Effect of Curing Age on Material Properties of Autoclaved Light-Weight Concrete Wallboard

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Abstract. The curing age of Autoclaved Light-weight Concrete (ALC) wallboards generally is not long enough in actual application, which may affect its material properties. By testing of various specimens for ALC with different curing ages, the relationship between the curing age of ALC and the dry density, moisture content, waterabsorption, compressive strength, splitting tensile strength, flexural strength, axial compressive strength and thermal conductivity is proposed, and the mathematic models were given. The results show that the growth of curing age is beneficial to most of the material properties of ALC, which are significantly different between those of 13 days and 10 days. In actual situation, the curing age should be 13 days at least while it cannot reach enough time.

1. Introduction
Lightweight concrete can be obtained by introducing large voids into the concrete, and it is called aerated or foam concrete [1-3]. And it can be cured by means such as high-temperature autoclaved to obtain Autoclaved Light-weight Concrete (ALC) [4, 5]. With the development of prefabricated buildings and the improvement of people's quality of living, Lightweight Wall Board of ALC have become more and more popular.

Important parameters [6-8] for measuring the materials performance of ALC include the dry density, moisture content, water absorption, compressive strength, splitting tensile strength, flexural strength, axial compressive strength and thermal conductivity. The main feature is high porosity and lower density and compressive strength compared to ordinary concrete [9]. For the material properties of ALC, it is affected by several parameters such as method of pore formation, load orientation, curing age, water absorption, admixture and curing method [10-12]. Just and Middendorf [13] found that the increase in compressive strength depends on the density, and the strength increases as the density increases. Zhen and Ning [14] show that the compressive strength of aerated concrete increases with curing age, and the growth trend decreases with curing age, the strength at 7 day has already increased to 70-75% of strength at 28 day. Jitchaiyaphum [15], Kearsley [16], Nambiar [17] et al, their study of the ALC also concluded that the compressive strength increases with curing age. And Correlation Study [18] have shown that the splitting tensile strength of ALC depends on curing method and curing age. As ALC is a brittle
material, it cannot provide great bending resistance in bending or tensile loading without admixture [19]. Compared with ordinary concrete, the pore structure of ALC is composed of various sizes, ranging from micropores to macropores [20], with excellent thermal properties. There is a direct relationship between thermal conductivity, density and compressive strength, and the curing growth of age can improve its thermal conductivity [21]. Due to the complexity of the factors affecting the material performance of Autoclaved Light-weight Concrete, it is difficult to improve its performance by changing the proportion. However, the material performance of ALC can be significantly and effectively improved by improving the curing age.

However, the production technology and application level of new wall materials are not high, and a lot of problems have been exposed in the process of engineering practice and application. In practice, the factory system is generally not in accordance with the standard curing age after maintenance on the factory to the construction yard. Due to the material properties of the ALC, if the curing age is reduced, it will have serious impact on the material properties, which will not only affect the overall performance of the wallboard, but also further affect the service life of the building [22]. Therefore, this paper uses the wallboard produced by actual manufacturers to make specimens for material properties test, studies the influence of different curing ages on the various materials properties of ALC, and establishes the relationship model between the properties of various materials and their curing ages (7 day-16 day), so as to better predict the material properties of each stage.

2. Experimental survey

2.1. Specimens fabricating

The ingredients of the studied ALC include First-rate quartz sand, P.O 42.5R silicate cement, GLY-95 lime, aluminum powder, and HRB400φ4.5, HRB400φ5.5 steel bar as presented in Table 1.

| Production Raw Material | Main Index            | Main Index |
|------------------------|-----------------------|------------|
| First-rate quartz sand  | SiO₂                  | 90%        |
|                        | K₂O & Na₂O            | 3.00%      |
|                        | NaCl                  | 0.03%      |
|                        | Fineness              | 15%        |
| P.O 42.5R Silicate cement, | Compressive strength | 42.5 MPa   |
|                        | Flexural strength     | 6.5 MPa    |
| GLY-95 Lime            | CaO & MgO             | 85%        |
|                        | Fineness              | 15%        |

2.2. Experimental method

This material performance test is carried out in Key Laboratory of Energy Engineering Mechanics and Earthquake Disaster Mitigation in Chongqing. The model of the test equipment used is: YH-40B standard constant temperature and humidity curing box, 01-2 thermostatic air-blower-driven drying closet, WDW-1000H universal testing machine and SK-DR300B+ plane table thermo-conductivity meter etc.

