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Use of Laterite Soil And Hydrated Lime as Material of Geopolymer Mortar Based Fly Ash

F A Wangsa[1]*, M W Tjaronge[2], A R Djamaluddin[3], A B Muhiddin[3]

[1] Doctoral Student, Department of Civil Engineering, Hasanuddin University, Indonesia
[2] Professor, Department of Civil Engineering, Hasanuddin University, Indonesia
[3] Department of Civil Engineering, Hasanuddin University, Indonesia

Abstract : Carbon dioxide emissions produced by the cement industry were one of the problems in the occurrence of environmental pollution in the air that could cause global warming. To reduce carbon dioxide emissions, geopolymer fly ash which was one of the eco-friendly alternatives used to replace function of cement. However, in the field, fly ash as a mixture of concrete and mortar required oven heat which became the obstacle in making geopolymer. Therefore, another alternative was sought to replace oven heat, one of which is the use of hydrated lime. Besides, mortar research using geopolymer fly ash as a binder, generally used sand as the fine aggregate. In this study used laterite soil which was quite widely available in nature as the fine aggregate material. These alternatives was developed in this study with the aim to determine the strength of laterite mortar fly ash geopolymer and the effect of hydrated lime as a substitute for oven heat. This study used experimental method in the laboratory using alkaline activator Sodium Silicate and Sodium Hydroxide at a ratio of 2.0 with concentration of 12 M NaOH. Used 3 variations in percentage of laterie soil and hydrated lime, 70:30, 80:20 and 90:10 with sample size 5 cm x 5 cm x 5 cm. The results of the study showed that laterite soil and hydrated lime can be used as geoplymer fly ash mortar with strength 19.70 MPa.
Keywords : Geopolymer fly ash, laterite soil, lime, mortar, compressive strength.

1. Introduction

Geopolymer is a term that has been known since 1978 which was introduced by Professor Joseph Davidovits. Geopolymers are concrete mixes where the use of portland cement material as a binder is replaced by other materials such as fly ash, rice husk ash and others that contain a lot of silica and aluminum[1]. Geopolymer is categorized as an environmentally friendly material because the production of basic geopolymer materials requires a low amount of energy compared to the production of Portland cement which produces large amounts of CO_2[2]. One of the geopolymer materials is fly ash. Fly Ash is the result of the remaining coal combustion process in the Steam Power Plant (PLTU). Fly ash materials can react chemically with alkaline liquids at certain temperatures to form mixed materials that have the same properties as cement. In a number of

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studies, geoplymer fly ash has been used in both concrete and mortar. The result of concrete and mortar have physical characteristics resembling mortars and concrete made from cement. In general, the research that has been carried out using Geopolmer fly ash requires oven curing with a temperature of ± 60-85 °C. Examined geopolymer mortar using fly ash whichwas given curing oven at a temperature of 60 °C[3]. Examined the effect of delay time and Na_2SiO_3 on the development of mortar geopolymer compressive strength using TOIFA, and the samples were given curing oven at temperatures of 65°C, 75°C and 85°C[4].Geopolymer requires alkaline activator to form strong bonds. Sodium Silicate and Sodium Hydroxide are used as alkaline activator[5]. The function of Sodium Silicate is to accelerate the reaction of polymerization, while Sodium Hydroxide functions to reactthe elements of Al and Si contained in fly ash in order to produce strong polymeric bonds.

Some geopolymer fly ash mortar studies, generally the fine aggregate material used is sand. However, in this study, laterite soil used as fine aggregate material. Laterite soil is quite widely available in nature and it is tried to utilize existing natural resources to become another alternative as fine aggregates beside sand. Several studies have been carried out using laterite soil. Using laterite soil for construction purposes to product Compressed Soil Blocks (CEB). Production technology for CEB provides lateral use of modern land for walls and meets building requirements for structural performance[6].Conducted a study on laterite gravel by adding cement to improve the slowness of laterite gravel because it has poor water stability compared to traditional cement gravel[7]. Examined the best percentage of geopolymers to improve the compaction parameters of laterite soils. Laterite soils were used as compacted soil by adding different geopolymer percentages [8].

From some studies geopolymer usage requires oven curing which becomes an obstacle for making the samples in the field. In order to solve this problem, several studies have begun to develop geopolymer use without using temperature curing. By adding the lime to the mortar mixture will be an activator that produces heat needed in the geopolymer reaction, in providing strength to the geopolymer mortar. Hydrated lime is calcium hydroxide $Ca(OH)_2$ and is derived fromCalcium Oxide. Lime is one of the materials for construction that has been widely used by humans. Lime is calcium oxide (CaO) which is made from carbonate rock which is heated at high temperatures. The lime generally comes from limestone (Hardestone).

