The Effect of Bagasse Ash on Fly Ash-Based Geopolymer Binder

R Bayuaji\textsuperscript{1}, M S Darmawan\textsuperscript{1}, N A Husin\textsuperscript{1}, R Banugraha\textsuperscript{1}, M Alfi\textsuperscript{1}, M M A B Abdullah\textsuperscript{2,3}
\textsuperscript{1}Infrastructure Civil Engineering Department, Faculty of Vocations, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia
\textsuperscript{2}Center of Excellence Geopolymer and Green Technology (CEGeoGTech), School of Materials Engineering, Universiti Malaysia Perlis (UniMAP), Perlis, Malaysia.
\textsuperscript{3}Faculty of Engineering Technology, Universiti Malaysia Perlis (UniMAP), Kangar, Perlis

E-mail: bayuaji@ce.its.ac.id

Abstract. Geopolymer concrete is an environmentally friendly concrete. However, the geopolymer binder has a problem with setting time; mainly the composition comprises high calcium fly ash. This study utilized bagasse ash to improve setting time on fly ash-based geopolymer binder. The characterization of bagasse ash was carried out by using chemical and phase analysis, while the morphology characterization was examined by scanning electron microscope (SEM). The setting time test and the compressive strength test used standard ASTM C 191-04 and ASTM C39 / C39M respectively. The compressive strength of the samples determined at 3, 28 and 56 days. The result compared the requirement of the standards.

1. Introduction
The green concept for ordinary cement Portland industry today is to substitute separately and replace it entirely using environmentally local materials. The fact shows the cement industry contributes CO\textsubscript{2} emissions close to 8% of the total emissions in the world.

This phnom is caused a ton of cement production produces a ton of CO\textsubscript{2} emissions in the air, and this contributes to global warming \cite{1}. Davidovits \cite{2} defines that the natural ingredients to replace portland cement in concrete high geopolymer should contain silica and alumina. These elements will react with the liquid alkali such as Na\textsubscript{2}SiO\textsubscript{3} and NaOH to make the process of polymerization in geopolymer concret.

Therefore, geopolymer concrete is now a popular material to develop continuously in Indonesia since approximately since 2010\cite{3-6}. The main problem of geopolymer concrete in Indonesia is the quality of fly ash which is so varied that it causes problems to its setting time.

Therefore, this study to reduce the dominance of fly ash on geopolymer binder by substituting fly ash with local material of alumina silicate \cite{10}. While, many challenges need to be solved, such as setting time for high calcium fly ash for geopolymer binder and geopolymer concrete. Previous study \cite{7-11} explored the bagasse ash (AAT) on normal concrete.
The bagasse has great potential to improve the properties of normal concrete still slightly reviewed in geopolymer concrete. Because of that, this study to explore the bagasse ash to reduce the domination of fly ash in binder geopolymer.

2. Methodology
Experimental laboratory used to answer this research. Bagasse ash from PG. Toelangan PTPN X-Sidoarjo. The fly ash samples were collected from Paiton steam power plant in Probolinggo, East Java, Indonesia. To determine the chemical composition contained in the waste bagasse ash and fly ash, tests will be conducted SEM-EDX, XRD (X-Ray Diffraction) and XRF (X-Ray Fluorescence).

Activators for alkaline solution used is sodium silicate ($\text{Na}_2\text{SiO}_3$) and sodium hydroxide (NaOH) with molarity 12 M. Table 1 showed eight different geopolymer binder compositions used during this experiments. Those are including the variation on alumina and silica material composition. The ratio between activator solution of NaOH and $\text{Na}_2\text{SiO}_3$ were 0.5 and 1.5. The binder sample prepared by mixing the materials then casting the sample into the mould. During this process, the setting time used the ASTM [12]. The sample harden by itself and followed by curing process afterwards. The curing process were monitored at the age of 3, 28 and 56 days. Then we can continue to test the sample’s compressive strength by using the ASTM[13] standard code.

| No | Binder code | Information |
|----|-------------|-------------|
| 1  | AAT12- 0.5  | AAT 100%, NaOH 12M, $\text{Na}_2\text{SiO}_3$/NaOH = 0.5 |
| 2  | FA12 - 0.5  | FA 100%, NaOH 12M, $\text{Na}_2\text{SiO}_3$/NaOH = 0.5 |
| 3  | 50AAT+50FA12 - 0.5 | AAT 50% + FA 50%, NaOH 12M, $\text{Na}_2\text{SiO}_3$/NaOH = 0.5 |
| 4  | 20AAT+80FA12 - 0.5 | AAT 20% + FA 80%, NaOH 12M, $\text{Na}_2\text{SiO}_3$/NaOH = 0.5 |
| 5  | AAT12- 1.5  | AAT 100%, NaOH 12M, $\text{Na}_2\text{SiO}_3$/NaOH = 1.5 |
| 6  | FA12 - 1.5  | FA 100%, NaOH 12M, $\text{Na}_2\text{SiO}_3$/NaOH = 1.5 |
| 7  | 50AAT+50FA12 - 1.5 | AAT 50% + FA 50%, NaOH 12M, $\text{Na}_2\text{SiO}_3$/NaOH = 1.5 |
| 8  | 20AAT+80FA12 - 1.5 | AAT 20% + FA 80%, NaOH 12M, $\text{Na}_2\text{SiO}_3$/NaOH = 1.5 |

3. Result and discussion
Some results from baggase ash and fly ash test physically and chemically are presented in the Figure 1-6 and the table 2 and 3 below:

Figure 1. Baggage Ash in magnification of 500x.  
Figure 2. Baggage Ash in magnification of 1000x.

