A Study on the Mix Proportion of Foamed Concrete to Early Compressive Strength Development and Tensile Strength Development

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ABSTRACT

Foamed concrete is cement-based slurry that is mechanically blended to form stable and homogeneous foam. The process can be either by mixing or by injecting. The compressive strength of foamed concrete is a function of density depends on many factors such as sand/ cement ratios, water/cement ratios, curing conditions and particle size distribution of sand. The scope of this paper is to study the effect of density, mix proportion of cement-sand ratio and admixtures to compressive strength of foamed concrete at early age and the tensile strength at age 28 days. Three types of concrete are used; normal foamed concrete, foamed concrete with Glenium C380 and foamed concrete with Calcium Nitrate. Results showed that the early compressive strength increases with increase in density for all types of concrete used. The effect of mix proportions of cement-sand ratio showed significant early compressive strength increases with increase in cement content. Mix 2:1 (for normal foamed concrete) shows highest early compressive strength to compare with other mix. It is also observed that, foamed concrete with admixtures (Glenium C380 and Calcium Nitrate) gives higher early compressive strength compared to normal foamed concrete. Results concluded that there has significant effect on tensile strength of 1:1 mix foamed concrete added with surfactant. The tensile strength value reduced with more percentage of surfactant added to the mix.

Keywords: *admixtures, compressive strength, foamed concrete, tensile strength*

Introduction

The term foamed concrete basically represent concrete that contained no large aggregates, only fine sands with extremely lightweight foamed materials contained only cement, water and foam. Foamed concrete is a lightweight building material combining good mechanical strength with low thermal conductivity and ease of working. The advantages of lightweight concrete are it reduced mass and improved thermal and sound insulation properties, while maintaining adequate strength. The reduced weight has numerous advantages, not the least of them being a reduced demand on energy during construction (Columbia, 2003).

The range of the density of lightweight concrete is from less than 400 kg/m^3 to 1800 kg/m^3 (Bennett, 2002). Decreasing the weight and density produces significant changes which improves many properties of concrete, both in placement and application. In the initial classification of lightweight concrete it was said that one method of reducing the density of concrete relies on the introduction of stable voids within the hardened cement paste or mortar. The voids can be produced by gas or by air; hence, the names gas concrete and aerated concrete. Because the air is introduced by a foaming agent, the term foamed concrete is also used.

Foamed Concrete or Lightweight Concrete Method (LCM) was developed in Europe over 60 years ago and has been on the international market for more than 20 years (Liew, 2002).Today foams are available which have a high degree of compatibility with many of the admixtures currently used in modern concrete mix designs. Foam used with either lightweight aggregates and/or admixtures such as fly ash, silica fume, synthetic fiber reinforcement, and high range water reducers (super plasticizers), has produced a new hybrid of concrete called lightweight concrete materials.

This paper discussed the effect of density, mix proportion of cement-sand ratio and admixtures to compressive strength of foamed concrete at early age. Early compressive strength is considered as compressive strength at age 1 day and below. However, for this study the samples were test at age 1 day. This is because in relation to the real industry practice, times taken for dismantle formwork is approximately to 3 days that refer to the original size of formwork at site. The development of tensile strength is tested at 28 days which focused on the effect of density and different percentage of surfactant added to concrete mix.

Materials

Ordinary Portland cement (OPC) brand Blue Lion supplied by Cement Industries of Malaysian Berhad (CIMA) was used throughout the experimental work in this study. Sieve analysis test shows that the sand used in this study was graded as Well graded sand (SW). The proportions are 93% sand, 1% gravel and 2.85% clay and silt. Water is a key ingredient in the concrete production. Therefore, ordinary tap water was used as mixing water throughout the study. Foaming agent that been used for the project is in liquid form supplied by LCM Technology Sdn Bhd. Two types of foaming agent that are used in this project are protein as surfactant and synthetic based foaming agent. Synthetic and protein based foaming agents are mix and mash into a concentrated liquid call Lightweight Concrete Method Foaming Agent is used to make the foam (BCRC, 2003). Foam generator was used to pressurize the foaming agents and produced excellent wet foam with stability and outstanding cured properties as shown in Figure 1. The two types of admixtures used in this study are Calcium Nitrate and Glenium C380 supplied by Master Builders, Inc.


