Utilization of Volcanic Ash of Mount Sinabung as a Substitute for Cement to Flexure Strength of Geopolymer Concrete

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Abstract: Concrete is one of the construction materials that have been commonly used for the construction of buildings, bridges, roads and so forth. The need for concrete will increase in line with the increasing need of basic human facilities and infrastructures. Therefore, the production of cement as a binder of concrete increases as well. In the process of cement production occurs a process of a huge amount of CO2 release into the atmosphere and then damage the environment which among them cause global warming. To overcome these problems, it's necessary to find another material as a substitute for cement. Geopolymer concrete is an alternative to substitute concrete that uses cement. Geopolymer concrete is made without the use of cement as a concrete binder, and instead, using sinabung ash which is rich in silica and alumina and can react with alkaline liquids to produce a binder. In this research, the flexure strength of concrete is tested to a number of samples in the form of 15x15x60 cm3 block with curing time variation of 4 hours, 8 hours, 12 hours and 24 hours at 60^{o}C temperature by using oven. From the results, it's obtained that the graph of flexure strength value increases with the length of curing time. Maximum flexure strength occurs at 24 hours curing time.

1 INTRODUCTION

(Davidovits, 1999) Geopolymer concrete is a construction material that is developed and offers many advantages compared to conventional concrete where the making process of concrete does not use cement. The advantages to be obtained from geopolymer concrete are its ability to withstand fire, corrosive resistance, reducing air pollution due to excessive CO2 emissions at the time of cement production. The base materials for the geopolymer binder used to create geopolymer concrete can be obtained from various sources where these materials have high silica and aluminum content.

In this research the cement substitute binder used is volcanic ash. Volcanic ash is a fine material and very small in size, bursting from a erupting volcano. Volcanic ash has some content that can support reinforcement in concrete. One of the most abundant types of material in volcanic ash is silica (SiO2). This material can react chemically with alkaline liquids at a certain temperature to form a cement-like mixed material.

Based on the descriptions described above, the author will conduct a test by using volcanic ash of Mount Sinabung as a substitute of cement in concrete mixture, to be able to know the result of flexure strength of concrete produced with the base material of volcanic ash.

2 MATERIALS

Sinabung Ash. Volcanic ash or volcanic sand is a falling volcanic material that is ejected into the air during an eruption. The ash and volcanic sand consist of large to fine-sized rocks, large ones usually falling around 5-7 km from the crater, while the fine ones can fall at a distance of hundreds of kilometers or even thousands of kilometers from the crater that caused by the wind (Sudaryo dan Sucipto, 2009). The characteristics of volcanic ash generally contain major elements (AI, Si, Ca and Fe), minor (I, Mg, Mn, Na, P, S and Ti), trace levels (Au, As, Ba, Co, Cr, Cu, Mo, Ni, Pb, S, Sb, Sn, Sr, V and Zn), have broad uses (AI, Si, Ca, Fe, Ti, V and Zn) and high values (Au). Based on the content of AI, Ca and Si elements in

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large ash (56%, 4% and 18% respectively), it is possible to use the ash as a cement material or cement-based goods (Wahyuni, 2012)

Table 1: Chemical Contents of Volcanic Ash of Mount Sinabung Eruption

No	Parameter	Result (%)	Method
1	Silika as SiO_2	85,6	Gravimetri
2	Aluminium as Al_2O_3	0,95	Perhitungan
3	Kalsium as CaO	4,78	Gravimetri
4	Magnesium as MgO	4,48	Gravimetri
5	Water content	1,43	Gravimetri

(*Source : Balai Riset dan Standarisasi Industri Medan, Laboraturium Penguji, Kementerian Perindustrian*)

