Characteristics Foam Concrete with Polypropylene Fiber and Styrofoam

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Abstract. Foamed concrete is one of the concrete technology applied to the building. The advantages of foamed concrete are light and fast material on building work. The use of styrofoam and polypropylene fibers in foam concrete increases the compressive strength and flexural strength. The Styrofoam used in this study is 3 type in diameter, they are 2-3 mm, 3-4 mm, and 5-6 mm with variation of styrofoam percentage in volume is 10%, 20%, and 30%. Polypropylene fibers used 0.8 kg/m^3 of foam concrete. The use of 3-4 mm in diameter styrofoam by 10% in volume and 0.8 kg/m^3 polypropylene fiber had the highest compressive strength in foam concrete of 11.34 MPa. The use of 2-3 mm styrofoam by 10% in volume and 0.8 kg/m^3 polypropylene fiber had the highest flexural strength in foam concrete of 4.46 MPa.

1. Introduction

Lightweight concrete has been applied to infrastructure buildings cause it has small density. Foamed concrete is one type of lightweight concrete. The density of lightweight concrete is ranges from 400-1,600 kg/m^3[1]. Foamed concrete is the material containing with foam. Foam concrete consists of cement, fine aggregate, water, and air bubbles. The air bubbles in foam concrete are made by adding liquid foam (foam agent) into the mixture.Foam concrete has a small density, therefore it suitable for non-structural building element [2, 3]. Foam concrete is used on building walls which can reduce the dead weight of the building. Reduced building load makes the building more economical in the use of its main structure. Some of the advantages of foam concrete are small density, impermeable, fireproof, absorbing heat, energy efficient, soundproof, and have a ideal compressive strength. Foam concrete also has a quick excess in forming and applying to buildings [3, 4].

Styrofoam is good material used in foam concrete. The use of styrofoam on concrete can reduce the density of concrete. In concrete, styrofoam is used as a substitute material of coarse aggregate or fine aggregate. Furthermore, the addition of styrofoam in concrete can increase the tensile strength [5].

Foam concrete is one of type the aerated concrete, foam concrete is made by adding foam agent, water, and air to be foamed and mixed in mortar. The curing process of foam concrete is the same as Non-Autoclaved Aerated Concrete (NAAC) curing which is staged by water-soaked. Foam concrete is generally used as a complement in building, cause the light material and efficient in working.

Foaming Agent is a chemical material as foamed formed. Foaming agent can decrease the concrete density, because the foam agent contains air bubbles so that make air cativy in concrete. [6, 7] proofed the difference in foam concrete density due to the variation percentage of foamed by volume in foam concrete.

Styrofoam known as polystyrene expand has a unit weight 13-22 kg/m^3. Styrofoam is a light material and impermeable to water. There are various types of styrofoam, such as cube, spheroidal, or other forms. [8, 9] said that expanded polystyrene (EPS) is a light material used in engineering applications since the 1950s. Polystyrene wastes is formed into granular and used as course aggregates that produced into 1,200 kg/m^3 – 2,000 kg/m^3 concrete density.

Polypropylene fiber is one of a type of artificiailfiber. Polypropylene fibers are made from polymer compounds that have high resilience. Polypropylene fibers have advantages in resistance to chemical attack. The surface of polyproyplefiber is sleek, so that prevent the agglomeration at the time of stirring. Polypropylene fibers have 855 - 946 kg/m^3 density. Polypropylene was first polymerized by Dr. Karl Rehn in Germany in 1951 and later rediscovered by Giulio Natta in 1954. In concrete, polypropylene fibers are used as composite materials for increasing the tensile strength and the flexural strength of the concrete [8]. Polypropylene fibers have good resistance in tensile strength. In foam concrete, polypropylene fibers are added in foam concrete mixture to increase the compressive strength, flexural strgeth, and split strength of the foam concrete. Hazlin[5] proves that the addition of polypropylene fiber in foam concrete in 0.05% by volume, increase the tensile strength by 35.06% and 40.30%. Polypropylene fiber is shown in Figure 1 (a) and styrofoam in Figure 1 (b).