Figure 1: Wet Foam (Liew, 2002)

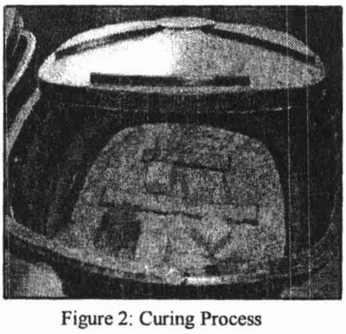
Figure 2: Curing Process

Experimental Design

Laboratory work for this study are divided into four phase which are preparation of forming agent, mixing of foamed concrete, curing of specimens and testing of specimens. The mixing process was performed based on volume. Bucket was used to measure the voluminous of materials, where 1 bucket represents 5.8 liters of materials.

For the compressive strength test, the foamed concrete mixed was prepared with foam chemical constant at 80% of synthetic and 20% of surfactant with five mix proportions which are 1:1, 1:2,1:3, 3:1 and 2:1 for cement-sand ratio.

The second mixed for indirect tensile test specimens was foamed concrete with foam chemical varies from 100% - 40% of synthetic and 0% - 60% of surfactant. The mixed were prepared in three mix proportions which are 1:1, 1:2 and 1:3 for cement-sand ratio. The range of density prepared are four which are 1200 kg/m^3 – 1250 kg/m^3, 1250 kg/m^3 – 1300 kg/m^3, 1300 kg/m^3 – 1350 kg/m^3 and 1350 kg/m^3 – 1400 kg/m^3.

Two types of admixtures (Calcium Nitrate & Glenium C380) were added to the mixed due to four different range of density which are 1200 kg/m^3 – 1250 kg/m^3, 1250 kg/m^3 – 1300 kg/m^3, 1300 kg/m^3 – 1350 kg/m^3 and 1350 kg/m^3 – 1400 kg/m^3. The mix was poured into cubes of mould 100 mm x 100 mm x 100 mm for compressive strength test and cylinder mould of 200 mm x 100 mm for indirect tensile test.

Curing process was required after the demoulding the cubes and cylinders. Method used for this study was water cure, where the foamed concrete cubes and cylinders were placed in the curing tank and soaked with water as shown in Figure 2. The foamed concrete cylinders were cured for 28 days. No curing treatment is done for samples to be tested at the age of 1 day.

Testing of Specimen

Compressive Strength Test was performed to determine the compressive strength of foamed concrete cube specimens according to BS 1881: Part 4: 1970 or MS 7.1 Part 1: 1971. The specimens were tested using a Universal Testing Machine (UTM) as shown in Figure 3. The load applied continuously and without shock until the specimen fails and the maximum load carrying by the specimen during the test was recorded. Early compressive strength can be considered as compressive strength at age 1 day and below. However, for this study the samples were test at age 1 day.

Indirect Tensile Strength Test was performed to determine the indirect tensile splitting strength of foamed concrete cylinder specimens according to BS 1881: Part 117: 1983. The specimens were tested using a ELE/EL 36-4160 compression machine. Figure 4 shows the setting up of the indirect tensile experimental testing. The load is applied continuously and without shock until the specimen fails and the maximum load carrying by the specimen during the test was recorded.

