

The High Temperature Influence on Geopolymer Fly Ash Mixture's Compressive Strength with Industrial Waste Material Substitution.

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Abstract

This research aimed to figure out the influence of fly ash mixture from the industrial waste at the temperatures of 150°C, 450°C, 750°C viewed from the strength and resistance of geopolymer paste. As a result, cement will be substituted by industrial waste like fly ash. This experimental research was conducted on the mix design of geopolymer concrete which was made by dimension with 2.5 cm in diameter and 5 cm in height from four mixture composition of fly ash and industrial waste i.e. 100% fly ash, 50% fly ash+50% bottom ash, 50% fly ash+50% sandblast, and 50% fly ash+50% carbide waste. Each mixture was tested in terms of porosity and compressive strength.

In conclusion, in the mixture of 50% fly ash+50% Sandblast and 50% fly ash+50% bottom ash in 12 molar, 1.5 activator comparison can be used to substitute fly ash at high temperature. Meanwhile, the mixture of 50% fly ash+50% carbide waste in 8 molar, 0.5 activator comparison has very small strength remaining if it is compared to the mixture of fly ash and other industrial waste (Bottom ash and Sandblast). The performance of mixture paste of 50% fly ash+50% carbide waste was very vulnerable after being burnt. Consequently, it cannot be used as the main structure at high temperature.

Keywords: geopolymer, fly ash, industrial waste, high temperature.

1. Introduction

Fire can strike at any type of buildings, ranging from home residences to high rise buildings. Considering fire strike based on the building type, home residence was the number one to have a high risk of fire strike with the total of 65,6% occurrences followed by 13,8% of industrial building and 20,7% of general building respectively [1]. The building's high temperature from the fire strike could decrease the concrete's compressive strength [2]. This situation could lead into various different structural damage, with the worst case of concrete cracking [3] which make it visible to see its steel confinement. In addition, the catastrophe damage caused by the fire strike could also showed the peeling effect in which we could see the segregation of cement paste and



aggregate, making the concrete lost its cohesiveness with binders and aggregates [4]. During this time, cement paste was compressed while the aggregate will swell, causing crack on concrete which can lower the concrete quality. Another reason to conduct this study was to eliminate the use of Portland cement. Recently, there is a dispute among the environment experts about the use of Portland cement as construction material. The environment experts showed a serious concern on the carbon foot print produced during the Portland cement production which could worsen the climate change. During the cement production, the kiln need to reach 1400°C in order to produce 1-ton cement, during the process it emit 0.55 ton of CO₂[6]. This fact reminded us to continue to find other alternative for Portland cement considering its danger to the nature. One of the alternative could be found by making geopolymer.[7-12]. Geopolymer concrete is a modern concrete which used natural binder rich in silica and alumina [13]. The silica and alumina content need to be dissolved with alkali solution in order to produce chemical reaction which later on used as the binder for the aggregate. In addition, there are other materials from coal burning waste material to use for geopolymer concrete called fly ash. There are also numerous of other resource of waste material to substitute the use of Portland cement in geopolymer concrete. Fly ash is a coal burning waste material. Each fly ash has its own distinctive content and varied in each place. This might happen due to the different resource and process used during the production. Therefore, it is hard to generalize all fly ash quality. This study will explain more on the influence of geopolymer pasta made from industrial waste in reducing the use of burned fly ash. Therefore, a new alternative will be found to substitute the use of Portland cement from industrial waste like fly ash. The fly ash was aimed to substitute the use of Portland cement in conventional concrete.

2. Research Method

The research method used in this study was based on the laboratory experimental. The source material of fly ash and bottom ash was collected from steamed power plant (PLTU) Paiton, Probolinggo. While the sandbasting (silica fume) waste was collected from PT. Swadaya Graha, Gresik. The carbide waste materials were collected from PT. Z.

