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To cite this article: Firdaus *et al* 2019 *J. Phys.: Conf. Ser.* **1376** 012008

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# The effects of fineness level of fly ash and accelerator on the setting time and the compressive strength of geopolymer mortar

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**Abstract.** This experimental study is part of fly ash based geopolymer research development. The type F fly ash which is the quite abundant by-product materials from power plant burning coal in Tanjung Enim, South Sumatera was the background of this research. However, this kind of fly ash was being treated before it would be used. As known that the mechanical properties of the harden of cementitious material is affected by its fineness of the binder material. The beginning researches about this fly ash based geopolymer concluded that early harden process was being difficult. By this problem, in this research some of accelerator/fly ash ratios are used as the one of the variables. This study aimed to determine the contribution of the fineness level of the fly ash as well as the accelerator/flyash ratio to the setting time and its compressive strength of the geopolymer mortar. The sodium hydroxide (NaOH) and sodium silicate ( $\text{Na}_2\text{SiO}_3$ ) as the activator and the accelerator with the 0%, 0.5%, 1%, 1.5% and 2% as the accelerator/fly ash ratios are used in this study. The 3 zones of the fineness level of flyash are being the other variable of the research. The results showed that the fineness level based on fall zone and the accelerator/flyash ratio affect the setting time and compressive strength significantly. The fineness level based on the fall zone increased the compressive strength and tended to produce the shorter setting time. While the higher accelerator/flyash ratio gives the higher compressive strength of geopolymer mortar. The initial setting time and final setting time ranged from 90 minutes to 225 minutes.

## 1. Introduction

The research for partial and full cement substitution in concrete has gained a lot of attention in the past decades. The using of cementitious materials such fly ash as the construction materials is one of the alternatives that demonstrated significantly. Fly ash as a waste material of coal combustion has the abundance availability since the number of industries using coal as a source of energy. Substitution about 10-15% flyash to the cement is commonly being used for concrete. While, using full substitution cement to the fly ash is another form of cementitious material which is called as geopolymer mortar or concrete.

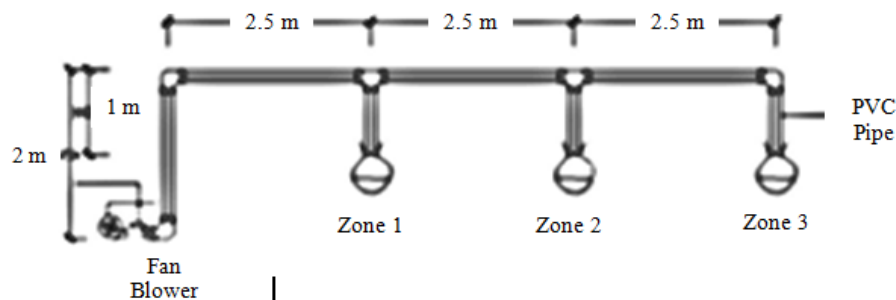
Geopolymer mortar is known as an alkali-activated mortar or inorganic polymer. As a pioneer, Daviddovits [1,2] has presented that geopolymer possess excellent mechanical and physical properties.



Many researchers have proved that the utilization of 100% fly ash in substituting cement as a binder showed good results in concrete production [3,4,5,6]. Natural material based geopolymer, which contains silica and alumina oxide [2], was combined with a type of activator that contains silica that is engineered as an adhesive material through a chemical reaction.

Many results in geopolymer researches [3,5,7] had shown the remarkable properties in strength and performance by using the fly ash with different mixture and test variables. However, the further explorations to develop this study is still needed. Since the physical and chemical properties of the final fly ash based geopolymer mortar product affect the geopolymer matrix, the different sources of fly ash characteristics requires attention. Furthermore, characteristics of the mechanical properties of geopolymer mortar is influenced by the properties of the ingredient of mortar. The fineness level of the cementitious material remarkably affects the mechanical properties of the harden. The early researches [8,9] showed that the fineness level of fly ash significantly influences the mineral composition of the fly ash. The finer filtered fly ash contains the higher silica and alumina. These materials are indispensable in geopolymer concrete since they are synthetic inorganic compound aluminosilicates [2]. That study demonstrated that there was a notably different fineness between untreated fly ash (Zone 0) and the most remote zone (Zone 4). It clearly concluded that there are differences in composition of the fly ash for each level of fineness.

Still, the different fineness level of fly ash in the geopolymer mortar was investigated in this study with new composition by using the accelerator material. The setting time of each mixtures was characterized to find out the behaviour of the fresh state of the geopolymer mortar as well as the compressive strength as the mechanical properties of the geopolymer mortar.