The studied ALC wallboard meets the Chinese code GB15762-2008. The preparation of the specimen and the dry density, moisture content, water absorption, compressive strength, splitting tensile strength, flexural strength, and axial compressive strength of ALC were tested according to the Chinese code GB11969-2008. And the thermal conductivity measurements meet the requirements of the Chinese code GB10294-2008.
2.3. Test cases
Batches 1#~4#, representing curing ages of 7, 10, 13, and 16 days, respectively. Curing was carried out at 20±1°C and above 95% humidity by YH-40B standard constant temperature and humidity curing box. And each batch is divided into 8 groups, each group of 3 repeating specimens, and a total of 96 specimens.

2.4. Experimental results
As shown in Table 2, the materials properties of the tested specimens at different curing ages.

Table 2. Experimental results

| Materials Performance                  | Curing Ages (Day) |
|---------------------------------------|-------------------|
|                                       | 7                | 10               | 13                | 16                |
| Dry density (kg/m³)                   | 604.7            | 605.5            | 608.2             | 605.1             |
| Moisture content (%)                  | 29.75            | 32.91            | 30.56             | 31.84             |
| Water absorption (%)                  | 66.76            | 67.14            | 66.80             | 66.31             |
| Compressive strength (MPa)            | 3.43             | 3.45             | 3.71              | 3.80              |
| Splitting tensile strength (MPa)      | 0.65             | 0.79             | 0.95              | 1.16              |
| Flexural strength (MPa)               | 0.21             | 0.24             | 0.45              | 0.53              |
| Axial compressive strength (MPa)      | 3.51             | 4.36             | 5.31              | 5.35              |
| Thermal resistance (m²·K/W)           | 0.19             | 0.22             | 0.23              | 0.23              |
| Thermal conductivity (W/m·K)          | 0.16             | 0.14             | 0.14              | 0.14              |

3. Curing age - materials performance analysis

3.1. Dry density, moisture content and water absorption
During the drying process, the sample was dried in a dry environment for 44 hours to constant quality. In the standard curing state, the dry density of ALC is 604.7 kg/m³-608.2kg/m³, the moisture content is 29.75%-32.91%, and the water absorption is 66.31%-67.41%, as shown in Table.3. As shown in Figure.1, under the condition of the specimen sawing error, the curing age (7-16 days) has no obvious influence on the dry density and water content of the specimen, but has a slight influence on its water absorption. With the increase of curing age, water absorption decreases gradually, but this trend is not obvious.

As the curing age increases, hydration products will be generated to fill the pores, improving the compactness of the system and reducing the number of connected pores [23]. This means that in the application of mortar connection and plastering in ALC wallboard, it is inevitable to absorb the moisture in the mortar and plaster layer in the later stage to increase the moisture content in the material and reduce the performance of the ALC wallboard material. Therefore, the selection of ALC wallboard with a long enough age is beneficial to avoid cracks and prevent cracks, empty drum of floated coat.
3.2. Compressive strength

Compressive strength is considered to be an ideal parameter to measure the material and an important mechanical property of this kind of lightweight concrete [24]. And aerated concrete products can also show considerable residual compressive strength after reaching peak strength [25]. In the normal state, the compressive strength of specimen within the tested curing age range is between 3.43 MPa and 3.80 MPa. As shown in Figure 2, there is a high correlation between curing age and compressive strength of specimen.