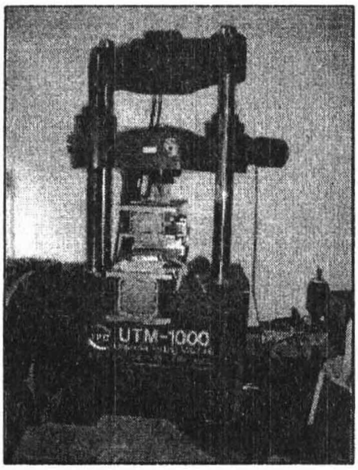

Figure 3: Universal Testing Machine (UTM – 1000)

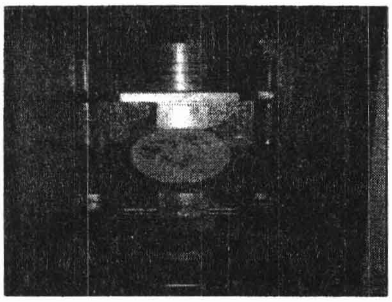

Figure 4: Preparation for Indirect Tensile Strength Testing

Result and Discussions

The results of the compressive strength test and indirect tensile strength test were summarized, tabulated and simplified in graphs and discussed with the following section. The concrete mixes were group to according to density as describe:

1. Group A – Density group of (1200 – 1250) kg/m^3
2. Group B – Density group of (1250 – 1300) kg/m^3
3. Group C – Density group of (1300 – 1350) kg/m^3
4. Group D – Density group of (1350 – 1400) kg/m^3.

Compressive Strength at Age 1 Day

The strength development between mix proportions of cement-sand for normal foamed concrete, foamed concrete added with Calcium Nitrate and foamed concrete added with Glenium C380 at age 1 day was compared and it was plotted as shown in Figure 5 for normal foamed concrete, Figure 6 for foamed concrete with Calcium Nitrate and Figure 7 for foamed concrete with Glenium C380.

From Figure 5, it could be seen that the highest compressive strength is in 3:1 mix proportion, which in density range 1350 kg/m^3 - 1400 kg/m^3. The value for the strength is 3.663 N/mm^2. While, the lowest value for compressive strength is 0.195 N/mm^2, which in 1:3 mix proportion and density range 1200 kg/m^3 - 1250 kg/m^3. Cement gives strong bonding between materials used in concrete to form compact mass. Therefore, more cement gives more strength to the concrete meanwhile less cement will result to lower strength to the concrete. In other word, it depends on the mix proportion of cement-sand to recognize the strength development of the concrete.

Besides that, the strength development for each mix proportion should increase as the density increases. Meaning that, higher density will give higher strength of concrete. At density

1300 kg/m^3 - 1350 kg/m^3 for 1:1 and 2:1 mix proportion, it could be seen that the value for the 1:1 is higher than 2:1 mix proportion.

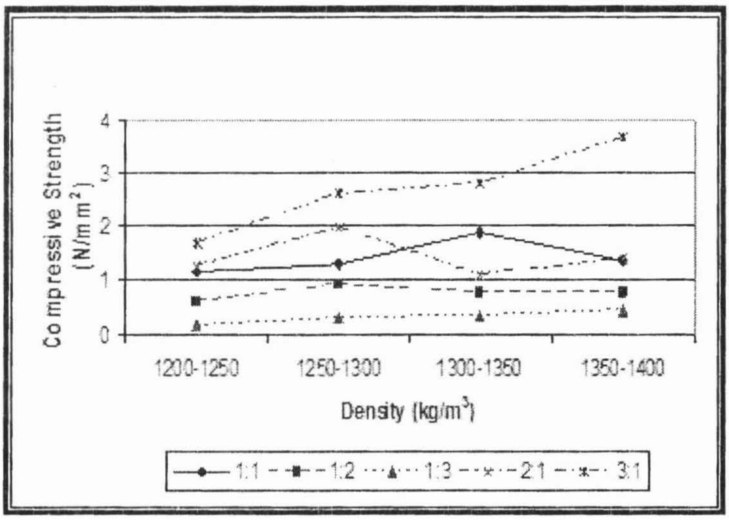

Figure 5. Relationship between compressive strength and density of normal foamed concrete at Age 1 Day

Based on graph from Figure 6, 3:1 mix proportion with density range 1350 kg/m^3 - 1400 kg/m^3 is the highest of compressive strength for the foamed concrete with Calcium Nitrate. The value is 6.740 N/mm^2. The lowest value for the compressive strength is 0.456 N/mm^2, which in 1:3 mix proportions with density range 1250 kg/m^3 - 1300 kg/m^3. This density range is lower than 1200 kg/m^3 - 1250 kg/m^3 because of the actual density that might be situated in border value such as the density for range 1200 kg/m^3 - 1250 kg/m^3 is 1250 kg/m^3.

