The Effect of Foam and Fly Ash Percentage on Properties of Foamed Concrete

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The Effect of Foam and Fly Ash Percentage on Properties of Foamed Concrete

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Abstract. Foamed concrete is a lightweight concrete innovation that utilizes foam materials to be added to concrete mixtures aimed at reducing the concrete's density. This research uses foam percentage of 30%, 40%, 50%, and 60% of the total mixture's volume. The percentage of fly ash substitution by 0%, 10%, 15%, and 20% of the total weight of cement. The purpose of this research is to analyze the effect of foam and fly ash percentage on the properties of foamed concrete. Tests include slump flow, setting time, density, and compressive strength. The maximum value of slump flow test result is on 30V-20FA mixture at 69.50 cm. The result of time setting test shows the fastest initial setting time and final setting time are 275 minutes and 600 minutes on 30V-0FA mixture. Meanwhile, the slowest initial setting time and final setting time are 405 minutes and 790 minutes on 50V-20FA. The lowest density is 901.27 kg/m^3 on 60V-20FA mixture meanwhile the highest density value is 1,487.90 kg/m^3. The optimum compressive strength value is 8.57 MPa on 30V-10FA mixture with 10% of fly ash percentage.

INTRODUCTION

Foamed concrete is a concrete composed of cement, aggregate, water and foaming agent that produce gas bubbles that are distributed in the mixture. This gas bubble plays a role in entrapping air which then loosens when the concrete hardens leaving pores on the surface as well as inside of the concrete. The number of pores in the concrete is what caused foamed concrete having lightweight density. Foamed concrete has several advantages including lightweight [1], fire resistance and high workability. The use of foamed concrete as wall coverings reduces the building's dead weight by 32% compared to conventional bricks [2]. The density of foamed concrete ranges from 300-1,700 kg/m^3 [3].

The properties of foamed concrete are strongly influenced by existing pores. With the increasing amount of pores being formed, the density of foamed concrete is decreasing. It also applied on compressive strength. With the increasing number of pores in foamed concrete, the compressive strength is decreasing. The pores formed in foamed concrete are influenced by the cement water factor and density of the concrete [4]. The higher water cement factor, then the bubbles formed in the mixture tends to be larger and fused, causing the pores to be formed larger.

Foaming agent produces foam which is then added to the concrete mixture to form foamed concrete. Foaming agent is a material that when added to the water to form air bubbles. The bubbles that are formed depend on the type of foaming agent that is used. Foaming agent can be categorized based on the basic material into two parts, synthetic and protein. Foaming agents with protein materials are often used for the manufacture of low-density concrete, while the use of foaming agents with synthetic materials is used to produce foamed concrete with higher specific gravity. Air bubbles generated by foaming agents with synthetic materials have a much smoother form than protein-based foaming agents. However, it produces a lower compressive strength concrete [5].

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There are two methods of foamed concrete production: mixed foaming method and pre-foaming method. In the mixed foaming method, the foaming agent materials are mixed with other materials and form the air bubbles during the mixing process. In the pre-foaming method, foam is produced separately then being added to the mortar. This method is easily controlled and being done [6].

The higher percentage of foams in the mixture can significantly reduce the density and compressive strength of concrete [7]. The variation of foam concentration in the foamed concrete mixture shows a decrease in compressive strength with the increment of foam concentration in the mixture [8]. The foam concentration in the foamed concrete mixture has a significant impact on the density and compressive strength. In addition to the effect of compressive strength and density of concrete, the concentration of foam in the mixture also determines the pore formation in foamed concrete [9]. The higher the concentration of foam in the mixture, the higher the porosity. However, it should be noted that the higher percentage of foam could form capillary pores.

Fly ash is the waste material generated by coal combustion. Fly ash is often used in the production of concrete for various mixes and compositions. Fly ash is used as a substrate material of cement because of its pozzolanic characteristic that is similar to cement. Fly ash may also act as a filler because of its fine grain. The fly ash should have a low carbon content and are reactive to provide advantages when added to the concrete mixture [10].

