ADDITION OF SUPERPLASTICIZER ON GEOPOLYMER CONCRETE

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ABSTRACT
It is already known that the Portland Cement process manufacturing produces CO\(_2\) as emission that interfere in environment. Therefore it is necessary to find an alternative materials as a substitute for PC or alternative concrete. Today one of the alternative solution is geopolymer concrete, it is based on fly-ash or other material pozzolanic. By adding some alkali activator in fly-ash would make geopolymer concrete. The addition of high-range water-reducing admixture up to approximately 2% of fly-ash mass have improved the workability of fresh geopolymer concrete. In this study the mixtures of geopolymer binder were made with the ratio of fly-ash and alkali activator were 74%: 26%, molarity of sodium hydroxide was 12 M. Ratio of sodium silicate to sodium hydroxide were varies from 1.5 to 3, the percentage of naphthalene-based superplasticizer (SP) were varies from 1.5 to 3 of fly-ash mass. Tests performed were compressive strength, tensile strength and density. The results showed that the highest compressive strength achieved for the proportion of Na\(_2\)SiO\(_3\)/NaOH = 2 and for the percentage of SP 1.5, the highest tensile strength achieved for the proportion Na\(_2\)SiO\(_3\)/NaOH = 2.5 and for the percentage of SP 1.5. The average density of geopolymer was 2400 kg / m\(^3\).

Keyword: geopolymer, pozzolanic material, alkali activator, molarity.

INTRODUCTION
It is already illustrated that the Portland Cement process manufacturing produce CO\(_2\) as emissions that interfere in environment. In manufacturing process one ton of PC produce 0.95 tons of CO\(_2\), represents the sum of the results of the coal burning process and exhaust gases from fuel [1]. Accordingly it is necessary to find an alternative materials as a substitute for PC or alternative concrete. Currently one of the alternative concrete solution is geopolymer, it is based on fly-ash or other material pozzolanic such as metakaolin, blast furnace slag, and others. By adding some alkali activator which is a mixture of sodium silicate (Na\(_2\)SiO\(_3\)) and sodium hydroxide NaOH in fly-ash would make geopolymer concrete [3]. Problem already known that the initial setting time binder of geopolymer based on some particular of fly-ash were very fast in scale of minutes with poor workability [2], consequently it is essential to find chemical additive to adjust the time settings. The addition of high-range water-reducing admixture, up to approximately 2% of fly-ash mass, improved the workability of fresh geopolymer concrete with very little effect on the compressive strength of hardened concrete [3]. In this study the mixtures of geopolymer binder were made of fly-ash and alkali activator, with certain molarity of sodium hydroxide. To facilitate the pouring then used superplasticizer. Tests performed were setting time, compressive strength and tensile strength.

RESEARCH CONDUCTED
This geopolymer research was based on fly-ash which was a waste of electricity industry in Paiton, Probolinggo East Java Indonesia. This binder geopolymer was performed with ratio of fly-ash to the alkali activator was 74% to 26%. The proportion of Na\(_2\)SiO\(_3\) to NaOH varies from 1.5 to 3 with the molarity of NaOH was 12, moreover the percentage of superplasticizer naphthalene based varied from 1.5 to 3 of fly-ash weight, form of binder specimens were 2 cm in diameter and 4 cm high. The geopolymer concrete specimens were made by adding some aggregate to the binder with the proportion of aggregate to the binder was 75% : 25%, the proportion of fine aggregate to coarse aggregate was 40%:60%. Form of geopolymer concrete specimens were 10 cm in diameter and 20 cm high. All specimens were treated in ambient environment. Tests conducted were setting time, value of compressive strength and tensile strength. Compressive strength tests were conducted at 7, 14, 21, and 28 days. While the tensile strength tests were conducted at 28 days.

EXPERIMENTAL RESULTS
Material analysis chemical analysis of Fly-Ash
The analysis of XRD (X-Ray Diffractometry) and XRF (X-Ray Fluorescence) were applied to determine the chemical compounds and oxides contained in fly-ash, the results are shown in Figure-1 and Table-1.

