Research on self-insulating block composed of ground rice husk and recycled aggregate in severe cold area

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Abstract: Aiming at severe cold areas, this paper replaces 5% cement and 30% natural gravel with the same amount of ground rice husks and recycled aggregates respectively, and designs a new self-insulating block structure model compared with traditional blocks. This new block is easy to assemble, short construction period and good seismic performance. The 28d splitting strength of concrete and 28d compressive strength of blocks are determined. The results showed that this mate is better than the cracking strength of the block that can act as a MU10 non-load-bearing wall, and the standard test piece is better than ordinary concrete.

1. Introduction

With the rapid development of my country's construction industry, a series of problems have followed. How to reduce construction costs? How to deal with construction waste? How to make building materials more multifunctional? These are the problems that my country's construction industry needs to solve urgently. In the context of the continued prosperity of the real estate industry, perhaps it is because the cost of this raw material, which is regarded as inexhaustible, is still relatively low today.

Most of the aggregates used in the construction industry come from quarries or mining of alluvial strata on the surface [1]. Literature [2] shows that my country produces 100 million tons of waste concrete every year. At present, due to the lack of effective utilization of waste concrete, it is usually treated by landfill. This method not only takes up valuable land resources, but also easily damages the environment. Therefore, studying the recycling of waste materials is of great significance to the sustainable development of society.

In the construction industry, the heat loss of the envelope structure is relatively large, and the walls of the envelope structure account for a large share. Therefore, the wall reform and the development of wall energy-saving technology are one of the most important aspects of building energy-saving technology, and the development of external wall insulation technology and energy-saving materials is the main way to achieve building energy saving. At present, existing and newly built wall insulation in severe cold areas generally have two forms: sandwich insulation and external insulation. The former requires a two-leaf wall with an insulation material layer, and the latter requires an additional insulation layer outside the wall, which is not only high-costly but also time-consuming and labor-intensive. Traditional blocks do not have sufficient thermal insulation performance in buildings in severe cold areas in the north, and an insulation layer is needed on the outer surface of the blocks to prevent heat loss. In recent years, the popular self-insulating blocks are very suitable for building walls in severe cold areas. It is more convenient and energy-saving than adding an additional insulation layer outside the wall. On this basis, this paper designs a new type of self-insulating block with both
environmental protection and assembly functions—a new structure of self-insulating block composed of ground rice husk and recycled aggregate. While saving raw materials, it also solves the disposal of construction industrial waste and agricultural waste to a certain extent. This is not only beneficial to the ecological environment, but also realizes the recycling of non-renewable resources and the low emission of harmful substances. Efficient use of rice husk resources can not only improve the environment, but also provide new research directions for improving concrete properties [3]. Zhang Ji et al. [4] showed that when the replacement rate of recycled aggregate is less than 30%, the mechanical properties of recycled concrete and ordinary concrete are not much different; when it exceeds 30%, recycled concrete cannot be designed as ordinary concrete. On the basis of the research in literature [3, 5], this paper replaces 5% cement and 30% natural gravel with the same amount of ground rice husk and recycled coarse aggregate, and innovatively designs a new type of block Self-insulating block construction, the block is not only energy-saving and heat-preserving, easy to assemble, short construction period, and good seismic performance. At the same time, the 28d anti-split strength of the concrete and the 28d compressive strength of the block were tested, and its compressive and anti-split properties were studied.

2. Design and manufacture of test materials and block structure

2.1. Selection of test materials
1) Cement: Cement is "Miaoling" brand P•O 42.5 ordinary Portland cement with low heat of hydration produced by Jilin Province Northern Cement Company, which is used after passing the inspection according to the current national standards;
2) Natural coarse and fine aggregate: Coarse aggregate is granite crushed stone (produced in Yanji City) with a maximum particle size of 31.5 mm in continuous gradation; fine aggregate is river sand (produced in Yanji City), medium sand, and graded grid;
3) Ground rice husk: 80 mesh low-moisture dried rice husk powder produced by Chutian Bran Powder Processing Plant in Badong County, Enshi Prefecture, Hubei Province;
4) Water: Water is the tap water used for life in Yanji City;
5) Recycled coarse aggregate: use concrete test blocks discarded after testing by Yanji Housing and Construction Testing Center. Use a jaw crusher to crush the test block (the screen opening is 20mm) to obtain recycled coarse aggregate;
6) EPS insulation board.

2.2. Block structure design and production

2.2.1. Design direction
This kind of block is designed to shorten the construction period and improve the seismic resistance of the structure.