With the increase of curing time, the compressive strength of specimens is increasing, and its growth trend decreases with the increase of curing age. As shown in Table 3, when the curing age increased from 13 days to 16 days, the strength increased by 0.09 MPa, which was only 2.57% of the standard strength (3.5 MPa); when the strength increased from 10 days to 13 days, the strength increased by 0.26 MPa, which was equivalent to 7.49% of the standard strength (3.5 MPa). The compressive strength at the curing age of 13 days and 16 days is close to or reached when compared with the quality control report documents of 3.80 MPa at the curing age of 28 days.
Nowadays more and more wallboards of fabricated building are studied for bearing [26, 27], so if the ALC wallboard of 7 day curing age is used as the bearing wall, the bearing capacity of it is about 11% lower than that of 16 day curing age.

It is found that the trend of the relation curve which is compressive strength test satisfies DoseResp function, the relationship is shown in Eq.1, where \( x \) was curing age (day) and \( y \) was compressive strength (MPa).

\[
y = 3.29 + \frac{0.57}{10^{1.18(11.82-x)+1}}
\]  

(1)

3.3. Splitting tensile strength

In the normal state, the splitting tensile strength of specimen within the tested curing age range is between 0.65 MPa and 1.16 MPa. As shown in Table 3, there is a high correlation between curing age and splitting tensile strength of specimen. As shown in Figure.3, with the increase of curing time, the splitting tensile strength of specimens is also increasing, and its growth trend decreases with the increase of curing age. However, when the curing age was reduced from 16 days to 13 days, the strength decreased by 0.21 MPa, and the reduction of strength was only 18.1% of the 16 days; when the strength decreased from 16 days to 7 days, the strength decreased by 0.51 MPa, which was equivalent to 44.0% of the 16 days. It means that the splitting tensile properties of specimens with a curing age of 7 days are far from reaching the average technical performance index, the properties of 10 days are slightly lower than the average technical performance index, while the properties of 13 days and 16 days are far higher than the average technical performance index.

It is found that the trend of the relation curve which is splitting tensile strength test satisfies DoseResp function, the relationship is shown in Eq.2, where \( x \) was curing age (day) and \( y \) was splitting tensile strength (MPa).

\[
y = 0.154 x + 0.641
\]  

(2)

Figure 3. Relation curve of curing age and splitting tensile strength

3.4. Flexural strength

In the normal state, the flexural strength of specimen within the tested curing age range is between 0.22 MPa and 0.53 MPa. As shown in Figure.4, there is a high correlation between curing age and flexural strength of specimen. With the increase of curing time, the flexural strength of specimens is also increasing, and its growth trend decreases with the increase of curing age. As shown in Table 3, the flexural strength of specimens with a curing age of 10 days are slightly lower than the average technical
performance index, while the flexural strength of 13 days and 16 days are far higher than the average technical performance index. And the flexural strength of ALC increased by 152% as the phase increased from 7 to 16 days. As the curing age increased from 7 days to 16 days, the flexural strength of specimen increased by 152%.

It is found that the trend of the relation curve which is flexural strength test satisfies DoseResp function, the relationship is shown in Eq.3, where \( x \) was curing age (day) and \( y \) was flexural strength (MPa).

\[
y = 0.21 + \frac{0.32}{10^{1.79(11.85 - x) + 1}}
\]  

(3)

3.5. Axial compressive strength

In the normal state, the axial compressive strength of specimen within the tested curing age range is between 3.51 MPa and 5.35 MPa. As shown in Figure.5, there is a high correlation between curing age and axial compressive strength of specimen. With the increase of curing time, the axial compressive strength of specimens is also increasing, and its growth trend decreases with the increase of curing age. When the curing age was reduced from 16 days to 13 days, the axial compressive strength decreased by 0.04 MPa, and the reduction of strength was only 0.75% of the 16 days; when the strength decreased from 16 days to 7 days, the strength decreased by 1.84 MPa, which was equivalent to 34.4% of the 16 days. It means that the axial compressive strength of specimens with a curing age of 7 days are far from reaching the average technical performance index, the strength of 10 days are slightly lower than the average technical performance index, while the strength of 13 days and 16 days are far higher than the average technical performance index.

