Study on Mechanical Properties of Light Aggregate Concrete for Filled Core Assembly

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Abstract. This paper mainly explores the mechanical properties of lightweight aggregate concrete used for core-filled assembly members. Through the design adjustment of the mix ratio, the results show that the concrete slump is about 100mm, its workability is good, and its compressive strength is lower than ordinary concrete, but it meets the strength design requirements of prefabricated components. By analyzing the tensile and compression ratio and elastic strength ratio, the crack resistance and ductility of light aggregate concrete are better than ordinary concrete, which can provide reference for light aggregate concrete engineering applications.

1. Introduction

With the development of urbanization, the demand for natural coarse aggregates is increasing, and the mining of natural aggregates and stones will inevitably cause a series of natural ecological problems such as the destruction of arable land and vegetation, and the frequent occurrence of earthquakes. People are paying more attention to the seismic performance and durability of building construction. The replacement of natural coarse aggregate by light aggregate can not only avoid the continuous use of natural stones, but the advantage of concrete made from light aggregate is lower in weight than ordinary concrete. It can also improve the durability and seismic performance of buildings. Lightweight aggregate concrete is made of light weight aggregate (natural industrial waste and artificial light weight aggregate), light sand (or ordinary sand), and cementitious materials. The dry apparent density of concrete and water is not more than 1950 kg/m\textsuperscript{3}. The apparent density of light aggregate concrete for non-load-bearing members does not exceed 1400 kg/m\textsuperscript{3}, and the apparent density of light-weight aggregate concrete for load-bearing members is 1450-1950 kg/ m\textsuperscript{3}. Its small density, light weight, convenient transportation and installation, and good thermal insulation performance, which is suitable for high-rise buildings and large-span structures. These advantages make the amount of lightweight aggregate concrete the second largest concrete after ordinary concrete. When the lightweight aggregate concrete is poured, it is easy to cause segregation, slump loss, and pumping difficulties due to its low weight and high water absorption. At the same time, pre-wetting can play a role of "micro pump" in the later period of curing. Increasing the compressive strength of lightweight aggregate concrete has an adverse effect on frost resistance. Therefore, the mix ratio and construction of lightweight aggregate concrete for load-bearing components are important to the mechanical properties of concrete. In recent years, China Extensive research has been done on the performance of ordinary flexural and shear members of lightweight aggregate concrete, but little research has been done on the use of fabricated lightweight aggregate concrete members\cite{1}. The workability and ease of lightweight aggregate concrete directly affect the assembly type construction.
quality of concrete members. Therefore, in this paper, the shale ceramsite with a cylinder pressure of 4.3MPa is used to analyze the mechanical properties of the lightweight aggregate concrete with design strength of LC30, and it is applied to the assembled lightweight aggregate concrete components.

2. Test content and method

2.1 Test material design
(1) Cement: P • O42.5 ordinary portland cement. Jilin Panshi Jidong Cement Panshi Co., Ltd.
(2) Ceramsite: Shale ceramsite selected as Yuanheng shui purification material in Zhengzhou, Henan Province is light and coarse aggregate. The main performance indicators are shown in Table 1.
(3) Natural fine aggregate: Yanji city sand and pottery sand are mixed with a mass ratio of 3:1, and its fineness modulus is 2.6.
(4) Water: Yanji City river water
(5) Fly ash: class II fly ash from Yanji Tienan Heating Company.
(6) Water reducing agent: Highly effective polycarboxylic acid water reducing agent. From Yanji Fangsheng Building Material Co., Ltd.

| Coarse aggregate type | Maximum particle size | Density grade kg/m³ | Softening coefficient | Cylinder pressure strength/MPa | Water absorption/% |
|-----------------------|-----------------------|----------------------|-----------------------|-------------------------------|-------------------|
| Ceramsite             | 25                    | 619                  | 1.0                   | 4.3                           | 4.3               |

