HIGH PERFORMANCE THERMAL INSULATION - EXAMPLES FROM THE SWISS BUILT ENVIRONMENT

S. Brunner, J. Wernery, M. M. Koebel

Empa, Laboratory for Building Energy Materials and Components, Ueberlandstrasse 129, CH-8600 Duebendorf, Switzerland

ABSTRACT

Aerogel based solutions offer opportunities which combine aesthetics and cultural heritage criteria, often times in a unique way. In the field of energy efficient buildings, the search for improved envelope solutions has established Switzerland at the forefront of this type of applied research. Examples with granulate, aerogel sheets and aerogel render from 2002, 2008 and 2011 are presented [1, 2, 3]. For the development of the aerogel render [4], the speaker and his team received the Swiss environmental award for innovation in 2014. These are only a few selected examples of aerogel-based superinsulating solutions with many new ones being developed all over Europe. Experts and market analysts predict that aerogel materials will have a significant impact on the future built environment offering slim solutions, assuming that the high cost of production can be lowered to allow main markets penetration.

Vacuum Insulation Panels (VIPs) are a second class of high performance thermal insulation products with earlier market entry than aerogels, thus allowing us to look back on a full decade of experience with their applications and aging behaviour [5, 6, 7]. It was found that the aging behaviour of VIPs installed in 2004 is linear under the challenging conditions existing in flat roof terrace installations. This confirms that the prediction model [8] is applicable. Sufficient data exists to confirm that VIPs in Europe are of sufficient quality to be used in the building envelope..

In the context of a new project - the IEA EBC Annex 65 - the long term questions of aerogel and VIPs will be discussed on a top level. Having a team at Empa that synthesises a whole variety of aerogel is clearly helpful [10].

Keywords: Aerogel, Vacuum Insulation Panels (VIP), aging 10 years, aerogel granulate, aerogel sheets and render

INTRODUCTION

High performance thermal insulation as covered in this paper deals with aerogel and vacuum insulation panels. What aerogels are and how they are produced is the topic of two other contributions presented at CISBAT (oral presentations of Ana Stojanovic and of Lukas Huber).

Three pioneering projects with aerogel are revisited in this work in the context of a case study on applications motivated by the recently started IEA EBC project Annex 65 “Long Term Performance of Super-Insulating Materials in Building Components and Systems” [10]. Worldwide these three applications are the first of their kind and show the role of the Swiss market in building retrofit which is amongst the few trend-setting players which promote new solutions to reach energy efficiency under the stringent conditions of aesthetic and/or cultural heritage constraints.

AEROGEL GRANUALTE TRANSLUCENT APPLICATION

Perhaps surpisingly, the very first building for which aerogel was used in large quantities in the building envelope was a new construction. In 2003 the use of aerogel in a wide part of the building envelope started with the school building "Buchwiesen" in Zürich (Fig. 1). In this pioneering application aerogel was filled into cavities in fibre-reinforced façade elements. This was possible, as in that year, big enough quantities of aerogel got available at Cabot's pilot plant in Frankfurt. Previously, the concept was shown at the ZAE Bayern Building constructed in 1999 with demonstration and testing areas. For the construction as used at the "Buchwiesen" building the testing of thermal Performance and Solar gains were performed at Empa considering the constructive thermal bridging effects (U-values 0.48 W/m^2 K and G-values 0.25± 0.03).

Figure 1: Translucent facade seen from the inner side in 2004 and the outer weathered façade photographed a decade later in October 2014. The inset visualises the granules which fill up the cavity and insulate.

Nowadays, similar façade solutions are offered by many companies worldwide with aerogel between polycarbonate or glass panes where the view on the aerogel granules is part of the sold aesthetical solution. (The Swiss pioneer product Scobatherm, by the way, is now offered by Supramat Swiss GmbH, where still the same key person, Mr. Steger, is involved.). With these applications, the original vision of Aerogel used in the building envelope (e.g. [11]) made a prominent market entry.

SHEET SHAPED AEROGELS

While the building mentioned above was the first large scale application of aerogel granulate, aerogel sheets / blankets did not make their first appearance in the building sector but in the oil and gas industry and in applications such as spacecraft and military in the USA. Related to the pipe insulation in the oil and gas industry general technical pipe insulation emerged as a promising business sector for aerogels. As early as 2004, first samples of these products were received at Empa which helped bringing pioneering industry partners together.

