ANALYSIS OF MICROSTRUCTURE OF FOAMED CONCRETE WITH VARIATION CURING TEMPERATURE AND FLY ASH

by Saloma Hasyim

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ANALYSIS OF MICROSTRUCTURE OF FOAMED CONCRETE WITH VARIATION CURING TEMPERATURE AND FLY ASH

Saloma, Hanafiah and Dea Risti Andani
Department of Civil Engineering, Faculty of Engineering, Sriwijaya University, Indonesia

ABSTRACT

Lightweight foamed concrete is one of the recent innovation of concrete technology in civil engineering which can be used as environmental friendly material and suitable for the thermal-insulation. Foam concrete contains fine sand, cement, water, and foam without using coarse aggregate. The experiment is variating curing temperature and analyzing the impact towards characteristic of foam concrete by adding 0% and 10% fly ash from total mass of applied cement. Slump flow test and setting time test are conducted for fresh concrete testing. Foam concrete characteristics which analyzed are density, compressive strength, and porosity. The test is using 10 x 20 cm cylinder concrete sample. Density test and compressive strength test is conducted by the age of 7, 14, and 28 days, while porosity test is conducted by the age of 28 days. This paper reports results of the impact of curing temperature towards physical and mechanical characteristic of foam concrete which cured by ambient and high temperature (60°C, 90°C, and 120°C).

Keywords: *Foamed Concrete*, *fly ash*, variation of temperature, physical and mechanical properties.

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1. INTRODUCTION

Lightweight concrete is one of the technological innovations of concrete that has been widely examined. This is because when compared to conventional concrete, lightweight concrete has a density that is smaller so that it can provide a reduction in load on buildings is made. One of a kind of lightweight concrete is foamed concrete with density between 300 – 1850 kg/m^3 (Jalal, 2017). Foamed concrete is a type of concrete made mixed results of cement, water, aggregate, and chemicals maker of foam (foaming agent) distributed in it, as well as mutually bound to each other.

Foamed concrete is a type of porous concrete. it can be treated as aerated concrete where the foam bubbles are formed through open air mechanical stirring using concrete hand mixer, after than an obtained foam are mixed into the water-cement slurry to make light weight concrete. Basically foamed concrete is a mixture of cement, fly ash, sand, water and foaming agent. When the foaming agent is diluted with water and air, further it is mixed into the cement slurry. The water-cement slurry sets around the foam bubbles and this paste have sufficient strength to maintain its shape around the bubbles, it entraine 30-35% of air by volume into the concrete, as result the low density foam concrete is obtained. It may also float into the water (Saloma, 2018).

The pre-formed foaming method is used more often than the mixed-foaming method because the foaming agent needs less and has a close relationship between the amount of foaming agent used and the mixed water content (Onprom et al., 2015). The pre-formed foaming method is more economical and easier to process than other methods (Awang et al., 2014). Admixtures are used to improve the characteristics of concrete. Admixtures consist of mineral admixtures and chemical admixtures. In addition to its role as a cement substitution material with its pozolan properties, fly ash also has an effect on the foamed concrete characteristics. The use of large fly ash proportions tends to produce foamed concrete that is formed with high density. Fly ash particles are mostly spherical tiny glass beads. Ground material such as Portland cement is solid angular particles. Fly ash particles provide a greater workability of the powder of the concrete mixture which results in greater workability of the concrete and a lowering of water requirement for the same concrete consistency. According to (Richard et al., 2013) in his research stated that the increase of fly ash substitution to cement can decrease the compressive strength of foamed concrete. This indicates the limitation of the use of fly ash to be substituted in foamed concrete so as not to affect the compressive strength produced. Therefore, the maximum limit for substitution of fly ash in Foamed concrete is 20% of the total cement.

Foamed concrete is formed by a mixture of foaming agent and water then incorporated into foam generator which is further added into the mortar. The stable foam produced pores that are distributed in mortar mixtures. The concentration of foam in the mixture influenced characteristics of foamed concrete. in which the amount of foam influenced the pores formed within determines the compressive strength and the density of foamed concrete. The higher concentration of foam in the mixture increased the porosity is formed (Lee et al., 2014).