The use of laterite soil and the addition of lime as a material for geopolymer fly ash mortar, no longer uses high temperatures with the oven during curing. The presence of lime in a mortar mixture will produces the heat needed in reaction of geopolymer to obtain maximum strength in geopolymer mortar. Therefore, this will reduce the use of oven in the curing period which has been carried out on geopolymer fly ash use. The amount of lime content has a considerable influence on hardened geopolymers.

2. Exsperimental

2.1. Material

Fly ash were used to prepare the geopolymers in this study. The Fly Ash sourced from Tonasa Cement plant in Makassar, whereas the laterite soil was collected from Gowa regency and Hydrated lime $Ca(OH)_2$ was obtained from a lime factory in Makassar. A solution of NaOH and Na_2SiO_3 was used as the alkali-activator solution. The NaOH used was commercial grade in white flake forms at 99.1% purity. The NaOH solution was prepared by dissolving the NaOH flakes in water at an appropriate concentration. The Na_2SiO_3 liquid was gray in color and highly viscous with a specific gravity of 1.34 g/cm^3. The mixing water used was local tap water (H_2O). All of the materials used in the present study conform to the relevant ASTM standards.

2.2. Specimens

The specimen from of test sample is cuboid with 5 cm x 5 cm x 5 cm. The samples were made with 3 variations in percentage of laterite soil and lime. Variations in test samples can be seen in table 2.1 below.

Table 1.Number of Specimen with 3 Variations

Sample Variation	The composition of laterite soil and lime		Number of Sample
	Laterite Soil (%)	Hydrated Lime (%)	(pieces)
Variation 1	70	30	9
Variation 2	80	20	9
Variation 3	90	10	9
		Total :	27

Table 2. Mix Proportion

Mol	Variation (%)	Laterite Soil (gr)	Hydrated Lime (gr)	Fly Ash (gr)	Ratio	Na_2SiO_3(ml)	NaOH (ml)	H_2O (ml)
	70;30	1350	150					
12 M	80;20	1200	300	750	2	375	187.5	390.6
	90;10	1050	450					

2.3. Method

This study used experimental method which was carried out at Structure and Material laboratory of Civil engineering of Hasanuddin University. There were 2 prepared steps before all material mixed together. Firstly, the NaOH solutions were initially prepared by dissolving the NaOH flakes in water in concentrations of 12 M. The solutions were mixed with the Na_2SiO_3solution and allowed to cool to room temperature for ± 30 minutes. The alkaline activator solution used was NaOH and Na_2SiO_3 with a ratio between Na_2SiO_3/NaOH was 2.0. Secondly, fly ash, hydrated lime and laterite soil were firstly added into the mixer and stirred manually, after which the mixer was started on a slow-rotation speed setting. For variation 1, the percentage of laterite and lime was 70; 30 from the total weight of fine aggregate. While the mixer was running, the Alkali activator solution was gradually added to disperse the dry material powders and produced a viscose paste. The mixer continued to run for 8 min on moderate speed in order to mix the materials homogenously into a paste and to achieve complete chemical reactions between the fine-powder materials and the alkali-activator solution. Then,the fresh pastes were poured into a cube mold that measured 50 x 50 x 50 mm and de-molded them after 24 hours after casting and placed in the room temperature until the required testing ages. The same process was conducted to the percentage of laterite and lime 80;20 (variation 2) and the percentage of laterite and lime soils 90; 10 (variation 3).

2.4. Sample testing

A compressive test was conducted to evaluate the compressive strength development of the geopolymer samples in accordance with ASTM C109. The test were carried out at 3, 7 and 28 days of age using Universal Testing Machine(UTM). The results of samples testing were obtained stress and strain values of the objects.

3. Experimental results and discussions

3.1. Results of examination of research material

Table 3 presents the composition of chemical compounds in general contained in laterite soils and Table 4presents the composition of laterite soil chemicals used with XRF.

