THE STUDY ON THE PREPARATION AND PROPERTIES OF TRFC

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ABSTRACT

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In this paper, thermoplastic fiberglass textile was embedded into the foamed cement matrix. Thermoplastic glass fiber textile reinforced cement-based foamed composites(TRFC) was prepared and modeled. The influence of glass textile on compressive strength, thermal conductivity, water absorption, drying shrinkage and flexural properties of textile reinforced composites were studied, and the mechanism of improvement was also analyzed. Compared to ordinary cement-based foamed plate, a consistent result can be obtained in two different apparent densities of (220-250) kg/m³ and (260-300) kg/m³. Compressive strength was obviously improved. Thermal conductivity increases a bit, but the composites still have a good thermal insulation property. The water absorption increased slightly, but drying shrinkage reduces. And flexural strength increased significantly, the maximum reached 0.67MPa and 0.9MPa, increased by 6.7 times and 7.5 times respectively.

1. INTRODUCTION

Faced with the serious pollution and energy depletion, energy-saving and emission-reduction has been a worldwide trend. According to statistics, energy consumption of buildings accounts for about 30% of the total consumption in China. And the consumption during the using process contributes most. The most cost-effective measure is to improve the insulation property of buildings, so the insulation of external wall plays an extremely important role in saving energy.

At present, the inorganic thermal insulation materials have many advantages, such as Class A fire-resistance rating, being friendly to environment and the same life with the building, etc., thus they are widely applied in engineering. However, most of the products existed in the market have some defects such as brittleness, high water absorption, low strength, high thermal conductivity and high defective index^[1], which, to some extent, limit and reduce the application of inorganic insulation materials and market share.

For the current situation above, the paper added thermoplastic glass fiber textile into the cement-based foamed plate in order to solve these drawbacks. Glass textile is a kind of woven fabric which is a hollow structure linked together between layer and layer by yarn to form a connected whole^[2]. Embedding the high-strength glass textile into foamed cement matrix can effectively improve the mechanical properties of the matrix, such as flexural strength and impact strength^[3,4]. Compared to chopped glass fiber and glass fiber mesh, glass textile can further improve the reinforcement ratio, and can also carry out three-dimensional orientation^[3,5], which will push the research and development of glass fiber reinforced cement plate towards.

In this paper, thermoplastic glass textile of three-dimensional orientation is embedded into the cement-based foamed plate as reinforcement to explore the influence on compressive strength, thermal conductivity, water absorption, drying shrinkage and flexural properties of cement-based foamed plate, which will expand the application areas of the plate.

2. Experimental materials and methods

2.1 Raw materials

(1) Cement: R-SAC 42.5, provided by Tangshan Liujiu Cement Co. Ltd.. Chemical composition is shown in Tab.1.

(2) Fly ash: Gradell, provided by Tianjin Beijiang power stations. Chemical composition is shown in Tab.2.

(3) Foaming agent: hydrogen peroxide, 30% concentration, provided by Tianjin Fengchuan Chemical Science and Technology Co. Ltd..

(4) water reducer: 26% water-reducing rate, Polycarboxylate Superplasticizer, provided by Tianjin Feitong Concrete Admixture Co. Ltd..

(5) Other additives include calcium stearate, redispersible emulsion powder and NaAlO₂ etc.

(6) Water: drinking water.

(7) Chopped fiber glass: length 10mm, diameter 0.02μm, provided by Cangzhou Yongxing Fiberglass Plant.

(8) Thermoplastic fiber glass textile: thickness 30mm, format 1730g/m³, produced by Changzhou Aohua Textile Co.Ltd.. The axial diagram and textile appearance are shown in Fig.1 and Fig.2.

Tab.1 The chemical composition of sulfur-aluminum cement /wt %

Composition s	SiO ₂	CaO	Fe ₂ O ₃	MgO	CO ₂	Al ₂ O ₃	SO ₃	Los s
S-Al-cement	9.5 9	45. 5	1.5 8	2.3 6	7.0 5	17. 53	13. 69	2.7

Tab.2 The chemical composition of fly ash /wt %

Composition s	SiO ₂	CaO	Fe ₂ O ₃	K ₂ O	CO ₂	Al ₂ O ₃	TiO ₂	Los s
S-Al-cement	39. 37	5.7 7	3.4 2	1.0 5	8.4 1	37. 52	1.7 8	2.6 8

2.2 Mixture ratio design

In this experiment, foamed plates of two dry apparent densities, I (220-250) kg/m³ and II (260-300) kg/m³, were tested. The mixture ratio design is shown in Tab.3.