The objective of curing is to provide appropriate temperature and humidity conditions to ensure the progress of hydration reactions causing the filling and segmentation of capillary voids by hydration products. Another benefit of curing temperature is the easy process, producing high initial strength, short production cycle, and superior economic benefits. Variation temperature of curing is to obtain a sufficiently high early strength. The characteristic of foamed concrete is influenced by its many pores formed, because its decreased the density of foamed concrete (Kearsley and Wainwright, 2001).

2. METHODOLOGY

Preparing material is is the main thing that has to be done before doing a research. In this research, material used cement of Portland type I (PC), water, fine aggregate and foam to decrease density of concrete. Concrete mix used type 1 cement of Ordinary Portland Cement (OPC), fine aggregate of Tanjung Raja sand that passed the filter No. 16 (1.18 mm), water with the pH 6-8, foaming agent, and fly ash. Foaming agent is raw material to make foam for concrete mix. Foaming agent used synthetic 50% from making volume of concrete with comparison 1:50 (foaming agent: water). The result of fly ash chemical composition can be seen in Table 1.

Table 1 Chemical composition of fly ash

No.	Chemical composition	weight (%)
1.	SiO_2	48.16
2.	Al_2O_3	25.18
3.	Fe_2O_3	2.88
4.	CaO	3.93
5.	MgO	4.32

Mix design foamed concrete was based on ACI 523.3R-93 as standard to determine foamed concrete mix. Mix design foamed concrete can be seen in Table 2.

Table 2 Composition of foamed concrete m^3

Mix design	PC	Fly ash	Water	Sand	Foam	
	(kg)	(kg)	(Liter)	(kg)	Foaming agent (gr)	Water (kg)
SK-1	453.4	0	204	453.4	502.2	25.1
SK-2	408.1	45.3	204	453.4	502.2	25.1
60-1	453.4	0	204	453.4	502.2	25.1
60-2	408.1	45.3	204	453.4	502.2	25.1
90-1	453.4	0	204	453.4	502.2	25.1
90-2	408.1	45.3	204	453.4	502.2	25.1
120-1	453.4	0	204	453.4	502.2	25.1
120-2	408.1	45.3	204	453.4	502.2	25.1

Note 1:1 is cement mix ratio: fine aggregate, foam volume is 500 Liter.

3. RESULT AND DISCUSSION

3.1. Slump Flow

The aim of slump flow was to find out workability of foamed concrete. The result test of slump flow was obtained from value of dissemination diameter of fresh concrete mix vertical and horizontal. Slump flow test was done by comparing used 10% and 0 % of fly ash toward test result of slump flow. In this research, slump flow was used in 2 mix compositions of mix composition for was used fly ash 10 % and 0 % by weight of the cement content. Comparison value of 2 mix compositions toward slump flow test is in Table 3.

Slump flow test which was done in Table 3 and resulted slump flow value about 56 – 60 cm examination result of slump flow showed the biggest slump flow number was in mix composition of used fly ash 10% with value 60 cm whereas the smallest slump flow in mix composition 0% of fly ash with value of 56 cm. Fly ash has become widespread due to their pozzolanic reaction and environmental friendliness these pozzolanic admixtures are used for reducing the cement content in mortar and concrete production so fly ash can increased workability of fresh concrete.

Table 3 The comparison of slump flow test

Mix design	Foam (%)	Slump flow (cm)
Non fly ash	30	56
Fly ash 10%	30	60

3.2. Setting Time

Cement when mixed with water forms paste which gradually becomes less plastic, and finally a hard mass is obtained. In the process of setting a stage is reached when the cement paste is sufficiently rigid to with stand a definite amount of pressure. The time to reach this stage is termed as final setting time. The time at which cement paste loses its plasticity is called initial setting time. The aim of test was to find out initial and final setting time of 2 mix composition was used 10% and 0% fly ash.

