Study on Physical and Mechanical Properties of New Self-Insulated Block

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Abstract. This paper has developed a dumbbell-shaped self-insulated block with recycled ceramsite concrete as the main body and filled with recycled foam concrete. Through the physical and mechanical properties test, it is concluded that the performance of the block is better than the specification requirements and can be used as a load-bearing block. According to the test results and the normative formula, the correction coefficient of the relationship between the block and the concrete cube is obtained.

1. Introduction

With the rapid development of society, the construction industry is also advancing with the times. In the process of replacing old and new buildings, there are more and more construction wastes. If it cannot be recycled reasonably, it will seriously affect our living environment. So how to properly reuse recycled materials to build green, energy-saving and emission-reducing buildings is a difficult problem to be solved. Many experts and scholars in China have carried out a lot of research on recycled concrete blocks[1-5], which proves that the use of recycled concrete can not only reduce the weight of the blocks but also improve the thermal insulation performance, and the compressive strength can meet the requirements. Incorporating ceramsite into recycled concrete can greatly improve the thermal performance of concrete[6-7]. Although the improvement in strength is not obvious, it will not reduce its strength.

The EPS board, which is commonly used in the cavity of the block, is flammable in the event of fire and generates harmful gases after combustion. Replacing the EPS board with foam concrete not only solves this problem, but also reduces noise pollution by the sound absorption and sound insulation characteristics of the foam concrete. Foam concrete is a kind of thermal insulation material with excellent light weight and excellent thermal insulation performance. It has some research results in China[8], which proves that filled foam concrete can effectively improve the thermal performance of the block[9-10], but little research has been done on filling reconstituted foam concrete blocks. The inclusion of some recycled aggregates in foam concrete can greatly increase the strength of concrete and speed up the recycling of waste concrete. It is a subject worth studying.

In response to the national sustainable development policy, this paper designed a double-row hole dumbbell type self-insulated block. The main material is recycled ceramsite concrete and the inner material is recycled foam concrete to reasonably recycle the recycled aggregate. The test results were compared with the normative formula to study the physical and mechanical properties of the block.

2. Test materials

Making concrete specimens of 150mm×150mm×150mm and hollow blocks of 390mm×240mm×190mm
mm in the experiment.

(1) Cement: PO42.5R ordinary portland cement, produced by Liaoning Yinsheng Cement Group;
(2) Recycled aggregate: The particle size range of aggregates is 1-5mm and 5-10mm. The waste test block transported back by Yanbian State Construction Bureau is screened by jaw crusher and the measured moisture content is 4%;
(3) Fine aggregate: Natural sand, original sand in the laboratory;
(4) Fly ash: Grade II fly ash produced by Guodian Longhua Yanji Thermal Power Co., Ltd., replacing 30% cement[11];
(5) Foaming agent: Plant protein high-efficiency foaming agent;
(6) Ceramsite: Fly ash ceramsite produced in Zhengzhou, Henan Province, with a particle size range of 8-10mm, and the measured water absorption rate is 20%;
(7) Water: Tap water in Yanji City.;
(8) Additives: Polycarboxylic acid high-efficiency water reducing agent.

3. Mix design

After reviewing a large amount of literature, it has been determined that the bulk material of the block is recycled concrete with 30% ceramsite[12]. Foam concrete is used as the filling material in the block, and the compressive strength test is carried out on the foam concrete with the recycled aggregate content of 0%, 10% and 20% respectively. According to the test results, the relationship between the compressive strength and the amount of recycled aggregate is obtained as figure 1.

![Recycled aggregate content-compressive strength diagram](image_url)

Figure 1. Recycled aggregate content-compressive strength diagram

It can be seen from the figure that as the amount of recycled aggregate increases, the compressive strength of the recycled foam concrete increases. When the dosage exceeds 10%, the strength increase rate is slowed down. Therefore, considering the comprehensive consideration, the dosage is 10%, and the best material is obtained as table 1.

| Group | Cement (kg/m³) | Sand (kg/m³) | Recycled aggregate (kg/m³) | Ceramsite (kg/m³) | Fly ash (kg/m³) | Water (kg/m³) | Water reducer (%) | Foaming agent (%) |
|-------|----------------|--------------|-----------------------------|-------------------|----------------|---------------|------------------|------------------|
| TC    | 219.0          | 384.5        | 566.7                       | 242.9             | 93.9           | 140           | 5.34             | -                |
| PC    | 221.0          | 94.7         | 10.5                        | -                 | 94.7           | 127.5         | -                | 8.42             |

4. Block basic performance test

After determining the mix ratio of the block materials, the template is made according to the design block shape, as shown in figure 2. The design strength of the block is MU7.5, the size is 390mm×240
mm×190mm, and the physical and mechanical properties are tested after 28 days of curing according to the standard.

![Block design plan](image)

**Figure 2. Block design plan**

### 4.1. Physical property test

According to the standard GB/T 15229-2011 "Light aggregate concrete small hollow block"[13], judging whether the water absorption rate, softening coefficient and dry shrinkage rate of the block meet the requirements of the specification, and the result is shown in table 2.

| Project                     | Average or maximum test value | Requirements    |
|-----------------------------|-------------------------------|-----------------|
| Water absorption rate       | 3%                            | Not more than 18%|
| Softening coefficient       | 0.95                          | Not more than 0.8|
| Dry shrinkage rate          | 0.0033%                       | Not more than 0.065%|

It can be seen from the test results that the physical properties of the blocks are better than the specification requirements, and the block density level is calculated to be 1400.

