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Influence of Artificial Lightweight Aggregate on Mechanical Properties of Foamed Concrete

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Abstract
The lightweight foamed concrete is a free flowing material containing only cement, water, foam and fine sand or any admixtures, if it requires in order to increase the mixture volume while rising up the quality of the lightweight concrete. This study describes the investigation on mechanical properties of lightweight foamed concrete with artificial lightweight aggregate. All the specimens used were tested at 1250 kg/m^3 of concrete density. The mix design proportion used for cement, sand and water ratio was 1: 2.67: 0.50. The artificial lightweight aggregate were used as additives by volume percentage of 10 %, 13% and 17% based on specific density of artificial lightweight aggregate. Specific density of artificial lightweight aggregate is 1200 kg/m$^{3.}$ The experiment was setup to investigate the mechanical properties with accordance to the standard method of testing. Based on the result interpretation, the artificial lightweight aggregate has contributed 2.95 N/mm^2 for the compressive strength of the lightweight foamed concrete when using 17% of artificial lightweight aggregate. While, 0.89 N/mm^2 result recorded for the flexural strength of the lightweight foamed concrete incorporated with the artificial lightweight aggregate. The aggregate inclusion in flexural strength proved to have contributed more strength in lightweight foamed concrete. Since the strength was below than 15 N/mm^2, therefore this study of lightweight foamed concrete with artificial lightweight aggregate can be recommended to be used as part of non-structural elements in the infrastructure such cladding, road curb, block drain and so forth.

Keywords: Lightweight foamed concrete; artificial lightweight aggregate; mechanical properties

Introduction

The Lightweight Concrete (LWC) is a concrete consists of slurry mortar in which the air- voids is entrapped in the structure by addition of foaming agent. The foaming agent used in producing the lightweight concrete should be in stable foam [1]. The production of stable foam concrete mix depends on many factors such as selection of foaming agent, method of foam preparation and addition for uniform air-voids distribution, material section and mixture design strategies, production of foam concrete, and performance with respect to fresh and hardened state are of greater significance [2]. The wide density of variation of Lightweight Concrete (LWC) from 500kg/m^3 to 1800kg/m^3 offers advantages to concrete in terms of lightweight, good in thermal and sound insulation and higher workability of concrete. Unfortunately, due to high cement content with low percentages of aggregate in Lightweight Concrete (LWC) are causes to higher shrinkage and weaker in tension [3]. Based on that disadvantage of LWC, some study needs to be processed to improve the weakness of Lightweight Concrete (LWC). Lightweight aggregate concrete (LWAC) has low density which can result in a significant benefit in terms of structural dead load if the concrete compressive strength is high enough. It allows to use smaller cross section of beams and columns as well as smaller foundation size and also to reduce the amount of required steels [4]. LWA used in the structural lightweight concretes are typically expanded clay, expanded shale or pumice. The oven-dry density of structural LWAC varies from 1500 to 1800 kg/m3 according to the properties and volume fractions of aggregates [5]. Many studies show that the thermal conductivity of low strength LWAC decreases due to lowering their density [6]. Previous researches have shown that, in addition to the aggregate density, their microstructure (pore size distribution), their mineralogical composition and the grain surface parameters (paste-aggregate bond quality) influence also the concrete strength [7].

Furthermore, the aggregate thermal conductivity does not only depend on the porosity of aggregates but also on their mineralogical composition and on the crystallinity degree of minerals. Because of higher porosity, the LWA has lower strength and is more deformable than the NWA [8]. So, in LWAC, and contrary to normal weight concrete (NWC), the weakest components are not the cementations matrix or the interfacial transition zone (ITZ) but the aggregates. The LWA density and water absorption capacity must be taken into account when determining the volume of LWA to be added to the mixture [9]. For this study, LWA were ‘‘saturated’’ in order to avoid any change of water to cement ratio due to water absorption of aggregates during mixing.

Experimental Setup

A. Compression Test

In this test, three cube specimens with a size of 100mm x 100mm x 100mm were used for every age on each mix. The test was conducted after the bulk density test was carried out and the mean result from 3 specimens was used as the final strength of each test.

This test was done according to BS 1881: 1983 and specimens were measured by using ELE International Compressive Testing machine with capacity 3000kN. The pace rate for this test was 2.0N/sec which was compatible to the standards to ensure each specimen that were to be tested does not have a shock load [10].