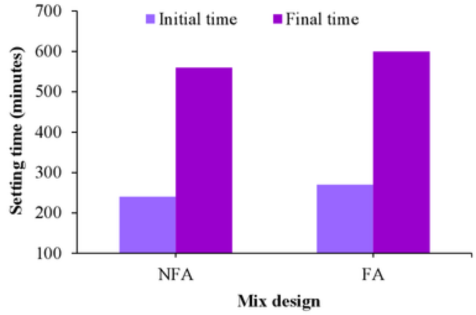


Figure 1 Setting time of foamed concrete with fly ash 10% and 0%

Setting time test which was done in Figure 1 and resulted setting time about 240 – 270 minutes for initial setting time and 560-600 minutes for final setting time. Examination result of setting time showed the longest setting time number was in mix composition of used fly ash 10% with initial time 270 minutes and 600 minutes for final time. The shortest setting time in mix composition 0% of fly ash with initial time 240 minutes and final time 560 minutes.

3.3. Density

Density test was done in concrete of 7, 14 and 28 days. This test aimed to find out the impact of curing with variation temperature towards density of foamed concrete was used 10% and 0 % fly ash.

Figure 2 is test result of concrete density that used fly ash 10% in 7, 14 and 28 days. The testing of concrete's density that cured in ambient and temperature 60°C, 90°C, 120°C. Figure 2 revealed the value of concrete's density of 1622 - 1794 kg/m^3. The biggest value of concrete's density was in 7 days old concrete with curing in ambient of 1794 kg/m^3 and the lowest density was in 28 days old concrete with curing temperature 120°C the value was 1622 kg/m^3.

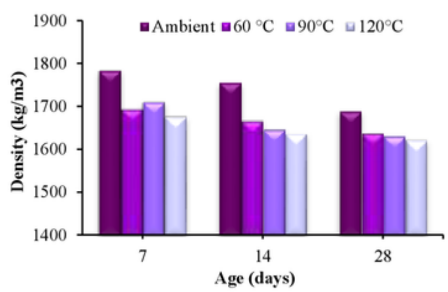


Figure 2 Density of foamed concrete with fly ash 10%

Figure 3 is test result of concrete density that used fly ash 0% in 7, 14 and 28 days. The testing of concrete's density that cured in ambient and temperature 60°C, 90°C, 120°C. It showed the value of concrete's density of 1504 - 1777 kg/m^3. The biggest value of concrete's density was in 7 days old concrete with curing in ambient of 1777 kg/m^3 and the lowest density was in 28 days old concrete with curing temperature 120°C the value was 1504 kg/m^3.

Figure 2 and 3 showed that elevated temperature can decreased density because in temperature 120°C got the lowest value and cured in ambient got the highest density and used fly ash 10% by weight of cement content can increased density of foamed concrete if compared with mix design 0% fly ash.

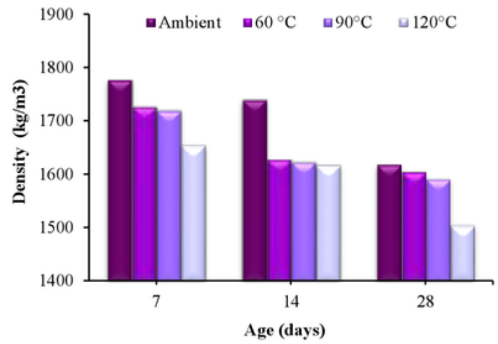


Figure 3 Density of foamed concrete without fly ash

3.4. Compressive Strength

The testing of compressive strength of concrete with comparison of mix composition was used 10% and 0% fly ash which cured in ambient and variation temperature. The test conducted by the age of concrete reached 7, 14 and 28 days. Concrete in 7, 14, 28 days old with comparison used 10% and 0% fly ash which cured in ambient and temperature 60°C, 90°C, 120°C showed the increasing age of concrete with increasing of compressive strength.