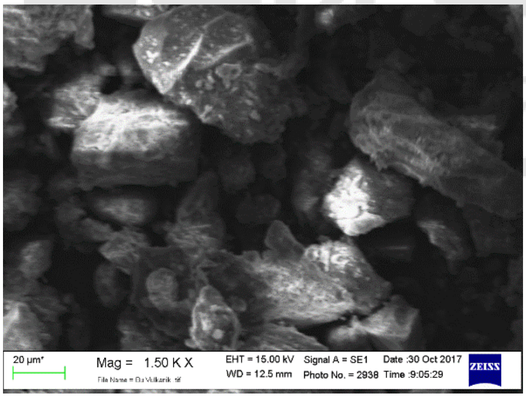

Figure 1: Magnification of Volcanic Ash Samples with SEM Test

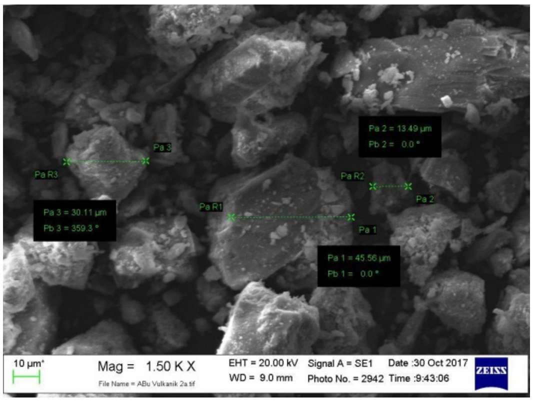

Figure 2: Magnification of Volcanic Ash Samples with SEM Test

Table 2: Results of EDS Spectrum Analysis of Volcanic Ash Samples of Mount Sinabung

El	An	C Norm (wt%)	C atom (at%)
Fe	26	37,96	16,72
O	8	33,28	51,16
Si	14	16,81	14,72
C	6	6,12	12,53
Al	13	4,26	3,88
K	19	0,89	0,56
Ca	20	0,69	0,42
Na	11	0,00	0,00
Mg	12	0,00	0,00
Br	35	0,00	0,00
Tl	81	0,00	0,00

(*Source : Laboratorium Fisika Universitas Negeri Medan*)

Table 3: Results of X-ray Diffraction Analysis of Activation Nature of Volcanic Ash

No	2 Theta (deg)	d (A)	I/II	FWHM (deg)	Intensity (Counts)	Integrated Int (Counts)
1	27,7584	3,211125	100	0,50580	297	7998
2	21,786	4,07619	73	0,412	217	4831
3	23,5594	3,77322	48	0,2811	144	2025

(Source : Laboratorium Fisika Universitas Negeri Medan)

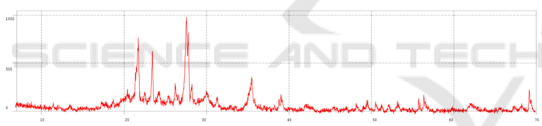

Figure 3: Diffraction Pattern of Activation Results of Volcanic Ash

Figure 3 shows the pattern of X-ray diffraction between intensities to the volcanic ash element pattern of modified nature (chemical and physical activation). The analysis of X-ray diffraction tool is intended to know the dase and crystal structure, and identification result crystallinity of a dominant composition on volcanic ash (Bambang Nurdiansyah, 2017).

From table 3, it can be seen that the maximum peak is at 2θ = 27.7584 with spacing of 3.21125A and FWHM 0,50580.

From the results of chemical content examination above, it is seen that sinabung ash has a very high silica content. The percentage of this content indicates that the ash can be used as a substitute for cement in a concrete mixture.

From the SEM test of volcanic ash samples above, it can be seen that the morphology of samples is irregular with varying sizes. And the magnitude of the volcanic ash particle distribution from the eruption of Mount Sinabung is 13.49µm - 45.56µm (Bambang Nurdiansyah, 2017).

