curing. In order to produce geopolymer mortar without oven curing, three variations of curing condition has been applied. Based on the result, all the curing condition showed that the hardener mortar can be produced and exhibited the increasing of compressive strength of geopolymer mortar from 3 days to 7 days without oven curing.

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1. Introduction

Portland cement has been widely used as a binding material in concrete and mortar production, where its demand increases along with rapid growth of infrastructure development. The problem emerges in Portland cement production because it releases much of carbon dioxide (CO₂) into the atmosphere and it could harm the environment. To reduce carbon dioxide emissions due to the Portland cement production, it is necessary to find other materials as Portland cement replacement materials. In this concern, fly ash geopolymer is one of the alternatives to Portland cement replacement as a binder on the concrete or mortar mixture. Geopolymer is a relatively new as a fastener material that can be a sustainable and economical because it was produced from industrial by-products such as fly ash. Number of studies have shown that fly ash geopolymer binders can form mortar and concrete, where geopolymer with fly ash has physical characteristics similar to cement mortar and cement concrete made from cement. Fly ash geopolymer mortar was made without the use of Portland cement, and instead used of fly ash which compound in Silica and Alumina that can react with alkaline liquids to produce binders. Sodium silicate and sodium hydroxide were used as an alkaline activator. Most previous studies that used fly ash geopolymer on concrete required curing ambient temperature of oven heat in hardening. From several studies indicated that geopolymer production requires heating ranging of 60-85°C at the curing period to provide the maximum strength of the test sample [1].

The geopolymer mortar using fly ash were investigated, when curing treatment was provided by using an oven curing with a temperature of 60°C. The effect of time delay and Na₂SiO₃ concentrations was examined on the development of compressive strength of synthesized mortar geopolymers, with curing treatment of mortars provided by varied oven curing of 65°C, 75°C, and 85°C [3].

Laterite soil is quite widely available, it is attempted to be utilized and developed as a mixture of mortar geopolymer for replacing the sand. Using of laterite soil is one of the innovations providing alternative material geopolymer mortar. The laterite soil is formed in the tropics through a weathering process that supports the formation of iron, aluminum, manganese, and titanium oxide. This process



breaks down silicate minerals into clay minerals such as kaolinite and illite. Iron and aluminum oxide stand out in the laterite soil, and with seasonal fluctuations in water tables, this oxide produces a reddish brown colour visible on the laterite soil.

Several studies have also used laterite soil as a material. Research on laterite soils and presented a global view of what has been done in the field of laterite soil repairs for construction purposes in tropical countries such as Cameroon as well as stabilizers. The laterite soil used is combined with Portland cement [4].

From previous research, producing of geopolymer requires curing temperature. Therefore several studies has begun to dev the use of geopolymer without using curing heat temperature. The presence of hydrated lime Ca(OH)_2 in the mortar mixture will be the activator that generates the heat required for the geopolymer reaction for giving maximum strength to the geopolymer mortar. Utilization of laterite soil and lime as a fly ash geopolymer mortar material are no longer using high temperatures with oven curing. The presence of lime in the mortar mixture will be the activator that generates the heat requirement for the geopolymer reaction. It was result that maximum strength to the geopolymer mortar. The amount of lime content has a considerable influence on the hardened geopolymer.

2. Experimental study

2.1. Materials

Table 1 and table 2 show the chemical contents of fly ash and laterite soil, respectively. The material is a laterite and lime soil with a ratio of 1:1. Geopolymer used is a combination of fly ash with alkaline activator used is sodium hydroxide and sodium thiosulfate comparison of sodium hydroxide and sodium thiosul was given by a ratio of 1.5. While sodium hydroxide concentrate is 6 Molar. The mortar mixture can be seen in Table 3 below.

Table 1. Chemical contents fly ash

MgO	8.10%
Al ₂ O ₃	19.16%
SiO ₂	34.63%
SO ₃	1.80%
K ₂ O	1.33%
CaO	12.74%
TiO ₂	1.26%
Cr ₂ O ₃	0.07%
MnO	0.25%
Fe ₂ O ₃	19.96%
CoO	0.05%
SrO	0.13%
BaO	0.21%
Pr ₆ O ₁₁	0.05%
Nd ₂ O ₃	0.07%

Table 2. Chemical contents laterite soil

MgO	1.90%
Al ₂ O ₃	26.53%
SiO ₂	40.12%
SO ₃	0.30%
K ₂ O	1.61%
CaO	4.26%
TiO ₂	2.26%
Na ₂ O	2.10%
MnO	0.20%
Fe ₂ O ₃	19.66%
Cl ₂	0.07%
SrO	0.11%
BaO	0.10%
Pr ₆ O ₁₁	0.05%
Nd ₂ O ₃	0.08%
P ₂ O ₅	0.31%
ZrO ₂	0.11

Table 3. The composition of a mixture of fly ash geopolymer mortar.