During the research, SEM-EDX, XRD (X-Ray Diffraction) and XRF (X-Ray Fluorescence) were used to determine the chemical composition of each material. While the alkali solution activator used in this study was natrium silicate (Na₂SiO₃) and natrium hydroxide (NaOH) with molarity of 12M for 100% fly ash mixture, 50% fly ash+ 50% bottom ash, and 50%fly ash + 50% sandblast. In addition, we also use 8M for the mixture of 50% fly ash + 50% carbide waste.

The sample used in this study was made from a cylinder with diameter of 2,5 cm x 5 cm. The curing sample age was determined as 28 days and 56 days which was burned at the temperature of 150°C, 450°C and 750°C for 2 hours. The compressive strength test for the cylinder was done at ITS structure lab Surabaya.

Table 1. The Composition of Materials And Sample Code

Code	Notes	Composition	
		74% of Materials	26% of Activator
FA 12-1.5	100% fly ash	74%	
BF 12-1.5	50% fly ash+50% bottom ash	50% dari 74%	26%
SF 12-1.5	50% fly ash+50% sandblast	50% dari 74%	
LKF 8-0.5	50% fly ash+50% limbah karbit	50% dari 74%	

3. Result and Discussion

3.1 Result and Discussion

Some of the material test results can be seen in Figure 1,2,3, and 4.

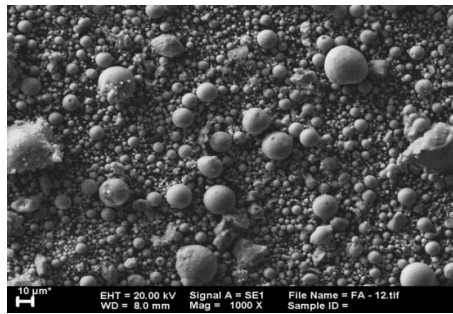


Figure 1. Fly Ash 1000x Zoom

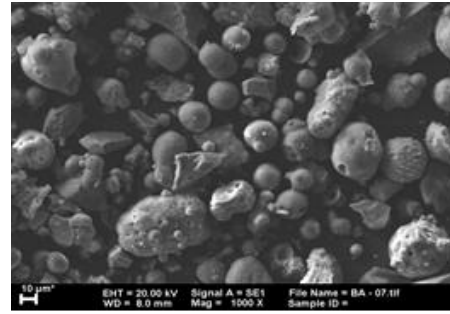


Figure 2. Bottom Ash 1000x Zoom

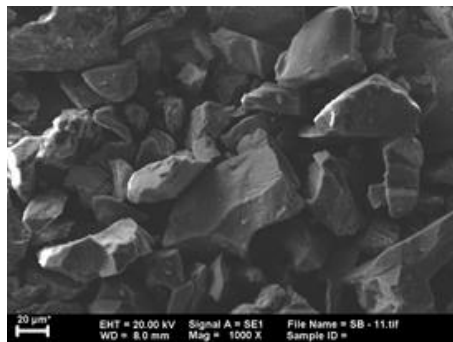


Figure 3. Sandblasting Waste Material 1000x Zoom

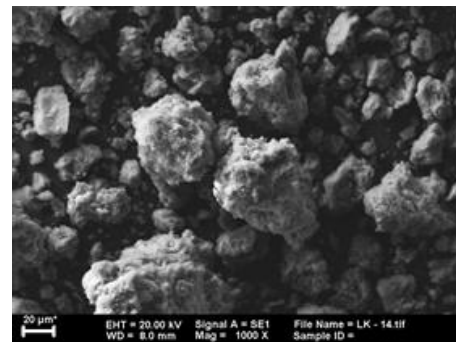


Figure 4. Carbide Waste 1000x Zoom

If we look at the content test from Scanning Electron Microscopy (SEM) above, we could see that fly ash tends to have a round and solid shape. While bottom ash showed that it has more oval, bigger shape and has more pores compare to fly ash. This fact has made bottom ash has less compressive strength compare to fly ash and sandblast even though bottom ash has more SiO_2 content. Sandblast material has a polygonal and solid shape. While carbide waste material has a fragile-look and abstract shape. Every particle shape on each material will affect the cohesiveness and influence the inter-locking force.

