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EXPERIMENTAL STUDY ON CLAY CERAMISITE THERMAL INSULATION MORTAR

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Abstract

Experimental study on the clay ceramisite thermal insulation mortar is carried out in this paper, through which, thermal conductivity of masonry wall plastered by the mortar and the cost of this mortar are calculated. The experimental results show that the ceramisite below 5mm can be used as aggregate to prepare the thermal insulation mortar, which thermal conductivity is not more than 0.319 W/(mK) and 28-day compression strength is not less than 3.9MPa.When the mortar studied in this paper is used as external rendering, the 240mm-thick walling system's thermal conductivity is 1.4 W/m2K, thus it meets the demands of the P.R.C. professional standard: Design Standard for Energy Efficiency of Residential Buildings in Hot Summer and Cold Winter Zone (JGJ134-2001), and the mortar has economic feasibility.

Key Words

mortar, clay ceramisite, thermal insulation, conductivity

1 Introduction

From the 1980's, a large number of experimental studies have been done on the building energy -saving in our country, especially on the exterior-wall-insulation of civil architecture. It has been found that the energy consumption of 240mm-thick outer wall takes more than 40% of heating energy in winter. As the building-energy-saving undertaking has been developing, a variety of measures has put forward. At present, Chinese government is vigorously developing the new insulation wall-materials, which save energy, utilize waste and protect earth. At the same time, the government has promulgated a series of codes and policies to restrict the clay brick's production and application and encourage the new wall-materials' development. Especially in recent years, under the guiding of the ninth 5-year's walling innovation, the new wall-materials of light weight, strong strength, energy saving, waste utilization were paid more and more attention. Under this condition, thermal insulation mortar becomes the focus to be developed and applied.

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2 Current research status

Thermal insulation mortar is a kind of mortar for coating. It is prepared at a certain ratio of insulation aggregate, cementing materials, admixtures and water for heat insulation of exterior wall and roofing.

The development application on thermal insulation mortar in others countries are earlier than in China. The demands of it are higher, as well. In German, 1995, it was demanded in code that the thermal conductivity of roof should be no more than 0.22 W/(m^2K), of exterior wall should be no more than 0.5 W/(m^2K), of window should be no more than 0.7 W/(m^2K). While the same maximum conductivities demanded in Beijing respectively are 0.6, 0.82 and 4.0. So thermal insulation mortar can be further developed and widely applied in China.

In 1998, Ten New Technique Items of Building Industry was widely applied by National Construction Department of China. In the part of energy saving and new walling application, it is said that the external heat-insulated technique of exterior wall should be well on with development.

The heat insulation mortar studied and applied presently, mainly includes the expanded pearlite mortar, the fly ash mortar, the EPS mortar and the composite mortar with no less than two kinds of heat-insulated aggregates. As is the walling innovation's beginning in our country, there are many kinds of thermal insulation mortar to be developed and tried. Under this condition, thermal insulation mortar applied today has characteristics which is showed below.

(1) Most kinds of the heat insulation mortar, including the expanded pearlite one, the fly ash one, and the shale pottery one, etc., are prepared with expanded pearlite as aggregate. Although the expanded pearlite has small density and good thermal insulation behavior, it still has limitation of high water absorption, which cannot be overcome. Thermal insulation behavior of a material not only is relevant to its density, but also has a great deal to do with its moisture content. Once expanded pearlite is in moist condition, its thermal insulation behavior will be desisted. So these kinds of thermal insulation mortar are only suitable to dry conditions, such as indoor environment. Now, there are also modification researches, by using admixture. Thus not only increases the mortar's cost, but also influences its heat-insulated behavior more or little.

(2) The surface of EPS is of hydrophobic nature and its unit weight is small. So in the freshly mixed mortar, EPS particle is not affined with cement paste. Also, it is be buoyed up. Thus will cause the segregation of mortar, the decrease of water retentivity and the destruction of workability. In practise, EPS surface modification is carried out before it was mixed. Requires of its work process and construction is strict, based on the special treatment. EPS thermal insulation mortar has good heat-insulated behavior as plaster of external wall, but its construction is complex and hard.

