Available online at www.sciencedirect.com

ScienceDirect

Vacuum 82 (2008) 700–707

VACUUM
SURFACE ENGINEERING, SURFACE INSTRUMENTATION & VACUUM TECHNOLOGY

www.elsevier.com/locate/vacuum

In situ performance assessment of vacuum insulation panels in a flat roof construction

Samuel Brunner, Hans Simmler*

Empa, Swiss Federal Laboratories for Materials Testing, Research Laboratory for Building Technologies, CH-8600 Duebendorf, Switzerland

Received in revised form 15 October 2007; accepted 31 October 2007

Abstract

The recently introduced vacuum insulation panel (VIP) is a space saving alternative to conventional thermal insulation, thanks to its five to eight times higher thermal resistivity. As gas permeation through the envelope barrier may drastically reduce the insulation efficiency, aging effects and service life expectation are crucial aspects of those high performance insulation units. In the present paper, monitoring data from a terrace construction over more than 3 years are reported. The results are compared with laboratory aging data at constant conditions by linear and Arrhenius weighting of the dynamic boundary conditions. Based on satisfactory agreement, a similar approach is applied for the prediction of the thermal performance after an installation time of 25 years, the common time used for building design regarding energy performance.

Keywords: Vacuum insulation panel; High-performance thermal insulation; Building envelope; Monitoring; Aging; Service life prediction

1. Introduction

The vacuum insulation panel (VIP) is a high-performance thermal insulation component for the building envelope that was introduced into construction technology in the last few years [1]. Its high thermal resistivity, which is five to eight times higher compared to conventional insulation materials, makes it suitable for designing energy efficient buildings even with slim insulation layers. Big potentials also exist in building renovation, where often little space is available for thermal insulation. In Switzerland, VIP are frequently installed in terrace areas of apartment houses in recent years, since the indoor and outdoor floor level can be kept equal, while maintaining the required low *U*-value for terrace areas with heated space underneath (Fig. 1).

A VIP consists of a micro-porous core material that is sealed in a gas tight envelope at low air pressure. While open cell organic foams were used earlier by the refrigeration industry, fumed silica powder (SiO_2 agglomerates) has become the favorite core component in VIP for building application [2,3]. With this core material, the gaseous conduction is negligible even at gas pressures up to 10 mbar, which is a benefit of the pore size below 0.3 μm (Fig. 2). In contrast to organic foams, which are in use for transportation units, SiO_2 shows no outgassing, is chemically stable, non-combustible and does not require metallic getters. Additional core ingredients are polymer or glass fibers for structural reasons and opacifier to eliminate radiative heat transfer, yielding a thermal conductivity of about $4\times10^{-3}\,\mathrm{W\,m^{-1}\,K^{-1}}$ for the dry core at 1 mbar. Massive aluminum foils used as gas barrier in the early stage of VIP production are favorable regarding the permeation properties, but thermal bridge effects around the panel edges strongly affect the overall thermal performance in building applications [4]. Actual barrier materials used for SiO_2-VIP are laminates of up to three aluminum coated polymer films made of polyethylene terephthalate (PET) and/or polypropylene (PP), and an additional polyethylene (PE) sealing layer [5].

Laboratory-based aging experiments and service life prediction models suggest sufficient service life for this type of VIP in building applications [6,7], as pressure increase

---

*Corresponding author. Tel.: +41 44 823 4276; fax: +41 44 823 4009.
E-mail address: hans.simmler@empa.ch (H. Simmler).

0042-207X/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.vacuum.2007.10.016

rates up to 2 mbar yr^{-1} are acceptable with fumed silica. However, since long-term experience with installed VIP is almost missing, there is a need to verify laboratory-based service life prediction by performance data from real applications. In the following, we present measurements on a VIP-insulated flat roof construction that has been monitored from June 2004 till June 2007. The results are compared with values obtained by laboratory aging measurements under defined temperature und humidity conditions. A simplified time dependence of the center-of-panel thermal conductivity is given that allows an estimation of the long-term thermal performance. It is shown that a service life of several decades can be expected for this VIP construction, where aging in terms of a continuous increment of the thermal conductivity is taken into account. Monitoring and comparative aging modeling results of other construction applications are described e.g. by Schwab et al. [8].