2.2.2. Structural design
In order to improve the seismic performance of the building, this paper designs interlocking blocks with tenon and riveting. Inspired by the jigsaw structure, three types of blocks that can fit are designed to fit perfectly while being staggered. In order to improve the seismic performance in all directions, the concave and convex parts are not in the same plane.

In order to enhance the thermal insulation effect, the self-insulating block is filled with thermal insulation material EPS. When the thickness of the air layer reaches 40mm, the thermal resistance tends to be constant. At this time, if the number of rows of holes is increased, the thermal resistance can be significantly improved [6]. Therefore, the shape of the filled EPS is rectangular [7], the thickness is 40mm, and the part is 35mm. The raw materials of block use ground rice husk and recycled coarse aggregate to replace 5% cement and 30% natural gravel in equal amounts respectively [3]. The blocks are connected by tenon and tenon joints, which is easy to assemble. The three views of
the main block and auxiliary block structure are shown in Figures 1 and 2.

![Front view](image1.png)
![Left view](image2.png)
![Top view](image3.png)

**Figure 1. Three views of main block structure**

![Front view](image4.png)
![Left view](image5.png)
![Top view](image6.png)

**Figure 2. Three views of auxiliary block structure**

2.2.3. **Block making**

Because the block structure is an innovative design, it is necessary to make corresponding trial models by yourself. Lubricating oil is applied to the inner surface of the mold and then concrete is poured. The concrete adopts the best mix ratio proposed by my team in the previous test [3]. The laboratory coordination ratio is shown in Table 1.

| Ingredient                   | kg/m³ |
|------------------------------|-------|
| Cement                       | 447.45|     |
| Ground rice husk             | 23.55 |     |
| Natural gravel               | 782.6 |     |
| Recycled coarse aggregate    | 335.4 |     |
| Sand                         | 602   |     |
| Water                        | 195   |     |

The 3D three-dimensional diagram of the block construction is shown in Figure 3, and the physical assembly diagram of the block is shown in Figure 4.
3. Test plan

3.1. Testing test of compressive performance of block
According to the "Standard for Test Methods of Concrete Physical and Mechanical Properties" (GB/T50081-2019), 3 sets of concrete test blocks were prepared according to Table 1. The 3 groups correspond to Figure 1 to Figure 3 to make blocks. When installing the mold, ensure that the built-in B1 EPS insulation board is in a good position. After the installation is completed, place the test mold on a vibrating table and vibrate, and let it stand at room temperature (10±5) °C for 48 hours before demolding. Secondly, the specimens after demolding are immediately placed in the standard curing room for curing, and the curing age is 28 days. Finally, a loading speed of 10000N/s was used to test the compressive strength of concrete blocks.

3.2. Testing test of anti-splitting performance of specimen
According to the "Standard for Test Methods of Concrete Physical and Mechanical Properties" (GB/T50081-2019), prepare 4 standard test blocks of 150mm×150mm×150mm according to Table 1, and put the test mold on the shaking table for vibrating after the mold is installed. After making it, let it stand for 48h at room temperature (10±5) °C and demould. The specimens after demolding were immediately put in the standard curing room for curing, and the curing age was 28 days. During the test, cushion blocks were placed in the middle of the blocks up and down, and the compressive strength of the concrete specimens was tested at a loading speed of 10000N/s. The block assembly is shown in Figure 5, and the test device for the anti-split test is shown in Figure 6.

4. Test results and analysis

4.1. Compressive performance of self-insulating block mixed with ground rice husk and recycled
5. Conclusion

1) The innovatively designed block in this paper has good occlusal ability, which can save energy and heat insulation, shorten the construction period, and make the wall have reliable seismic performance. The test results show that the block can be used as a non-load-bearing wall for existing and new buildings in severe cold areas; the splitting strength of concrete mixed with ground rice husk and recycled coarse aggregate is better than ordinary concrete.

2) The economic benefits are very considerable, the social benefits are even more. Calculated based on the equivalent replacement rate of 5% ground rice husks proposed in this paper, each 1m3 of concrete can save about 11.5 yuan (the average price of PO 42.5 cement in 2020 is 0.48 yuan/kg). At the same time, it significantly reduces the emission of harmful gases when the rice husk is burned. In addition, the recycled coarse aggregate replaces natural gravel in the same amount by
30%, and each 1m³ of concrete can save construction waste treatment costs by about 23 yuan (the average price of construction waste treatment fees in the second ring road in 2020 is 85 yuan/m³).

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