Research and Development of Micro Porous Concrete and Polystyrene Foam Plastics in Composite Wall Material

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Abstract-This paper introduces the rapid hardening sulphoaluminate cement as cementitious materials, polypropylene short cut fiber as reinforcing material. Through the development of physical foaming cellular concrete and polystyrene foam plastic board, craft processes and product performance of non-load-bearing wall by sandwich composite, which provides a technical idea for the development of new wall materials in northern China.

Keywords-cellular concrete; polystyrene foam board; wall material products; building energy conservation; durable fire protection

I. INTRODUCTION

Wall material is the key to determine whether the structure of the building for lifetime energy saving. External thermal insulation of building has exterior insulation, internal insulation and sandwich insulation in three ways. After years of market choice, polystyrene foamed plastic board thin plastering exterior insulation system accounted for more than 95% in China external wall thermal insulation projects. However, there are two major defects in the system: one is the durability problem, two is the fire safety problem. The inevitable trend of large area cracking of the national external wall thermal insulation layer as well as large and small fires in building exterior wall, which did not slow down the application pace of polystyrene board exterior wall insulation system, one of the main reasons is lack of real sense of all fire protection, durability, self insulation, construction convenient, affordable wall materials.

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specification for exterior thermal insulation of external walls(JGJ144-2004)shall not be less than 25 years for the use of external insulation for external walls. Code for design of civil buildings provides the use of important buildings and high-rise buildings life span of 100 years, general building 50-100 years. Obviously, the service life of external wall insulation project is less than half of the main building.

To consider from the fire prevention requirements, inorganic materials as wall insulation materials are the most ideal. However, the thermal conductivity of inorganic materials can not meet the requirements of building energy efficiency in cold and chill regions. It is difficult in aspects of process control, quality assurance and raw material source. Organic foaming materials are compounded with inorganic materials, they can completely overcome the problem of poor fire resistance and durability and are the most realistic choice of building external wall thermal insulation materials.

Based on the above background, we developed a composite sandwich product that micro porous concretes encased polystyrene foaming board, and promoted rapidly in the country.

II. PRODUCT STRUCTURE

Through inorganic non combustible and refractory micro porous concrete thermal insulation material wrapped organic foaming thermal insulation core material, blocking the contact of organic material with air, making the final products achieve fire prevention at the same time of heat preservation and heat insulation.

Building block specifications: long 600(1200)mm, high 300mm, thick 250(200,150,120)mm; volumetric weight: 400-600Kg/m³. Base material micro porous lightweight concrete volumetric weight: 800-1200 kg/m³, compressive strength 2.0-4.5Mpa.

Outer wall thickness of sandwich block is not less than 25mm, rib thickness is not less than 15mm.

III. DEVELOPMENT OF FIBER REINFORCED LIGHTWEIGHT AGGREGATE MICROPOROUS LIGHTWEIGHT CONCRETE MATERIALS

This kind of concrete we developed is based on rapid hardening sulphoaluminate cements and a few common portland cements as the main cementitious materials, polypropylene and inorganic modified short fiber as reinforcing material, the ceramsite, slag, slag brick, expanded perlite, etc. as lightweight aggregate. A lightweight concrete is made by the method of introducing a small foam in the preparation process, lightweight concrete with fiber reinforced light aggregate.

A. Raw Materials for Micro Porous Concrete

1) *Cementitious materials*: 42.5 level rapid-hardening sulphoaluminate cement, can conform to sulphoaluminate cement (GB 20472-2006) standard requirements. Ordinary portland cement as modified materials of cementitious materials, can meet the requirements of Common Portland Cement (GB 175-2007) standard requirements.

2) *Lightweight aggregate*: the choice of ceramsite, blast furnace slag, slag, waste brick slag and expanded perlite use cooperatively. Natural aggregate gradation, due to the limitation of the wall thickness of the product, maximum particle size should be less than 10mm. Bulk density of ceramsite and slag 600-800 kg/m³; bulk density of blast furnace slag 1100-1200 kg/m³; bulk density of waste brick slag 800-1000 kg/m³; bulk density of expanded perlite 100-200 kg/m³.

3) *Reinforced fiber*: choose 8 mm long inorganic mineral fiber and polypropylene chopped fiber composite, after the treatment of highly efficient dispersing agent developed by ourselves can be evenly dispersed in lightweight aggregate micro porous concrete.

