Energy and Buildings 93 (2015) 208–216

Contents lists available at ScienceDirect

Energy and Buildings

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

Degradation of VIP barrier envelopes exposed to alkaline solution at different temperatures

Huiqiang Li [a], Huisu Chen [a,*], Xiangyu Li [b,*], Wenhui Duan [b]

[a] Jiangsu Key Laboratory of Construction Materials, School of Materials Science and Engineering, Southeast University, Nanjing 211189, China
[b] Department of Civil Engineering, Monash University, Clayton, Victoria 3800, Australia

ARTICLE INFO

Article history:
Received 18 November 2014
Received in revised form 6 January 2015
Accepted 2 February 2015
Available online 12 February 2015

Keywords:
Vacuum insulation panels
Barrier envelopes
Alkali
Stress
Temperature
Degradation
Thermal conductivity

ABSTRACT

As covering layers, barrier envelopes of VIPs are always exposed to severe environmental conditions, including high temperatures, alkaline environments and local stress concentration when used as thermal insulation material in concrete structures. This study investigated the time-dependent degradations of three types of commonly used envelopes (aluminium film, metallized film and metallized film coated with alkali-resistant (AR) fibreglass mesh) and VIPs covered by these three envelopes by simulating environmental conditions with four types of alkaline solutions (NaOH solution with pH = 7, 11, 13 and saturated $Ca(OH)_2$), two different temperatures (20 °C and 60 °C) and local stress concentration. The results showed that stress and high temperature accelerated the degradation of envelopes and that such degradation became more serious with increased pH value and temperature. It was also observed that the thermal conductivity of VIPs increases quickly when they are exposed to higher alkalinity combined with high temperatures. After 6-week submerged in saturated $Ca(OH)_2$ solution at 60 °C, the thermal conductivity of VIPs increased from 4.413 mW/m K to 13.049 mW/m K for aluminium foil, from 5.375 mW/m K to 10.982 mW/m K for metallized film, and from 5.786 mW/m K to 8.110 mW/m K for AR fibreglass mesh-reinforced film, respectively.

1. Introduction

Compared with traditional building-oriented thermal insulation materials, vacuum insulation panel (VIP) has excellent thermal insulation performance. Its lowest thermal conductivity can reach 0.00186 W/m K, around 1/10–1/20 of that of traditional insulation materials [1]. For this reason, it has been widely applied in building envelopes, such as flat roof terraces and wall insulation materials. Currently, most VIPs are installed directly in construction on-site. There are several forms in which VIPs can be installed in concrete structures, such as wooden sandwiches framework, prefabricated panels and naked panels without external protection [2–5]. Commonly used VIP barrier envelopes include Al foil (AF), multi-layer metallized polymer barrier film (MF), and alkaline-resistant (AR) fibreglass mesh-reinforced film (GF). The AF consists of one 23 μm aluminized PET as a gas-tight layer and one 50 μm LLDPE as a heat-sealing layer. The MF consists of three 12 μm aluminized PET films as a gas-tight layers and one 50 μm LLDPE as a heat-sealing layer. The GF also consists of an aluminized PET film as a gas-tight layer and is coated with an AR fibreglass layer. The purpose of AR fibreglass is to improve both the bonding strength of VIP with substrates and the alkali-resistant capacity of the barrier envelope, and to provide mechanical protection until the VIP is installed.

The envelope works as an air- and vapour-tight barrier and is the most important component of the VIP. If ambient air or vapour penetrate through the envelope and into the core the internal gas pressure will increase, causing the thermal conductivity of the panel to increase and so reducing service life [6]. Schwab et al. [7] developed a model and found that the long-term performance of VIPs is closely relevant to the properties of their envelopes. Thus more attentions should be paid to degradations of envelopes.

VIP envelopes are easily damaged during transportation and construction of VIPs without any protection. Haavi et al. [3] developed a wooden sandwiches framework that vacuum insulation panels were sandwiched between traditional insulation in walls. A combined panel of EPS and VIP was developed to protect the VIPs by Concretech [7]. And a prefabricated composite insulation board was fabricated by polyehtylene and VIP. VIPs are packed by polyehtylene against various threats from handing damage and the like [8]. These combined panels can protect VIPs from damage during the application process. However, complicated fabrication process as well as high cost limits the utilization of these combined panels.

* Corresponding authors.
E-mail addresses: chenhs@seu.edu.cn (H. Chen), xiangyu23@gmail.com (X. Li).