Fly ash is divided into 3 types of fly ash class N, class C and class F [11]. In some research fly ash has been proven as pozzolanic material that could replace cement in the mixture while also giving advantages to the concrete's properties. Higher levels of fly ash can provide an increase in compressive strength, but it depends on the composition of fly ash and its reactivity [12]. Addition of fly ash can also reduce the volume of pores in the concrete because of its nature as a filler. The use of fly ash as an added material needs to be estimated precisely because the excessive use of fly ash would give a disadvantage to the concrete. In their research concluded that foamed concrete with fly ash substitution to cement took longer to reach the ultimate strength [8]. However, the ultimate strength could be higher than the mixture that only uses cement. Compressive strength of concrete with fly ash substitute is higher at the longer concrete age [13-15].

MATERIALS AND METHODS

This research used a variation of foam percentage with value of 30%, 40%, 50%, and 60% to the total volume of the mixture. The percentage of fly ash substitution used are 0%, 10%, 15%, and 20%. The density and compressive strength were tested on10 x 20 cm cylindrical test objects at 7, 14 and 28 days of concrete age. Foamed concrete is composed of cement, water, fine aggregate, fly ash, and foaming agent. The type of cement used is OPC (Ordinary Portland Cement). The fine aggregate used is natural sand from Tanjung Raja region, and foaming agent used is in liquid form and synthetic based surfactant. This researched used fly ash from PT Bukit Asam. The test of fly ash composition was done in PT Semen Baturaja Laboratory, Palembang. Fly ash SEM test conducted at Survey and Geology Center Bandung, West Java with 1000x magnification. The SEM result of fly ash is shown in Figure 1 and the composition of fly ash is shown in Table 1.

The mix design used foam percentage of 30%, 40%, 50%, and 60% of the total volume. The variations of fly ash percentage used are 0%, 10%, 15%, and 20% of the total weight of cement. Foamed concrete mix proportion is shown in Table 2.

TABLE 1. The Composition of Fly Ash.

No.	Chemical elements	Weight (%)
1.	Silicone Dioxide (SiO_2)	52.96
2.	Aluminum Oxide (Al_2O_3)	27.14
3.	Iron (III) Oxide (Fe_2O_3)	5.80
4.	CalciumOxide (CaO)	5.30
5.	Magnesium Oxide (MgO)	2.06
6.	Sulphur Trioxide (SO_3)	1.12

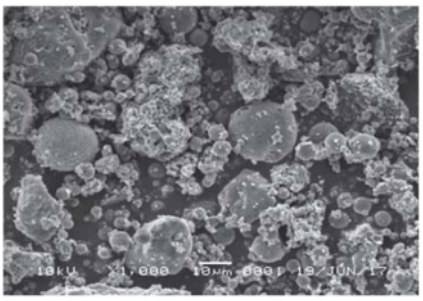

FIGURE 1. Fly ash SEM.

TABLE 2. Mix Proportion of Foamed Concrete of 1 m^3.

Label	OPC (kg)	Fly ash (kg)	Water (kg)	Sand (kg)	*Foam solution*	
					FA *(gr)*	Water (kg)
30V-0FA	618.0	0.0	278.1	618.0	483.8	14.5
30V-10FA	556.2	61.8	278.1	618.0	483.8	14.5
30V-15FA	525.3	92.7	278.1	618.0	483.8	14.5
30V-20FA	494.4	123.6	278.1	618.0	483.8	14.5
40V-0FA	535.6	0,0	241.0	535.6	645.1	19.3
40V-10FA	482.1	53.5	241.0	535.6	645.1	19.3
40V-15FA	455.3	80.3	241.0	535.6	645.1	19.3
40V-20FA	428.5	107.1	241.0	535.6	645.1	19.3
50V-0FA	453.3	0.0	204.0	453.3	806.4	24.1
50V-10FA	408.0	45.3	204.0	453.3	806.4	24.1
50V-15FA	385.3	68.0	204.0	453.3	806.4	24.1
50V-20FA	362.7	90.6	204.0	453.3	806.4	24.1
60V-0FA	371.0	0.0	166.9	371.0	967.7	29.0
60V-10FA	333.9	37.1	166.9	371.0	967.7	29.0
60V-15FA	315.4	55.6	166.9	371.0	967.7	29.0
60V-20FA	296.8	74.2	166.9	371.0	967.7	29.0