2.2 Light aggregate concrete mix design
In this paper, the proportion of ceramsite lightweight aggregate concrete designed by the "absolute volume method" is used. The design refers to the "Technical Regulations for Lightweight Aggregate Concrete" (specified by JGJ51-2012) [2]. The mildness of compression has a significant impact, determining these three important parameters, and calculating the amount of fine aggregate and coarse aggregate. The basic failure form of light aggregate concrete is different from ordinary concrete and can be divided into two types, firstly, splitting failure, which light aggregate splitting failure in light aggregate concrete. The second type is the boundary failure of cement stone. For the latter, it is the basic failure form of ordinary concrete, the elastic modulus of cement and aggregate. Compared with light aggregate concrete, its overall density is not dense enough, and the damage is generally at the boundary between cement and aggregate. In this paper, shale ceramsite with moderate cylinder pressure strength is selected to ensure that no cracking occurs. Sand rate generally has a great impact on the compactness and workability of light aggregate concrete. Generally, the sand rate of aggregate concrete is generally between 30% and 50%. Within this range, the strength of light aggregate concrete will vary. With The sand rate increasing, the workability of light aggregate concrete is significantly improved. However, excessively increasing the sand rate will cause the density difference between the enlarged mortar and the light aggregate to increase, resulting in the segregation of the light aggregate concrete. In this test, the sand rate was initially selected as 50%. Finally, for the determination of the water-cement ratio and the net water consumption, as the water-to-binder ratio is reduced, the strength of the concrete will increase, but it is different from light aggregate concrete, which has a lower strength increase than ordinary concrete because the interior is not uniform like ordinary concrete. Too low a water-cement ratio will affect the workability of the concrete. According to the current "Technical Regulations for Lightweight Aggregate Concrete" (JGJ51-2012) [3], this article selects a net water volume of 180Kg/m³ and a water-cement ratio of 0.38. The formula for determining the fit of the lightweight aggregate concrete is shown in Table 2.
### Table 2. Concrete mix ratio and material usage

| Concrete type | Cement | Fly ash | Ceramsite | Light sand + medium sand | Water | Water reducing agent | Water-cement ratio |
|---------------|--------|---------|-----------|--------------------------|-------|---------------------|-------------------|
| Light aggregate | 379kg  | 74kg    | 420kg     | 682kg                    | 180kg | 86g                 | 0.38              |
| Ordinary      | 379kg  | 74kg    | 839 kg    | 700kg                    | 180kg | 86g                 | 0.38              |

#### 2.3 Feeding sequence and slump test

In this paper, ceramsite is immersed in water about 3 days to reach 90% of the saturated state. According to the provisions of the "Technical Regulations for Lightweight Aggregate Concrete" (JGJ51-2002), the material is fed as shown in Figure 1 and poured into 150 x 150 x 150 mm cube test block model was vibrated for 12s after mixing. The amount of ceramsite was 440 kg/m³ in the design of the mix ratio of the lightweight aggregate concrete at first. However, the specific surface area of the ceramsite in the mixed concrete was found to be large, and a large amount of cement mortar was required to cause the mixing process. When the concrete test block appears ceramsite floating, this article chooses 420 kg/m³ within the applicable range of coarse aggregate. The concrete has good workability. The slump is about 100mm as shown in Figure 2. After the vibration is compacted, the test piece is disassembled for 24 hours. After being cured for 3d, 7d, and 28d under standard conditions, the mechanical properties are tested.

![Figure 1. Feeding sequence using pre-wet lightweight aggregate](image1)

![Figure 2. slump test](image2)

![Figure 3. slump test](image3)