Agregates. The fine aggregate (sand) used is sand from Medan Sunggal with dry, SSD and apparent specific gravity of 2460 kg / m3 and 2510 kg / m3 and 2590 kg / m3. Coarse aggregate (gravel) is split with the maximum size of 20 mm with SSD and apparent specific gravity of 2630 kg / m3, 2680 kg / m3 and 2770 kg / m3

Admixtures. Admixtures are materials used in concrete mixture other than water, aggregates (fine and coarse aggregate), ashes, and alkaline activators added in concrete mix. In this research is using highrange water reducer admixture such as Master Ease 3029 and Accelerator.

[2][3]**Alkaline Activators (*Sodium Silicate dan Sodium Hidroxyde*).** Alkaline activators to be used in this research are sodium hydroxide and sodium silicate. NaOH is a powder with a content of 98%. Sodium hydroxide serves to react the Si and Al elements contained in the volcanic ash so as to produce a strong polymer bonds. Na_2SiO_4 contains 96% gel-shaped sodium silicate. Sodium silicate serves to speed up the polymerization reaction.

3 METHOD

(Mulyono, 2004) Research method is stages, processes, sequences or workflows to get the purpose of a research conducted. The method used in this study is an experimental study conducted at the Concrete Laboratory of Faculty of Engineering of Department of Civil Engineering of University of Sumatra Utara. A complete mix design calculation can be seen in the attachment. From the mix design results, it is obtained 1m³ concrete mixture proportion among others are as follows :

Table 4: The proportion of concrete mixture per m^3

Material	Weight
Sinabung Ash	553,57 kg/m³
Sodium Silicate	138,40 kg/m³
Sodium Hidroxyde	230,65 L/m³
Coarse Aggregate	900,16 kg/m³
Sand	808,46 kg/m³
Master Ease 3029	11,07 L/m³
Accelerator	5,54 L/m³

Concrete Flexure Strength. The loading system in the flexure test, ie the specimen is loaded so that it will only experience a failure caused by pure flexure (two point loading system). The flexure strength of concrete (modulus of rupture) is calculated as follows:

If the failure occurs in the middle of the span:

$$fr = \frac{PL}{bd^2} \quad [1]$$

If the collapse occurs in the drag outside of the center of the span then the following formula is used:

$$fr = \frac{3Pa}{bd^2} \quad [2]$$

Where :

Fr = *modulus of rupture*
P = the maximum load that occurs
L = the effective span length
b = average width of fault specimen
d = average height of fault specimen
a = the average distance from the failure line from the nearest placement point measured at the specimen's drag

4 RESULTS AND DISCCUSIONS

Visible Properties

Volume Weight of Geopolimer Concrete. The volume weight of concrete is the ratio between the weight of the concrete and its volume. The average volume weight of the geopolymer concrete can be seen in table 5 below :

Table 5: Table of average volume weight of *Geopolymer* Concrete

No.	Curing Time (Hours)	Number of Samples	AverageVolume Weight (kg/m^2)
1	4	3	2329,04
2	8	3	2381,04
3	12	3	2386,00
4	24	3	2369,41

From the results obtained, the volume weight of geopolymer concrete volume ranges between 2329,04 kg/m^2 – 2386,00 kg/m^2. The examination results of the geopolymer concrete volume weight, it is included a normal weighted concrete (SNI 03-2847-2002).

Flexture Strength of *Geopolymer* Concrete. In this research, flexure strength test is performed on a beam of geopolymer concrete with the size of 15 x 15 x 60 cm at 7 days of age. The results of the average flexure strength test can be seen in Table 6.

Table 6: Average Flexure Strength of *Geopolymer* Concrete

No	**Curing Time (Hours)**	**Curing Temperature (°C)**	**Average Flexure Strength (Mpa)**
1	4	60	2,78
2	8	60	3,29
3	12	60	3,79
4	24	60	4,53

[6]From the table and graph above, it can be seen that there is an increase of flexural strength of geopolymer concrete along with the length of treatment time in the oven (Curing Time) at 60°C. The longer the curing time on the concrete samples, the higher the strength of the concrete flexure is. Maximum flexure strength occurs at 24 hours curing time.