RESULTS AND DISCUSSIONS

Results

Fresh Concrete

Slump Flow Test

The result of the slump flow test isshown in Fig. 2 and Fig. 3. Slump flow test results ranged between 50-70 cm. The maximum slump flow value is 69,50 cm. Based on Fig. 2, the increasing value of foam percentage, the lower slump flows value gets. This is due to the nature of foam that tends not to flow like water and adding consistency to the mixture instead. Fig. 3 shows that the increasing percentage of fly ash substitution to cement, the greater the slump flow value. This is due to the fly ash's microstructure which has granules that tend to be rounded providing minimal friction on other materials,producing a high workability fresh concrete.

Setting Time Test

The result of time setting test based on the percentage variation of foam is shown in Figs. 4 and 5. Testing time setting is done to get the initial setting time and final setting time. Initial setting time rangedbetween 275 - 405 minutes and final setting time ranged between 600 - 790 minutes. Based on Fig. 4 and Fig. 5, the greater the percentage of foam added to the mixture causes the mixture to slowly harden. The result of the time setting test based on the percentage variation of fly ash is shown in Figs. 6 and 7. Based on Figs. 6 and 7, the increment of foam percentage is affecting setting time. The greater percentage of fly ash substitution to cement caused longer binding time. This is due

to the decreased amount of cement replaced by fly ash causing reduced heat hydration which causes the slower concrete mix to harden.

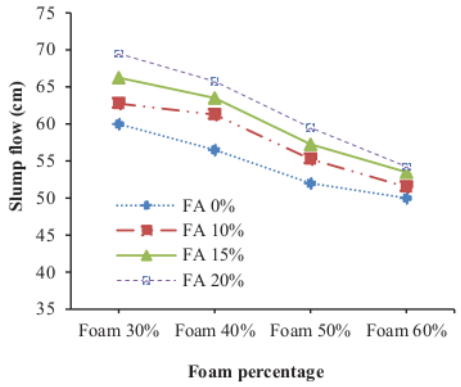

FIGURE 2. The Effect of Foam Percentage on Slump Flow.

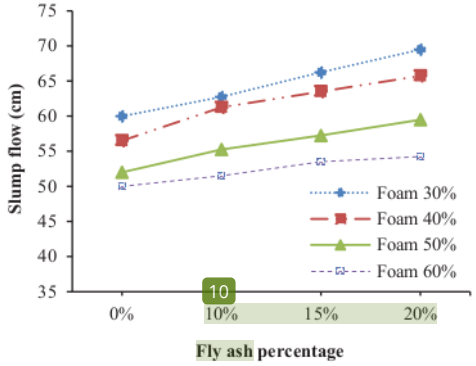

FIGURE 3. The Effect of Fly Ash Percentage on Slump Flow.

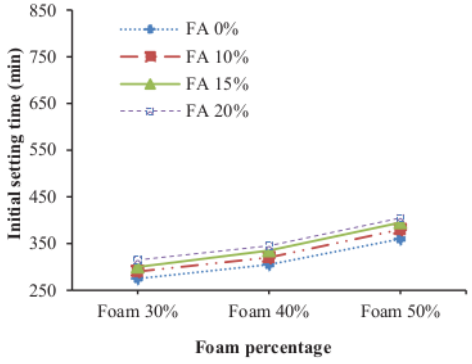

FIGURE 4. The Effect of Foam Percentage on Initial Setting Time.

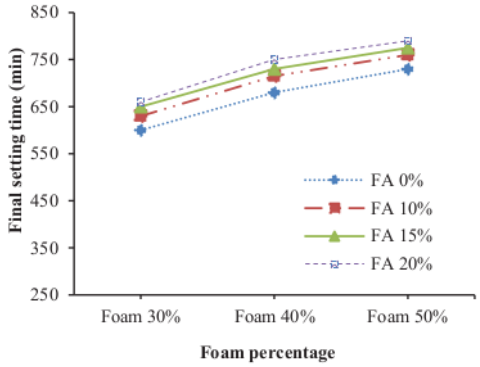

FIGURE 5. The Effect of Foam Percentage on Final Setting Time.