(3) Most kinds of the mortar, talked about before, have low compression strength. They are used as interior insulation at common, and not suitable for the exterior insulation or the thermal insulation masonry mortar, which strength should be high enough. On the other hand, the masonry of light and heat-insulated block is built much more than before, because of the improvement in architectural energy saving criteria. Apparent density of this kind of block is 450-950 Kg/m^3. Thermal conductivity of them is 0.15-0.35 W/(mK). While common masonry mortar's density is 1600-1800 Kg/m^3, thermal conductivity is 0.8-1.0 W/(mK). Because of the great difference between the mortar and the block, there must be cold-bridges in the masonry, which caused almost 25% energy losing. Therefore such kind of masonry mortar, with good heat-insulated behavior, is greatly needed in construction.

3 Experimental study

Ceramisite is an artificial light aggregate used magmaphile clay or shale as material. It was manufactured after high temperature fast baking. It has strong shell and distributed by internal disconnected micropores. As thermal insulation ceramisite, its packing density is no more than 800 Kg/m^3. Because of the characteristics of ceramisite, which is light and low heat conductivity, the ceramisite mortar has the same properties for improving building's thermal insulation, cutting down the architectural energy consumption, saving energy. In this experiment, the clay ceramisite is produced by Changsha Ceramisite Factory and its physical properties is showed in Table 1.

Table 1 Physical properties of the ceramisite

Grain size (mm)	Tube strength (MPa)	Density (Kg/m^3)	Packing density (Kg/m^3)	Thermal conductivity (W/mK)	Water absorption ratio (1h, %)	Soft coefficient
0.05-5	1.3	730	670	0.151	10.8	0.9

3.1 Mixing ratio design

The way of trial mixing is used in the experiment, for the basis of mixing proportion to be calculated is unavailable. The mixing proportion is showed in Table 2. Simultaneously, the compression strengths after 7days and 28 days were also determined and listed in Table 3.

Table 2 Mixing proportion of the mortar

Number	Cement (Kg/m^3)	Fly ash (Kg/m^3)	Lime (Kg/m^3)	Ceramisite (Kg/m^3)
D0-1	469	0	0	670
D0-2	328	183	0	670
D0-3	234	280	0	670
D0-4	187	280	56	670
D0-5	163	280	84	670
D1-1	283	0	0	670
D1-2	203	100	0	670
D1-3	227	0	56	670
D1-4	170	100	30	670

Table 3 The mortar's compression strength

Number	7-day compression strength (MPa)	28-day compression strength (MPa)
D0-1	4.5	10.7
D0-2	3.3	8.7
D0-3	2.6	5.8
D0-4	1.9	4.8
D0-5	1.9	4.0
D1-1	3.6	5.8
D1-2	2.7	4.9
D1-3	2.2	4.6
D1-4	1.9	3.9

3.2 Thermal conductivity of the mortar

Thermal conductivity of the ceramisite thermal insulation mortar designed to be studied in the experiment, is commissioned inspection, by Hunan Authorized Architectural Material Quality Supervision & Test Station. Testing results are listed in Table 4.

Table 4 Heat conductivity of the mortar

Number	Heat conductivity (W/mK)
D1-1	0.319
D1-2	0.256
D1-3	0.279
D1-4	0.238

According to the results in Table 4 and considering the figures of Table 2, the conclusion can be drew as below:

(1) Cement's content has a certain effect on the mortar's heat conductivity. When cement's content is increased, the mortar's heat conductivity goes higher.
(2) Mortar's thermal conductivity will become lower, after the fly ash was mixed.
(3) Comparing the thermal conductivity of common mortar and the ceramisite thermal insulation mortar, which is studied, the former is much higher than the later.
(4) The mortar's 28-day compression strength, which was determined in the experiment, is between 3.9 MPa and 10 MPa. Mortar of expected strength can be prepared by changing the mixing ratio.

4 Economical analysis on the mortar

4.1 Calculation of the heat transfer coefficient

According to the demands of the heat transfer coefficient of external wall, stipulated by NCDC's Design Standard for Energy Efficiency of Residential Buildings in Hot Summer and Cold Winter Zone (JGJ134-2001), the heat transfer coefficient of Changsha should not beyond 1.5 W/m^2K.

There are four kinds of walling composition studied in this paper. Two of them are common brick and concrete construction, which external wall's thickness is 240mm, with common mortar on surface (Table 5). The other two kinds is with the ceramisite thermal insulation mortar on surface (Table 6).

