Energy and Buildings 87 (2015) 220–225

Contents lists available at ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

Preparation and characterization of a reflective and heat insulative coating based on geopolymers

Zhetao Zhang, Kaituo Wang, Binghui Mo, Xinfeng Li, Xuemin Cui*

School of Chemistry and Chemical Engineering and Guangxi Key Lab of Petrochemical Resource Processing and Process Intensification Technology, Guangxi University, Nanning 530004, China

A R T I C L E I N F O

Article history:
Received 23 August 2014
Received in revised form 5 November 2014
Accepted 8 November 2014
Available online 18 November 2014

Keywords:
Coating based on geopolymer
Hollow glass microsphere
Titanium dioxide
Reflective and heat insulation

A B S T R A C T

A reflective heat insulation coating was prepared using a geopolymer, which was mainly made of sodium silicate solutions and metakaolin, as the primary film forming material before adding sericite powder, talcum powder, titanium dioxide and hollow glass microspheres as fillers. This coating is a new, environmentally friendly inorganic coating with many capabilities, such as good water-retention, simple spraying, the compacted paint, high durability, dirt resistance, high reflectivity and remarkable heat insulation. The results indicate a titanium dioxide content of approximately 12% yields 6% hollow glass microspheres yielded a reflective heat insulation coating with a reflectivity over 90% and thermal insulation performance (internal and external surface temperature difference) of up to 24 °C. These mechanical and insulative properties could achieve the China National Standard (GB/T25261-2010).

1. Introduction

Heat insulation coatings are new, energy-saving materials developed in recent years [1–8]. Čekon et al. found that coatings of hollow microspheres can contribute to the thermodynamic performance up to 5% in daytime [1]. According to Guo's study, the heat reflective insulation coating could reduce the exterior wall surface temperature effectively, and the maximum temperature change is about 8–10 °C [4]. Jose et al. found new type of pigments Y_2BaCuO_5 and lanthanum–strontium copper silicates, not only possess high chemical and thermal stability, and they have high near-infrared reflectance (61% at 1100 nm) [7,8]. All above heat insulation coatings painted onto the building's exterior wall can effectively reduce the temperatures at the surface and within the building and thus protect the building, which result from the reflection, separation and radiation of the sunlight energy can obviously reduce the energy absorption of a building's exterior wall, roof, and indoor area [9]. However, above heat insulation coatings are organic binder coating so that they are easy aged under ultraviolet. Therefore, to seek an inorganic heat insulation coating should be a promising option.

Geopolymers [10] are an aluminosilicate inorganic polymer material formed via earth chemistry or geological synthesis. The aluminosilicate material belongs to a cement system and has many good properties, such as excellent hardness and strength, strong corrosion resistance, low thermal conductivity, easy bonding and high durability. In contrast to organic exterior wall coatings, geopolymer-based coatings have anti-ultraviolet and anti-aging capability [11–13]; thus, they are more suitable for fabricating inorganic exterior wall building coatings. In addition, a heat insulative paint, including pigments and fillers, was added to the film forming material and had an important effect on the heat insulation coating performance.

In this paper, a reflective heat insulation coating was prepared using a geopolymer as the primary film forming material. We discussed the influence of the types of pigments and fillers, titanium dioxide content and hollow glass microsphere had on the coating's various mechanical properties and heat insulation performance.

2. Experiments and calculation

2.1. Materials and experiments

In these experiments, the coatings were mainly prepared from metakaolin and commercial sodium silicate solutions. Metakaolin was prepared from commercial kaolin calcined at 800 °C for 2 h. A commercial sodium silicate solutions with a modulus (SiO_2/Na_2O molar ratio) of 3.3 and solid content of 38 mass% was used for the alkali-activation. The following materials were also used as pigments and fillers added to the coating: titanium dioxide, hollow

* Corresponding author. Tel.: +86 0771 3233718; fax: +86 0771 3233718.
E-mail address: cui-xm@tsinghua.edu.cn (X. Cui).

http://dx.doi.org/10.1016/j.enbuild.2014.11.028
0378-7788/

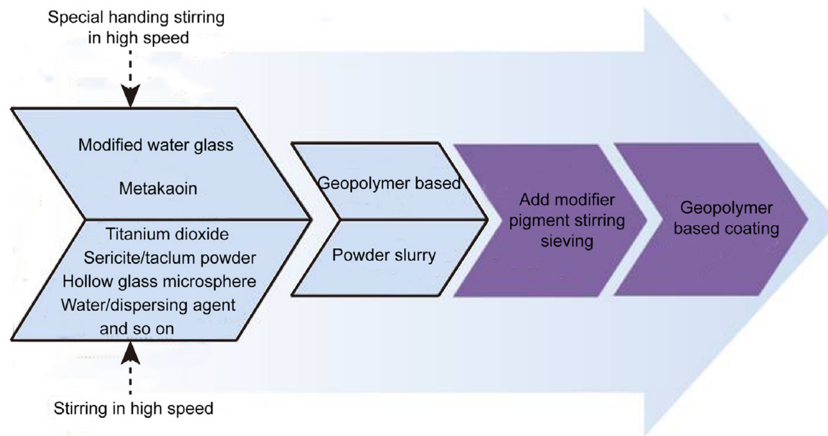

Fig. 1. Process flow chart for preparing reflective and heat insulation coatings based on geopolymers.