<table>
<thead>
<tr>
<th>Notation</th>
<th>Mineral</th>
<th>Chemical Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>q</td>
<td>Quartz Silicon</td>
<td>SiO(_2)</td>
</tr>
<tr>
<td>h</td>
<td>Hematite Iron</td>
<td>Fe(_2)O(_3)</td>
</tr>
<tr>
<td>s</td>
<td>Silicate Aluminum</td>
<td>Al(_2)SiO(_5)</td>
</tr>
</tbody>
</table>
As shown on the Table-2, the total quantity of oxides (SiO₂ + Fe₂O₃ + Al₂O₃) in fly-ash are not more than 70% however close to 70% (69.715%) , so the material is not classified as pozzolanic material according to ASTM C618-2012. Furthermore the volume of CaO in fly-ash more than 10% , so that fly-ash classified as type C.

Proportion of mixture
Proportion of geopolymer concrete mixtures are shown in Table-3.

Setting time initial setting
All of geopolymer binder mixtures were observed the value of setting time, the results of initial setting are shown in Figure-2.

On Figure-2 indicated that the influence of superplasticizer might say almost no influence against the initial setting time. Conversely, the ratio of Na₂SiO₃/ NaOH have significantly affects to the initial setting time, the greater the ratio of Na₂SiO₃/ NaOH the faster the initial setting value. It happens as the increasing ratio of Si / Al, with increasing ratio of Na₂SiO₃ / NaOH the ratio of Si / Al will increase as well so that the amount of reaction Si-Al is also increase. The important role of sodium silicate as catalyst can be seen , the higher amount of sodium silicate in the mixture deliver the faster setting time [4].

Final setting
All of geopolymer concrete mixtures were investigated the value of final setting time, the results are shown in Figure-3.

Different to the effect of the initial setting, the role of superplasticizer in final setting time seems has effect although the value are relatively small. The more the amount of superplasticizer, the longer the final of setting time. Influence ratio of Na₂SiO₃ / NaOH on the final setting similar to its effect on the initial setting. The greater the ratio Na₂SiO₃/ NaOH the faster the initial setting value. The role of sodium silicate as catalyst can be seen clearly, the higher amount of sodium silicate in the mixture deliver the faster final setting time [4]. This result has corresponds with previous research, that sodium silicate can accelerate the polymerization reaction [3].

Influence Ratio of Si/Al
Influence ratio of Si/Al on final setting is shown on Figure-4.

The effect of Si / Al on setting time is evident, the greater the value of Si / Al the faster the final setting. The increasing ratio of Si / Al there is relation to the increasing in volume Na₂SiO₃. This result in accordance with previous research [4] the higher amount of sodium silicate in the mixture, deliver the faster final setting time.
Table-3. Materials proportion of geopolymer concrete.

<table>
<thead>
<tr>
<th>Notation of Specimen</th>
<th>Mass of Concrete</th>
<th>Coarse Aggregate</th>
<th>Fine Aggregate</th>
<th>Fly Ash</th>
<th>Alkali Activator</th>
<th>Superplasticizer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kg</td>
<td>Kg</td>
<td>Kg</td>
<td>Kg</td>
<td>Kg</td>
<td>gram</td>
</tr>
<tr>
<td>B-1.3-1.5</td>
<td>3.454</td>
<td>1.554</td>
<td>1.036</td>
<td>0.639</td>
<td>0.135</td>
<td>0.090</td>
</tr>
<tr>
<td>B-1.5-2</td>
<td>3.454</td>
<td>1.554</td>
<td>1.036</td>
<td>0.639</td>
<td>0.135</td>
<td>0.090</td>
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<tr>
<td>B-1.5-3</td>
<td>3.454</td>
<td>1.554</td>
<td>1.036</td>
<td>0.639</td>
<td>0.135</td>
<td>0.090</td>
</tr>
<tr>
<td>B-2.1.5</td>
<td>3.454</td>
<td>1.554</td>
<td>1.036</td>
<td>0.639</td>
<td>0.150</td>
<td>0.075</td>
</tr>
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<tr>
<td>B-3.1.5</td>
<td>3.454</td>
<td>1.554</td>
<td>1.036</td>
<td>0.639</td>
<td>0.168</td>
<td>0.056</td>
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</tbody>
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Note: \( x \) = ratio of NaOH to Na₂SiO₃  
\( y \) = percentage of superplasticizer