B. Bending Test

This test was carried out based on standards of BS 1881: 1983 and using Gotech Universal Testing machine. The specimens with the size of 100mm x 100mm x 500mm (prism) was used in this testing, which each test involved 2 specimens and it was the same with other tests, the mean result from specimens was used as the final result. The procedure involved placing a concrete prism on the loading frame [11].

C. Splitting Tensile Test

Cylindrical mould with the size of 100mm x 200mm was used in averages of specimens as a result. The testing machine was using GT-7001-BS300. The specimens were then wrapped with plastic sheets wrapping and seal with one layer of cellophane tape to ensure there will be no loss of moisture during period. All of the specimens were then left cured up to 180 days according to days of test under controlled temperature and relative humidity [12].

D. UPV test

This test was conducted by using Portable Ultrasonic Non-destructive Digital Indicating Tester (PUNDIT) and this test followed the standards of BS 1881: part 203: 1986. In this test, 3 cubes and 3 prisms of each mix and age were tested to determine their quality of specimens. The PUNDIT instrument consisted of two transducers which were acting as transmitters and as receivers. To use it, both transducers were coupled with grease on the specimen's surface to ensure the ultrasound applied was perfectly transmitted and received [13].

Results and Discussion

A. Compression strength

Based on the result shown Figure 1, the compressive strength of LWAC was increasing due to the ages of specimens. The CTRL specimens without Lightweight aggregate are achieving the compressive strength of 1.77 kN/m^3 at age of 7 days and increasing with 28.9% to 2.49 kN/m^3 at 28 days. The specimens LWAC 10 and LWAC 13 was achieving the lower strength compare to CTRL specimens at all ages of test. the increasing percentages of compressive strength of specimens LWAC 10 and LWAC 13 were 23.2% and 24.9%. they was achieve the strength of 1.98 kN/m^3 and 2.05 kN/m^3 at ages of 28 days.

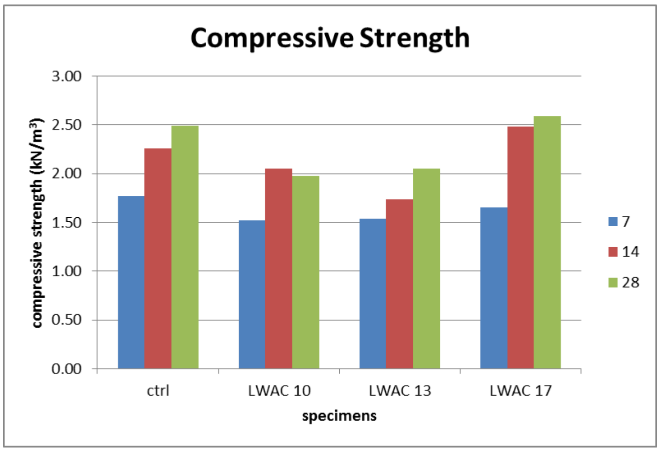

Figure 1: Compressive Strength Result for LWCA

Meanwhile, a result for specimens LWAC 17 also shows lower compressive strength compare to CTRL specimens at ages of 7 days and 14 days but with high percentages of increasing strength, it was achieve better result compare to CTRL specimens at ages of 28 days with strength of 2.59 kN/m^3. This pattern trend the result was occurs because of the presence of artificial lightweight aggregate in lightweight concrete in low percentages will affected to compressive strength of LWAC. With the low percentages of lightweight aggregate, it causes unstable condition of concrete because the presence lightweight aggregate inside the concrete became a weaker point to concrete. However, with increasing percentages of lightweight aggregate to 17% will help to improving the strength of concrete. This is happen because of the higher volume of lightweight aggregate in concrete will made the lightweight aggregate to support the load and the lightweight concrete became as a binder between them. So the lightweight aggregate will not became as a weaker point in concrete [14].

B. Bending Strength

The flexural strength test is being conducted to define the ability of specimens to have the bending force. The flexural strength tests results are obtained from all specimens are being summarized in Figure 2 the overall result shows an increasing strength of specimens when the ages increase. The CTRL specimens were achieve the flexural strength of 0.39 MPa at ages of 7 days and increasing with 43.7% to 0.69 MPa at 28 days. for others specimens with containing lightweight aggregate in concrete mix, all of them was achieving higher flexural strength compare to CTRL specimens at ages of 7 days and 28 days.