(a) (b)

Figure 1. (a)*Polypropylene fiber (b) Styrofoam*

The synthetic fibers used are polypropylene fibers. There are technical data of polypropylene fiber:

Base	: *Polypropylenefibres*
Colour	: *Natural*
Specific Grafity	: 0.91 g/cm^3
Length	: 12 mm
Diameter	: 18 *micron* – nominal
Tensile strength	: 300 – 440 MPa
Elastic Modulus	: 6,000 – 9,000 N/mm^2
Water absorption	: Nil
Packaging	: 0.6 kg/bag.

2. Material and Research Methodology

Foamed concrete is made in several stages such as material preparation, fabrication process, and curing. The primary materials used in the fabrication of foamed concrete are cement, fine aggregate, fly ash, foamed, styrofoam, polypropylene fibers, and water. Foam concrete is made with the ratio of cement: sand as 1: 1 and added fly ash 10% by cement weight with w b equal to 0.38. The usage of polypropylene fiber is 0.8 kg/m^3. Variations of styrofoam are used 2-3 mm, 3-4 mm, and 5-6 mm in diameter with variation of styrofoam percentage by volume are 10%, 20%, and 30%. Foaming agent used in this mixture is synthetic type, with dosage is 1 kg foaming agent : 30 liters of water. Foamed is used 40% by volume in foam concrete. The composition of the mixture in foam concrete styrofoam (FCS) can be seen in Table 1.

Table 1. Mix proportion of foamed concrete

Mix. No	*FA* %	Styrofoam dia. (mm)	Styrofoam %	PP kg/m^3	Water l/m^3	Cement kg/m^3	Fly ash kg/m^3	Sand kg/m^3
FCS2-3.10	40	2-3	10	0.8	169.27	400.90	44.54	556.81
FCS2-3.20	40	2-3	20	0.8	169.27	400.90	44.54	556.81
FCS2-3.30	40	2-3	30	0.8	169.27	400.90	44.54	556.81
FCS3-4.10	40	3-4	10	0.8	169.27	400.90	44.54	556.81
FCS3-4.20	40	3-4	20	0.8	169.27	400.90	44.54	556.81
FCS3-4.30	40	3-4	30	0.8	169.27	400.90	44.54	556.81
FCS5-6.10	40	5-6	10	0.8	169.27	400.90	44.54	556.81
FCS5-6.20	40	5-6	20	0.8	169.27	400.90	44.54	556.81
FCS5-6.30	40	5-6	30	0.8	169.27	400.90	44.54	556.81

The test specimens were used in of cylinder measuring 100 x 200 mm for compressive strength of 7 and 28 days concrete of each 5 test specimens. The beam test specimen is 100 x 100 x 350 mm for flexural strength of concrete at 7 and 28 days of each 5 test specimens. The procedure for making foamed concrete starts from the preparation of materials such as cement, fine aggregate, fly ash, foamed, styrofoam, polypropylene fiber, and water. After the material is prepared, fine aggregate material and fly ash are tested for material test result. After the early testing of the fine aggregate and fly ash done. The material were weighedbased on the mix proportion of the specimen.

After material preparation processed, foam concreteis made. Cement, sand, and fly ash are mix first using concrete mixer. After the mix of cement, sand, and fly ash are homogeneously, water is added to the mixture. The stirring process continues constantly while adding styrofoam and polypropylene fiber in the mixture. After that, foamed addedinto the mixture and re-stirring in the concrete mixer.

The slump flow testing is performed on the foam concrete mix. After all material are mixed, the slump flow testing is done. The foam concrete mix must classified in foam concrete criteria through slump flow testing to see the workability foamed concrete. After slump flow testing, the foam concrete mixture is molded with cylinder and beam formwork. The release process of the specimen from forwork is carried out after ± 24 hours. After the specimen is released from the formwork, concrete treatment is applied at room temperature for 28 days.

After the specimen is going through the process of curing, compressive strength and flexural strength test is done. Compressive and flexural strength is tested by universal testing of machine. Procedure testing of material must be based on international standard of testing. Compressive and flexural strength testing is done until the specimen broken. The universal testing machine was showed the highest force value, so that the value was be converted into compressive and flexural strength.

