Experimental study on heat-preservation wall materials made from waste foam

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Abstract

In this paper, a new energy-saving-and-environmental-protection heat-preservation wall material is studied. This material is mainly made by waste foam, cement and sand in the structure of "sandwich" - cement foamed plastic is in the middle of cement mortar. Experimental study reveals that the heat-preservation block of this material has lighter self-weight and higher compressive strength and better performance in heat preservation, sound insulation and frost resistance, that is to say, its overall property is obviously superior to that of others such as aerated concrete block. This block consumes a large amount of waste foam that is difficult to dispose, which conducive to environmental protection and energy is saving. It can bring favourable social, economic and environmental benefit. Besides, less energy is consumed in the production of this material and it is easy to realize volume production, so this material is a new wall material of energy saving and environment protection.

Keywords: waste foam, heat preservation, wall material, new technologies

1 Introduction

With heavy self-weight and high energy consumption, the traditional wall materials in China waste lots of land resources, so it is to the disadvantage of environment protection and energy saving. Heat preservation property of the building envelope is a major factor influencing energy consumption of a building and different envelope materials need different energy costs. In China the insulating layer is generally not built in the outer wall of house by tradition, resulting in poor heat preservation and deafening effect as well as more energy consumption [1]. There is one important aspect in the architectural idea of "sustainable development": laying emphasis on energy conservation [2]. Currently the development priority in wall materials is to develop the new wall material, which needs low energy consumption and causes less pollution local resources by utilizing local resources [3]. Meanwhile, the waste foam is difficult to resolve in natural environment, causing serious pollution in modern times. With the development of social economy and rapid improvement of living standard, the demand for foamed plastic is increasing and waste foam is bringing more serious pollution and some experts have listed this pollution on the top three public pollution following water pollution and air pollution. As the aggregate of concrete heat presservation block, recycled polyphony l granule cannot only avoid "white pollution", but has many advantages such as good particle size gradation, being easy to be coated by size, good property and low price. The concrete heat preservation block in this paper is produced through simple technique, consumes less energy and has many advantages including light self-weight, good heat preservation property and high strength. This block consumes a large amount of waste polystyrene foam, opening up a way of removing white pollution and helping to environmental protection and energy saving, so it is a new green wall material with broad prospect.

2 Experiment materials

Cement: PO 32.5, PO 42.5 and PO 52.5 ordinary Portland cement from Luoyang Yellow River Cement Plant.

Foamed plastics particles: waste polystyrene foam is broken into particles of 0.4 mm~5 mm.

Sand: medium sand with the fineness modulus of 2.6 and qualified grain size gradation.

Tackifier: new environment-friendly II glue from Luoyang Kelong Coating Co. Limited.

Water: drinking water.

3 Experimental study

3.1 MAKING BUILDING BLOCK

1) To make the test mould in size of $150mm \times 150mm \times 150mm$ and its size and structure are shown in Figure 1. Steel plates with the thickness of 5mm are selected to make the test mould in the net size of $150mm \times 150mm \times 150mm$; the plates can be disassembly and place together flexibly and no gap is allowed after the assembly. 2 scale marks which are 20mm to the upper and lower surfaces are drawn on the side wall of the test mould in order to control the thickness of screed and that of cement foam layer. Waste engine oil is painted on inwalls for easy mold release.

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2) Cement:Sand:Water $= 1:2:0.6$ and cement mortar is mixed mechanically. Put the cement mortar on the bottom of test mould as thick as 10mm.

3) Cement:Sand:Tackifier=1:10:0.10 to make the cement paste; fully mix the paste with recycled polyphony l granule; after the paste attaché evenly to polyphony l granules, to put the mixture in the test mould about 5mm to the top edge of the block.

4) To spread the cement mortar to the top edge and smooth it over with a spatula.

5) To cover the surface of the test mould immediately once it shapes up to prevent evaporation of water. After 24 hours standing at the temperature of 20°C±5°C, to mark serial numbers and remove the block from the mould.