http://dx.doi.org/10.1016/j.enbuild.2015.02.006
0378-7788/

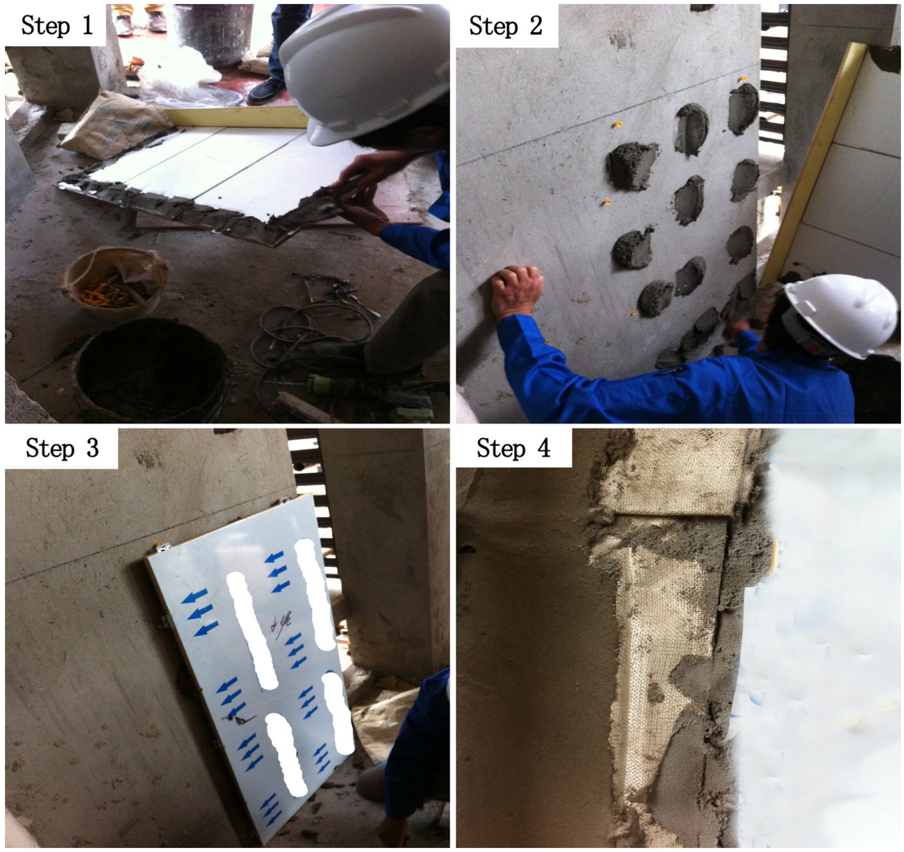

Fig. 1. Cement mortar used in the installation of VIPs.

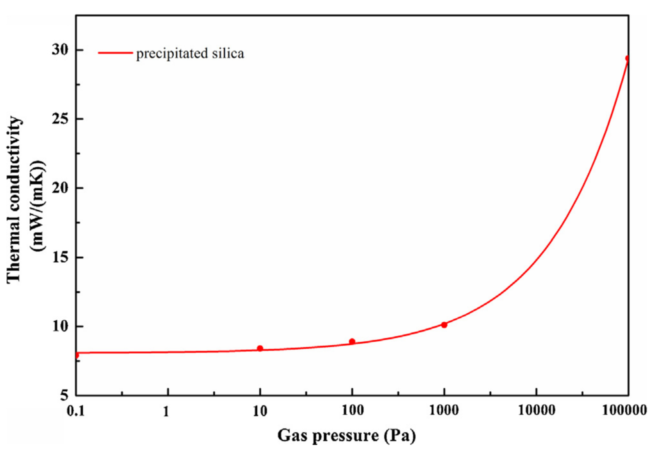

Fig. 2. Relationship between the inner pressure and thermal conductivity of VIPs with core material precipitated silica.

When VIPs are used on concrete substrate, cement mortar is commonly employed to tightly bond them to the target structure in the building and construction market of China, as shown in Fig. 1. Consequently, VIPs will be exposed to a highly concentrated alkaline environment, which may cause the envelopes to deteriorate [10]. Under these conditions, the permeability of envelopes can increase rapidly, and the internal gas pressure further rises to a level beyond the critical value. The relationship between internal gas pressure and thermal conductivity of the panel with precipitated silica as the core material is showed in Fig. 2. It can be seen in Fig. 2 that the thermal conductivity of VIP arises along with increasing internal gas pressure. Helgerud [10] has also observed the rise of thermal conductivity when VIPs are exposed to an alkaline environment.

It would appear that, the service life of VIPs is determined by the integrity of barrier envelopes. Therefore it is very important to investigate the degradations of barrier envelopes when they are exposed to severe environmental conditions including high temperature and an alkaline solution.

Garnier et al. [11] investigated the physical properties of metallized PET films. Their results indicated that a number of small pinholes existed in the film. Sammon et al. [12] studied the degradation of PET films submerged in deionised water and 1% KOH solution at 90 °C and found that hydrolytic degradation in KOH occurred much more rapidly than that in deionised water. Wegger et al. [13] studied the moisture and temperature ageing of VIPs. Helgerud [10] investigated the thermal conductivity of VIPs submerged in different alkali solutions at 20 °C and 70 °C, respectively. Schwab et al. [14] experimentally evaluated permeation rates for different envelopes and different temperature and moisture conditions. Yrieix et al. [15] studied the degradation of envelopes under different temperature and relative humidity (RH) conditions. A curve was given to represent the degradation trend of VIP caused by damaged envelopes, as shown in Fig. 3.

Envelopes play an important role in the long-term performance of VIPs from the pervious research. Considering the situation that cement mortar was commonly employed to tightly bond VIPs to the target structure in China, it is necessary to investigate the degradations of envelopes in alkaline or high temperature environment. Although some papers have studied the degradation of VIP envelopes, there is no comprehensive study that presents detailed experimental data and theoretical analysis of the degradation of different kinds of VIP barrier envelopes exposed to various alkaline conditions and high temperatures. This study aims to predict