STRENGTH DEVELOPMENT OF FOAMED CONCRETE

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Abstract

Foamed concrete is classified as a lightweight concrete. Hardened foam concrete contains a lot of pore whereas this pore makes it lighter than normal weight concrete and reduces the density. Thus, it causes an ultimate compressive strength of foamed concrete that tends to be lower than normal weight concrete. Portland cement, fine aggregate, water and stable foam are basic materials that been used in this study to produce the foam concrete mixture. This study focuses on understanding the effectiveness of curing and drying method and investigates variety of mix proportions in order to achieve the ultimate strength of foam concrete with density below 1000kg/m³. There are two tests that have been done which are Mini Slump Cone Test and Compressive Strength test. The compressive strength test of the foamed concrete cubes was measured at the ages of 7, 14 and 28 days. The experimental result showed that the slump spread of fresh foam concrete in this study was affected by water cement ratio and amount of cement, thus caused the internal segregation of hardened foam concrete. The combination of water and air (drying) cured with equal volume of mix proportion increased the strength of foamed concrete sample as the ages increased and achieved the ultimate strength in this study.

Keywords: Foamed Concrete, Mini Slump Cone Test, Compressive Strength, Curing Method, Internal Segregation

1.0 INTRODUCTION

Foam concrete is classified as one type of lightweight concrete. Foam concrete is widely used in the construction field as a favorable substitution conventional concrete. According to Pan Pacific Engineering Pty Ltd (2006), the properties of lightweight concrete have been undergoing changes through technological advancement [1]. This type of concrete lighter than normal concrete due to the foam that been used. The main specialties of this concrete are its low density and thermal conductivity. Like normal concrete, it can easily be mould to any desired shapes or sizes. Foam concrete also an economical solution, particularly in large volume application (Mohamad and Noridah, 2010) [2]. According to John and Ban Choo (2003) study research, foam concrete can be removed easily after hardening using normal equipment [3].

These foam concrete materials basically consist of Portland cement, fine aggregate, water and stable foam. By adding materials such as stable foam, small cell or air bubble will form inside the concrete which this is one of the factors makes it lighter. It is also can be call homogeneous void structure, this process is the result from introducing air in form of bubble where this action incorporates small enclosed air bubbles within the mortar there by making the concrete lighter than a normal concrete. The entrapped air bubbles increases the volume and thereby reduces the densities of a concrete (Dhir et al., 1999) [4]. The density of foam concrete is determined by the amount of foam and water that added to the mixture.

The design of variety mix proportion and method of curing is done in this project to obtain the Mini Slump Cone test and Compressive Strength test, whereas this will show the development of high strength of foam concrete. According to Gambhir (2013), Mini Slump Cone test is perform to check the consistency of freshly made concrete, meanwhile the Compressive Strength Test is measure the strength of hardened foam concrete cube [5]. The strength of foam concrete will be affected by the ages of curing process, cement content of mix proportion, water cement ratio and the properties of the sand (Shetty,
1982) [6]. High compressive strength is generally achieved by using high cement content with a low water cement ratio and sand.

2.0 METHODOLOGY

2.1 Experimental Program

The mix proportion of this experiment is consist of densities below 1000 kg/m³ and there are 35 cubes and 9 cylinders sample of foam concrete is produced in this study. Sample C₁ (C:S- 1:1): 27 cubes and 3 cylinders, Sample R₂ (C:S- 2:1): 9 cubes and 3 cylinders, and Sample R₃ (C:S-3:1): 9 cubes and 3 cylinders. All the sample C₁, R₂, and R₃ was used the same 0.08 water cement ratio (w/c = 0.08). Curing is to minimize any tendency to cracking and allow it to develop foam concrete strength Ali H. Hameed (2009) [7]. There are three methods of curing is used in this experimental program as follow:

i. Curing in the water following ages test
ii. Air Curing (Drying)
iii. Curing in water followed by air curing

Cube sample of C₁ was tested and the different compressive strength of foam concrete is determined through the different method of curing with the different ages. Therefore, all of three different curing methods as stated as above is used in the Sample C₁ as a curing process. In every method of each curing process was divided into three different ages; 7 days, 14 days and 28 days. Meanwhile for Sample R₂ and R₃ were using air curing method as a curing process, and divided into different ages; 7 days, 14 days and 28 days. Both of this sample was produced to test and determined the different strength of foam concrete through the different days by using the different mix proportion. The purpose of cylinder samples for Sample C₁, R₂ and R₃ of foam concrete is to check the internal segregation. After 24 hours casting, samples was cut into two part and weighted to check the internal segregation.