#### 3. Test results

##### 3.1 Compressive strength of concrete

The uniaxial compression test of the cube concrete test blocks at the age of 3 days, 7 days, and 28 days. The average value of multiple groups of tests is shown in Table 3. It can be seen from the table that the strength of the lightweight aggregate concrete cube reaches 37.4 Mpa. It can meet the basic design
requirements of light aggregate concrete slab. However, compared with ordinary concrete, it is 7.4MPa lower. The cylinder pressure strength of light aggregate ceramsite is still the determinant of the strength of light aggregate concrete. However, from the concrete test block in Figure 4 it can be found in the failure form that the aggregate test pieces of the broken light aggregate concrete did not show obvious aggregate split failure of the light aggregate concrete, because once the split failure occurs, the water-cement ratio of the concrete is reduced. Strength has little effect, so it is still possible to reduce the water-cement ratio and increase the concrete strength according to its mix ratio and under the premise of ensuring workability. In this paper, light aggregate is immersed in water for 7 days, which is close to a saturated state. During the later curing process, due to the anti-water characteristics of the ceramsite, it can play the role of "micropump" for self-maintenance; 20% fly ash the penetration will also make the strength of the lightweight aggregate concrete continue to increase. From the figure and the test, it can be found that compared with ordinary concrete, the lightweight aggregate concrete is more complete, and its integrity and ductility are better. Because of the rough and porous nature of the ceramsite, the interface between the aggregate and mortar in the lightweight aggregate concrete is not good. Weakness means better mechanical bite. As shown in Figure 6, according to the concrete strength of 3 days, 7 days, and 28 days, using the origin software to analyze and fit the light aggregate concrete with age (3 days, 7 days, and 28 days) relationship: 
\[ Y = -0.054x^2 + 2.345x + 14.456 \]
provides reference for light aggregate concrete engineering applications.

Table 3. Main parameters of coarse aggregate

| Type                        | \( F_{cu,3}/\text{MPa} \) | \( F_{cu,7}/\text{MPa} \) | \( F_{cu,28}/\text{MPa} \) |
|-----------------------------|---------------------------|---------------------------|---------------------------|
| Ordinary concrete           | 28.0                      | 34.5                      | 44.8                      |
| Lightweight aggregate concrete| 21.0                      | 28.2                      | 37.4                      |

Figure 4. LC Failure Form prefabricated concrete slab
Figure 5. NC Failure Form

Figure 6. Fitting relationship of compressive strength of concrete with age
3.2 Split tensile strength
Table shows the results of a 28-day concrete test block subjected to a split tensile test and an elastic modulus test. The split strength of lightweight aggregate concrete is lower than that of ordinary concrete, but there is not much difference. The tensile-compressive ratio is a key indicator for measuring the brittle strength of concrete. The smaller the tensile-compressive ratio, the more obvious the test piece is. [5] Fortunately, this is consistent with the phenomenon of concrete compressive failure. The elastic strength ratio (the ratio of the elastic modulus to the compressive strength of the prism) is one of the indicators to measure the crack resistance of concrete. As can be seen from the table, the elastic strength ratio of light aggregate concrete is significantly lower than that of ordinary concrete feet, that is, light bone the crack resistance of concrete is better than ordinary concrete.

| Type | Tensile strength /MPa | Compressive strength of prism /MPa | Elastic Modulus | Pull pressure ratio | Elasticity ratio |
|------|-----------------------|----------------------------------|-----------------|---------------------|------------------|
| NC   | 4.67                  | 35.57                            | 23500           | 0.104               | 661              |
| LC   | 3.96                  | 29.77                            | 15000           | 0.106               | 504              |

4. Conclusions
(1) Through the design of the mix ratio of lightweight aggregate concrete, the concrete work performance meets the requirements, and the compressive strength of the cube is lower than that of ordinary concrete, but the strength meets the design requirements of the core-assembled lightweight aggregate concrete slab; the lightweight bone can be found from the failure form. The sample is relatively complete, and the failure is not a splitting failure of the light aggregate. The water-cement ratio can be adjusted appropriately to increase the compressive strength of the light aggregate concrete.

(2) From the compression ratio and elasticity ratio of light aggregate concrete, it can be found that the crack resistance and ductility of light aggregate concrete are due to the crack strength of ordinary concrete, which is lower than that of ordinary concrete. This article proposes that an appropriate amount of fiber material can be added.

(3) Based on the cubic compressive strength of light aggregate concrete at 3, 7, and 28 days, this paper uses the origin software to fit the compressive relationship of the strength of light aggregate concrete with age (Y=-0.054x^2+2.345x+14.456)

References
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