**Figure 1.** Fly ash filtering based on the fall zone

## 2. Materials and methods

This research continued the former researches [8,9] which used the treatment flyash as the basic material of geopolymer. Fly ash from coal combustion of PLTU was treated by using the fly ash filtering tools which modified from the former research. The treatment was carried out based on the fall zones of fly ash which are considered to be affected by the fineness of fly ash. The fall zone parameter of fly ash was modified with filtering tool, which is shown in Figure 1, as explained at [8,9]. 5 zones of filtering fly ash used at the geopolymer mortar showed the the relatively identical compressive strength for the zone 4 and zone 5. Therefore, 4 zones is chosen as a fly ash fineness levels variables in this research (zone 0 – zone 3).

The other variable is accelerator/fly ash ratios which consists of 0%, 0.5%, 1%, 1.5% and 2%. All of the variables were compared according to the parameter of setting time and compressive strength.

Five mixtures of geopolymer mortar by using the sodium hydroxide and sodium silicate as the alkaline activator were prepared based on the compositions which were differentiated by the amount of accelerator/flyash ratio and fly ash based on the fall zone. Table 1 shows the mix proportion for 1 m<sup>3</sup> geopolymer mortar using water/fly ash ratio of 0.4.

**Table 1.** Composition of geopolymer concrete

No	Material (kg)	Accelerator Ratio				
		0 %	0.5%	1%	1.5%	2%
1	Fly ash	408	408	408	408	408
2	Sand	652	652	652	652	652
3	Sodium silicate (water glass)	131.3	131.3	131.3	131.3	131.3
4	Sodium hydroxide (potassium)	52.1	52.1	52.1	52.1	52.1
5	Water	163	163	163	163	163
6.	Accelerator (SIKA Viscocrete 3115N)	0	2.04	4.08	6.12	8.16

### 3. Results and discussions

#### 3.1. Setting time

Table 2 shows the initial and final setting time of the geopolymer mortar. Initial setting time shows different mechanism to the final setting time due to the using of the accelerator at each zones. The higher accelerator ratio, the longer time was needed for the initial setting at each zones, while the shorter time was needed for the final setting. The initial and final setting time of mortar geopolymer at zone 0 are about 90-135 miutes and 165-210 minutes respectively. While, those of at zone 1,2,3 are about 90-135 minutes and 150-225 minutes respectively

These results show that the accelerator affected the harden process of geopolymer mortar more easily. As known that one of the problem of geopolymer mortar is the difficulties of harden process with longer time.

**Table 2.** Setting time of geopolymer mortar

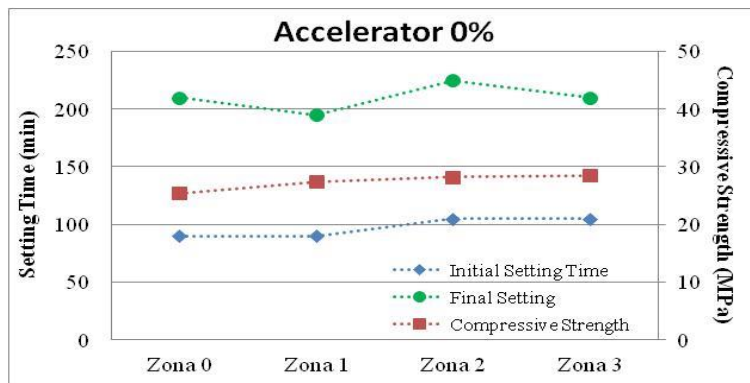
Accelerator	Initial Setting Time (minutes)				Final Setting (minutes)			
	Zone 0	Zone 1	Zone 2	Zone 3	Zone 0	Zone 1	Zone 2	Zone 3
0%	90	90	105	105	210	195	225	210
0.5%	105	90	120	90	210	195	210	195
1%	120	105	105	105	195	180	210	195
1.5%	135	120	135	120	180	165	180	165
2%	135	105	135	120	165	165	165	150

#### 3.2. Compressive strength

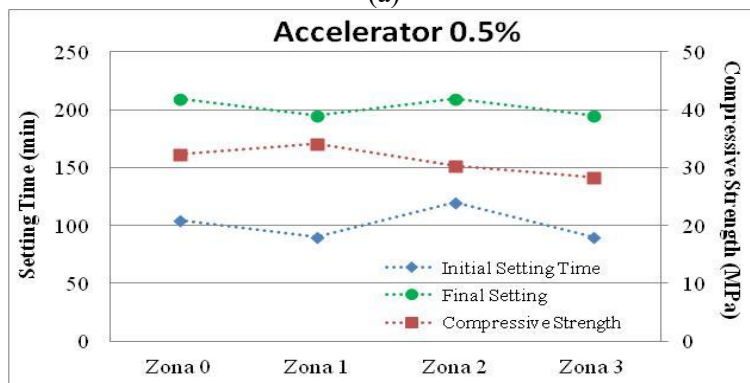
Table 3 shows the compressive strength of the geopolymer mortar. The compressive strength according to the accelerator/fly ash ratio at each zone shows different trend. At zone 0,1 and 2, the maximum compressive strength is shown at the 0,5% of the accelerator/fly ash ratio . While at zone 3, the maximum compressive strength is shown at the 1.5% of the accelerator/fly ash ratio.