2.2 Material Preparation

To produce a low density of foam concrete with the higher strength, selection of the material must base on quality, economical and good performance. Material used in this research is an Ordinary Portland Cement, fine aggregate (sand), water and foam agent. These materials are important in order to achieve the aim and objective of the study.

2.3 The Machinery and Equipment Preparation

In conducting the foam concrete experiment, few equipment and machinery were used in the Makmal Konkrit dan Struktur, Politeknik Kuching Sarawak and UNIMAS Civil Engineering laboratory to obtain the result needed. For preparation of the foam concrete, the equipment that been used was laboratory foam concrete drum mixer, foam generator, air compressor, cube and cylinder mould, 600 µm BS 410 test sieve, sieving machine and weighing scale machine. The mini slump cone with flat larger glass and compression test machine is used for the test method.

2.4 Mixing Procedure

Preparation of mixing procedure was based on BS 1881-125:1996 Part 125: Method for mixing and sampling fresh concrete in the laboratory [8].

i. The target volume and density of the foamed concrete were determined and materials of required quantity were prepared.
ii. A base mix of cement paste was put into the mixer to mix for 30 second and pour off. This is to ensure the mixing process to be more efficiency.
iii. Fine aggregate (sand) and cement were then poured into the mixer and mix for 1 minute.
iv. The mixers then stop for hand mixing about 30 second and start again mixing for 30 second.
v. The mixer stop for volume reading.
vi. After taken the volume reading, while the mixer in motion, the required amount of foam is added to the mix through the foam generator.
vii. The mixing was continued for 3 until 4 minute, and make sure the foam was completely mix with the mixture to prevent segregation.
viii. After that, the mixers then stop for hand mixing about 60 s and mixer start again for 30 second. Hand mixing is to ensure that the mixture at the side was proper mix and all material is homogeneous before adding the foam.
ix. After 30 second mixing, the mixer stop for volume reading, density check, and workability test.
x. After workability test, mixer start again for 30 second.
xi. Amount of water added into the mixture and mix using mixer again about 120 s.
xii. The mixer must stop again for hand mix for 30 second to ensure that the mixture at the side was proper mix and mixer start again for 60 second
xiii. After 60 second mixing, mixer stop for volume reading, density check and workability test again.
xiv. After workability test, mixer start again for 30 second and after that the sample is ready for casting.

2.5 Curing Method

a. Water Curing
The concrete sample for this experiment program was cured in mould in the room with the temperature of 25°C for 24 hours. After that, the concrete sample was remould and moist cure in water at 25°C until the time of testing. The condition of water curing method is shown in figure 1.0.

![Figure 1.0: Curing in the Water](image1.png)

b. Air Curing (Drying)
The concrete sample was remould and let it dry in the room with the temperature 25°C until the time of testing. The condition of air curing method is shown in figure 2.0.

![Figure 2.0: Air Curing](image2.png)

c. Curing in water and then followed by air curing
This method is the combination of curing in the water and air curing. This method is used to determine the ultimate strength for the hardened cube samples of foam concrete.
3.0 RESULT AND ANALYSIS

All the experiment tests were conducted in accordance with the methods describe in the methodology, and there are Mini Slump Cone Test for fresh foam concrete, Compressive Strength Test for harden foamed concrete cube samples and the segregation analysis that have been done on the cylinder foam concrete samples.

3.1 Mini Slump Cone Test

Mini Slump Cone Test result graph as presented in figure 3.0 show the slump spread of Sample C₁, R₂ and R₃. It can been seen that Sample C₁ (cement + sand + foam) mixture before addition of water whereas it obtained 120 mm diameter of slump spread with density 400 kg/m³. Then after adding 1.5179 of water, the mixture spread until 170 mm diameter with density 500 kg/m³. Sample R₂ (cement + sand + foam) mixture before addition of water whereas it obtained 125 mm diameter of slump spread with density 900 kg/m³. After adding 0.588 L of water, the mixture spread until 160 mm diameter with density 950 kg/m³. Meanwhile for Sample R₃ (cement + sand + foam) mixture before addition of water whereas it obtained 129 mm diameter of slump spread with density 800 kg/m³. Then after adding 0.625 L of water, the mixture spread until 150 mm diameter with density 850 kg/m³. From the results that have been obtained, workability of this Sample C₁ is increased 50 mm of diameter, Sample R₃ is increased 21 mm, and R₂ is increased 35 mm of diameter after addition of water.

