The effect of open-air curing on compressive strength of geopolymer mortar containing laterite soil and slaked lime

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Abstract. Most surface layers in the Papua and Kalimantan regions are Laterite Land. When dry lateritic soil dries but when containing large amounts of water, laterite soil becomes overtime. Cement production requires a lot of energy so that geopolymer concrete and mortar is a material that has great potential as an alternative to reduce the use of Portland cement because it has mechanical properties that almost resemble Portland cement-based concrete. This study discusses the use of fly ash and alkali activator (NaOH and Na2SiO3) to bind laterite soil by adding quenched lime to reduce the use of ovens to form geopolymer mortar. Comparison of laterite and lime outages is used, namely 95%: 5% and 90%: 10%. Testing of the flow of fresh geopolymer mortar shows that all materials can be bonded well and no segregation occurs. The hardened test material is treated in air-exposed for 3, 7 and 28 days. Testing of compressive strength was analyzed to determine the behavior of geopolymer mortar. The test results showed that there was an increase in compressive strength from the age of 3 to 7 days but decreased at the age of 28 days due to rainy weather, sunlight which resulted in the specimen experiencing flowers (during rain) and shrinkage (during hot weather) so that cracks occurred in specimens, as well as the use of comparison of laterite and lime soils, extinguished 90%: 10% resulting in better compressive strength compared to the use of the ratio of laterite and lime outages of 95%: 5%.

1. Introduction
Most surface layers in the Papua and Kalimantan regions are Laterite Land. When dry lateritic soil dries but when containing large amounts of water, laterite soil becomes overtime. The soil has different specifications from each type, so it requires different handling both mechanically and chemically. This handling must be carried out appropriately because if it is not right, there will be damage to the structure of civil structures caused by mechanical and chemical reactions of the soil.

Soil improvements known in geotechnical engineering are generally divided into three categories, namely mechanical, chemical, and physical methods. Mechanical ways are based on mechanical efforts, such as compacting and consolidation. Chemically, an additive in the form of binders (cement, lime, fly ash) is mixed in the soil which will then change the properties and strength of the soil. Whereas physically, a reinforcing material such as a geotextile is inserted or arranged in the soil layer to strengthen the soil. Adding lime and Portland composite cement to improve the performance of lateritic soils found in the Merauke region of Irian Indonesia [1].
One type of material to produce geopolymer is fly ash. The use of fly ash-based geopolymer as a material binder was also developed, in providing environmentally friendly products, considering that cement plants, in addition to producing cement also produce considerable carbon dioxide emissions into the atmosphere. Based on the International Energy Agency (IEA) report, cement production is widely recognized as a major contributor to greenhouse gas emissions, which amounts to 6-7% of total CO2 gas emissions to the earth's atmosphere. It is estimated that around 0.9-1.0 tons of CO2 are produced from burning one ton of clinker [2]. The use of fly ash can reduce the total demand for energy to produce concrete, reducing greenhouse gas emissions into the earth's atmosphere from the concrete industry by recycling fly ash.

Curing or treatment is one of the important steps after making an object. Curing or regular maintenance is carried out after the formwork has been opened from the specified time to ensure the maintenance of the test material needed for the chemical reaction process contained in the mixture. Also, curing is done to ensure the reaction of the hydration of cement compounds, which means added ingredients or substitutes can take place optimally and keep the excessive shrinkage from occurring which results in too fast or not uniform loss of moisture so that it can cause cracks/cracks. In this study, one type of treatment was used, namely direct exposure to external air.

From several studies, existing geopolymer concrete or mortar requires an oven at temperatures between 35 - 80˚C for 24 hours or even seven days to achieve the same strength as normal concrete. This can be difficult when working in the field. The thing that can be done is by special treatment of the existing laterite soil. One method of increasing material capability is by using lime and fly ash mixed with laterite soil. Based on this, research is needed to reduce the oven curing process on geopolymer concrete or mortar. One of them is by adding lime out. The presence of cation Ca2+ elements in lime can provide a bond between larger particles to counteract the expanding properties and increase the carrying capacity of the soil. Therefore, this study aims to see the effect of adding lime to the geopolymer mortar compressive strength containing laterite soil.

2. Methods

2.1. Location and type of research
The type of research used in this study is experimental studies and literature studies from various literature, both national and international journals. This research was conducted at the Civil Department Laboratory, Faculty of Engineering, University of Muhammadiyah Buton. The time of the study was carried out for approximately two months.

2.2. Research methods and variations of the objects
The method used in this study is experimental in the laboratory. Geopolymer mortar mixtures made from laterite soil, fly ash, lime (Ca(OH)2), alkaline activator in the form of NaOH (sodium hydroxide) and Na2SiO3 (sodium silicate) are produced using local materials from South Sulawesi. Then the assessment and testing of the compressive strength test were carried out. Fifteen specimens were made by outside curing (exposed) with variations on the comparison of laterite and lime soils which were 95%: 5% with NaOH concentrations of 12 M and alkaline activator ratio of 1.5.