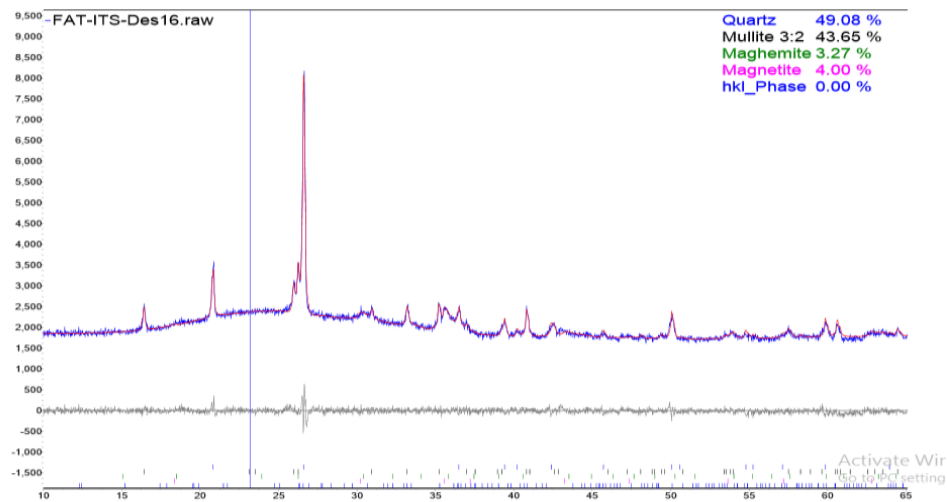


Figure 5. XRD Test Result-Fly Ash

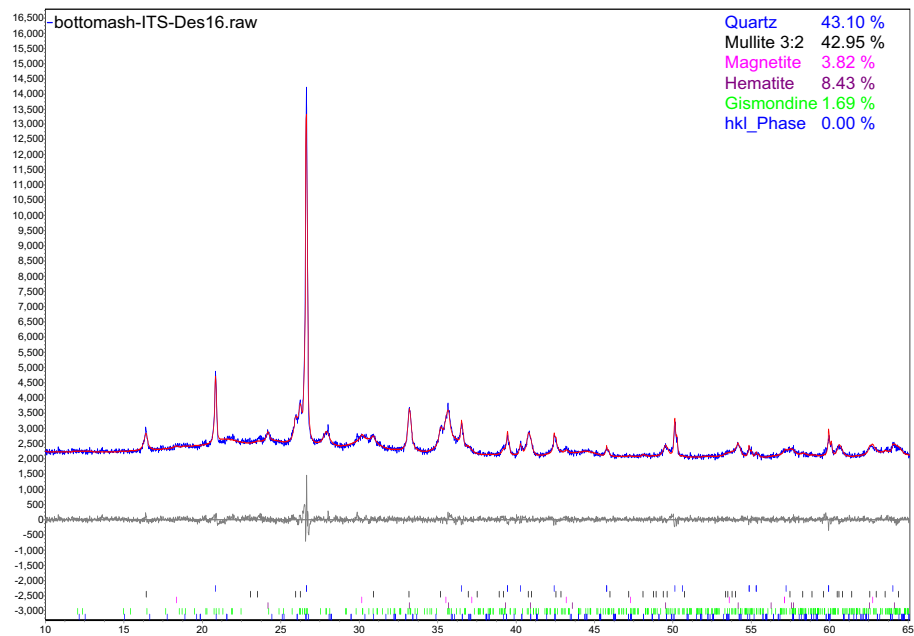


Figure 6. XRD Test Result -Bottom Ash

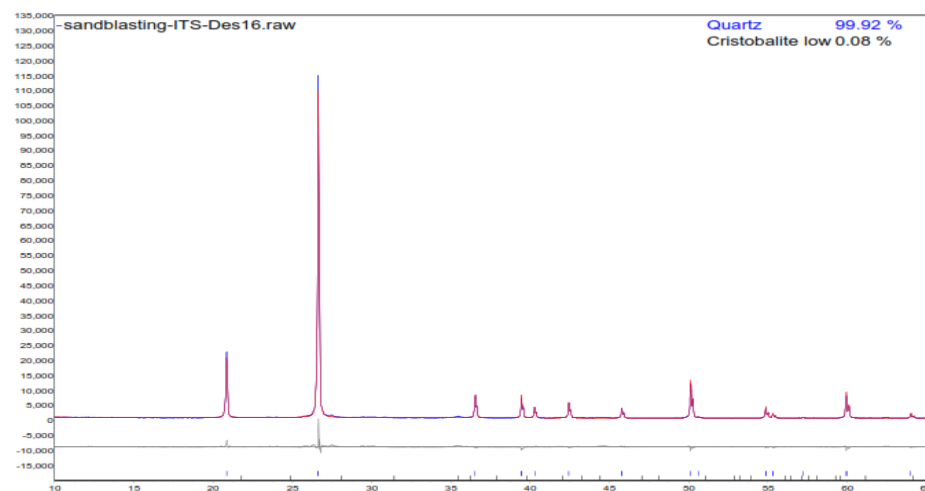


Figure 7. XRD Test Result – Sandblasting Waste Materials

Table 2. XRF Material Test Result

NO	Chemical Oxide	Fly Ash	Carbide Waste	Bottom Ash	Sandblasting
1	Al ₂ O ₃	24.25	2.01	2.93	22.01
2	SiO ₂	47.10	3.91	89.91	49.53
3	Fe ₂ O ₃	16.07	0.87	4.71	18.80
4	CaO	5.83	91.48	0.73	4.56
5	MgO	2.62	0.23	0.16	1.98
6	K ₂ O	1.64	0.07	0.68	1.12
7	TiO ₂	1.16	0.14	0.28	1.15
8	Na ₂ O	0.65	0.72	0.08	0.39
9	P ₂ O ₅	0.19	0.02	0.02	0.13
10	SO ₃	0.21	0.27	0.03	0.07
11	Others	0.29	0.27	0.46	0.26
Total		100.00	100.00	100.00	100.00

According to XRF test, it is noted that the fly ash used in this study has more than 70% content of Si + Al + Fe and less than 10% content of CaO (5,83%). Therefore, the used fly ash was considered as F class fly ash based on ASTM C 618-84. Considering the chemical content on each material (Table 4.7), fly ash and sandblast has SiO₂ content twice more as Al₂O₃. While bottom ash has more SiO₂ content than Al₂O₃. Carbide waste material has the most CaO among other with the total percentage of 91,48 %. In addition, Carbide waste material also has the least compressive strength among other materials. These facts have supported the theory of geopolymer bond whereby Al and Si combined with NaOH as activator to form a strong geopolymer bond