Table 3. The general chemical composition of laterite soil

Chemical Compounds	Composition (%)	Chemical Compounds	Composition (%)
MgO	1,90%	Fe_2O_3	19,70%
Al_2O_3	26,53%	Cl	0,07%
SiO_2	40,12%	SrO	0,11%
SO_3	0,30%	BaO	0,10%
K_2O	1,61%	Pr_6O_{11}	0,05%
CaO	4,26%	Nd_2O_3	0,08%
TiO_2	2,26%	P_2O_5	0,31%
Na_2O	2,10%	ZrO_2	0,11%
MnO	0,20%		

Table 4. The Chemical Content of Laterite Soil with XRF

Chemical Compounds	Percentage (%)
Al_2O_3	49.38
SiO_2	34.81
Fe_2O_3	12,49
MnO	0.10
TiO_2	1.39
K_2O	0.35

The general chemical composition of laterite soil as seen in table 3compared to the composition of laterite soil used in this study in table 4 showed the similarities of three the largest number chemical compounds, SiO_2, Al_2O_3 and Fe_2O_3. Although they have different percentage due to distinct location of the sources where the laterite soil were extracted.Laterite soil contains numerous of Seskuioxide, Oxides and Hydroxides from Fe and Al which can be seen in table 4.1 and table 4.2. Therefore, it can be said that laterite soil used in this study has similarities with the characteristics of laterite soil in general.

Table 5. Chemical characteristics of Sodium Silica

Composition	Concentration (%)	Composition	Concentration (%)
SiO_2	98.88	Si	46.23
P_2O_5	0.79	P	0.346
Cl	0.102	Cl	0.102
K_2O	0.063	K	0.052
TiO_2	0.054	Ti	0.0325
Nb_2O_5	0.0261	Nb	0.0182
ZrO_2	0.021	Zr	0.0158
MoO_3	0.0194	Mo	0.0129
SnO_2	0.0108	Sn	0.0085

From the results of examination of the composition of Sodium Silicate with XRF in table 5 above, it shows that there are 3 components of the largest chemical compounds, SiO_2, Si and P_2O_5.

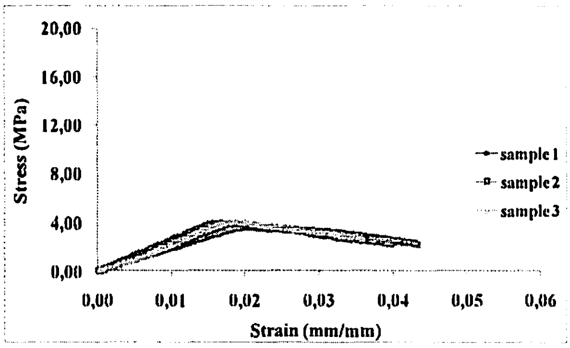
Table 6. Characteristics of Hydrated lime

No	Material Characteristics	Results
1	Specific Gravity,kg/m^3	2.248
2	Sieve Analysis	< 50% passes No.200

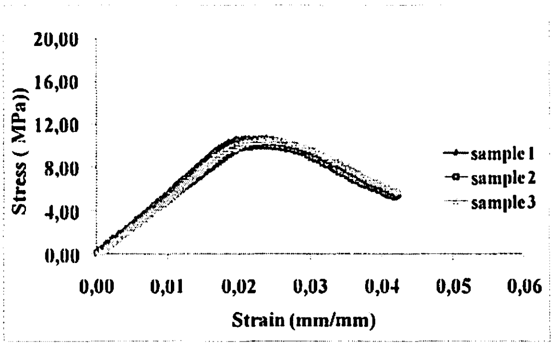
3.2. Percentage 70 :30 of laterite soil and lime sample

The test results of mortar sample with the percentage of laterite soil and hydrated lime at 70:30 at the ages of 3, 7 and 28 days are shown in Figure 1a-1c. From the figures, it can be seen that the value of the test samples from 3 test samples at 3, 7 and 28 days show the value which was almost similar. The average compressive strength values for samples 3, 7 and 28 days present respectively at 3.9 MPa, 10.4 MPa and 19.7 MPa.

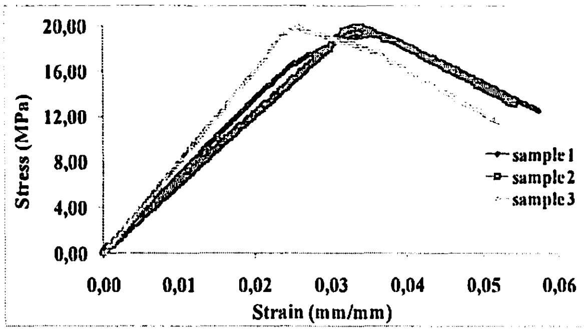
The sample with a variation of the percentage of laterite soil and hydrated lime at 70:30 shows that the test sample still provides strength without using the oven temperature. In several studies, the oven temperature used ranged from 60°C - 85°C needed by geopolymer to be hard and strong. The presence of hydrated lime in this geopolymer fly ash mixture provides heat hydration which makes the test sample have strength without using oven temperature



(a)



(b)