No.	Material	Amount	Unit
1	Fly ash	600	gram
2	Laterite Soil	900	gram
3	Ca(OH) ₂	900	gram
4	Water	915	ml
5	NaOH	146,4	gram
6	Na ₂ S ₂ O ₃	219,6	gram

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2.2. Preparation of geopolymer mortar specimens and cubicles

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The first stage is mixing a fly ash, laterite soil and lime for three minutes using the mixer to ensure homogeneity. Secondly, a solution of sodium hydroxide in the form of pellets is melted with a concentration of 6 Molar, then it was made the 27% of sodium hydroxide and sodium thiosulfate by a ratio of 1.5. Thirdly, the solution of the ratio of sodium hydroxide and sodium silica 19 then it was stirring in 15 minutes. After a mixture was done then it was put in a cube mold with the size of 5 cm x 5 cm x 5 cm. Then the mold that has been filled then vibrated on the platform for 4 minutes to release the trapped air bubbles. After 24 hours the mold was opened cured to the test. The curing of sample test was performed in three conditions, i.e. air curing, where the sample is left in room temperature, then curing the water in which the sample is immersed in water and curing the lifting soap, wherein the test sample, soaked a day in water is then removed and dissipated for a day in air, then soaked again, done repeatedly until the time of testing.

2.3. Stage of test

This research is an experimental test and was done at Eco Material laboratory of Civil Engineering department, Hasanuddin University.

Table 4. Fine aggregate inspection (laterite soil).

No.	Testing Material	Standard Method
1	Sieve Analysis	SNI 03-1968-1990 (Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates)
2	Absorption and Specific Gravity	SNI-1970-2008 (Standard Test Method For Specific Gravity And Absorption of Rock For Erosion Control)
3	Volume Weight	SNI 03-1973-1990 (Standard Test Method for Calculation of Volume and Weight of Industrial Aromatic Hydrocarbons and Cyclohexane [Metric])
4	Water Content	SNI 03-1971-1990 (Standard Test Method for Determination of Water Content of Soil By Direct Heating)
5	Mud Content	SNI 03-4142-1996
6	Organic Content	SNI 03-2816-1992 (Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils)

Table 5. Lime stone inspection.

Testing Material	Standard Method
Specific gravity	SNI 03-1964-2008 (Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer)

2.4. Uniaxial compression strength (UCS) test

There were three condition of curing used in this test (i.e. air curing, water curing, and dry-wet curing) and three samples prepared for each curing condition and tested by using compressive strength test used Universal Testing Machine (Tokyo Testing Machine Inc.). Strain of each test sample obtained by two Linear Variable Displacement Transducers (LVDTs). The compressive strength of specimen calculated by the average of compressive stress from three samples of each curing condition.

3. Result and discussion

3.1. Compaction result

Visual investigation was carried out to observe the compaction result of specimens prior to compressive strength test. All specimens showed that the hardened fly ash geopolymer mortar with laterite soil can be produce by using hydrated lime instead of using heat from oven to produce the specimen with ambident temperature. The heat that release from the hydration process between

hydrated and water provide suitable temperatures to generate bonding between silica and activator alkaline 7 days curing in air.

3.2 Effect of air curing on stress strain relationship of geopolymer mortar containing laterite soil

Figure 1 shows the stress strain of relationship of specimen cured in air remain linear until reach the stress and compressive strength evolution to avoid environmental degradation.

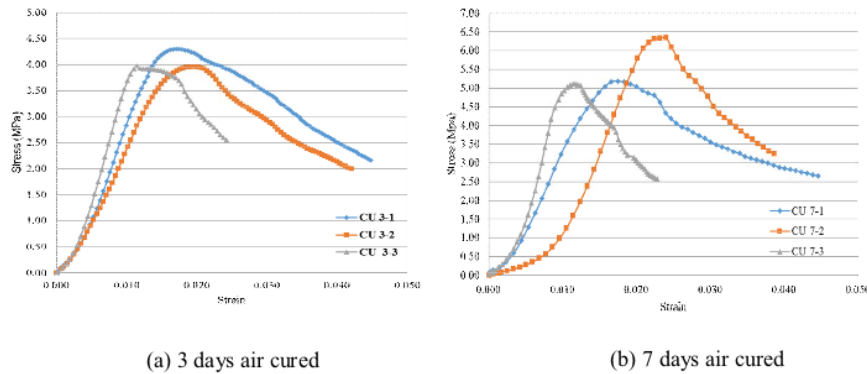


Figure 1. Stress-strain relationship of geopolymer mortar with air curing.