2.3. Method of collecting the data
Stage I (Introduction) literature study is carried out at this stage to determine the problems and objectives of the study. Also, an examination of the physical characteristics of the materials used to produce geopolymer mortar specimens, including laterite soil, fly ash and lime extinguished Ca(OH) 2.

Stage II (Object Preparation) is the stage where all the materials and tools to be used during the research are prepared in advance including laterite soil, fly ash, lime out Ca (OH) 2, Sodium Hydroxide (NaOH) and Sodium Silicate (Na2SiO3). Then the weighing of materials will be used to produce geopolymer mortar (laterite soil, fly ash, lime Ca (OH) 2, Sodium Hydroxide (NaOH) and
Sodium Silicate (Na2SiO3) based on predetermined mixture composition and making test specimens. The mixture made consisted of a ratio of 95%: 5% laterite and lime soils with 12 M NaOH concentration and 1.5 alkaline activator ratio.

Stage III (Testing of The Objects) at this stage is tested for the object that has been made in the previous stage, namely the compressive strength test to determine the mixed characteristics of the object that has been made. Variations of the object have been explained in the previous point, where for all specimens carried out treatment (curing) that is the outside air which is directly exposed to the age of the specimen that is at the age of 3 days, seven days, 28 days.

Stage IV (Data Analysis) at this stage is processing primary data obtained from the results of tests carried out in the laboratory-based on the results obtained from the tests carried out on the specimens (samples), namely an analysis of the performance of the mixture well on the strong test describe the ability of the object to accept compressive loads. Next, a discussion about the results is obtained so that it can answer the objectives of the study.

2.4. Data analysis
Data collection in this study begins with testing the characteristics of the material used which consists of laterite soil, fly ash and lime out Ca (OH) 2. Next, make a mixture design (mix design) based on previous research and preliminary research with a concentration of NaOH molarity of 12 M. After that, making test specimens and compressive strength testing according to the age of the specimens are 3, 7 and 28 days. The collected data is then used to analyze the ability of geopolymer mortar specimens made from laterite soil in receiving compressive loads regarding SNI 03-6825-2002 [3].

3. Results and discussion

3.1. Environmental care behavior and citizen responsibility

3.1.1. Material characteristics. The tests carried out included testing the physical and chemical characteristics of laterite soils, physical and chemical characteristics of fly ash and physical characteristics of lime out of Ca (OH) 2. All materials used in this study were obtained from various sources whose extraction was located in South Sulawesi Province.

3.1.2. Physical and chemical characteristics of laterite soil. Examination of the physical and chemical characteristics of laterite soils that function as fine aggregates is shown in table 1.

| No. | Checking type          | Inspection Results |
|-----|------------------------|--------------------|
| 1   | Density                | 2.74               |
| 2   | Moisture content       | 38.85 %            |
| 3   | Liquid Limits (LL)     | 60.81 %            |
|     | Plastic Limit (PL)     | 38.95 %            |
|     | Plastic Index (PI)     | 21.86 %            |
| 4   | $W_{opt}$              | 31.38%             |
|     | $\gamma_{dry}$         | 1.40 gr/cm$^3$     |
| 5   | Filter Analysis        | > 50 % pass the filter no.200 |
| 6   | ASTM                   | CH (Inorganic clay with high plasticity, fat clays) |
|     | AASHTO                 | A – 7 – 5          |
| 7   | Compressive strength   | 0.09 MPa           |
Based on table 1, it can be seen that the examination results for the specific gravity of the sample are 2.74. The type of clay obtains the value of the density. From the results of the examination of the moisture content obtained water content of 38.85%. From the results of testing atterberg boundaries which show the relationship between the number of beats and the water content obtained the liquid limit value (LL) = 60.81% and the plastic limit (PL) = 38.95%. The plasticity index is obtained from the difference between the liquid limit and the plastic limit, so that the plasticity index (PI) value = 21.86% is obtained. Based on Table 2 the results obtained are, the percentage value of Manganese (MnO) content of 0.10%, Aluminum Oxide (Al2O3) of 49.38%, Silicon Dioxide (SiO2) 34.81%, Potassium Oxide (K2O) of 0, 35%, Ferric Oxide (Fe2O3) of 12.49% and Titanium Dioxide (TiO2) of 1.39%.

3.1.3. Characteristics of physical and chemical properties of fly ash. Table 2 shows the results of testing the physical characteristics of fly ash. From the test results, the specific gravity values were 2.65. From the results of testing the filter analysis and hydrometer, the percentage of fly ash that passed the no. 200 by 90%, with grain diameters ranging from 0.00277 - 0.07522.