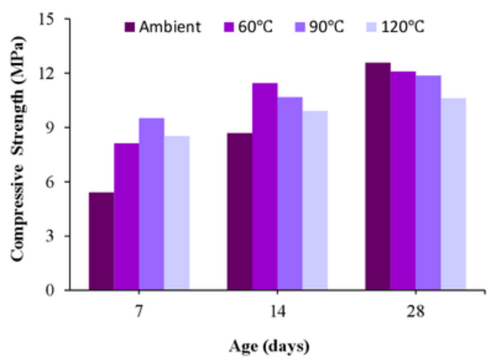


Figure 4 Compressive strength of foamed concrete with fly ash 10%

The result compressive strength test of mix design 10% fly ash that has been done in Figure 4 resulted value of concrete compressive strength about 5.04 – 12.31 MPa. The biggest value of concrete curing with temperature 60°C when age of concrete reached 28 days, 12.31 MPa. In 7 days old concrete the biggest of compressive strength of concrete curing with temperature 90°C with value 9.51 MPa. In 14 days old concrete, the biggest compressive strength of concrete curing with temperature 60°C the value was 11.45 MPa.

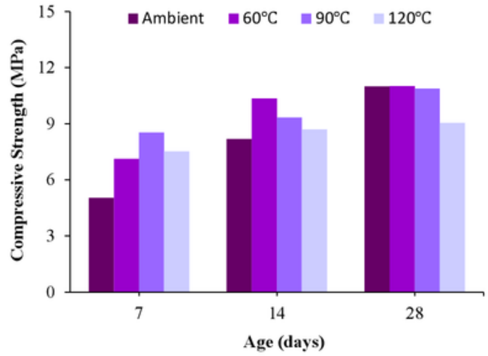


Figure 5 Compressive strength of foamed concrete without fly ash

The testing of concrete compressive strength of mix design 0% fly ash that has been done in Figure 5. Resulted the value of concrete compressive strength about 5.04 – 11.34 MPa. The biggest compressive strength in cured with temperature 60°C when age concrete reached 28 days, the value was 11.34 MPa. In 14 days old concrete, the biggest compressive strength of concrete curing with temperature 60°C the value was 10.35 MPa. In 7 days old concrete the biggest of compressive strength of concrete curing with temperature 90°C with value 8.53 MPa

3.5. Microstructure of Foamed Concrete

Microstructures of testing done by SEM (Scanning Electron Microscope). The test results of SEM 50 x magnification with foamed concrete can be seen on the Figure 6 to 9. SEM samples obtained from testing compressive strength age 28 days. Testing was conducted on a sample of SEM with fly ash and fly ash 0% 10% for variation curing temperature are ambient, 60°C, 90°C and 120°C.

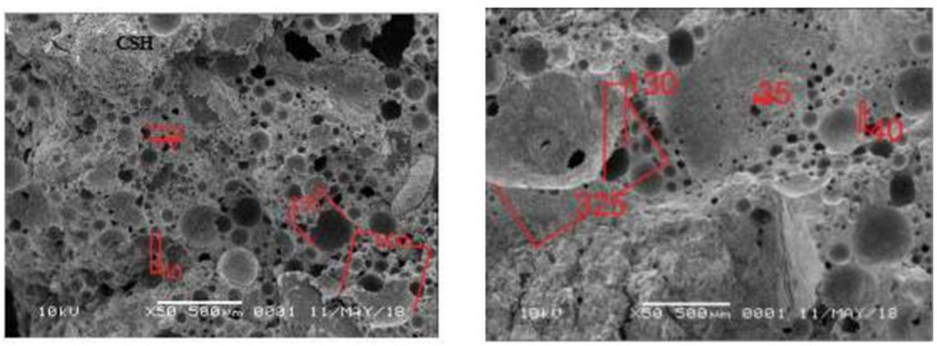
Figure 6(a) SEM photo of foamed concrete is the FC SK-NFA, seen many a pore surrounded by a cement paste (bubble). The resulting bubble spread evenly with the size range 30-600 μm. While there are some porous with a width of 70-255 μm. There were 90 μm in width microcrack. Figure 6(b) SEM photo is the FC SK-FA, porous and bubble spread evenly and looks microcrack with wide less than 50 μm that occurs in the bubble. The distribution of the resulting foamed concrete bubble without substitution of fly ash more compared with substitution of fly ash.