In Switzerland, a first application was pipe insulation in a joint heating system for several older, existing buildings. With this high-performance insulation already validated in oil and gas applications, the same marketing and communication channels were adopted for building

systems. As a result contemporary insulations standards could be met with ease, which would not have been possible otherwise due to extreme space constraints.

A second application for aerogel sheets are existing buildings of particular cultural and aesthetical value with insufficient thermal insulation. Here, conventional insulation materials are often not a convincing or possible solution because of the necessary thickness or the potential for moisture problems. An old mill, shown in Fig. 2, was retrofitted with double-layered aerogel sheets in 2008, constituting the worldwide going-to-market for building envelopes. The improvement of the thermal envelope thus allows the usage of heat pumps or other low carbon-emission heat sources, which otherwise would be too energy inefficient in these kinds of buildings. For the IEA EBC project Annex 65 [10] dealing with the long time performance of superinsulation material, the mentioned building (Fig. 2) was reviewed by Valentina Zanotto, Amstein+Walthert AG. It still performs well after 7 years. On that building two layers of 1cm thick sheets were used as outside insulation in order to achieve high enough temperatures on the inside, in particular around the wooden ceiling beams, in order to prevent damage of the building structure or mould on the walls.

Figure 2: Aerogel sheets of 1 cm thicknesses like the old mill in Oberhallau near Schaffhausen, CH

With the year 2012 thicker aerogel solutions became available on the Swiss market in the form of aerogel render and plates. Both forms constitute the solutions used nowadays on Swiss facades while the sheet type in its high temperature variation is used in technical insulations. Also ducts for controlled air circulation are under the reference objects [12]. A list of the reference buildings where aerogel panels are used on the facade is [13]. 50% of these building are Swiss examples which can be found in more details at [14].

AEROGEL INSULATION RENDER

The third pioneer building with the aerogel high performance insulating aerogel render (“Dämmputz”) was completed in 2012. While granulate is a form of a material which can be poured directly into a cavity, sheets and plates have roughly constant thickness. The advantage of a granulate-based plaster is to equalize surface roughness at mm to cm scale which is typical for historical facades in one step allowing for an original curved or wavy topography which is so typical for classical historical facades.

Figure 3: Aerogel granules (left) as used in the aerogel plaster (centre images), and the 2012 retrofitted old mill at Sissach near Basel, CH (left)

Following the first buildings in 2012, about 70 buildings were retrofitted in that way in the subsequent two years, with now 19 reference objects online at one of the producing companies' website [15].

Looking at a second class of high performance thermal insulation, a decade of experience with aging behaviour of Vacuum Insulation Panels (VIPs) has been gained [5, 6, 7]. It was found that the aging behaviour of VIPs installed in 2004 is linear under the demanding conditions of a flat roof terrace installation. This confirms that the prediction model [8] is applicable. Consistent with an earlier presentation dating back to CISBAT2003, sufficient data exists to confirm that there are VIPs in Europe offered by leading companies of sufficient quality to be used in the building envelope.

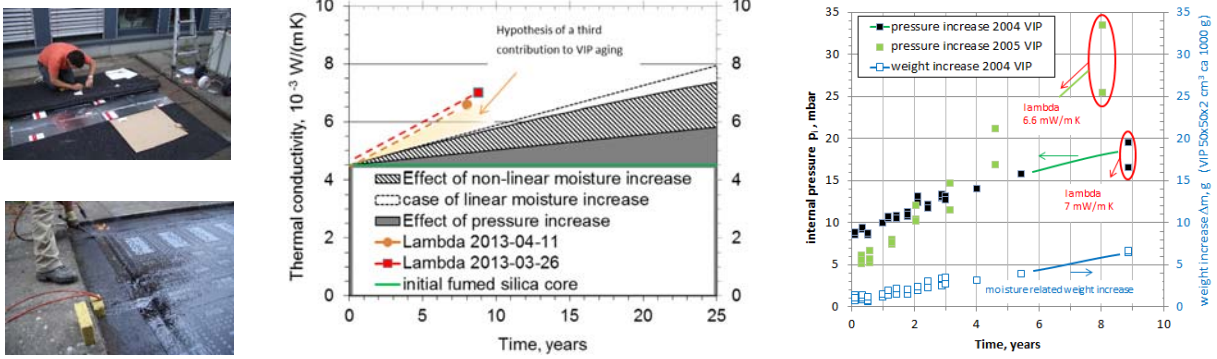

Figure 4: Vacuum Insulation Panels (VIPs) showed a thermal conductivity of 6.8 mW/(m K) after 8.8 years, constituting the best known performance in a real application. Building insulation is regarded as critical in [16] with more severe uncertainties than most other VIP applications: Photos from the installation in 2004 (left), a graph with the 2008 prediction plot [9] which is calculated for the measured temperature histogram at 80%rh moisture load (centre) and internal pressure increase curve showing the linear in both pressure and moisture increase (right) [5].