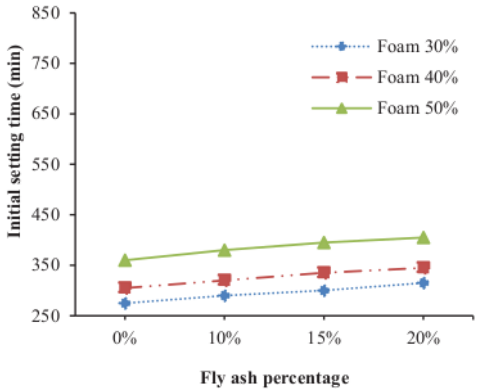

FIGURE 6. The Effect of fly Ash Percentage on Initial Setting Time.

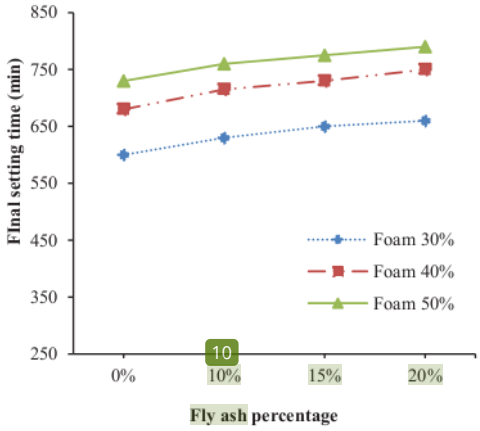

FIGURE 7. The Effect of fly Ash Percentage on Initial Setting Time.

Hardened Concrete

Density

The results of the density tests based on the effect of foam percentage are shown in Fig. 8 for 7-days concrete, Fig. 9 at 14-days concrete, and Fig. 10 for 28-days concrete. The lowest density yielded at 60V-20FA mixture with a value of 901.27 kg/m^3.Meanwhile the highest density is 1,487.90 kg/m^3 on 30V-0FA. Density of foamed concrete is greatly affected by percentage of foam being added to the mixture and percentage of fly ash substitution to cement.The increase of foam percentage decreasedensity resulted significantly on all mix design in Fig. 8. This is due to number of pores formed by foamthat was being added. The increasing number of pores resulting in lower density of foamed concrete.

Fig. 9 shows that an increase in the percentage of foam indicates a decrease in the specific gravity of the concrete. An increase in the foam percentage from 30% to 40% on 15% fly ash percentage indicates a decrease in concrete's density from 1,494.90 kg/m^3 to 1,268.15 kg/m^3. The percentage of density change that occurred was -15.17%. The largest percentage change occurred in the mixture of 15% fly ash and 60% foam of -36.21% with a value of 933.76 kg/m^3.

Based on Fig. 10, an increase in foam percentage decrease the density on all mixtures. An increase in the percentage of foam from 30% to 40% in the 15% fly ash percentage decrease the density from 1,445.22 kg/m^3 to 1,210.83 kg/m^3 with a decrease percentage of -16.22%. The largest density was produced by a mixture of 30V-0FA with a value of 1,487.90 kg/m^3, while the smallest density was produced by 60V-20FA mixture with a value of 901.27 kg/m^3. The increase in foam percentage decrease the density of concrete. This is because the foam added to the concrete mixture traps air and as the concrete hardened leaving pores. The presence of pores causes a decrease in the density of concrete. The effect of fly ash percentage on density is shown in Fig. 11 for 7-days concrete, Fig. 12 for 14-days concrete, and Fig. 13 for 28-days concrete.