Figure 7 shows the relationship between compressive strength and density of foamed concrete with Glenium C380. It could be seen that 1:1 mix proportion is the highest compressive strength among others mix proportion. The highest value is 5.519 N/mm^2 which the density is in range 1350 kg/m^3 - 1400 kg/m^3.This is followed by 1:2 mix proportions and 1:3 mix proportions as the lowest one. The lowest value is 0.602 N/mm^2 in range 1200 kg/m^3 - 1250 kg/m^3. For this type of foamed concrete, the 2:1 mix proportions and 3:1 mix proportion could not be conducted because the mixes settled while mixing process. This is maybe due to the water-cement ratio which is 0.5 that used in the project.

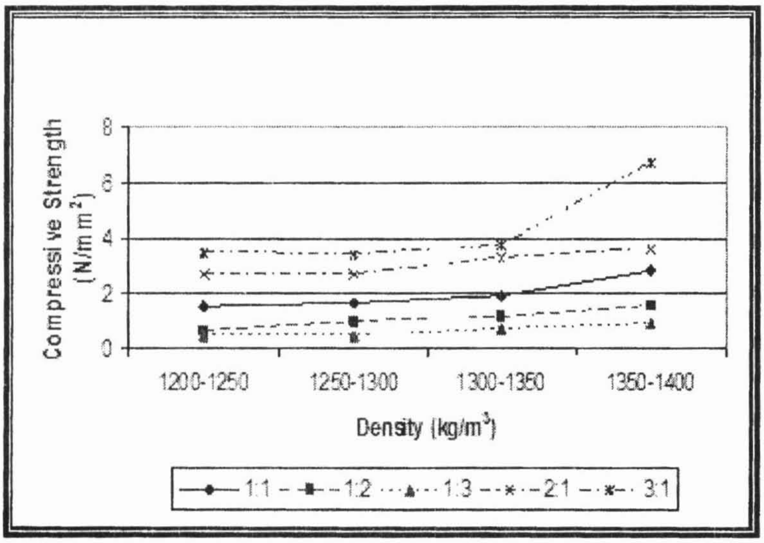

Figure 6. Relationship between compressive strength and density of foamed concrete with Calcium Nitrate at Age 1 Day

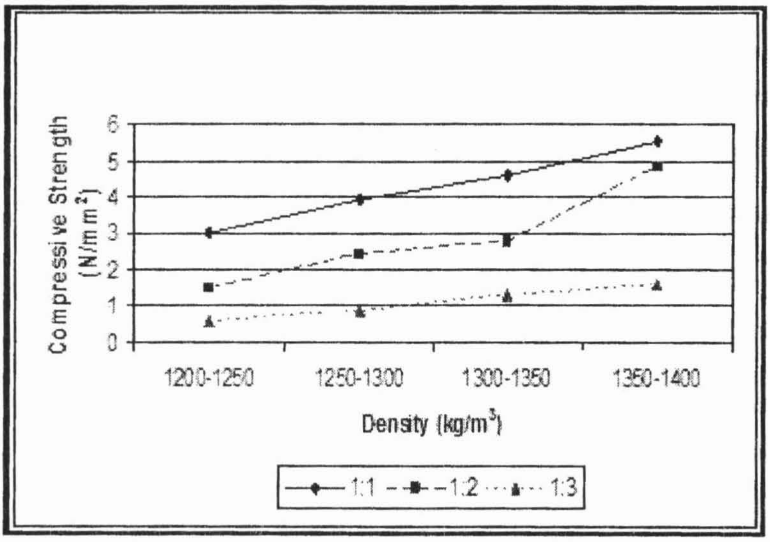

Figure 7. Relationship between compressive strength and density of foamed concrete with Glenium C380 at Age 1 Day

Indirect Tensile Strength Test

The Indirect Tensile Strength test or splitting test was performed using compression machine. The readings of maximum load and maximum strength were taken with the pace rate of 0.94 kN/sec. Generally, the results of tensile strength were less that the compressive strength at age 28 days foamed concrete. This is because after 28 days of curing the tensile strength development became slowly compare to the development of compressive strength. This is because concrete is well known as a material, which is very good in compression but weak in tension. In conjunction to this, the tensile-compressive ratio decreases with the curing age (Paulo and Kumar, 2006).