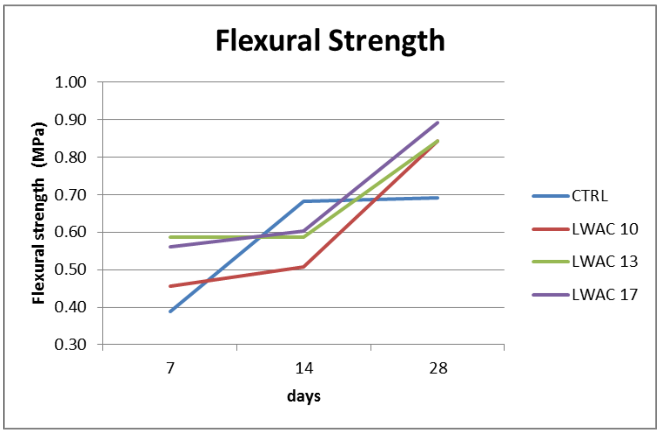

Figure 2. Flexural Strength Result for LWCA

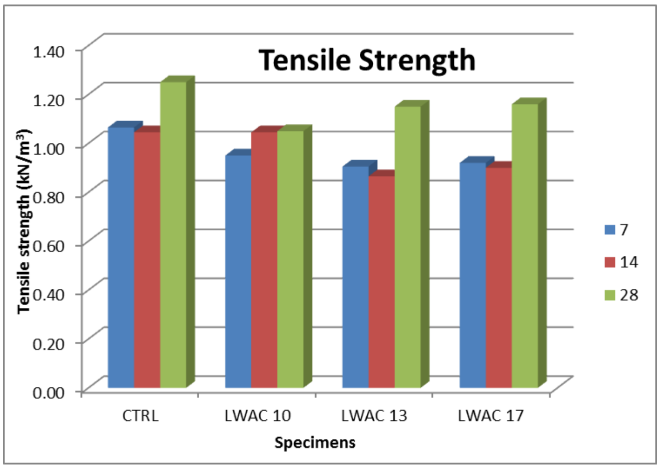

Figure 3: Splitting tensile strength Result For LWCA

Meanwhile, the flexural result between concrete with lightweight aggregate was shows that the increasing percentages of lightweight aggregate in concrete will increased the strength of specimens. The highest flexural strength of specimens was being achieved by specimens LWAC 17 which is 0.89 MPa at ages of 28 days. at the same ages, the result was being follow by specimens LWAC 10 and LWAC 13 which achieve same strength with 0.84 MPa and the lowest result was 0.69 MPa by CTRL specimens.

The increasing percentages of specimens are 45.8% by LWAC10, 30.4% by LWAC13 and 37.2% by LWAC17. The overall result shows that the presence of lightweight aggregate in concrete will contribute to increasing the flexural strength of concrete.

The higher volume of lightweight aggregate presence in concrete will produce better flexural performance of concrete [15].

C. Splitting tensile

Based on the result above, the splitting tensile was increased when the ages of specimens increase. It happen due to the improvement of concrete when the ages of concrete increase. Through Figure 3, the CTRL specimens was achieving the highest tensile strength compare to others at all ages of testing day which is 1.07 kN/m^3 at 7 days and it increase with 14.8% to 1.25 kN/m^3 at 28 days. For other specimens, LWAC10 was achieving the second highest which is 0.95 kN/m^3 at 7 days and it been follow by LWAC17 and LWAC13 with 0.92 kN/m^3 and 0.91 kN/m^3. At ages of 28 days, the specimens LWAC17 was increasing with 20.7% to 1.16 kN/m^3 and overpass the result from LWAC10.

Meanwhile the LWAC10 was achieving the strength 1.05 kN/m^3 with increasing 9.5% of their strength. From the result, it shows that the presence of lightweight aggregate in concrete will affected to reduce the tensile strength of concrete at early ages. However, based on the result LWAC17, the tensile strength was increase to almost a same strength to CTRL specimens.

Besides that, with the increasing percentage of lightweight aggregate used will reduce the strength of tensile strength at early ages but it will increase back at ages of 28 days. The optimum percentages of lightweight aggregate need to be determine to balance the strength at early age with the long term ages [16].