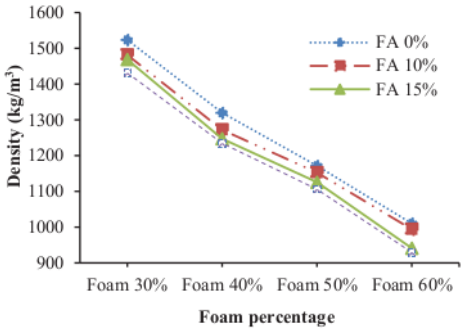

FIGURE 8. The Effect of Foam Percentage on Density at 7 Days.

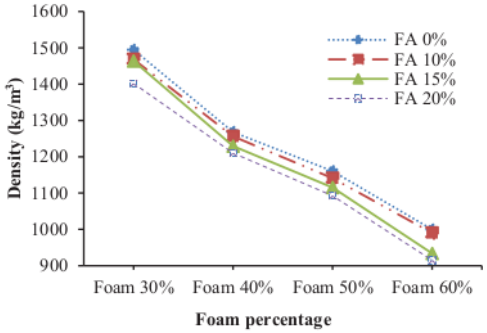

FIGURE 9. The Effect of Foam Percentage on Density At 14 Days.

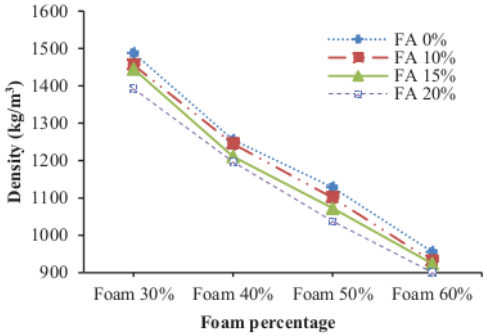

FIGURE 10. The Effect of Foam Percentage on Density at 28 Days.

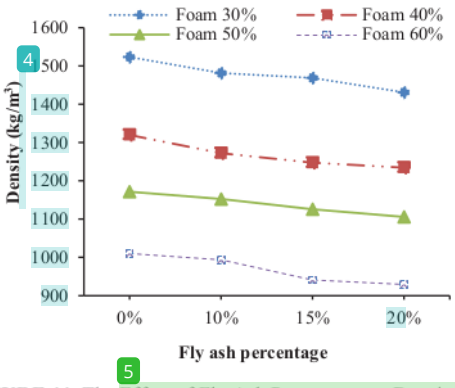

FIGURE 11. The Effect of Fly Ash Percentage on Density at 7 Days.

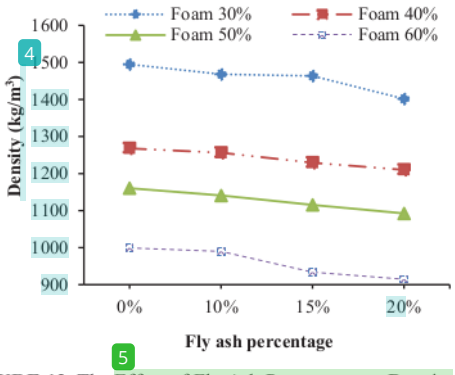

FIGURE 12. The Effect of Fly Ash Percentage on Density at 14 Days.

The increase of fly ash percentage decrease density of foamed concrete (Fig. 11). This is due to fly ash's specific gravity is lighter than cement. The greater percentage of fly ash substitution to cement, the lower density of foamed concrete resulted. The increase of fly ash percentage at foam percentage of 50% didn't give significant changes. The increase of fly ash percentage from 10% to 15% on foam percentage of 60% give a significant decrease of density

from 993.63 kg/m^3 to 940.76 kg/m^3. An increase in fly ash percentage of 15% to 20% indicates a significant decrease in specific gravity from 1,463.69 kg/m^3 to 1,401.91 kg/m^3 on 30% foam percentage (Fig. 12). This also occurred on the fly ash percentage of 10% to 15% at 60% foam percentage.

Based on Fig. 13, there was no significant decrease of density from 1,455.41 kg/m^3 to 1,445.22 kg/m^3 at 10% to 15% fly ash percentage increase with 30% and 60% foam percentage. The largest percentage change occurred in mixture with 50% foam percentage and 20% fly ash percentage equal to -8,07% with value 1,037.58 kg/m^3.The fly ash substitution to cement can reduce the density of concrete. It's because ofthe specific gravity of the fly ash is lower than cement. Providing a lighter weight concrete. So, the greater the percentage of fly ash substitution to cement the smaller density resulted.

