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Declaration of thermal performance of vacuum-insulation-panels (VIPs) for buildings according to the draft product standard prEN 17140

Background

Thermal performance of a VIP is depending on the thermal bridging effect on the edges of the panel and on the permeation of water vapour and air into the panel while in use. Therefore the dimensions of the panel and the boundary conditions from the application affect the performance. Therefore declaration of thermal performance has to be done by the manufacturers, depending on the dimensions of the panels and their edge effects, including statistical variation of the production and including ageing of the panels. The following procedure has to be applied.

Ageing procedure

The proposed method to determine ageing of Vacuum-Insulation-Panels (VIPs) in prEN 17140 allows the determination of the performance over time by using well explained and derived accelerating factors. The artificial ageing in the standard is done in comparison to the laboratory climate at 23°C/50%r.H..

The procedure separates the effects of the permeation of dry air and water vapour into the panels, allowing for the first time the determination of a performance of an insulating material over time, making it possible to declare the thermal performance at a specific point (e.g. as the mean value of performance for the first 25 years).

In comparison to other ageing methods used in product standards for insulating materials, this is a crucial difference in the intention: For VIPs a performance of thermal conductivity over time can be derived from the accelerating testing; for all the other materials it is the durability of thermal conductivity or the end-value after ageing. All other standards are just using artificial ageing in a way that after some time in an elevated temperature the sample still has to have a specific performance – without deriving accelerating factors for the elevated climate in comparison to the real climate.

Ageing in VIPs occurs as a digressive incline in thermal conductivity of the VIPs. Despite this, the ageing method in the VIP product standard is using a linear approach for the extrapolation of the derived thermal conductivity increases over time. As the linear approach is the envelope curve of the digressive curves, this is far on the safe side for the climate used for comparison (23°C/50%r.H.), but also on the safe side for all intended applications for VIPs. The higher temperature and relative humidity around the VIPs in the application, the faster is the natural ageing. The linear approach is on the safe side for the extrapolation of the 12.5 years value – which is considered to be the mean value for 25 years.

Determination of thermal bridges

The determination of the linear thermal transmittance ψ at the edges of the panels is usually carried out by numerical simulations according to EN ISO 10211. It is strongly recommended to use the Finite-Difference- Method (FDM) instead the Finite-Element-Method (FEM), because of better accuracy and greater tolerance on the size and shape of numerical cells when simulating the thin component layers

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of the envelope materials. Numerical modelling should take into account even smallest gaps filled with air or sealing material between two panels and all assumptions should be documented carefully. The simulations shall be done for the edge designs relevant for the panels and for all components that belong to the panels as they are placed on the market by the manufacturers.
The determination of the linear thermal transmittance values ψ can be done by measurement in Guarded-Hot-Plate (GHP) and Heat-Flow-Meter (HFM) apparatuses as well, if additional measures take the non-uniform temperature distribution within the surfaces of the VIP assembly with joints into account.

Factory production control

The necessary factory production control (FPC) testing of thermal conductivity in the center of panels is outlined in the product standard prEN 17140 in Annex B. Within the FPC testing one thermal conductivity value per day has to be measured by the manufacturer. For the type testing (TT) own values of the manufacturer and at least 4 results for thermal conductivity from a notified body can be combined and processed according to the statistical approach given in prEN 17140 Annex A.

Obtaining values for declaration of thermal performance

Annex C of prEN 17140 gives the procedure for the determination of declared values for the thermal performance of VIPs. Thermal conductivity λ_{COP} or R_{COP} are measured in the center of panels shortly after production. On a set of at least 10 measurements the statistics from Annex A are applied, deriving $\lambda_{COP\ 90/90}$ or $R_{COP\ 90/90}$, representing at least 90 % of the production, determined with a confidence level of 90 % in accordance with EN ISO 10456.

The results from the accelerated ageing tests $\Delta\lambda_{COP,mean}$ are then added on top of $\lambda_{COP\ 90/90}$, leading to $\lambda_{90/90\ COP\ aged}$. Then the thermal bridging effects have to be added to incorporate the dimension related aspects into the thermal performance. This result is then rounded upwards to the nearest 0,0001 W/(m·K) and declared in levels with steps of 0,0005 W/(m·K) for λ_D.

The declared thermal resistance, R_D, shall be calculated from the nominal thickness d_N, the nominal perimeter length S_N, the surface area S of the VIP and the corresponding thermal conductivity value λ_D, and shall be rounded downwards to the nearest 0,05 m²·K/W, and declared in levels with steps of 0,05 m²·K/W respectively. The following formulae are used:

$$\lambda_{COP,90/90,aged} = \lambda_{COP,mean} + k \cdot s_\lambda + \Delta\lambda_{COP,mean\,(25\,years)}$$
$$\lambda_D = \lambda_{COP,90/90,aged} + \psi \cdot d_N \cdot \left(\frac{S_N}{S}\right)$$

The manufacturer can declare the thermal performance of their VIPs as separate values for each single product and each single thickness, or could group a range of thicknesses (e.g. thick, thin and medium products) and declare thermal performance for each of these groups. If grouping is done, the tested results have to cover the full range of grouped products.

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Just neglecting the edge effect in the declaration of performance will lead to much too low (too positive) values of equivalent thermal conductivity[1], especially if the linear thermal transmittance ψ is rather severe, for example, if Aluminium foils are used as envelope material. The following table shows the impact of typical edge effects of two types of envelope materials on VIPs of different sizes, using λCOP,90/90,aged = 0,006 W/(m·K) for the center of the panels.

	size of panel	Typical linear thermal transmittance for foil used Ψ	equivalent (effective) thermal conductivity incl. Edge effects λ_{eff}	increase on λ_{COP}	thermal conductivity (rounded upwards) $\lambda_{eff,r}$	declared thermal conductivity λ_D
	m x m	W/(m·K)	W/(m·K)	%	W/(m·K)	W/(m·K)
20 mm VIP - metallized film	0.40 x 0.40	0.0040	0.0068	13%	0.0068	0.0070
	0.60 x 1.00	0.0040	0.0064	7%	0.0065	0.0065
20 mm VIP - Aluminium foil 9 µm	0.40 x 0.40	0.0300	0.0120	100%	0.0120	0.0120
	0.60 x 1.00	0.0300	0.0092	53%	0.0092	0.0095

Summary

Thermal performance declaration of VIPs shall include statistics on the measurements in the center of panel according to the product standard. Then the result from the accelerated ageing process has to be added to cope with the degradation of performance over time. In addition, the declared value shall include the edge effects of the panels obtained for the panels as sold by the manufacturer – including all auxiliary materials, such as e.g. adhesive tapes.

*With thanks to Christoph Sprengard, FIW

[1] Equivalent thermal conductivity is also called effective thermal conductivity in many papers and articles.