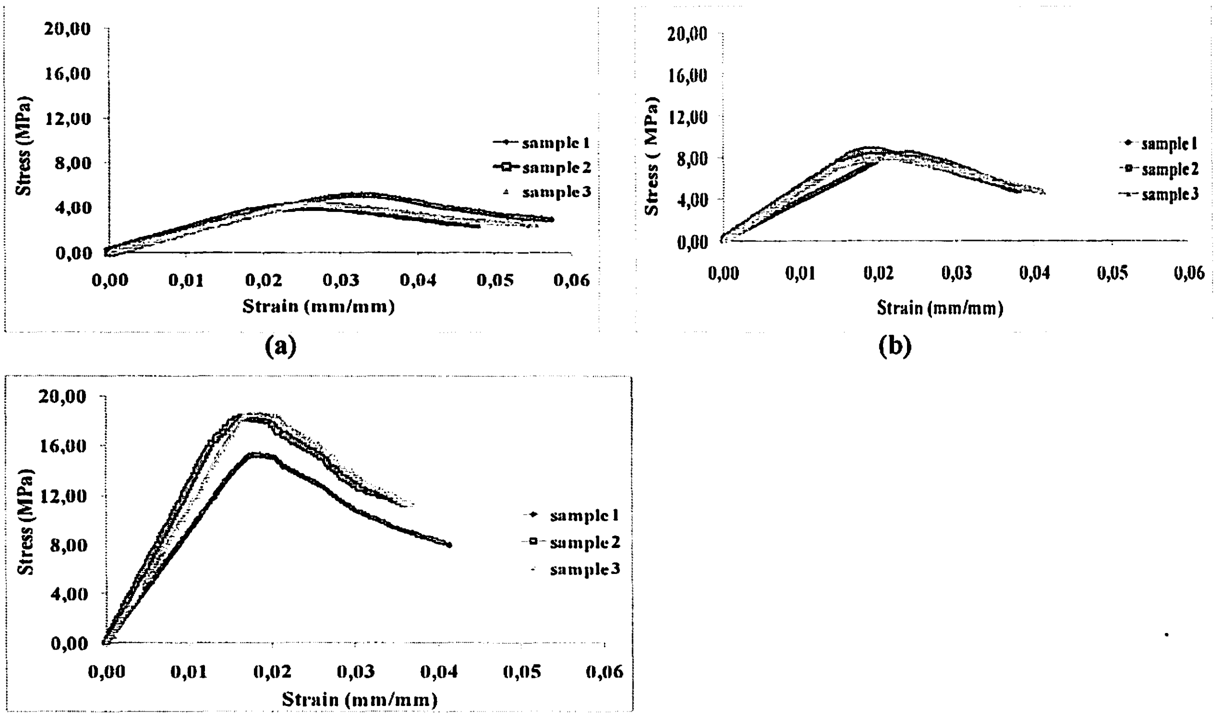


(c)

Fig 1. Stress – Strain Geopolymer Mortar Ratio 2.0 with The Percentage of Laterite Soil and Hydrated Lime70; 30 ages (a) 3 days (b) 7 days dan (c) 28 days

3.3. Percentage 80 : 20 of laterite soil and lime sample

The results of testing the strength of the sample with the percentage of laterite soil and hydrated lime 80:20 are shown in Figure 2a-2c.It can be seen that the average strength of the test samples aged 3, 7 and 28 days was given continuously with a value of 4.45 MPa and 8.34 MPa, 17.36 MPa.Reducing the percentage of lime hydrated in the percentage variation from 70:30 to this 80:20 percentage variation, still shows a hard test sample, even though the strength decreases.



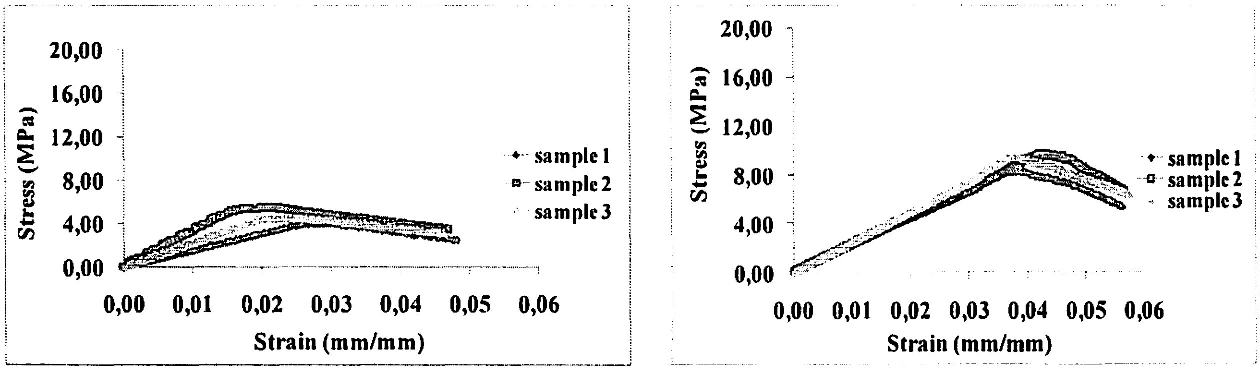
(a) (b)