From the results of the research of flexure strength of geopolymer concrete, it is obtained a concrete conversion value at 4 hours, 8 hours, 12 hours, to 24 hours curing time.

Table 7: Conversion Table of *Geopolymer* Concrete Flexure Strength

Curing Time (Hours)	**Flexure Strength (Mpa)**	**Conversion Value of Flexure Strength**
4	2,78	0,61
8	3,29	0,73
12	3,79	0,84
24	4,53	1,00

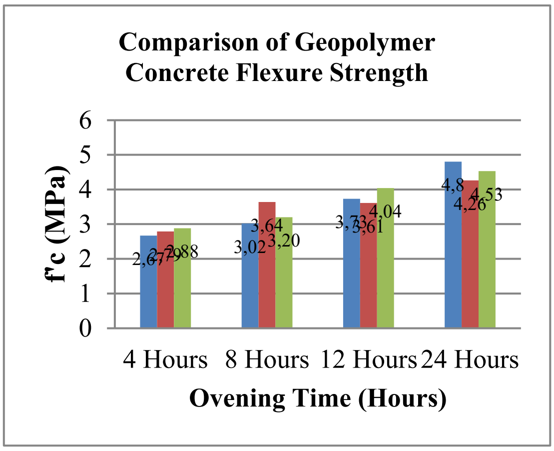

Figure 5: Flexure Strength Comparison

5 CONCLUSIONS

From the test results, data processing and analysis, it can be concluded as follows:

1. Based on the test results, it can be concluded that the optimum variation is on the variation with 24 hours curing time because it has the highest flexure strength. For 24 hours curing time variation, the average flexure strength is 4.53 MPa.
2. Based on the discussion, it can be concluded that the flexure strength value of geopolymer concrete increases along with the length of treatment time in the oven (Curing Time) at 60oC. The average flexure strength of 7days of age concrete and being ovened for 24 hours has a flexure strength of . The longer the curing time on the concrete samples, the higher the strength of the concrete flexure is. Maximum flexure strength occurs at 24 hours curing time.

6 SUGGESTIONS

Based on the results obtained in this research, the author provides some suggestions as follows :

1. Conducting variation of curing temperature more than 60°C and more than 24 hours curing time and more than 7 days of concrete age to obtain an optimum flexure strength of concrete.

2. Conducting further research by varying the molarity of NaOH and the ratio between Na2SiO3 and NaOH to obtain an optimum value.
3. Noticing the use of vaseline for formwork of samples because the incorrect use of vaseline can cause a sticky samples when opening the formwork.
4. Conducting research on the mechanism and method of mixing of geopolymer concrete materials connected with concrete workability.

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REFERENCES

Davidovits, J. (1999). Chemistry of Geopolymeric Systems, Terminology In: Proceedings of 99 International Conference. *eds. Joseph Davidovits, R. Davidovits & C. James, France*.

Ekaputri, J. J., & Triwulan, T. (2013). Sodium sebagai Aktivator Fly Ash, Trass dan Lumpur Sidoarjo dalam Be

GEOPOLIMER, TERHADAP KUAT MEKANIK BETON. "PENGARUH MOLARITAS AKTIFATOR ALKALIN TERHADAP KUAT MEKANIK BETON GEOPOLIMER DENGAN TRAS SEBAGAI PENGISI."

Karolina, Rahmi, M. Agung Putra, and Tito Agung Prasetyo. "Optimization of the use of volcanic ash of Mount Sinabung eruption as the substitution for fine aggregate." *Procedia Engineering* 125 (2015): 669-674.

Mulyono, Tri. "Teknologi Beton." *Yogyakarta: Andi*(2004).

Risdanareni, Puput, Adjib Karjanto, Januarti Jaya Ekaputri, Poppy Puspitasari, and Febriano Khakim. "Mechanical properties of volcanic ash based geopolymer concrete." In *Materials Science Forum*, vol. 857, pp. 377-381. Trans Tech Publications, 201