3. Result and Discussion

Foamed concrete is made in several stages such as material preparation, fabrication process, and curing. The primary materials used in the fabrication of foamed concrete are cement, fine aggregate,

3.1. Density.

Density test is performed to see the density of each mixture foam concrete's compositions. In each mixture composition foam concrete is produced different density. Figure 2 shows the density of the specimen for each styrofoam size and the styrofoam's in foam concrete. In density test, there were 30% variation of styrofoam percentage showed the smallest density of 1,013.09 kg/m^3 for 2-3 mm in diameter, 1,099.64 kg/m^3 for 3-4 mm in diameter and 1,037.27 kg/m^3 for 5-6 mm in diameter. The small density of foam concrete is influenced by the cavities in the foam concrete more due to the greater percentage of styrofoam usage.

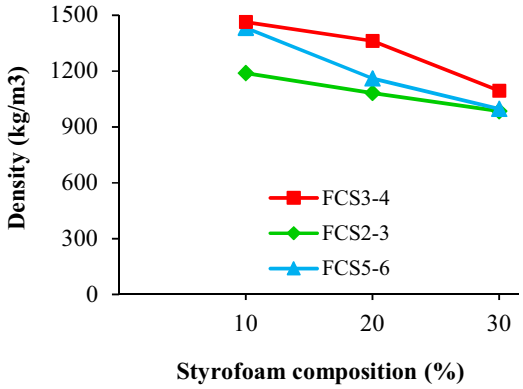


Figure 2.Density of foamed concrete with various percentage of styrofoam

3.2. Compressive Strenght

Compressive strength test in foam concrete was done at 28 days of concrete. The test is carried of each mixture foam concrete's compositions. The results of foam concrete compressive strength test showed that the use of 3-4 mm in diameter styrofoam has the highest compressive strength than the use of 2-3 mm and 5-6 mm styrofoam in diameter. Figure 3. shows compression strength of foam concrete at 11.34 MPa for 3-4 mm in diameter with 10% styrofoam and 0.8 kg/m^3 of polypropylene fiber usage. 3-4 mm in diameter styrofoam is obtained the highest compressive strength due to more optimum cavity size in foam concrete, so that the pressure distribution retained by foam concrete is more balanced.

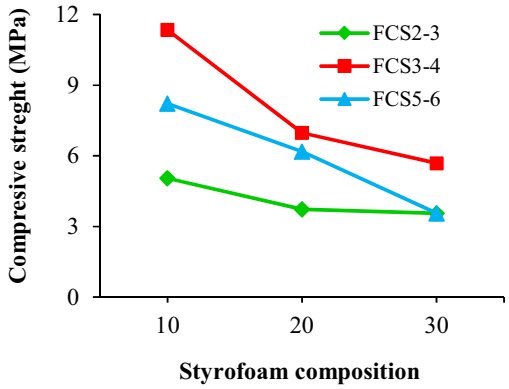


Figure 3.Compressive strength of foam concrete with various percentage of styrofoam

3.3. Flexural Strenght

Flexural tests are shown to see the difference flexural strength of the concrete foam. Styrofoam percentage and Styrofoam size variations have different flexural strengths. Figure 4 shows the difference in the flexural strength of the concrete foam. Foam concrete with 2-3 mm and 3-4 mm in diameter of styrofoam as much as 10% by volume has a higrest flexural strength than the usege of 5-6 mm in diameter styrofoam. This is caused by the more dense concrete obtained from 2-3 mm and 3-4 mm styrofoam diameter so that the bonding power between the concrete material and styrofoam become larger. Figure 4. shows the highest flexural streght of foam concrete at 4.46 MPa for the use of 2-3 mm in diameter styrofoam with 10% by volume and polypropylene fiber of 0.8 kg/ m^3.