B. Micro Porous Concrete Mix Proportion

Taking the density 500 grade block as an example, control slurry density less than 1200 kg/m³. Per cubic meter of micro porous concrete materials dosage, rapid hardening cement 300 kg, lightweight aggregate 640 kg, micro bubble agent 20 kg, short fiber 1.0 kg, rubber powder (HF2000 water solubility) 1.5 kg, water cement ratio 0.9.

C. Fabrication Process and Properties of Micro Porous Concrete

Micro porous lightweight concrete using our invention "compressed air foam generator" technology, using air compressor, under the pressure of more than 0.5 MPa, the pH value of about 8 HF-1 type sulfonate series micro bubble

agent through the "compressed air foam generator" convert into tiny bubble diameter of less than 1mm, and then mixes with self-leveling concrete slurry which water cement ratio greater than 0.6, make porous lightweight concrete slurry with a volume quality of 800~1100 kg/m³, implement a uniform and stable formation of micropores. Adding lightweight aggregates to the above micropore lightweight concrete can produce volumetric weight 900~1200 kg/m³ light aggregate micro porous lightweight concrete.

The basic properties of micro porous concrete are shown in Tab.1.

TABLE I. BASIC PROPERTIES OF MICRO POROUS CONCRETE

Volumetric Weight (Kg/m ³)	Weight Water Absorption (%)	Thermal Conductivity (W/(m·K))	Compressive Strength (MPa)
800~1200	28.06	0.14-0.22	2.0-4.5

As shown in fig. 1, the structure of the hole is enlarges 40 times. It can be seen that most of its hole's diameters are 0.3mm or less, several around 0.5mm. There is a 0.1-0.2mm thickness of the hole wall between holes. Holes are independent of each other and not through.

Figure 1. The photo that micro porous concrete section magnifies 40 times

IV. PRODUCTION PROCESS OF COMPOSITE SANDWICH PRODUCTS

The composite of the above micropore concrete and the thermal insulation core material forms sandwich composite block, photo is shown in fig. 2.

Figure 2. Sandwich composite block product photo

A. Raw Materials for Sandwich Blocks

1) *Micro porous concrete*: meet the requirements of table 1.

2) *Thermal insulation core material*: Organic core material is polystyrene foaming board, volumetric weight less than 15kg/m^3 , thermal conductivity is not more than $0.042\text{W/m}\cdot\text{K}$. Fire resistance meet national standards (GB 8624-2006) A2, B or C level requirements.

3) *Foaming agent and release agent*: use homemade third generation HF-3 sulfonate series foaming agent. Foaming and foam stability good, apply to air compression foam process. Release agent chooses homemade HF-2 type emulsified oil soap lye, with non-toxic, tasteless, high isolation and non polluting properties of product surface, etc. can be used in spraying technology.

B. Material Composition

Micro porous concrete and thermal insulation core material each 0.5 m^3 , release agent 2kg per cubic meter.

C. Production Process

1) Process key link

Batching system, foam production and supply foam system, stirring casting and slurry scraping system, molding system, product automatic clamping and stripping crane system, automatic palletizing system, chain plate conveyor system, model car ferry system, maintenance system, etc. For the above system we developed special equipments and DCS, PLC automatic control system. This technology has

strong adaptability, the core materials can be organic foaming materials, also can be full of inorganic glass cotton, rock wool, hydrophobic glass beads or perlite insulation board.

2) Main technical parameters

Volume quality of micro porous lightweight concrete slurry $900\text{--}1100\text{kg/m}^3$.

casting cycle	6min
casting temperature	$40\text{--}50^\circ\text{C}$
rest time	30min
dry and thermal curing time	4h
dry and thermal curing temperature	$40\text{--}50^\circ\text{C}$
pressure of air pressure and foaming	$\geq 0.5\text{MPa}$

In the casting cycle, the 2min is put into the dry materials, making foam and stirring 2min, pouring into mold 2min.

V. MAIN TECHNICAL INDEXES OF PRODUCTS

Product combustion performance: inorganic base material and organic core material composite (sandwich) products fireproof performance meet GB 8624-1997 *Classification on burning behaviour for building materials* incombustible materials A grade composite (sandwich) materials requirements.

Drying shrinkage, freezing resistance, thermal conductivity, masonry thermal resistance, sound insulation, fire endurance and other physical performance indicators are shown in Tab. 2.