Based on figure 1, it can be seen that sample of 3 days air curing has average compressive strength value of 4.07 MPa and the average strain of 0.0160 while 7 days air curing arised 5.55 MPa of average compressive strength corresponding to 0.018 of average strain. Compressive strength at 7 days air curing increase 26.67% as compared with the compressive strength at 3 days air curing. This result shows that the compressive strength developed without oven curing. Similar with the samples those cured in air and water, the presence of hydrated lime in mortar mixture, hence without the curing of oven temperature, the fly ash geopolymer mortar with this laterite soil material can still provide strength.

Effect of water curing on stress strain relationship of geopolymer mortar containing laterite soil
Figure 2 shows the stress strain of relationship of specimen cured in air remain linear until reach the stress and compressive strength evolution to avoid environmental degradation. Based on Figure 2, it can be seen that sample of 3 days water curing has average compressive strength value of 3.13 MPa and the average strain of 0.016 while 7 days water curing arised 4.62 MPa of average compressive strength corresponding to 0.016 of average strain . Compressive strength at 7 days water curing increase 32.29% compared with the compressive strength at 3 days air curing.

This result shows that the compressive strength developed without oven curing. As attribute by the presence of hydrated lime in this mortar mixture, which induced the heat, hence without the curing of oven temperature, the fly ash geopolymer mortar with this laterite soil material can still provide strength.

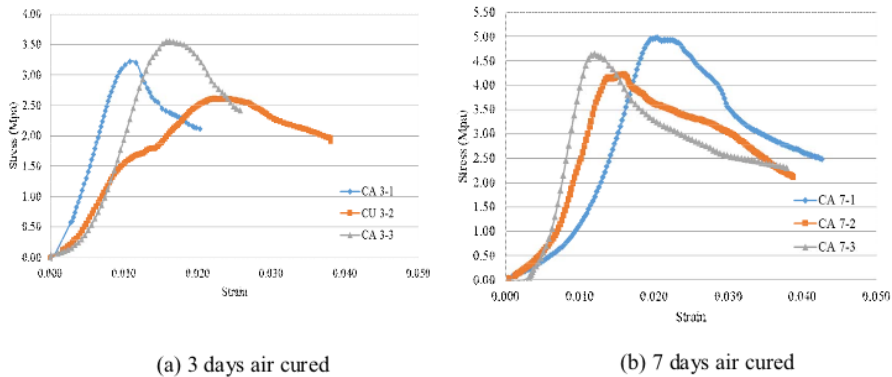


Figure 2. Stress-strain relationship of geopolymer mortar with water curing.

3.4. Effect of wet-dry curing on stress strain relationship of geopolymer mortar containing laterite soil

Figure 3 shows the stress strain of relationship of specimen cured in wet-dry condition remain near until reach the stress and compressive strength evolution to avoid environmental degradation. Based on Figure 3, it can be seen that sample of 3 days water curing has average compressive strength value of 3.57 MPa and the average strain of 0.015 while 7 days air curing arised 4.11 MPa of average compressive strength corresponding to 0.016 of average strain. Compressive strength at 7 days air curing increase 13.13% compared with the compressive strength at 3 days air curing. This result shows that the compressive strength developed without oven curing. As attribute by the presence of hydrated lime in mortar mixture without the curing of oven temperature, the fly ash geopolymer mortar with this laterite soil material can still provide strength.

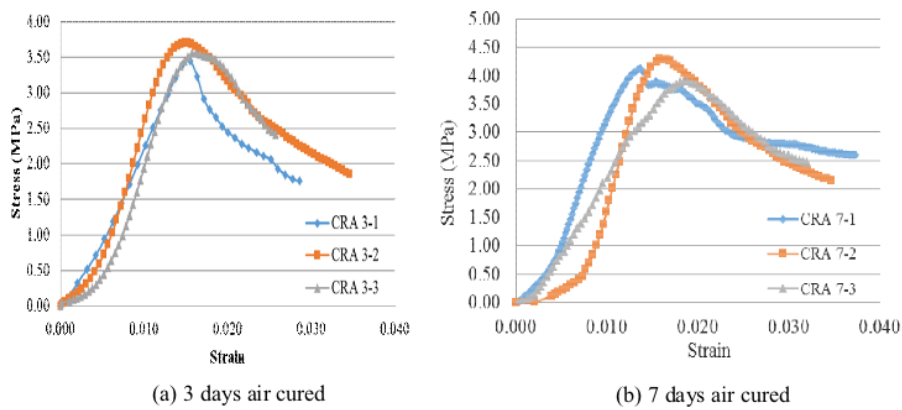


Figure 3. Stress-strain relationship of geopolymer mortar with dry-wet curing.

4. Concluding remarks

Based on the experimental test, fly ash laterite soil geopolymer mortar can provide strength for all curing condition without heat which produced by oven. Three variations of curing for fly ash laterite soil geopolymer mortar has been conducted, the result shows that mortar with air curing had highest strength compared with two others curing (water curing and dry-wet curing).

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