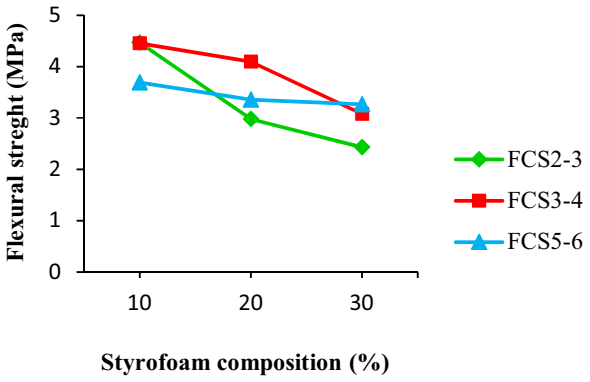
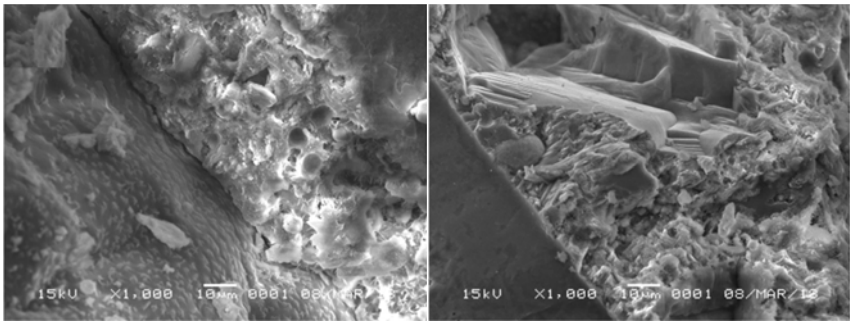


Figure 4. Flexural streght of foam concrete with various percentage of Styrofoam

3.4. Scanning Electron Microscope (SEM)

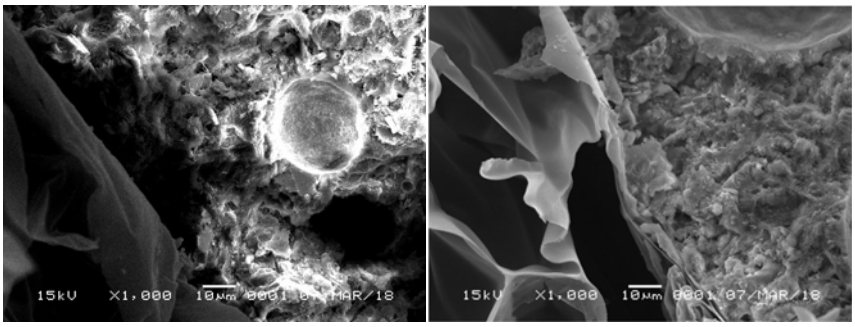
SEM test is done to shown the bond of each material. SEM test is done in 1,000 X magnification. Variation of styrofoam's size is influced in bonding to foam concrete. Figure 5. shows FCS2-3.30 and FCS3-4.30 which are bonded in foam concrete. It showed a bond to foam concrete which more solid, so that can made higher compressive and flexural strength.



(a) FCS2-3.30 (b) FCS3-4.30

Figure 5. SEM photo of 2-3 mm and 3-4 mm styrofoam's diameter

Figure 6. shows FCS5-6.20 and FCS5-6.30 which are bonded in foam concrete. It showed a bond to foam concrete had a bigger cavity in foam concrete. The usage 5-6 mm styrofoam in diameter made the bond to foam concrete had a gap. The gap of them made foam concrete not solid, so that compressive and flexural strength for 5-6 mm in diameter of styrofoam is lower that 2-3 mm and 3-4 mm in diameter of Styrofoam usage.



(a) FCS5-6.20 (b) FCS5-6.30

Figure 6. SEM photo of 5-6 mm styrofoam's diameter

4. Conclusion

The conclusions can be drawn from the results of research on the mechanical properties of foamed concrete with the addition of styrofoam and polypropylene fibers that have been done as follows:

a. Based on the results of the density test, the smallest density was produced by variation 30% of foam concrete volume 1,013.09 kg/m^3 for 2-3 mm , 1,099.64 kg/m^3 for 3-4 mm , and 1,037.27 kg/m^3 for 5-6 mm in diameter.
b. Foam concrete with 3-4 mm in diameter styrofoamwith 10% styrofoam and 0.8 kg/m^3 of polypropylene fiber mixture has the highest compressive strength of 11.34 MPa. This is caused by the optimum styrofoam cavity size in foam concrete.
c. The highest flexural strength obtained by 4.46 MPa resulting from styrofoam 2-3 mm in diameter with the percentage of use 10% by volume and polypropylene fiber of 0.8 kg/m^3. The use of 2-3 mm in diameter styrofoam causes the cavity contained in the foam concrete smaller and causes the bond between the concrete to be larger.

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