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Structure of vacuum insulation panel in building system

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ABSTRACT

Energy used for heating, ventilation and air conditioning in commercial and residential buildings contributes to a significant portion of the total energy consumed in many countries. Energy efficient vacuum insulation panels (VIPs) present thin but highly effective insulation solutions, to reduce thermal losses for both new and renovated buildings. This study presents a comprehensive review of VIP comprising glass fibre core and laminated aluminium foil envelope materials, which are used in building envelopes in China. Characterization of the material composition, procedures for installation method, as well as future outlook have been investigated and discussed. The outer barrier layer of fibreglass cloth (FGC) protects VIP from localized alkaline cement and mechanical stress. Insulation assembly debonding from building walls was curbed by a combination of reinforced fibreglass mesh and plastic spacer. Besides, masonry cavities are created in some narrow spacing between the VIP and existing wall against unforeseen moisture conditions. Furthermore, owing to an interlocking surface topology of novel Peephole-VIP/wall interface, bond strength is increased to about 50%. Nonetheless, energy lost due to thermal bridge effect was rather high.

1. Introduction

Energy usage in residential and commercial buildings is responsible for significant CO_2 emissions. Passive insulation measures focused on improving air-tightness of new and existing buildings, can achieve significant reductions in heating and cooling energy demands. Thus, beneficial to reduce CO_2 emissions [1,2]. Owing to the glaring impact of energy usage on world climate and environment, policy makers are turning their attention to energy-efficient solutions. The most relevant environmental and energy policies relating to the built environment in China are Agenda 21, Twelfth Five-Year Plan, and Clean Production Promotion Law [3–5]. Agenda 21 promotes green technology and energy preservation through improved efficiency as a sustainable development strategy. Agenda 21 stipulates that priority should be given to the development of renewable energy in the state energy development strategy, and to that encourage energy-saving, energy efficiency, and developing energy should become a fundamental state policy. The Twelfth Five-Year Plan (2011–2015) proposes major objectives, and key actions in the fields of energy conservation and emission reduction. A core aim is to strengthen energy conservation in industry, and to promote building energy conservation through construction of green buildings, and comprehensively advanced energy conservation in buildings, as well as energy-saving renovation of existing buildings. The Clean Production Promotion Law was enacted in order to promote cleaner production, increase the efficiency of resource utilization rate, reduce and avoid the generation of pollutants, protect and improve environments, among others. Cleaner production simply means the continuous application measures for design, improvement, and utilization of clean energy and raw materials. Space heating and cooling together consume about 65% of the total building energy consumption in China [3]. Besides, air conditioners are now very common, and their numbers will only continue to rise, especially in urban areas in the coming years. Thus, the urgency for energy-efficient solutions cannot be underestimated. The vacuum insulation panel (VIP), an energy saving thermal insulation system, has been introduced into the Chinese building industry for about half a decade now. VIP is exceptionally useful for space constrained applications owing to low thermal conductivity, allowing a significant reduction in the required minimum insulation thickness [6–9]. Owing to vast differences in longitude, latitude and altitude, the climate in China is categorized into five zones, namely: severe cold zone, cold zone, hot summer and cold winter zone, hot summer and warm winter zone, and warm zone [10]. At present, VIPs have been used mostly for building wall

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insulation in Northern and Eastern regions of China, which correspond to the coldest and warmest regions during winter and summer, respectively. Furthermore, applications of VIPs in buildings are growing in China; owing to safety precautions against other conventional insulation materials, which pose a hazard due to burning and release of harmful gases in buildings. Running from early 2009 to early 2011, three major high rise building structures were destroyed by fire in China; unfortunately resulting in loss of lives and destruction of property worth millions of dollars. In two of the three scenarios, some other traditional insulators were used as insulation materials resulting in huge tonnage of toxic hydrocarbons being released into the environment. According to the new Chinese Governmental law, the burning requirements for building materials upgrades 'non-flammable' Al, which is comparable to French Standard NF P92-510, which can be compared to the 'non-flammable' label Al conforming with the new European classification standard EN 13501-1 and EN ISO 1182 [9,11]. VIPs are nonflammable and therefore satisfies the requirements for building insulation materials in China. The most common VIP purposely used for building applications in China is composed of centrifugal glass fibre core material encapsulated in a laminated aluminium foil envelope material. Glass fibres are widely used as a VIP core material due to their excellent moulding properties, low density, outstanding thermal and acoustic insulation properties, as well as superior chemical and thermal stability (>1000 °C) [12]. Other common types of glass fibres used as core material for other purposes include flame attenuated glass fibre mat, aerocor glass fibre mat, and chopped strand glass fibre mat. The laminated aluminium foil envelope material is composed of (from inside to outside): 80 μm metallocene linear low density polyethylene (mLLDPE)/15 μm polyamine (PA)/7 μm aluminium foil (Al)/12 μm polyethylene terephthalate (PET)/340–350 μm fibreglass cloth (FGC); laminated together using polyurethane (PU) glue. The resulting VIP is well known as glass fibre VIP. Some studies on concrete wall systems [6], wooden door systems [13], terrace constructions [14], and flat roof constructions [15], insulated with VIPs in some European countries, have been reported in literature. Likewise, the manufacturing process and parameters, and some durability issues related to glass fibre VIPs have been studied by experimental and modelling techniques [12,16–18]. However, to the best of our knowledge, no studies have focused on the procedures for installation method and performance of glass fibre VIP, especially in building structures in China. In this work, some major installations of VIPs in building structures in China have been investigated. The characteristics of the as-produced VIPs, specific procedures of the installation method being used, condensation and associated mechanical stress effects, were also discussed.