4. Analysis and Result of Compressive Strength

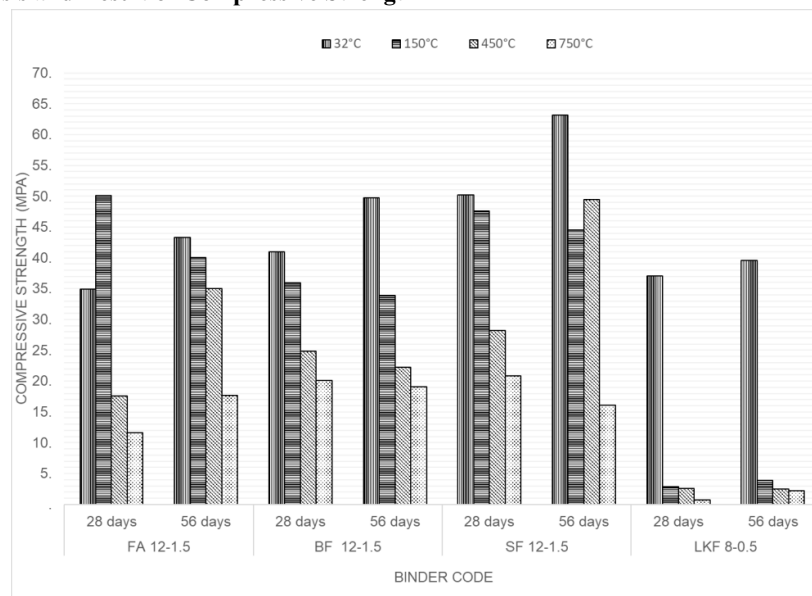


Figure 8. Result of Compressive Strength

According to Figure 8, the highest compressive strength gained at the 100% fly ash composition, reaching its strength at 50,11 MPa under the heating temperature of 150°C and followed by 28 days of setting time. While the least compressive strength gained at the combined carbide waste material with fly ash composition, reaching its strength at 0.75 MPa under the heating temperature of 750°C and followed by 28 days of setting time. The heating temperature observation at 150°C and 28 days of setting time showed a better compressive test result than those for 56 days for all geopolymer pasta composition except the composition of 100% Fly Ash + 100% carbide waste material. While the heating temperature observation at 450°C showed that only 100% Fly Ash + 100% Bottom Ash and 100% Fly Ash + 100% carbide waste material compositions have more compressive strength at 28 days of setting time than those in 56 days. The heating temperature observation at 750°C showed that only 100% Fly ash + 100% Sandblast and 100% Fly ash + 100% Bottom Ash compositions have a good compressive strength at 28 days of setting time.

5. Conclusion

Based on the conducted research, it could be concluded that:

1. The higher the temperature set, the less compressive strength gained and the bigger porosity for geopolymer pasta. Unless the composition changed into 50% Fly ash + 50% Sandblast with 56 days of setting time heated at the temperature of 450°C. this composition will resulted into a higher compressive strength than 150°C heating temperature.

2. The highest compressive strength was obtained at the composition of:
 - 50% fly ash + 50% sandblast, heated at the temperature of 150°C. resulted in 47.57 MPa compressive strength.
 - 50% fly ash + 50% sandblast heated at the temperature of 450°C resulted in 49.50 MPa compressive strength.
 - 50% fly ash + 50% sandblast, heated at the temperature of 750°C resulted in 20.81 MPa compressive strength.
3. Sandblast and fly ash materials have twice more SiO₂ content as Al₂O₃ and has a good compressive strength at high temperature. These facts have supported the theory of geopolymer bond whereby Al and Si combined with NaOH as activator to form a strong geopolymer bond
4. Based on SEM test, it is noted that fly ash particle has smaller rounded and more solid shape compare to bottom ash. While sand blast seems to have a polygonal and solid shape. These facts will determine each material's compressive strength.
5. The advantage and disadvantage of each composition based on the compressive strength and porosity are:
 - 50% Fly ash + 50 % Sandblast composition produce the best compressive strength and the least porosity at each heating temperature. Yet, it has inconsistency of compressive strength towards the vary heating temperature.
 - 50% Fly ash + 50 % Bottom ash has a consistency fall in compressive strength due to the fall in heating temperature. In addition, it also has a fair compressive strength compared to the other sandblast substitution material.
 - 50% Fly ash + 50 % carbide waste material have no advantage compare to other materials substitutes due to its bad compressive strength consistency and porosity.
6. Sandblast and bottom ash materials could be used to substitute fly ash for geopolymer pasta which resisted in high temperature.

6. Reference

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