Table 2. Results of examination of physical characteristics of flying ash

| No. | Checking type                  | Inspection results       |
|-----|--------------------------------|--------------------------|
| 1.  | Density                        | 2.65                     |
| 2.  | Filter and hydrometer analysis | > 90 % pass the filter no. 200 |

3.1.4. Physical characteristics of lime are extinguished. Table 3 shows the test results obtained by the specific gravity values of 2.25. While testing the analysis of the lime filter results in the value of lime passing the No. filter. 200 more than 50%.

Table 3. Results of examination of quenched chalk characteristics

| No  | Material characteristics | Inspection results |
|-----|--------------------------|--------------------|
| 1.  | Density                  | 2.25               |
| 2.  | Filter Analysis          | < 50% pass No. 200 |

Design geopolymer mortar mixture, the composition of the design of the geopolymer mortar mixture using NaOH molarity variations of 12 M and each age there are 5 samples, 5 of which are 3 days of testing, 5 of the 7 days of testing and 5 of the 28 days of testing, can be seen in table 4. from molds of 5 x 5 x 5 cm cubes, geopolymer mortar specimens and then curing the outside air (exposed) until the ages of 3, 7 and 28 days.

Table 4. Composition of mixed designs of geopolymer mortar for 11 pieces (5x5x5 cm cubes)

| Alkali Activator Ratio Na2SiO3/NaOH | Comparison | NaOH (gr) | Na2SiO3 (gr) | Flying Ash (gr) | Laterite soil (gr) | Slaked Lime (gr) | Water (gr) |
|------------------------------------|------------|-----------|--------------|----------------|--------------------|------------------|-------------|
|                                    | Laterite Soil | 336       | 504          | 600            | 1140               | 60               | 700         |
|                                    | Slaked Lime  | 95%       | 5%           | 90%            | 1080               | 120              |             |

3.1.5. Geopolymer mortar compressive strength. Table 5 shows the table of compressive strength values for each treatment age, 3, 7 and 28 days. Increased compressive strength at ages 3 to 7 days but decreased at the age of 28 days. The comparison of laterite and lime soils is extinguished by 90%:
10% resulting in better compressive strength compared to the use of a ratio of 95%: 5% to laterite and limestone soils.

Table 5. Value of compressive strength for each specimen based on age

| Age (Day) | Compressive Strength (MPa) | Percentage % |
|-----------|----------------------------|--------------|
|           | 95% : 5%                   |              |
|           | 90% : 10%                  |              |
| 3         | 1.40                       | 48           |
| 7         | 2.91                       | 100          |
| 28        | 2.64                       | 90.7         |

3.1.6. Crack pattern. The crack pattern that occurs in the outdoor curing spalling occurs on the surface of the geopolymer mortar resistance of the object frequently decreasing with the addition of age and in each test sample, it is seen that there is still chalk which is clumped.

4. Conclusion
The chemical composition of fly ash contains chemical elements including Silica Oxide (SiO2) of 34.63%, Aluminum Oxide (Al2O3) of 19.16%, Ferric Oxide (Fe2O3) of 19.96% and Potassium Oxide (CaO) 12, 74%. Based on ASTM C618-05, fly ash is divided into three categories, namely class N, class F, and class C. Flying ash used in this study is class F because it has a content of Potassium Oxide (CaO) smaller than 20%, which is 12.74 % and CaO elements contained in class F fly ash is less than 20% [4].

Based on the results of the study, it can be seen that the compressive strength value increases with age change. Several studies have revealed that the addition of lime can improve and improve the performance of stabilized so that the soil is capable of having the properties or carrying capacity of the soil that is better than the carrying capacity of the original soil. Several studies have revealed that the addition of lime can improve and improve the performance of stabilized so that the soil can have properties or soil carrying capacity that is better than the original soil carrying capacity [5–9].

The results of testing geopolymer mortar containing laterite soil and lime extinguished in the outdoor curing (exposed) experienced an increase in compressive strength at ages 3 to 7 days but decreased at the age of 28 days. The decrease in the value of 28-day geopolymer mortar compressive strength in outdoor curing (exposed) caused by rainy weather, sunlight which results in specimens experiencing growth (during rain) and shrinkage (during hot weather) so that cracks occur on the object. In addition to curing age, laterite and lime soil variations also affected the value of geopolymer mortar compressive strength.

The use of the amount of extinguished lime by 5% and 10% of the amount of laterite soil and alkaline NaOH solution added by Na2SiO3 was able to work to form a binder which gave strength to
the mixture of geopolymer laterite soil so that it could be exposed to open air. The use of the ratio of laterite and lime soils extinguishes 90%: 10% resulting in better compressive strength compared to the use of the ratio of laterite and lime soils to 95%: 5%. Variations in addition of extinguished lime have an effect on the resulting compressive strength, which is an increase in compressive strength at the age of 3 to 7 days but has decreased at the age of 28 days due to rainy weather, sunlight which causes the specimen to experience growth (during rain) and shrinkage (during hot weather) so that cracks occur on the object.

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