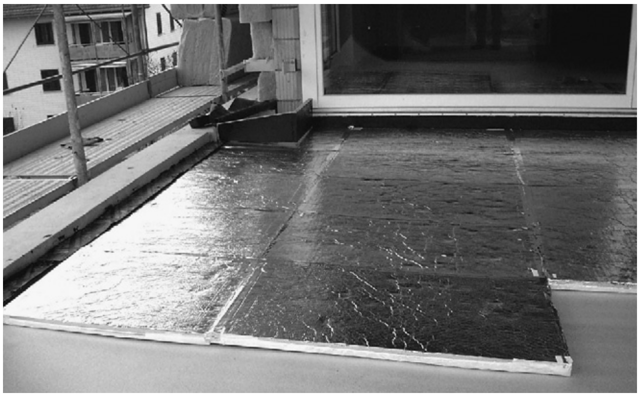


Fig. 1. Example of a slim balcony insulation with VIP giving equal levels for indoor and outdoor zones (2003). Today, panels for on-site installation are normally shipped with glued-on protection layers.

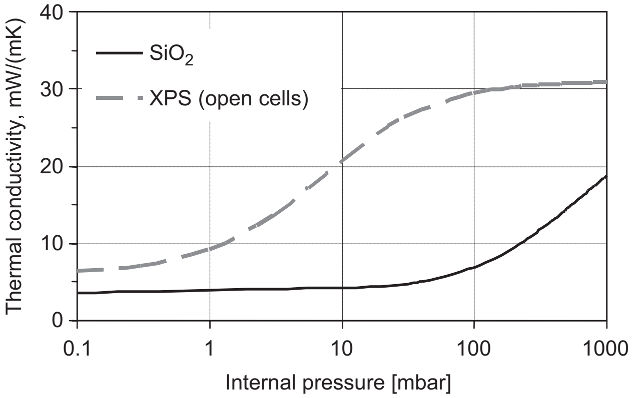
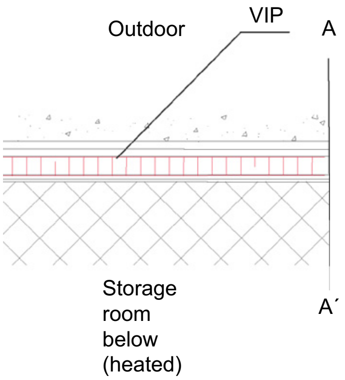


Fig. 2. Thermal conductivity of nano-porous fumed silica (SiO_2) and open cell extruded polystyrene foam (XPS) as a function of gas pressure.

2. Experimental set-up

An existing flat roof construction as illustrated in Fig. 3 was chosen for investigation. The location of the building is in Regensdorf, near Zurich (Switzerland). SiO_2-VIPs with a three-fold metallized polymer laminate barrier, and dimensions of 25 × 25 cm^2 or 50 × 50 cm^2 and a thickness of 20 mm, were installed in two square areas of about 200 × 200 cm^2. Larger VIP formats are normally used to reduce the pressure increase. For the test set-up, small formats were chosen in order to get more significant aging effects. The sequence of material layers in vertical direction is listed in Fig. 3. Pictures from the installation process are shown in Fig. 4. In one area, temperature and humidity sensors were installed in the indoor and the outdoor surfaces near the center and at the cross joints of a number of VIP surrounded by a guard area consisting of similar panels. Details of the area layout, sensor locations and labeling are shown in Fig. 5. Combined temperature–relative humidity (RH) sensors labeled "*TF x*/*y*", where *x* indicates the inside and *y* the outside surface of the VIP layer, were used at specific locations such as center-of-panel, joint and cross joint. These sensors ("Rotronic Hygroclip SC04", diameter 4 mm) were installed on both sides at the center-of-panel location and at the central cross joint of the test area. The temperature is measured by a



Layer (A-A')	2 [mm]	d
Crushed gravel	4	30
Bituminous water barrier (3 layers)	6	10
Protective layer	8	7
VIP	10	20
Protective layer	12	5
Water barrier (existing construction)	14	10
Porous concrete (existing construction)	16	200

Fig. 3. Cross-section of the flat roof construction used for monitoring and sequence of the material layers including VIP insulation (A–A′ from outside to inside).