D. Ultrasonic Pulse Velocity (UPV)

The ultrasonic pulse velocity test was one of the test that use to identify the denseness of concrete and also define any imperfection of concrete either crack and honeycomb. In this study, we test the specimens to identify the denseness of lightweight aggregate concrete. In theory, with presence of lightweight aggregate in concrete, it makes concrete denser than normal lightweight concrete. Data collected based on time travel and velocity is then generated. In theory, the pulse travels faster with high velocity when concrete density is high and if there are imperfections to concrete like honeycombs or cracks, it delays the time travel. The result of this test can been shown in Figure 4.

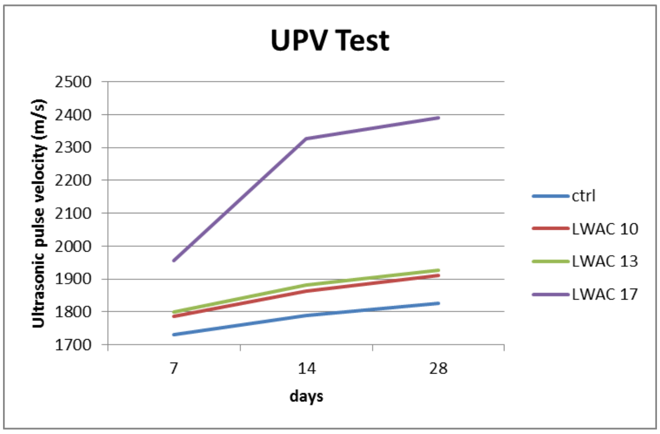

Figure 4: Ultrasonic pulse velocity Result For LWCA

Based on the result shown in Table 4 and Figure 5, the Ultrasonic pulse velocity value was increased when the ages of specimens increase. It happen due to the improvement of denser in concrete when the ages of concrete increase. Through the Figure 4.4, the LWAC17 specimens was achieving the highest Ultrasonic pulse velocity value compare to others at all ages of testing day which is 1957m/s at 7 days and it increase with 4.34% to 2391 m/s at 28 days. For other specimens, LWAC13 was achieving the second highest which is 1799 m/s at 7 days and it been follow by LWAC10 and CTRL with 1786 m/s and 1730 m/s. Meanwhile at ages 14 days specimens LWAC 13 was increase the pulse velocity of concrete with increasing 8.3% of their result at 7 days and its follow by LWAC10 and CTRL with 7.7% and 6%. From the result, it shows that the presence of lightweight aggregate in concrete will affected to increase the denser of concrete. However, based on the result LWAC13, the value of Ultrasonic pulse velocity test was increase to almost a same to LWAC10 specimens. Besides that, with the increasing percentage of lightweight aggregate used will increase of denser of concrete at all ages [17].

Conclusion

In this study, all the mechanical properties and durability which are compressive strength, flexural strength, splitting tensile, Ultrasonic pulse velocity, water absorption and drying shrinkage of lightweight foamed concrete with artificial lightweight aggregate at 1250 kg/m3 have been determined and analyzed. Based on data collected, shows:-

a) Dry density of Lightweight aggregate concrete for CTRL and LWAC10 shows that the dry density is below the target and density of LWAC13 AND LWAC17 are higher than target density. This situation happens because of the different percentage of aggregate in the Lightweight foamed concrete. The presence of lightweight aggregate in concrete will increase the density of concrete because of the aggregate absorbed and stored the water from concrete.

b) Compressive strength of foamed concrete 1250kg/m³ with 17% of artificial lightweight aggregate show more higher strength than control specimen. The strength of the compressive developed is not like what that expected to escalate by the curing age of the concrete but the compressive strength. From previous study, shown that the strength of the aggregate may not be directly related to that concrete and the use of small aggregate particles could reduce the restriction on strength of LWAC.

c) Flexural strength analysis also, it can be conclude that flexural strength of foam concrete at density 1250kg/m³ is achieved. The value of flexural strength is expected to be more than the ratio to compressive strength which are 10% to 15%. In other words, the higher compressive strength the higher flexural strength will be.

d) Splitting tensile result shows that the presence of lightweight aggregate in concrete will affected to reduce the tensile strength of concrete at early ages. However, based on the result LWAC17, the tensile strength was increase to almost a same strength to CTRL specimens. With the increasing percentage of lightweight aggregate used will reduce the tensile strength at early ages but it will increase back at ages of 28 days.

e) Ultrasonic pulse velocity (UPV) test shows that with the increasing percentage of lightweight aggregate used will increase of denser of concrete at all ages.

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