Figure 7(a) SEM photo is foamed concrete FC 60-NFA more pore formed by the results of the concrete using curing temperature of 60°C. The resulting bubble diameter larger than the more uniform size however foamed concrete curing with room temperature, i.e., the range between 76 – 500 μm. There are microcrack of 30-60 μm wide pore formed revolves around 45 - 340 μm. Figure 7(b) SEM photo is FC 60-FA, pore less due to new silica reaction results CSH from fly ash with cement hydration reaction. Wide pore formed revolves around 30 - 310 μm. CSH resulting make the concrete becomes more dense than concrete without substitution of fly ash. The walls of the bubbles are more powerful and stable when compared to the non fly ash concrete.

Figure 8(a) SEM photo is foamed concrete FC 90-NFA, the size of the bubble diameter ranging between 36 - 220 μm. Bubbles that are formed are smaller. This contributes to the high temperatures caused due to the size of the bubble is smaller and much less when compared to the temperature of 60°C. Figure 8(b) SEM photo is FC 90-FA, more dense concrete when compared to FC 60-NFA. The number of bubble more and solid. Bubble sizes ranging between 50 - 215 μm.

Figure 9(a) SEM photo is foamed concrete FC 120-NFA, there are many pore with a small size and a bubble in the range 35-200 μm. Due to the extremely high temperature causes the bubble to become brittle and break. The least amount of bubble caused the concrete to be not solid. SEM showed strong concrete press concrete are low, according to the data of the powerful press foamed concrete FC 120-NFA has strong press the lowest, i.e. 9.05 MPa.

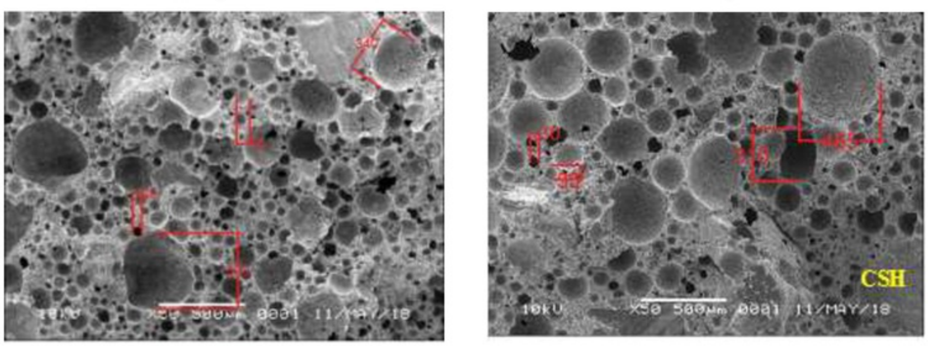
Figure 9(b) SEM photo is FC 120-FA, a bubble generated more solid compared with the test FC 120-NFA. The resulting bubble concrete curing temperature of 120°C becomes smaller and brittle. This is because the temperature used is already too high so many bubble that burst and cause the moisture content in the concrete evaporates and causes the process of hydration does not occur. On concrete temperature curing 120°C produce the lightest type of weight compared to other mixture. The higher the temperature of the curing then the bubble sizes become smaller and fewer. This caused temperature is too high can cause the process of hydration doesn't happen perfectly and concrete experience loss of water due to evaporation. High temperature causes the walls of the bubbles become unstable and break apart so that the effect on the density of the concrete.