The value of slump spread for these three experimental test was classified as workable and flow-able. As a result, all fresh foam concrete sample is affected by water cement ratio and amount of cement.

![Mini Slump Cone Test Result Graph](image)

Figure 3.0: Mini Slump Cone Test Result Graph

3.2 Compressive Strength Test

The highest compressive strength of samples C₁ that used water curing method, air curing method, and as illustrate in compressive strength graph shown in figure 4.0 and 5.0 is the sample of C₁-28W with strength 0.63 MPa and been cured for 28 days and sample of C₁-28A with strength 1.50 MPa whereas it been cured for 28 days. Meanwhile for the highest compressive strength of samples that using the combination of water and air cured (cured in water following cured in the air) is the sample of C₁-28WA with strength 1.67 MPa whereas it also been cured for 28 days as shown in compressive strength graph in figure 6.0.
The compressive strength result of sample C₁ shows that by using air curing method, the sample gained a higher strength compare to samples that used water curing method. This result has been proven through Shan (1995) in Khaw (2010) research whereas the strength for air cured samples is higher than water cured sample. This is because water can enter the foam concrete pores and crevices that make it freeze and easily crack \[9\]. According to Kearsley (1996) in Park et. al., (2013) research concluded that testing water-cured specimens gave low strengths due to the build-up of pore water pressure in the saturated microstructure of the foamed concrete \[10\].

The strengthens of cube samples which using the combination of water and air curing (cured in water following cured in the air) is higher compare to cube samples that cured in water and in the air.

![Compressive Strength Graph of Cubes Sample C₁ that Cured in Water](image1)

![Compressive Strength Graph of Cubes Sample C₁ that Cured in Air](image2)
Sample R₂ and R₃ are tested to measure strength through a different mix proportion. Both of this samples had a different density, where density for R₂ is 950 kg/m³, meanwhile for R₃ is 850 kg/m³. The compressive strength both of this samples are increase when the ages is increase same as happen to samples of C₁.

Samples of R₂ is increasing until 9.35 MPa - R2-28WA, compare to other samples. This happen because of un-homogeneous mixture occurred in fresh foam concrete. The material in the mixture tends to settle to the lower part of mould whereas foam rises to the surface and disappeared after 24 hours after casting. Thus, their shrink after 24 hours casting and become mortar whereas it has a little void inside the samples, which is makes it heavier and has extra strength.

The highest compressive strength of samples R₃ is the sample of R3-28A with strength 0.75 MPa whereas it is cured in the air for 28 days. Based on result analysis of Sample C₁, air curing method proves that it can gained more strength in foam concrete structure. In this case, based on the result that been obtained, increasing the cement ratio will decrease the strength of the foam concrete, whereas cement hydration reaction toward water will lead to the cracking although this sample are cured in the air. Increasing the cement ratio will also increase the density of this foam concrete and has a little shrink compare to sample R₂ as shown in dimension as presented in figure 7.0.

### 3.3 Segregation

Based on method that described in Methodology, the cylinder samples are cut into two parts: upper and lower part, in order to check the internal segregation. Based on result for all cylinder sample of C₁, R₂ and R₃ shows that the lower part of cylinder is heavier than the upper part. As a result, this sample can be categorized as non homogeneous mix whereas the material in the mixture tends to settle to the lower part of mould. Other than that, foam of the mixture rises to the surface and makes its shrink.
4.0 CONCLUSION AND RECOMMENDATION

As result according to the experimental test that has been done, the amount of density and materials that has been used influence the performance of foamed concrete. The slump spread of fresh foam concrete in this study was affected by water cement ratio and amount of cement, thus caused the internal segregation of hardened foam concrete. The combination of water and air (drying) cured with equal volume of mix proportion increased the strength of foamed concrete sample as the ages increased and achieved the ultimate strength in this study. The physical descriptions of the cube sample, it shows that shrinkage occurred due to un-homogenous mix. Thus, the material in the mixture tends to settle to the lower part of mould whereas foam rises to the surface and disappeared. Due to unlimited time, there are only few tests that can be conducted in the study. Thus, the water absorption test, thermal insulation and fire resistance are highly suggested for the future study.

REFERENCES

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