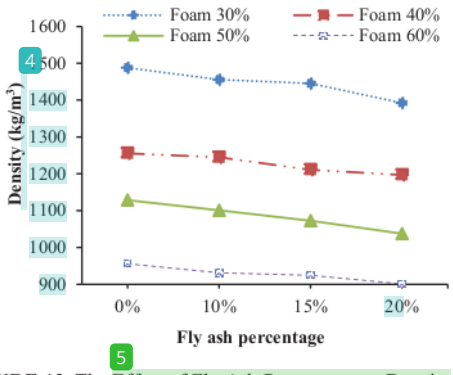

FIGURE 13. The Effect of Fly Ash Percentage on Density at 28 Days.

Compressive Strength

The results of the compressive strength test based on the percentage variation of foam are shown in Fig. 14 for 7-days concrete, Fig. 15 for 14-days concrete and Fig. 16 for 28-days concrete.

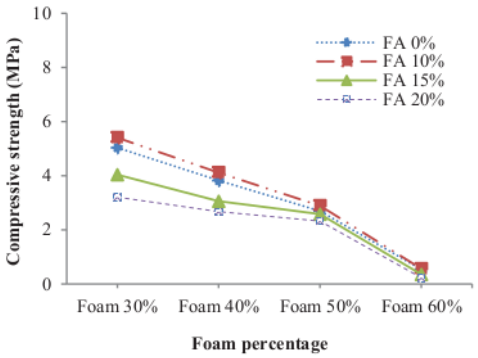

FIGURE 14. The Effect of Foam Percentage on Compressive Strength At 7 Days.

The effect of foam percentage causes reduction in the compressive strength of the concrete (Fig. 14). The foam in the mixture formspores which decrease the density and compressive strength. The decrease of concrete compressive strength significantly from 2.89 MPa to 0.56 MPa occurred at 50% foam percentage increase to 60%. An increase in the percentage of foam from 30% to 50% did not give a significant decrease of 3.21 MPa to 2.32 MPa in the mixture with 20% fly ash. An increase in the percentage of foam from 40% to 50% also does not give too large a decline from 3.05 MPa to 2.58 MPa in a 15% fly ash mix. The largest percentage change was found in the mixture of 60% foam with 20% fly ash is -94.44% of 0.23 MPa. The maximum compressive strength of concrete at 7 days is found in 30% foam and 10% fly ash mixture with 5.41 MPa value.

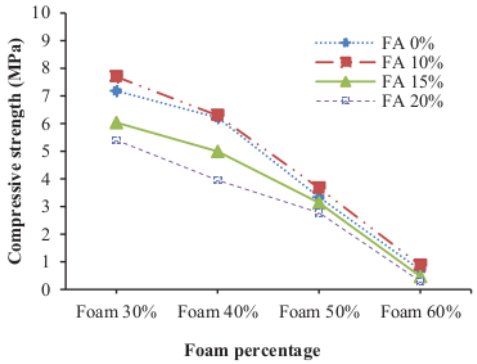

FIGURE 15. The Effect of Foam Percentage on Compressive Strength At 14 Days.

An increase in the percentage of foam causes a decrease in compressive strength of each mixture (Fig.15). An increase in the percentage of foam from 40% to 50% in the mixture with 10% fly ash gives a greater decrease than in the other mixture, from 6.29 MPa to 3.67 MPa. The largest percentage change occurred in mixture with fly ash percentage 20% and 60% foam percentage equal to -94.58%. With the increasing value of foam percentage, the more pores being formed. This is because the foam added to the concrete mixture entrap air and as the concrete hardened leaving pores. The presence of pores caused a decrease in the density of concrete. However, it is inversely proportional to the value of the compressive strength decreasing as the density of the concrete is reduced due to the pores causing the concrete to be more vulnerable to the compressive strength. The results of the compressive strength test based on the percentage variation of fly ash are shown in Fig. 17 for 7-days concrete, Fig. 18 for 14-days concrete, and Figure 19 for 28-days concrete.