6) To put the test block in a standard curing room with the temperature of 20°C±1°C and working humidity above 95%. After the test block is maintained for 28d, the cement heat preservation block can be formed.

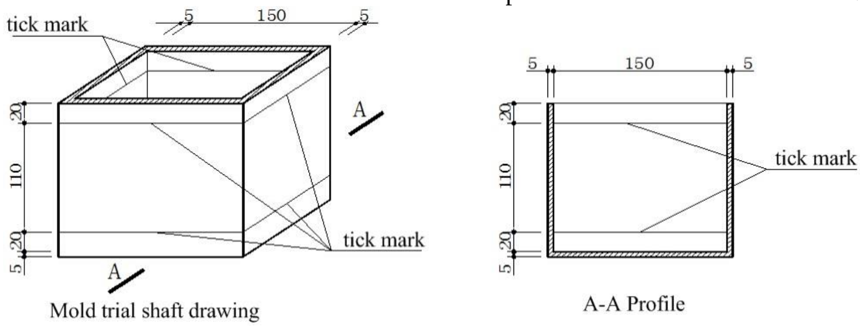

FIGURE 1 Test mould dimension drawing

3.2 PERFORMANCE DENSITY TEST

There are 18 test blocks in 6 groups for this test. The performance density is tested in the following steps:

1) To bake the test block in a 105~110°C baking oven until it has constant weight and to cool it to room temperature in a dryer.

2) To measure the size of the block with a straightedge (mm). Since it is a cube, the arithmetic mean value of 3 extents on all surfaces is used as the test value. Note down the value and calculate the volume (V_0).

3) To weight the mass with a balance and calculate its performance density ρ_0 according to the Equation - $\rho_0 = m / V_0$. Table 1 displays the test data.

TABLE 1 Performance density test data

Groups	**No**	**Test block size/ cm**			**Test block volume V_0/cm³**	**Test block mass m/ g**	**ρ_0/(g/cm³)**	**Mean value/(g/cm³)**
		Side length	*Side length*	*Side length*				
Group 1	1	15.0	15.1	15.2	3442.80	2065.7	0.600	0.610
	2	15.0	14.9	15.1	3441.90	2109.9	0.613	
	3	14.9	15.0	14.9	3330.15	2054.7	0.617	
Group2	1	15.0	15.0	15.2	3420.00	2072.5	0.606	0.607
	2	14.9	14.9	15.0	3330.15	2034.8	0.611	
	3	15.0	15.1	15.2	3442.80	2082.9	0.605	
Group3	1	14.9	15.0	15.1	3374.85	2058.3	0.610	0.606
	2	15.0	15.1	15.2	3442.80	2093.2	0.608	
	3	14.9	15.1	15.2	3419.85	2047.8	0.599	
Group4	1	15.0	14.9	15.0	3452.50	2106.0	0.610	0.612
	2	15.1	15.0	15.2	3442.80	2107.3	0.612	
	3	15.0	14.9	15.0	3352.50	2061.2	0.615	
Group5	1	15.1	15.0	15.2	3442.80	2105.4	0.612	0.611
	2	15.0	14.9	14.8	3307.80	2040.5	0.617	
	3	15.0	15.0	15.1	3374.85	2042.3	0.605	
Group6	1	15.0	15.0	14.9	3352.50	2038.3	0.608	0.613
	2	15.1	15.0	15.1	3442.80	2110.3	0.613	
	3	15.0	15.0	14.9	3352.50	2071.4	0.618	

According to Table 1, the performance density is:

$$\frac{0.610+0.607+0.606+0.612+0.611+0.613}{6} = 0.61.$$

The performance density is 0.61g/cm³, that is 610 kg/m³.

3.3 COMPRESSIVE STRENTH TEST

There are 18 test blocks (used in the above test) in 6 groups for the compressive strength test. The compressive strength is tested in the following steps:

1) To wipe and measure the size of the test block (1mm) as soon as it is taken out from the curing room and to calculate its compression area A (mm2).