Graph of initial setting to proportion of Na₂SiO₃/NaOH

![Graph](image)

Figure-2. Correlation graphs of initial setting and ratio of Na₂SiO₃/NaOH.
Influence percentage of superplasticizer to the geopolymer concrete compressive strength are shown in Figure-5. As on previous results in this studies, the highest value of compressive strength was obtained on proportion of Na$_2$SiO$_3$/NaOH = 2.
From the graph shows that the highest value of compressive strength obtained on the mixture of 1.5% superplasticizer. The results almost the same as previous research [5] where the highest value of compressive strength obtained on the mixture of 1% superplasticizer. The addition of superplasticizer decrease the compressive strength. The other research the highest value of compressive strength obtained on the mixture of 1% with the same type of superplasticizer, naphthalene based [6].

**Influence of proportion of Si/Al to the compressive strength**

Influence of proportion of Si/Al to the compressive strength are shown in Figure-6.

There is correlation among compressive strength and proportion of Si/Al. The maximum compressive strength value occurs in the proportion of Si/Al 1.500. The concentration of silicon in the activating solution of geopolymers has significant effect on compressive strength [8].

![Figure-6. Correlation graphs of compressive strength and proportion of Si/Al.](image)

A mixture of the specimen with the higher content of Si / Al will be given a special meaning exhibited significantly increases in strength [7], the maximum yield of the compressive strength occurs at a ratio of Si / Al was 1.9. The other research indicated that the maximum yield of the compressive strength occurs at a ratio of Si / Al was 2. [9]

**Split tensile strength**

All of mixture were observed the value of split tensile strength. The influence percentage of superplasticizer to the geopolymer concrete split tensile strength are shown in Figure-7.

![Figure-7. Correlation graphs of split tensile strength and ratio of Na2SiO3/ NaOH.](image)
On Figure-7 are illustrated the influence of superplasticizer have significantly affects against the split tensile strength. Conversely, the ratio of Na$_2$SiO$_3$/NaOH have a very small affects to the split tensile strength. The higher value of split tensile strength achieved for presentation of Superplasticizer = 1.5 with the value of split tensile strength is 3.5 MPa. The result is the same as the effect of Superplasticizer on the compressive strength. Other study show the maximum result of direct tensile strength was 5 MPa [10] in the geopolymer with activator liquid fly ash ratio of 0.40.

**Ratio of split tensile strength (ft) to the compressive strength (fc)**

Ratio of Split Tensile Strength (ft) to the Compressive Strength (fc) are shown in Figure-8.

![Figure-8. Correlation of ratio of ft/fc and proportion of Na$_2$SiO$_3$/NaOH.](image)

From the Figure-8 indicates that the highest ratio of ft/fc is 1.0, achieved on the proportion of Na$_2$SiO$_3$/NaOH= 3 with activator liquid fly ash ratio of 0.33. Viewed from the previous results of compressive strength, for the ratio Na$_2$SiO$_3$/NaOH = 3 has the lowest value. The other research has the highest ratio ft/fc was 1.4 [10] with activator liquid fly ash ratio of 0.40, this experiments were used Analytical Grade Sodium Hydroxide pellets with 98% purity and Sodium Silicate Solution.

**CONCLUSIONS**

- The influence of superplasticizer might say almost no influence against the initial setting time, in final setting the superplasticizer seems has effect although the value are quite small. But the effect of Si / Al on setting time is evident, the greater the volume of Si / Al the faster the final setting.
- The highest value of compressive strength obtained on the mixture of 1.5% superplasticizer. And the maximum compressive strength value occurs in the proportion of Si / Al 1,500
- The higher value of split tensile strength achieved for presentations of Superplasticizer = 1.5.

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