glass microspheres and talc powder. The dispersing agent, wetting agent, and water-retaining agent were also used to the coating so as to promote its performances.

The coating was added to an approximately 120 × 80 × 2 (mm) steel substrate or fiber reinforced calcium silicate board. Initially, the steel substrates were cleaned using sand paper followed by washing with a diluted hydrochloric acid solution, hot water, alkaline liquor, distilled water and ethanol [12,13]. The fiber reinforced calcium silicate boards were cleaned using detergent and distilled water.

The inorganic paints were prepared from metakaolin and sodium silicate solutions with the additives. After mixing and stirring at high speeds to disperse evenly, the resultant slurries were used as the coating. The coating was applied by brushing onto the metal plate or fiber reinforced calcium silicate board and cured at 35 °C for 7 d after labeling. The coating process is explained in the diagram in Fig. 1.

The coating adhesive strength was measured according to China GB/T172021979 (film adhesion determination method).

The coating hardness was tested according to China GB/T 173021993 (paint film hardness testing method "(double pendulum stem method)).

The coating flexibility was measured according to China GB/T 173121993 (film flexibility determination method).

The resistance strength was tested according to China GB/T 173221993 (film impact resistance mensuration)

2.2. The calculation and test of reflectivity of the coating

Based on the U.S. army standard MIL-E-46136 standard [14–16] for choosing a simple reflecting solar heat test mechanism and its device photo (as shown in Fig. 2), holes were made in the geometric center of the line from the lamp axis. A black enamel and reflected heat insulation coating was painted onto the tinplate chip. The dry film thickness was 90 μm for a fixed room temperature of 28 ± 1 °C. A 500 W infrared lamp was used to simulate sunlight irradiating the coating. Adjusting the distance of the infrared lamp to the test plate controlled the surface temperature of black enamel board at 87.8 ± 1 °C. This experiment used a distance of 30 cm after adjustments after testing both sides of the board with a surface thermometer and recording data every 10 min until the temperature stabilized. Finally, this paper determined the coating reflectivity calculation using a formula based on experience (Eq. (1)) [17].

$$\text{Coating reflectivity } \rho = \frac{t_1 - t_2}{t_2 - t_3} \quad (1)$$

where ρ = reflectivity, t_1 = the back temperature of black enamel board, t_2 = the back temperature of coating sample, t_3 = room temperature.

2.3. The calculation and test of heat insulation performance of coating

A simple self-made heat insulation performance test mechanism and its device photo were made according to Chinese construction industry standards (GB/T25261-2010) as shown Fig. 3, and the cavity dimensions were 300 × 300 × 300 (mm). A temperature measurement box with made from 30 mm thick polystyrene board with a coefficient of thermal conductivity no more than 0.03 w/m after digging a 125 × 85 (mm) hole above it. The board was covered in the reserve slot above the box, sealed with adhesive plaster and debugged at room temperature to ensure the initial

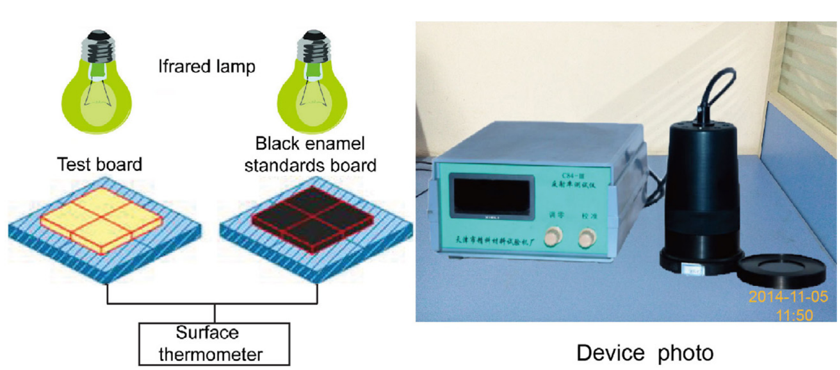

Fig. 2. Heat reflectivity testing mechanism and device photo.