### 4.2. Mechanical property test

#### 4.2.1. Compressive strength test

The compressive strength test of the block is carried out in groups of 5 test pieces and loaded with a 200t press of YAD-2000 model produced by Changchun Kexin Test Instrument Co., Ltd., as shown in figure 3, and the supporting GTC350 full digital power is also used. During the test, the liquid servo controller performs control, and the press is controlled at a constant speed with a rate of 2.4 kN/s and a displacement rate of 0.1 mm/s.

![Block compression strength test](image)

**Figure 3. Block compression strength test**

As the load gradually increased, the first crack appeared on the front surface of the block, and then many small cracks appeared on the side of the block, the side skin began to crack and fall off.
Subsequently, the crack on the front of the block gradually develops and prolongs, and finally the block structure is destroyed and the carrying capacity is lost. After the failure, the fracture section was observed. The damage of the main part of the recycled ceramsite concrete was more serious. The recycled foam concrete in the cavity was well protected, indicating that the block was mainly loaded by the hollow body. The state of destruction is shown in figure 4 and figure 5.

![Figure 4. The front of the block](image1)

![Figure 5. The lateral of the block](image2)

The compressive strength $f$ of the block is calculated as shown in equation 1. The calculation results are shown in table 3:

$$f = \frac{P}{LB}$$  \hspace{1cm} (1)

Where $f$ is compressive strength of the block; $P$ is block failure load; $L$ is length of the bearing surface of the block; $B$ is width of the bearing surface of the block.

| Numbering | $f$ (Mpa) | Average intensity (Mpa) | Minimum strength (Mpa) |
|-----------|-----------|-------------------------|------------------------|
| 1         | 10.79     |                         |                        |
| 2         | 10.69     |                         |                        |
| 3         | 10.68     | 10.73                   | 10.68                  |
| 4         | 10.72     |                         |                        |
| 5         | 10.75     |                         |                        |

It can be seen from the test results that the average compressive strength of the block is 10.73 Mpa, and the minimum compressive strength is also up to 10.68 Mpa, which meets the design strength MU7.5 and can be used as a load-bearing block. The compressive strength of the block exceeds the expected strength, which may be due to the fact that the later strength of the concrete is continuously increased due to the incorporation of the recycled aggregate. The materials selected for the blocks are matched with each other and mixing evenly, which has an unexpected effect. According to the norm formula 2 and using the Origin software to fit, the correction coefficient between the compressive strength of the ceramsite block and the compressive strength of the concrete cube is 0.9:

$$R_K / R_L = (0.9577 - 1.129K)\alpha$$  \hspace{1cm} (2)

Where $R_K$ is the compressive strength of the block; $R_L$ is the compressive strength of the concrete cube 28d; $K$ is the hollow rate of the block.

4.2.2. Flexural strength test

The compressive strength test of the block is also carried out in groups of five test pieces. The loading system is the same as the compressive strength test. The test mode is shown in Figure 6.
Figure 6. Block bending strength test

During the test, as the load increases, the first crack appears from the bottom and extends upwards quickly, and finally the block structure is brittle. A group of 5 blocks were damaged by shear failure, as shown in figure 7.

Figure 7. Cracks in the surface of the block

The bending strength $f_z$ of the block is calculated as follows according to equation 3, and the calculation results are shown in table 4:

$$f_z = \frac{3PL}{2BH^2}$$  \hspace{1cm} (3)

Where $f_z$ is block bending strength; $P$ is block failure load; $L$ is axis spacing of two support rods; $B$ is width of block; $H$ is the height of the block.

Table 4. Block flexural strength test results

| Numbering | $L$ (mm) | $f_z$ (Mpa) | Average strength (Mpa) | Minimum strength (Mpa) |
|-----------|----------|-------------|------------------------|------------------------|
| 1         | 360.0    | 3.34        |                        |                        |
| 2         | 360.0    | 3.44        |                        |                        |
| 3         | 360.0    | 3.44        | 3.39                   | 3.34                   |
| 4         | 360.0    | 3.34        |                        |                        |
| 5         | 360.0    | 3.38        |                        |                        |

The recorded results show that the average flexural strength of the block is 3.39 MPa and the minimum strength can reach 3.34 MPa. Compared with other blocks of the same size, the block has higher flexural strength.

5. Conclusion

The test results show that the new self-insulated block with 10% foam concrete mixed with recycled aggregate not only ensures the strength of the block but also increases the blending amount of recycled aggregate and fly ash, reached the purpose of recycling, energy-saving and environmental protection.
Through the physical property test of the block, it is found that the physical properties of the block are better than the standard.

It can be seen from the mechanical performance test of the block that the compressive strength of the block reaches the standard of the load-bearing block, and the flexural strength is higher than the ordinary recycled concrete block. According to the formula, the correction factor for the relationship between the block and concrete cube strength is 0.9.

In summary, the materials selected for the block design are low-carbon and environment-friendly. Under the reasonable combination of the materials, the block has good physical and mechanical properties and can be used as load-bearing blocks to provide a reliable reference for similar block research.

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