2.3 Control groups settings

Four control groups were set respectively for two different densities. A is blank group, B is chopped fiber group, C is fiber mesh group and D is textile group. Experimental mold is shown in Fig.3 and its size is 300mm×300mm×30mm. The mold that is added with textile and ready to be poured is shown in Fig.4. Pores on the surface of foamed plate are shown in Fig.5. Thermoplastic fiberglass textile reinforced cement-based foamed composites (TRFC) which has been modeled is shown in Fig.6.

2.4 Experimental methods

2.4.1 Molding method

The main operation process of preparing TRFC is shown in Fig.7. After the foamed cement was cast, the composites were cured naturally in the laboratory. One day later, the composites were released from model and put into the cement

standard curing box whose temperature is (20±2)°C and relative humidity is more than 95%. Three days later, place the composites into the oven whose temperature can keep (65±2)°C, until they were dried to remain constant weight. According to *JC/T 2200-2013 Cement-based Foamed Insulation Plate*, the cement-based foamed composites were cut into test-piece and tested.

2.4.2 Test method

Dry apparent density, compressive strength and water absorption are tested according to *GB/T 5486-2008 Test Methods for Inorganic Hardened Insulating Products*. Drying shrinkage and flexural strength are tested according to *GB/T 11969-2008 Test Method for Autoclaved Aerated Concrete*. Thermal conductivity is tested according to *GB/T 10294-2008 The Steady Resistance of Thermal Insulation Materials and Related Characteristics Test Method*.

3. Experimental results and discussion

3.1 Compressive strength

Tab.3 Compressive strength of two densities foamed plate/MPa

	A	B	C	D
I	0.42	0.43	0.51	0.85
II	0.51	0.51	0.65	1.12

As is seen in Tab.3, compared to Group A, 3d compressive strength of Group B do not almost change at the two densities. However, 3d compressive strength of Group C and Group D both improves in different degree, increasing 1.4%, 102% respectively at I density and 27.4%, 119%

respectively at II density. The increase of compressive strength of Group C and Group D was mainly attributed to the cracking mechanism of fiber. Fiber can effectively restrict the generation and development of cracks in foamed cement matrix under load which can alleviate the stress concentration of the crack tip to some extent. Thus fiber prevents the generation and further expansion of the micro-cracks in the concrete and delays the process of the matrix from cracks generation, expansion to the destruction, and consequently improve the bearing capacity of the foamed plate^[6].

Meanwhile, when TRFC (Group D) is subjected to the upper load, the synergistic effect will be produced between the matrix and the fiber core. In addition, the thermoplastic textile itself has a certain rigidity. After the textile is embedded into the matrix, the stiffness and elastic modulus of TRFC are obviously enhanced, thus the compressive bearing capacity is improved significantly.

3.2 Thermal conductivity

Tab.4 Thermal conductivity of two densities foamed plate /W/(m·k)

	A	B	C	D
I	0.06538	0.06679	0.06835	0.07376
II	0.07198	0.07221	0.07512	0.07954

As is seen in Tab.4, the thermal conductivity of the four groups with I density is higher than that of II density. The thermal conductivity of Group B, Group C and Group D with I density were higher than that of group A by 2.1%, 4.5% and 12.8%, respectively. And with II density, 0.2%, 3.0%, 10.5%, respectively.

Thermal conductivity is an important indicator of measuring the thermal insulation properties of materials. The thermal conductivity of still air is lower than that of the solid, So the thermal conductivity becomes lower with the increasing of porosity or decreasing apparent density^[7].

With the same density, the smaller the pore size is, the lower the thermal conductivity becomes. When the pore is smaller to a certain size, the air in the pore will be completely adsorbed by the pore wall, then the pore is close to a vacuum state, and thermal conductivity reduces to a minimum. When the pore volume is large enough to a certain extent, the air convection will appear inside the pores, and then the thermal conductivity increases^[7].

The fiber meshes of Group B were placed on the upper and lower surfaces of the test-piece, which have no effect on the internal structure of the matrix. However, the fiber meshes damage some pores in the interface of the mesh and the matrix, so the thermal conductivity increased by 2.1% and 0.2% compared to Group A. The chopped fiber of Group C can destroy the structure of pores during the dispersion process, and cause the micropores developing into interconnected pores, thus increase the internal porosity. Therefore, the thermal conductivity is increased by 4.5% and 3.0% compared with group A.