2) To place the test block on the bearing plate according to Illustration 2: the pressure-bearing surface of the block should be perpendicular to the top surface when it shapes up and its centre should align with the centre of the tester. To start the tester and adjust the ball seat for balanced contact between the top and bottom platens and the top and bottom surfaces of the test block.

3) In this test, loading should be increased constantly and uniformly with the speed of 0.3MPa/s. When the test block begins to deform, stop to adjust the accelerator of the tester until the block is destroyed. Note down the collapse load $P(N)$.

4) To calculate the compressive strength according to $f_{cu} = P/A$. 3 arithmetic mean value of the strength is used as the compressive strength value of their group (0.1MPa). If $minimun\ value - mediam > 15\%$ median or $maximun\ value - mediam > 15\%$ median, the minimum value and the maximum value should be removed in the calculation; that is the median is the compressive strength value. If $minimun\ value - mediam > 15\%$ median and $maximun\ value - mediam > 15\%$ median, the test results are invalid.

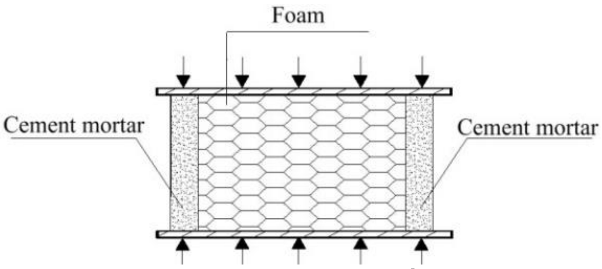

FIGURE 2 Compressive Strength Test

Table 2 presents the compressive strength test data.

TABLE 2 Compressive Strength Test Data

Groups	NO.	Size(mm) a	Size(mm) b	A(mm²)	P (N)	CS(MPa)	
	1	150	151	22650	90250	3.98	
1	2	150	149	22350	85250	3.81	3.81
	3	149	150	22350	80850	3.62	
	1	150	150	22500	78400	3.48	
2	2	149	149	22201	72550	3.27	3.41
	3	150	151	22650	78750	3.48	
	1	149	150	22350	84000	3.76	
3	2	150	151	22650	81200	3.58	3.63
	3	149	151	22499	79550	3.54	
	1	150	149	22350	85500	3.83	
4	2	151	150	22650	91500	4.04	3.84
	3	150	149	22350	81550	3.65	
	1	151	150	22650	82500	3.64	
5	2	150	149	22350	77800	3.48	3.57
	3	150	150	22500	80550	3.58	
	1	150	150	22500	84000	3.73	
6	2	151	150	22650	89500	3.95	3.75
	3	150	150	22500	80500	3.58	

According to Table 2, the compressive strength is: $\frac{3.81+3.41+3.63+3.84+3.57+3.75}{6} = 3.67$.

The average value of compressive strength is 3.67MPa and the minimum value is 3.27MPa.

3.4 HEAT PRESERVATION PROPERTY TEST

This test is a comparison test. The property of heat preservation is compared between heat-preservation concrete block, aerated concrete block and common brick to conclude the heat preservation property and heat conductivity of this block.

3 sealed experiment rooms of the same size are built up with common bricks, aerated concrete block and the concrete block studied in this paper [7]. Place an electric stove (power: 2500w) in each room to heat the experiment rooms. Stop the heating when the temperature reaches 95°C and observe how the temperature changes in each room at the interval of 30m for 9 times. Note down the temperatures observed.

Do this test for 3 times. The temperature-time variation curves in the 3 experiment rooms are shown in Figures 3, 4 and 5.