**Table 3.** Compressive strength geopolymer concrete

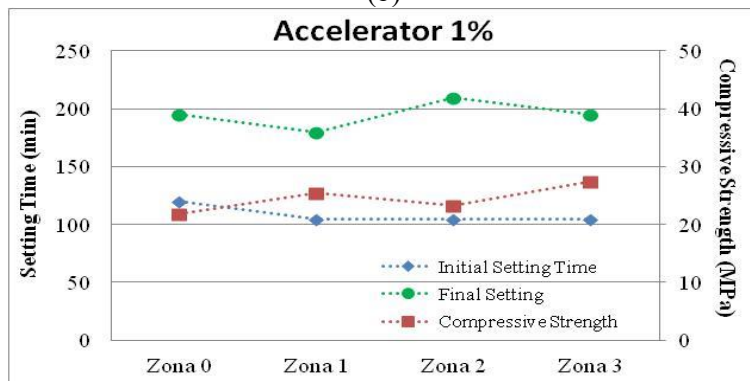
Accelerator	Compressive Strength (MPa)			
	Zone 0	Zone 1	Zone 2	Zone 3
0%	25	27	28	28
0.5%	32	34	30	28
1%	22	25	23	27
1.5%	26	29	30	32
2%	21	24	25	30



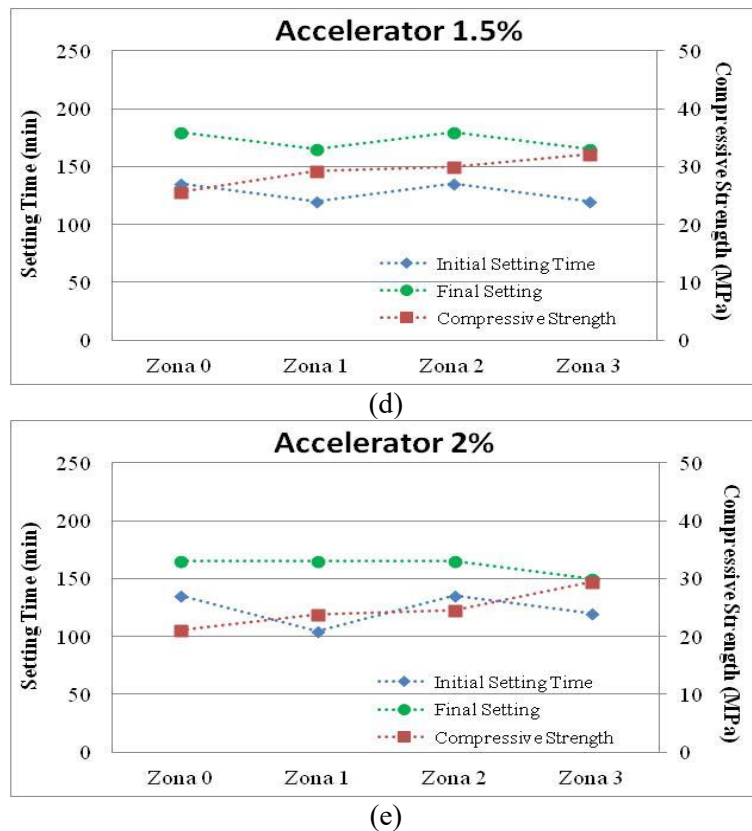
(a)



(b)



(c)



**Figure 2.** Setting time and compression strength

Figure 2(a)-2(e) describe the comparison of initial setting time, final setting time and compressive strength of geopolymer mortar. Those graphs indicate that there is a relationship trend between compressive strength and setting time. The higher compressive strength is showed at the higher initial setting time and the lower final setting time. This phenomenon shows that the higher compressive strength needs the longer initial setting time and the faster final setting time.

#### 4. Conclusions

From the present study, the following conclusions can be drawn :

- The fineness level based on the fall zone as well as the accelerator/flyash ratio affects the setting time and compressive strength significantly.
- The fineness level based on fall zone increases the compressive strength and tends to fast the setting time on the binder.
- The higher accelerator/flyash ratio results in a higher compressive strength of geopolymer mortar.
- The initial and final setting time time which ranged from 129 minutes to 270 minutes shows that longer initial setting time and faster final setting time produce the higher compressive strength.

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### **Acknowledgments**

This paper was based on a work supported by Research Program of Penelitian Unggulan Perguruan Tinggi (PUPT) 2018. The authors would like to acknowledge support provided for this project.