Table 5 Common walling composition

Composition 1	Thickness (mm)	Heat conductivity (W/mK)
Internal lime plaster	10	0.35
Brick wall	240	0.81
External cement plaster	20	1.40
Composition 2	**Thickness (mm)**	**Heat conductivity (W/mK)**
Internal lime plaster	10	0.35
Brick wall	370	0.81
External cement plaster	20	1.40

Table 6 Walling composition with ceramisite thermal insulation plaster

Composition 3	Thickness (mm)	Heat conductivity (W/mK)
Internal lime plaster	20	0.256
Brick wall	240	0.81
External ceramisite heat insulation plaster	30	0.256
Composition 4	Thickness (mm)	Heat conductivity (W/mK)
Internal lime plaster	10	0.35
Brick wall	240	0.81
External ceramisite heat insulation plaster	20	0.256

The equation of the heat transfer coefficient of the multiple materials' shield structure is:

$$K = \frac{1}{\frac{1}{\Delta_i} + \sum_{i=1}^{n} \frac{\Gamma_i}{\mathrm{O}_i} + \frac{1}{\Delta_e}} \tag{1}$$

K is thermal conductivity;

Δ_i is internal transfer coefficient;

Δ_e is external transfer coefficient;

Γ_i is thickness of material in layer i;

O_i is heat conductivity of material in layer i;

All the walling compositions' heat transfer coefficient can be evaluated, using the equation (1).

$$K_1 = \frac{1}{\frac{1}{8.7} + \frac{0.01}{0.35} + \frac{0.24}{0.81} + \frac{0.02}{1.40} + \frac{1}{23.26}} = 2.01$$

$$K_2 = \frac{1}{\frac{1}{8.7} + \frac{0.01}{0.35} + \frac{0.37}{0.81} + \frac{0.02}{1.40} + \frac{1}{23.26}} = 1.52$$

$$K_3 = \frac{1}{\frac{1}{8.7} + \frac{0.02}{0.256} + \frac{0.24}{0.81} + \frac{0.03}{0.256} + \frac{1}{23.26}} = 1.49$$

$$K_1 = \frac{1}{\frac{1}{8.7} + \frac{0.01}{0.35} + \frac{0.37}{0.81} + \frac{0.02}{0.256} + \frac{1}{23.26}} = 2.01$$

These coefficients show that the 240mm-thick wall with common plaster, which coefficient is 2.01 W/(m^{2}K), has a great difference from the energy saving design code, which demands 1.5 W/(m^{2}K) as the maximum of the walling thermal transfer coefficient. While the coefficient of the same thick wall with ceramisite thermal insulation plaster is 1.49 W/(m^{2}K)•1.50 W/(m^{2}K). So it can satisfy the demands of Design Standard for Energy Efficiency of Residential Buildings in Hot Summer and Cold Winter Zone (JGJ134-2001). In order to lower down the heat transfer coefficient, the 370mm-thick external wall can be used in Changsha. Its heat transfer coefficient is 1.52 W/(m^{2}K), a little bit more than the code, but still be very closed to it. On the other

hand, replacing the 240mm-thick wall for the 370mm-thick wall not only waste a great deal of architectural material but also increase the building area. Simultaneously the improving of the building's thermal-insulated behavior is not notable.

4.2 Economical analysis

The ceramisite thermal insulation mortar's preparation process, design and construction methods are all same to the common plaster. The cost of both mortar are calculated in Table 7.

Table 7 Cost analysis of the exterior plaster

Project	Common plaster			Ceramisite thermal insulation plaster		
	Dos rate	Unit cost	Cost (RMB)	Dos rate	Unit cost	Cost(RMB)
Cement	237 Kg/m^3	0.03 RMB/Kg	8.03	203 Kg/m^3	0.03 RMB /Kg	6.88
Fly ash	0	0.02 RMB/Kg	0.00	100 Kg/m^3	0.02 RMB /Kg	1.94
Lime	0.09 m^3/m^3	10.07 RMB/m^3	0.91	0	10.07 RMB/m^3	0
Sand	1.28 m^3/m^3	3.95 RMB/m^3	5.06	0	3.95 RMB /m^3	0
Ceramisite	0	24.2 RMB/m^3	0	1 m^3/m^3	16.94 RMB /m^3	16.94
Admixture	0	0	0	2 Kg/m^3	2.42 RMB /Kg	4.84
Cost of 1m^3 mortar (RMB)			13.99			30.59

According to the Table 7, it can be concluded that the increasing cost from the common mortar to the ceramisite thermal insulation mortar is about 138RMB/m^3. The mortar needed to be plastered on the 1m^2-wall is 6.9 RMB. The heat transfer coefficient of this wall-composition meets the energy saving design code, and thus cutting down the energy consumption of heating and cooling. So this mortar is completely useable in economic.

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