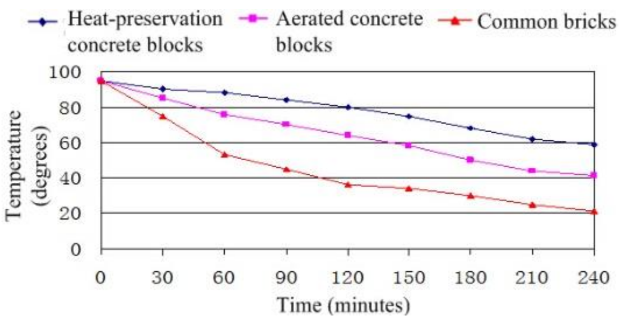

FIGURE 3 Temperature variation curve in rooms (1st time)

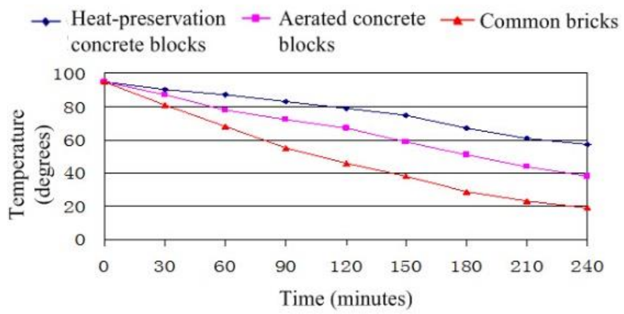

FIGURE 4 Temperature variation curve in rooms (2nd time)

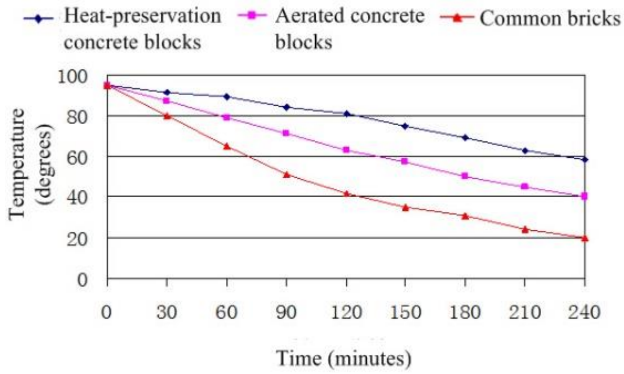

FIGURE 5 Temperature variation curve in rooms (3rd time)

Test results show that the temperature drops slowest in the room made by heat-preservation concrete blocks followed by the room made by aerated concrete blocks and common bricks. Thus, it can be inferred that the heat preservation property of the block studied in this paper is obviously superior to aerated concrete block and common brick, and that its heat conductivity is smaller than that of aerated concrete block, that is its heat conductivity $\lambda < 0.12 \ w/m.k$.

4 Conclusions

1) The concrete block studied in this paper can fully meet the requirement of new wall materials in properties such as performance density, compressive strength and heat presservation. Compared with the autoclaved aerated concrete blocks, this block has obvious advantages.

2) In engineering practice, the cement mortar layer on the outer coat of block is the main framework and the polystyrene granule in the block can bears little external force, so cement mortar of high strength can produce the heat-preservation concrete block of higher strength.

3) The technique in this paper is quite simple and easy and consumes less energy. Large equipment is not needed; small investment requires; desired results are produced rapidly and it is easy to realize volume production.

4) Blocks of various specifications can be produced according to the thickness of wall for different environment. For example, the $190*190*H$ (the mortar layer is as thick as 15mm) and $240*240*H$ (the mortar layer is as thick as 20mm).

5) This concrete blocks have digested a lot of waste polystyrene plastics, protecting the environment and steering the building materials in the direction of saving resources, utilizing wastes and protecting environment.

6) To carry out the studies on heat-preservation concrete blocks made from recycled polyphony l granules can acelerate the progress of wall material innovation in China and the greenization of building materials industry and is conducive to the popularization of energy saving construction. To build houses with high-quality new wall materials has obvious building energy efficiency and improves comfort level of living and can meet the requirement of economic and social development and upturn living standarts. To launch the studies plays a positive role in propelling the progress of wall material innovation and the greenization of building materials industry and the popularization of energy saving building in China.

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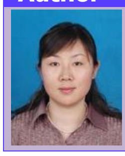

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