(c)

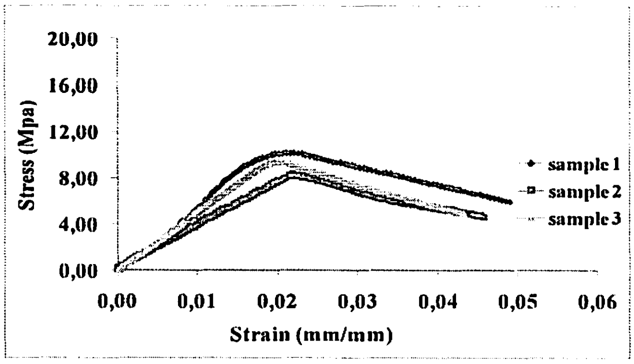
Fig 2. Stress – Strain Geopolymer Mortar Ratio 2.0 with The Percentage of Laterite Soil and Hydrated Lime80 :20 ages (a). 3 days (b). 7 days dan (c) 28 days

3.4. Percentage 90 :10 of laterite soil and lime sample

The results of testing the strength of the test sample with the percentage of laterite soil and hydrated lime at 90:10 are given in Figure 3a-3. The average compressive strength of the test sample at 3, 7 and 28 days stand at 4.60 MPa, 9.07 MPa and 11.51 MPa.



(a) (b)



(c)

Fig 3. Stress – Strain Geopolymer Mortar Ratio 2.0 withThe Percentage of Laterite Soil and Hydrated Lime90; 10 ages 7 days

E5. The Average Strength at aged 3, 7 and 28 days

Figure 4 gives the average compressive strength of the test sample on 3 variations in the percentage of laterite soil and hydrated lime, at ages 3, 7 and 28 days. It shows that the percentage of 70: 30 gives a higher strength than the percentage of 80:20 and 90:10, both at the sample age of 3, 7 and 28 days. The strength 19.7 MPa was the best average strength obtained at aged 28 days that is shown at the percentage of laterite soil and hydrated lime 70:30. While for the percentage of 80:20 and the percentage of 90:10, it presents the strength of 17.36 MPa and 11.51 MPa.

The percentage increase in strength from the percentage variation of 90:10 to the percentage variation of 80:20 at the age of 28 days was 33.7% and from the percentage variation of 80:20 to 70:30 variation, it increased by 11.9%. Overall an increase from the percentage variation of 90:10 to the percentage variation of 70:30 at the age of 28 days by 41.6%.

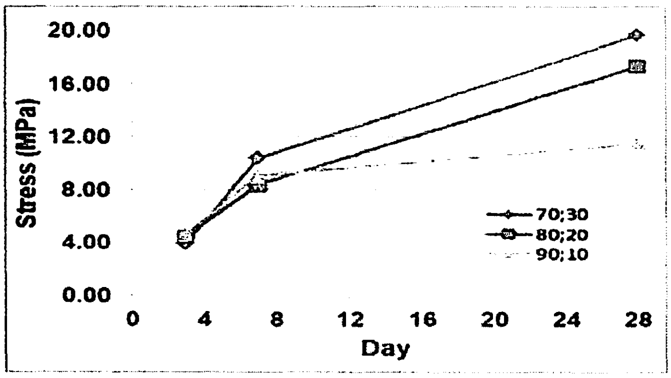


Fig 4.The Average Strength at aged 3, 7 and 28 days

F. Conclusion

1. From 3 variations in the percentage of laterite soil and hydrated lime, the percentage of 70:30 gives the biggest strength of the geopolymer fly ash mortar with a value of 19.7 MPa. The increase of the strength from percentage 90:10 to percentage 70:30 at age 28 days showed 41.6%
2. Increasing the percentage of hydrated lime also increases the strength of mortar.
3. Laterite soil as the fine aggregate in the mixture of geopolymer fly ash mortar can give the strength.
4. Hydrated lime is an alternative to replace the oven heat in giving strength to geopolymerfly ash mortar

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