Figure 8 shows that the tensile strength of foamed concrete was reduced as the surfactant added in foaming agent was increased. From the results, the density range of 1350 N/ mm^2 – 1400 N/mm^2 gives the highest tensile strength of 1.588 N/mm^2 with 0% of surfactant. While the lowest tensile strength is 0.428 N/mm^2 for the density ranged of 1200 N/mm^2 – 1250 N/mm^2 with 60% of surfactant. This is due to the very slow strength development effect from the surfactant.

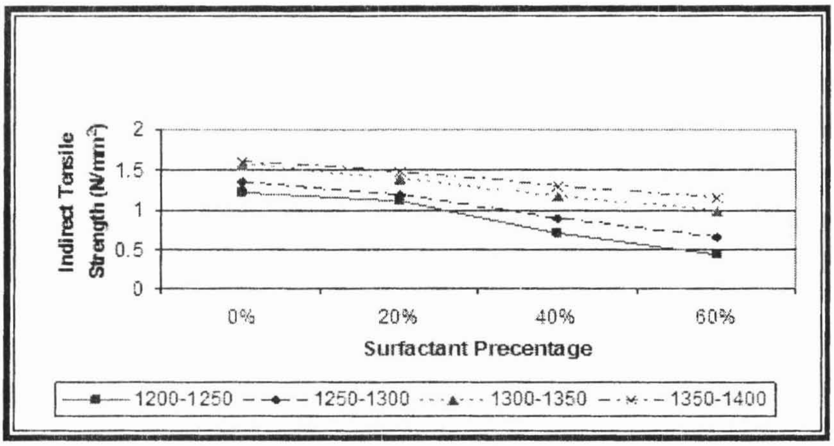

Figure 8. Relationship between tensile strength and surfactant percentage at age 28 days for 1:1 mix proportion

Conclusion

Compression strength test and indirect tensile test were performed in this study to investigate the influence of mix proportion of cement-sand ratio, admixtures and density of foamed concrete. The tests were performed at age of foamed concrete 1 day to assess the early compressive strength development of foamed concrete and 28 days to assess the tensile strength. From the observation and results presented in this study, the following conclusions can be drawn.

1. The strength development was very similar between normal foamed concrete, foamed concrete with Calcium Nitrate and foamed concrete with Glenium C380. The compressive strength of foamed concrete with 2:1 and 3:1 mix proportions was higher than 1:1, 1:2 and 1:3 mix proportions. There was a measurable effect of mix proportions of cement sand ratio to the compressive strength values obtained in this study for all foamed concrete density. The compressive strength values obtained were in the range of 0.195 N/mm^2 (1:3 mix proportions) to 11.363 N/mm^2 (3:1 mix proportion) for the normal foamed concrete, 0.4 (1:3 mix proportions) to 16.427 N/mm2 (3:1 mix proportion) for the foamed concrete with Calcium Nitrate and 0.6 (1:3 mix proportion) to 12.585 N/mm2 (1:1 mix proportion) for foamed concrete with Glenium C380.
2. Commonly admixture used in concrete mix in order to modify or improve the properties of concrete. From this study, there was a significant effect of admixtures to the compressive

strength. The compressive strength value increased significantly with Glenium C380 and increased slightly with Calcium Nitrate as compared to normal foamed concrete.

3. There was a significant effect of mix proportion of cement sand ratio to the tensile strength of foamed concrete. The tensile strength value reduced with reducing in cement content. There was a measurable effect of density to the tensile strength of foamed concrete. The tensile strength value increased with increasing in density of foamed concrete.

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