The optimum compressive strength is achieved by the fly percentage of 10%. The usage of fly ash in the concretecould give positive impact when used at a certain percentage. Fly ash in concrete mixture not only acts as a substitute material of cement, but also as filler.

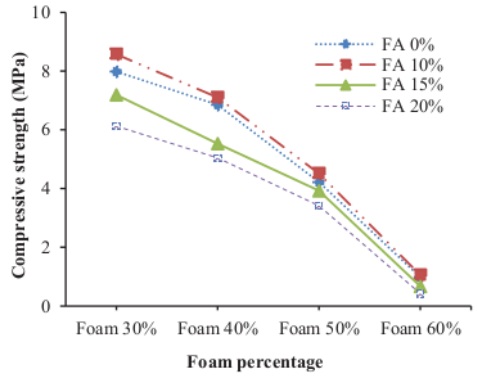

FIGURE 16. The Effect of Foam Percentage on Compressive Strength At 28 Days.

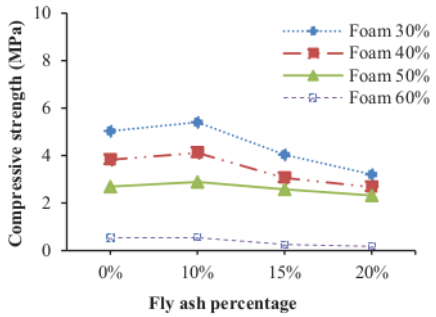

FIGURE 17. The Effect of Fly Ash Percentage on Compressive Strength At 7 Days.

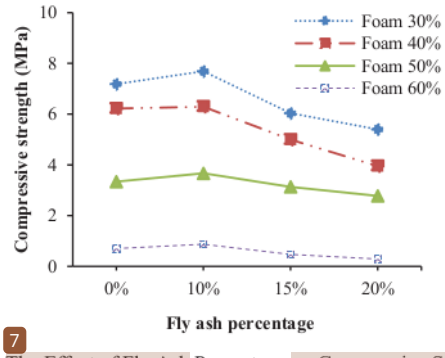

FIGURE 18. The Effect of Fly Ash Percentage on Compressive Strength at 14 Days.

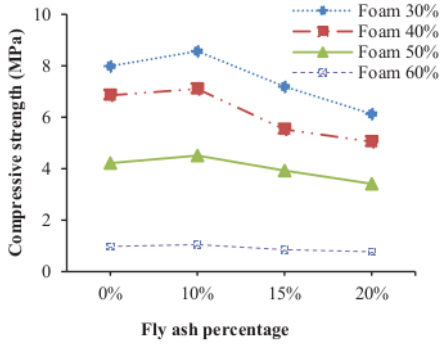

FIGURE 19. The Effect of Fly Ash Percentage on Compressive Strength at 28 Days.

CONCLUSIONS

Based on the research the result can be concluded as follow:

1. The optimum composition of foamed concrete is on 30V-10FA with 10% percentage of fly ash. The compressive strength is 8.57 MPa.
2. Based on the research, the effect of foam and fly ash percentage on fresh concrete are:

a. The result of slump flow tests showed that maximum slump flow value is 69.50 cm on 30V-20FA. The greater foam percentage, the smaller slump flow gets. The greater fly ash percentage, the larger slump flow gets.
b. The result of setting time test showed the fastest initial setting time and final setting time are 275 minutes and 600 minutes. The larger percentage of foam and fly ash, the longer it took for setting time.

3. Based on the research, the effect of foam and fly ash percentage on fresh concrete are
   a. The results of density test indicate that the minimum density on the 28-days concrete is found in the 60V-20FA mixture with a value of 901.27 kg/m3. The greater percentage value of foam and fly ash, the smaller density gets.
   b. The results of density test indicate that the lowest density on the 28-days concrete is found in the 30V-10FA with a value of 8.57 MPa. The greater percentage value of foam, the smaller compressive strength gets. The optimum percentage of fly ash is 10%.

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