Among the different parts of the building envelope the application to build a terrace is ranked as the most severe one regarding water vapour permeation [16], and luckily, it is the best documented application worldwide [5,9] regarding the aging of VIPs.

In the context of a new project - the IEA EBC Annex 65 - the long term questions of aerogel and VIPs will be discussed on a top level. Having a team at Empa that synthesises a whole variety of aerogel is clearly helpful [10 and CISBAT contributions of Ana Stojanovic and of Lukas Huber].

REFERENCES

1. "Handbook of Aerogel " from 2011, chapter "Aerogels for Superinsulation: A Synoptic View". 2011, http://www.springer.com/materials/special+types/book/978-1-4419-7477-8
2. Koebel. M, Arnaud Rigacci, A., Achard R., Aerogel-based thermal superinsulation: an overview, Journal of Sol-Gel Science and Technology, 2012, 63, 3, 315-339 http://dx.doi.org/10.1007/s10971-012-2792-9
3. www.forumholzbau.com/pdf_05/nl11_turnhalle.pdf 2005
4. Stahl Th., Brunner S., Zimmermann M., Ghazi Wakili K., Thermo-hygric properties of a newly developed aerogel based insulation rendering for both exterior and interior applications, Energy and Buildings 44 (2012) 114–117 http://dx.doi.org/10.1016/j.enbuild.2011.09.041
5. Brunner, S., Ghazi Wakili K., Hints for an additional aging factor regarding the thermal performance of vacuum insulation panels with pyrogenic silica core, Vacuum , 2014:100:4–6, http://dx.doi.org/10.1016/j.vacuum.2013.07.033
6. Brunner S., Ghazi Wakili K., Stahl Th., Binder B., Vacuum insulation panels for building applications—Continuous challenges and developments, Energy and Buildings 85 (2014) 592–596, http://dx.doi.org/10.1016/j.enbuild.2014.09.016
7. Brunner S., IEA EBC Annex 65 Kick-off meeting, 2014-09-11/12 Grenoble, France
8. H. Simmler, S. Brunner, Vacuum insulation panels for building application Basic properties, aging mechanisms and service life, Energy and Buildings 37 (2005) 1122-1131 http://dx.doi.org/10.1016/j.enbuild.2005.06.015
9. S. Brunner, H. Simmler, In situ performance assessment of vacuum insulation panels in a flat roof construction, Vacuum 82 (2008) 700–707 http://dx.doi.org/10.1016/j.vacuum.2007.10.016
10. Wong J.C.H, Kaymak H., Brunner S., Koebel M., Mechanical properties of monolithic silica aerogels made from polyethoxydisiloxanes, Microporous and Mesoporous Materials , 183, 23-29, 2014 http://dx.doi.org/10.1016/j.micromeso.2013.08.029
11. Fricke J., Spektrum der Wissenschaft 1988, 7, 60 in German / English in Sci. Am. 1988, 256(5), 92.
12. http://agitec.ch/referenzobjekte/spezial-anwendungen , -> http://agitec.ch/fileadmin/images/img/Referenzobjekte/Deutsch/Lueftungsisolation_Coop_St._Annahof__Zuerich.pdf , downloaded 2015-05-10
13. http://www.wall-systems.com/produkte/referenzobjekte.html -> with selection of Warengruppe "WDVS Multitherm Aero"
14. http://agitec.ch/referenzobjekte/fassade
15. Yrieix B., Benoît M., Pons E., VIP service life assessment: Interactions between barrier laminates and core material, and significance of silica core ageing, Energy and Buildings, 85, 2014, 617–630 http://dx.doi.org/10.1016/j.enbuild.2014.07.035
16. www.fixit.ch/aerogel ->Referenzobjekte