(a) FC SK-NFA

(b) FC SK-FA

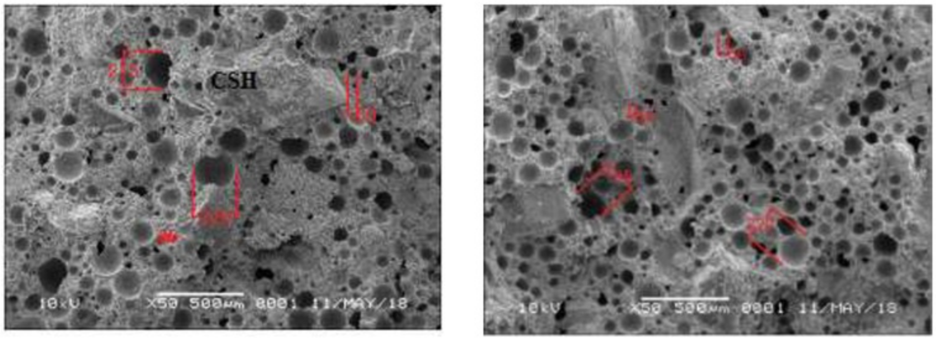
Figure 6 SEM of foamed concrete with ambient curing



(a) FC 60-NFA

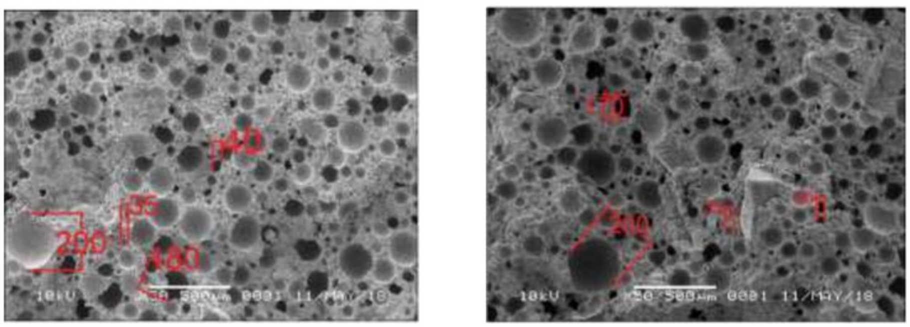
(b) FC 60-FA

Figure 7 SEM of foamed concrete with curing temperature 60°C



(a) FC 90-NFA (b) FC 90-FA

Figure 8 SEM of foamed concrete with curing temperature 90°C



(a) FC 120-NFA (b) FC 120-FA

Figure 9 SEM of foamed concrete with curing temperature 120°C

4. CONCLUSIONS

The conclusion from this research about mechanical and microstructure properties of foamed concrete with curing temperature variation as follow:

1. The effect of curing temperature variations with room temperature, 60°C, 90°C and 120°C on the characteristics and microstructure of foamed concrete, are:
   a. The variation treatment of temperature 90°C and 120°C can increase the strength of the initial pressure of concrete. However, the strength of long-term is lower than the concrete that treated at room temperature.
   b. The optimum curing temperature was 60°C because it was able to increased the compressive strength of 7, 14 and 28 days concrete, and produced the highest compressive strength of 12.31 MPa.
   c. Concrete that curing at a temperature of 120°C has the lowest compressive strength at 28 days of concrete that is 10.61 MPa.
   d. Curing with a temperature of 60°C, 90°C, 120°C is able to reduce the specific gravity of concrete compared to concrete that curing at room temperature. The higher the maintenance temperature used, the lower the specific gravity of the concrete produced.
   e. The results of microstructure testing using SEM show that the higher the curing temperature the smaller the bubble will produce. And the resulting pores become

larger and irregular. This is because the temperature is too high to cause the wall on the bubble becomes brittle until it eventually becomes broken.

f. Temperatures that are too high also reduces the weight of the type and density of concrete because of the hydration process that does not happen perfectly as a result of the extremely high temperatures cause the water in the concrete experience of evaporation in large quantities.

2. The influence of the used of fly ash on the mechanical and microstructure properties of foamed concrete, are:
   a. The use of fly ash produces maximum compressive strength of concrete at the age of 28 days is 12.31 MPa.
   b. The use of fly ash affects the weight of the concrete so that the weight of the concrete is higher than the non fly ash concrete.
   c. The use of fly ash improves slump flow, workability and slows the setting time of foamed concrete.
   d. The use of fly ash affects concrete density. Concrete using fly ash produces more solid concrete than concrete that does not use fly ash.
   e. The use of fly ash resulted in a bubble spread evenly and homogeneous in concrete compared to non fly ash concrete.

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