TABLE II. PHYSICAL PROPERTY INDEXES OF HEAT INSULATION AND ENERGY SAVING COMPOSITE BLOCK

Density Level			B03	B04	B05	B06
Drying shrinkage value	Standardized approach, $\leq$	mm/m	0.5			
	Express method, $\leq$		0.8			
Freezing resistance	Mass loss rate%, $\leq$		5.0			
	Post freezing strength loss rate%, $\leq$		25			
Thermal conductivity of substrate(dry state)W/m·K, $\leq$			0.14	0.18	0.20	0.22
Products equivalent coefficient of thermal conductivity(dry state)W/m·K, $\leq$			0.075	0.085	0.090	0.100
Masonry thermal resistance $m^2 \cdot K/W$	120mm thick, $\geq$		1.60	1.41	1.33	1.20
	150mm thick, $\geq$		2.00	1.76	1.67	1.50
	200mm thick, $\geq$		2.66	2.35	2.22	2.00
	250mm thick, $\geq$		3.30	2.90	2.75	2.50
Sound insulation of air sound meter (dB)	150mm thick, $\geq$		45			
	250mm thick, $\geq$		50			
Fire endurance (h)	240mm thick, $\geq$		3.5			

Annotation: 1. Masonry thermal resistance uses calibration and protection hot box power method measurement, heat flow meter method can not be used to detect. Masonry thickness is equal to product thickness.
2. Fire endurance test the thickness of the masonry that is equal to product thickness add plaster layer thickness. Such as 200mm thick masonry, products 200mm, 1:3 cement mortar on both sides are 20mm.
3. The thermal conductivity of the substrate is measured by the plate thermal conductivity meter: Products equivalent coefficient of thermal conductivity is measured by electric simulation, also can be calculated by the latest method of thermal calculation.

According to The Nation Prevents Fire Building Material Quantity Direct Examination Center in accordance with *Fire-resistance tests-Elements of building construction* GB/T9978.1-2008 and GB/T9978.8-2008 detection, the fire endurance of the product masonry wall can be up to 3.5 hours. Detection with metope 3×3m, by the 200mm thick block staggered joint masonry, the ash seam is less than 10mm, the both walls use ordinary cement mortar plaster 20mm after they turn into the wall. Wall surface by fire in the furnace temperature 1136.40°C calcinates after 3.5 h, on the other side of the wall, the surface temperature rise average of 10 monitoring points is 16.26°C, only the standard set limit of the average temperature rise 140°C of 12%. The highest point heating up value 93.32°C, only half of the standard requirements 180°C, two surfaces of the wall are not destroyed, polystyrene core materials near the outer surface are intact. The polystyrene core material softens near the fire surface, but they are not on fire. We can see from fig. 3 the wall state near fire side, after the experiment is finished, the plaster layer expands and drops, block is intact. Fig. 4 is the experiment that brazing torch grills for 10 minutes in high temperature without destruction of the product.

Figure 3. The wall is out of the furnace by the fire side when barbecued after 3.5h

Figure 4. Experiment that brazing torch grills for 10 minutes in high temperature without destruction of the product

VI. SOCIAL BENEFITS AND APPLICATIONS

As the building external wall thermal insulation use, per cubic metre block compared with traditional aerated concrete, can use industrial waste slag 250kg, saving heating energy consumption 119kg standard coal, saving production energy consumption 33kg standard coal. Compared with the traditional materials energy-saving wall of composite masonry, the cost of the wall is reduced about 30%, the wall thickness thinning about 33% and wall weight reduce more than 40%. According to the calculation of the annual new wall materials' total 674 million m³, if the product market share can reach 15%, they can save 107.8 billion yuan, energy-saving 15.37 million tons standard coal, using industrial waste residue 25.28 million tons, reducing carbon dioxide emissions 38.3 million tons.

Products can be used for the frame structure infilled wall, shear wall structure and brick concrete structure load-bearing wall exterior insulation. Project in Northwest China and Shandong province promotes and applies for five years, engineering application more than 300, total more than 550000 cubic meters, sales greater than 210 million yuan, the savings amount 590 million yuan.

VII. CONCLUSIONS

- Through inorganic non combustible and refractory micro porous concrete thermal insulation material wrapped organic foaming thermal insulation core material, blocking the contact of organic material with air, making the final products achieve fire prevention at the same time of thermal insulation and heat insulation.
- The surface layer of the sandwich product is fully inorganic micro porous concrete, which can realize the same life with the main body of the building, which avoids the unavoidable maintenance and replacement of the traditional thermal insulation layer, and saves resources.
- The product are firmly bonded to plastering layer mortar, the wall is not easy to hollowing and cracking.
- Product raw material source is wide, the technology is easy to operate, the area is strongly adaptable.
- Compared with the traditional approach, the cost of the wall is reduced about 30%, the wall weight is reduced more than 40%.

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