It is found that the trend of the relation curve which is axial compressive strength test satisfies DoseResp function, the relationship is shown in Eq.4, where \( x \) was curing age (day) and \( y \) was axial compressive strength (MPa).

\[
y = 3.51 + \frac{1.84}{10^{1.79(10.22 - x) + 1}}
\]  

(4)

3.6. Thermal conductivity

Thermal conductivity is a function of water conditions, namely the higher the water content, the greater the conductivity coefficient [28]. Therefore, it is necessary to consider moisture content when testing thermal properties and to conduct a drying procedure prior to testing. In the process of thermal...
conductivity measurement, the specimen generally tends to be constant after about 0.5 hours and enters the steady state after about 4 hours.

![Figure 5](image_url)

**Figure 5.** Relation curve of curing age and axial compressive strength

As shown in Table 3, the thermal resistance of the specimen within the tested curing age range is between 0.185 and 0.23 m²·K/W, and the thermal conductivity ranges from 0.136 to 0.160 W/m·K. As shown in Figure 6, curing age (7 to 16 days) has a significant effect on the thermal resistance and thermal conductivity of ALC specimen. With the increase of curing age, the thermal resistance of the specimen increases continuously, and its growth trend decreases; and the thermal conductivity decreases gradually and the thermal resistance increases gradually.

The technical index of 0.16 W/m·K is equivalent to the thermal conductivity when the curing age is 7 days. However, the thermal conductivity at the curing age of 7 days to 16 days is lower when compared with the quality control report documents of 0.13 W/m·K at the curing age of 28 days. Therefore, the influence of curing age on thermal conductivity of ALC should be considered when applying ALC wallboard.

![Figure 6](image_url)

**Figure 6.** Relation curve of curing age and thermal conductivity, thermal resistance value
It is found that the trend of the relation curve which is axial compressive strength test. Data analysis was conducted on the test results of thermal conductivity, and the relationship between thermal conductivity coefficient and thermal resistance value of ALC lightweight wallboard materials at any time period between 7 and 16 days in age was estimated, as shown in Eq. (5) and (6).

As shown in Eq. 5 and Eq. 6, the relationship between curing age and thermal conductivity, thermal resistance of ALC with curing age between 7 days and 16 days was estimated, where \( x \) was curing age (day), \( y_1 \) was thermal conductivity (W/m·K) and \( y_2 \) was thermal resistance.

\[
y_1 = 0.160 - 0.029x + 0.0171x^2 - 0.00334x^3
\]

\[
y_2 = 0.185 + 0.045x - 0.0175x^2 + 0.0025x^3
\]

4. Conclusion

Physical and mechanical properties of Autoclaved Light-weight Concrete were investigated in this work. The performance of 96 ALC specimens was tested, and the curing age, dry density, moisture content, water absorption, compressive strength, splitting tensile strength, flexural strength, axial compressive strength and thermal conductivity of ALC were discussed. Based on the review, several conclusions can be drawn and these are listed below:

1) The increase of curing age is beneficial to the materials properties of ALC. With the increase of curing age, the compressive strength, splitting tensile strength, flexural strength, axial compressive strength and thermal resistance gradually increase, while the thermal conductivity gradually decreases.

2) By using the fitting function, the relationships between the materials properties and the curing ages (7d~16d) of ALC were established. The DoseResp function was used to respectively establish the relationship between compressive strength, flexural strength, axial compressive strength and curing age. Linear and cubic polynomial fitting was used to respectively establish the relationship between splitting tensile strength, thermal conductivity and curing age.

3) The compressive strength, splitting tensile strength, flexural strength and axial compressive strength of ALC, which are significantly different between those of 13 days and 10 days, and the reduction of strength is 7.5%, 87.5%, 20.3% and 18.2%, respectively.

4) Curing age has obvious influence on ALC, and it should be 13 days at least while it cannot reach enough time in actual situation.

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