The test results SEM fly ash has a relatively round grain shape so it is more easily oxidized than baggase ash shaped like coral. The faster the oxidation process faster binding occurs.
This test is used to determine the elemental composition of the material analysis. From the test results XRF known that fly ash used in this study is Si + Al + Fe > 70%. CaO content of fly ash used in this study was 5.83%, according to ASTM [12] fly ash which has a CaO content of less than 10% are classified into type F fly ash.

Figure 7 presented the test results of setting time. This figure described the fastest setting time occurred in the composition of FA 100%, NaOH 12M, Na$_2$SiO$_3$/NaOH = 0.5. The longest setting time was showed the binder composition of AAT 20% + FA 80%, NaOH 12M, Na$_2$SiO$_3$/NaOH = 0.5.

![Figure 3. Fly Ash in magnification of 500x.](image3)

![Figure 4. Fly Ash in magnification of 1000x.](image4)

![Figure 5. The XRD Test Result of Baggase Ash.](image5)

![Figure 6. The XRD Test Result of Fly Ash.](image6)
XRD test results, the highest intensity on bagasse ash highest intensity occurred in 9100 while in fly ash occurs at an altitude of 8,100.

The compressive strength test was shown Figure 8. There were two highest compressive strength presented the binder composition. The composition were FA 100%, NaOH 12M, Na$_2$SiO$_3$/NaOH = 1,5 and AAT 20% + FA 80%, NaOH 12M, Na$_2$SiO$_3$/NaOH = 1,5 at the 56 days 42.52 MPa and 42.32 MPa, respectively.

**Table 2.** The XRF Test Result of Baggase Ash.

| No | Code sample | Name of chemical | Results analysis (%) |
|----|-------------|------------------|----------------------|
| 1. | Silica dioxide | SiO$_2$ | 72.14 |
| 2. | Ferry oxide | Fe$_2$O$_3$ | 7.75 |
| 3. | Corundum | Al$_2$O$_3$ | 4.86 |
| 4. | Calcium dioxide | CaO | 7.13 |
| 5. | Magnesia | MgO | 1.63 |
| 6. | Sodium oxide | Na$_2$O | 0.46 |
| 7. | Potassium oxide | K$_2$O | 3.6 |
| 8. | Manganese oxide | MnO | 0.32 |
| 9. | Iron oxide | ZnO | 0.15 |
| 10. | Lead oxide | TiO$_2$ | 0.31 |
| 11. | Phosphate | P$_2$O$_5$ | 1.27 |

**Table 3.** The XRF Test Result of Fly Ash.

| No | Code sample | Name of chemical | Results analysis (%) |
|----|-------------|------------------|----------------------|
| 1. | Silica dioxide | SiO$_2$ | 47.10 |
| 2. | Ferry oxide | Fe$_2$O$_3$ | 16.07 |
| 3. | Corundum | Al$_2$O$_3$ | 24.25 |
| 4. | Calcium dioxide | CaO | 5.83 |
| 5. | Magnesia | MgO | 2.62 |
| 6. | Sodium oxide | Na$_2$O | 0.65 |
| 7. | Potassium oxide | K$_2$O | 1.64 |
| 8. | Manganese oxide | MnO | 0.10 |
| 9. | Iron oxide | ZnO | 0.29 |
| 10. | Lead oxide | TiO$_2$ | 1.16 |
| 11. | Phosphate | P$_2$O$_5$ | 0.18 |

**Figure 7.** The Setting Time Test Result.

**Figure 8.** The Compressive Strength Test Result.
4. Conclusions
The bagasse ash could be able to improve its performance to substitute fly ash in a geopolymer binder mixture. The properties chemical and physical of bagasse ash adequate to work together with fly ash. The Baggage ash in the low NaOH molar could increase the setting time of geopolymer binder. However, the bagasse ash required higher NaOH molar to produce better compressive strength.

5. References
[1] Bilodeau A and Malhotra V M 2000 Materials Journal 97(1) 41-48
[2] Davidovits J 1984 Synthetic mineral polymer compound of the silicoaluminates family and preparation process Google Patents
[3] Ekaputri J J, Maekawa K and Ishida T 2010 The use of geopolymerization process for boron fixation in fly ash in Jinan, China: Proceeding the 7th International Symposium on Cement & Concrete (ISCC2010) and the 11th International Conference on Advance in Concrete Technology and Sustainable Development
[4] Ekaputri J J, et al 2015 Applied Mechanics and Materials Trans Tech Publ
[5] Bayuaji R, et al 2015 Applied Mechanics and Materials Trans Tech Publ
[6] Dwijayanti L Y, Ekaputri J J and Bayuaji R 2016 Lightweight geopolymer binder with abaca fiber in different curing in Materials Science Forum Trans Tech Publ
[7] Wani A H, Sharma S and Siddique R 2018 International Journal of Civil and Environmental Engineering 5(3)
[8] Rajasekar A, et al 2018 Construction and Building Materials 171 350-356
[9] Moretti J P, Nunes S and A Sales 2018 Construction and Building Materials 172 635-649
[10] ASTM-C191-13 2013 Standard Test Methods for Time of Setting of Hydraulic Cement by Vicat Needle
[11] Burduhos Nergis D D, Abdullah M M A and Vizureanu P 2017 European Journal of Materials Science and Engineering 2 111-118
[12] Popovici A, Corbu O, Popita GE, Rosu C, Proorocu M, Sandu AV and Abdullah MMAB 2015 Materiale Plastice 52(4) 588-592
[13] ASTM C39/C39M-18 2018 Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
[14] ASTM-C618-03, Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete Annual Book of ASTM Standards, 4-2, ed ASfTa Materials, 2003, Philadelphia, USA

Acknowledgement
Researchers would like to thank the Directorate of Research and Community Service of the Ministry of Research, Technology and Higher Education for research assistance and research results that can be successfully published