2. Experimental

All materials, including centrifugal glass fibre core material, Al foil envelope material and glass fibre VIP investigated in this work are commercial grade, supplied by Suzhou V.I.P. New Material Co. Ltd. The general manufacturing process of glass fibre VIP

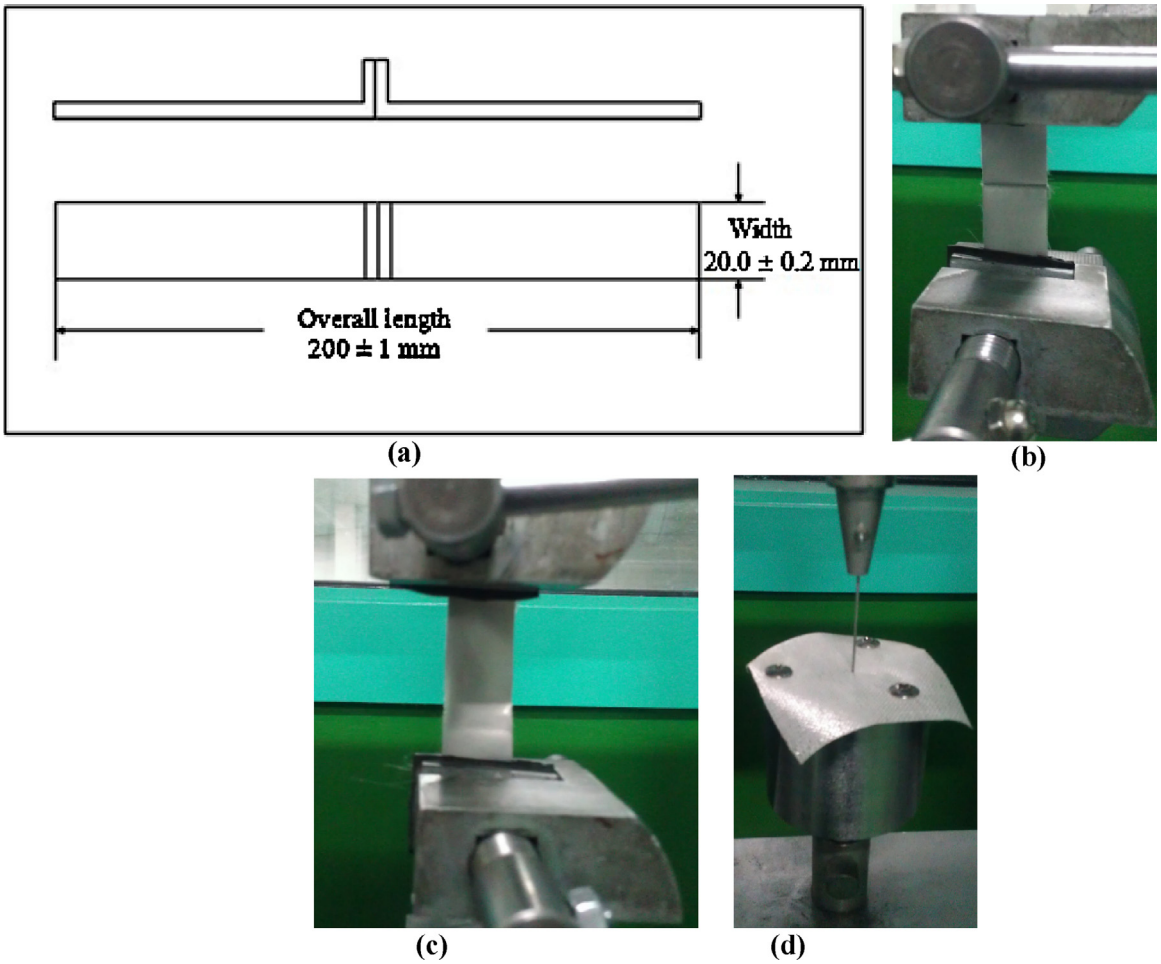

Fig. 1. (a) Schematic diagram of heat seal region, (b) orientation of HSS specimen in text fixture, (c) orientation of TS specimen in text fixture, and (d) orientation of PS specimen in text fixture.

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