For Group D, there are three reasons for that the thermal conductivity increases by 12.8% and 10.5% respectively as follows. Firstly, when the test-pieces are modeled, the internal core pillars of warp and weft will destroy the bubbles in the foamed matrix and enlarge the size of pores near the core pillars, so the air convection will appear inside the pores, and then the thermal conductivity increases. Secondly, after the textile were embedded, the weight of TRFC increases, thus the thermal conductivity increases. Thirdly, the energy transports through the textile transport much faster than matrix, and the heat flow is more intensive, so cause the thermal bridge effect which is also called the physical effects of heat transfer. The effect can decrease the average heat-transfer resistance, thus the thermal conductivity increases^[8].

3.3 Water absorption

Tab.5 Water absorption of two densities foamed plate /%

	A	B	C	D
I	9.3%	9.4%	9.8%	10.7%
II	8.6%	8.6%	9.2%	10.1%

As is seen in Tab.5, the water absorption of the four groups with I density is higher than that with II density. The water absorption of Group B, Group C and Group D with I density were higher than that of group A by 2.1%, 4.5% and 12.8%, respectively. And with II density, 0.2%, 3.0%, 10.5%, respectively. Thus, with the increase of density, the water absorption is getting lower and lower. In addition, the textile has the most significant influence on water absorption.

The main factor affecting the water absorption of the matrix is pore wall which includes capillary pores, interconnected pores and the thickness of pore wall. At the same density level, the smaller the pore size is, the more well-distributed the porosity of the bubbles are, and then there are more and thinner pore walls. The matrix absorbs water mainly through two modes, which is capillary penetration and interconnected penetration^[9]. Thinner pore walls is prone to appear defects in the condensation process, and then the interconnected pores are formed. Once the permeate channel is formed, the water penetrating speed will be accelerated by the capillary pressure arising from capillary pores produced in the initial stage of cement setting and hardening, thus water absorption increases. Therefore, the water absorption decreases with the size of pores increase and the porosity increases^[10]. Obviously, the II density is lower than the I density. The lower the density is, the higher the porosity is, the smaller the pore diameter is, the higher the water absorption is.

The mechanism of water absorption is partly similar to that of the thermal conductivity. At the same density, the fiber meshes of Group B damage some pores in the interface of the mesh and the matrix, and caused some interconnected pores. The chopped fiber of Group C can destroy the structure of pores during the dispersion process, and cause the micropores developing into interconnected pores. For Group D, the internal textile core column of warp and weft will destroy the bubbles in the foamed matrix, which is prone to lead to defects in the process of cement setting and obvious increase of porosity at the interface.

3.4 Drying shrinkage

Tab.6 Drying shrinkage of two densities foamed plate /mm/m

	A	B	C	D
I	2.1	2	1.8	1.4
II	2.8	2.8	2.5	1.2

As is seen in Tab.6, chopped fiber, fiber mesh and textile can all decrease drying shrinkage of the matrix. Chopped fiber has a certain effect on the shrinkage, and textile shows a better limit shrinkage effect.

During the normal shrinkage of the matrix, the interface between textile and matrix can generate friction which can reduce the shrinkage. To some extent, the action and reaction between textile and matrix prevent the deformation of TRFC, thus the self-shrinkage deformation is reduced and the shrinkage is limited. In addition, The adhesive force and mechanical force arising from the interface between textile and matrix will also promote the ability of materials to resist shrinkage^[11].

3.5 Flexural strength

Tab.7 Flexural strength of two densities foamed plate /MPa

	A	B	C	D
I	0.10	0.22	0.30	0.67
II	0.12	0.26	0.42	0.90

As is seen in Tab.7, compared to Group A, the flexural strength of Group B and Group C both increases obviously, but that of Group D increases significantly which is 6.7 times and 7.5 times respectively higher than the corresponding Group A.

The fracture elongation of the textile used in the test of Group D is much higher than that of the matrix. Therefore, initially, when TRFC is under flexural load, the textile on the upper surface of the fiberglass are subjected to tensile stress and the lower surface bears compressive stress, and then part of the textile core columns show stress instability and the matrix begins to appear micro-cracks^[12,13]. With the continuous load, the matrix is

destroyed. At this time, there will be a sudden drop of stress. Then the textile still works, and the flexural force gradually increases. Finally, the flexural force maintains at a high level and remains stable^[14].

4. Conclusions

(1) At (220-250) kg/m³ and (260-300) kg/m³ the two different densities, some properties of TRFC with high density are higher than those of TRFC with low density. These properties include compressive strength, thermal conductivity, dry shrinkage and flexural strength.

(2) With the same density, compared to the ordinary cement-based foamed plate, the compressive strength of TRFC is obviously improved. Thermal conductivity increases a bit, but composites still have good thermal insulation properties. The volume of water absorption increased slightly, but drying shrinkage reduces. And flexural strength increased significantly, the maximum reached 0.67MPa and 0.9MPa, increased by 6.7 times and 7.5 times respectively.

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