The ψ -Value

Evaluation of the thermal performance of windows and facades

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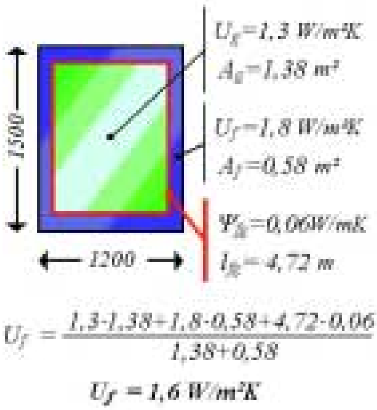

Figure 1: Example of the calculation of a standard sized window with glazing (1.3 W/m²K) and frame (U=1.8 W/m²K) taking into account a linear thermal transmittance of 0.06 W/mk.

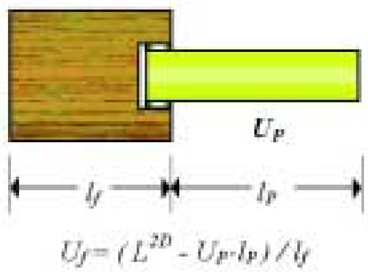

Figure 2: Definistion of the thermal transmittance of the frame (U_f-value)

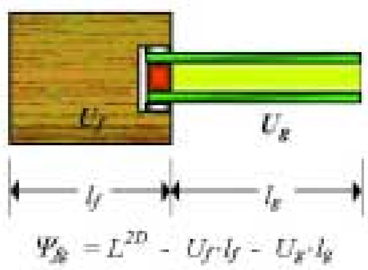

Figure 3: Definition of the linear thermal transmittance (ψ-value)

The thermal quality of windows has substantially improved during the last few years. The U-value of the window framework has improved, as has the U-value of the glazing, but what about the linking zone between the frame and the glazing? The condensation risk at the glass edges was well known and some attempts were made, known as 'warm edge', to increase the interior surface temperature, but, this improvement was not qualified and hence disregarded.

The German standard DIN 4108 differentiates only between five groups of framing materials. A table will give the U-value of the window depending on the group and the type of glazing - a pleasingly simple procedure. Today, this approximate distinction is no longer appropriate, with European legislation ever tougher. With few people knowing about these new European developments, this article intends to set out the most important standards for the thermal evaluation of windows and extend these ideas.

BASICS

The U-value

The thermal quality of a building component is defined as the thermal transmittance or the U-value. The U-value is by its definition a 'square' measure. E.g it applies to square dimensional components, for example walls:

$$\Phi = A \bullet U \bullet \Delta T \qquad (1)$$

Where

- Φ is the heat flow in W/m²,
- A is the area or square dimension of the component in m²,
- U is the thermal transmittance in W/m²K and
- ΔT the difference of temperature between room air and outside air.

German standards

The still valid standard DIN 4108 [1] was originally implemented in 1981. At present the complete standard is being revised and amended, with special attention being given to thermal bridges. A new supplement to the original standard is proposed to arrange 'cold bridge free' planning examples. One new part of DIN 4108 is intended to bring in procedural proof that the German energy saving regulation (EnEV) is being adhered to. This part is essentially based on the European standard EN 832 [2], dating from 1998.

The definitions and calculation rules given in part 5 of DIN 4108, as well as the determination of the thermal transmission coefficient of windows and frame profiles, will be superseded by the corresponding European standards. What the German reader will immediately notice will be a new symbol for thermal transmittance. It will change from the German symbol 'k' to the European symbol 'U'. But there are far more important consequences for the assessment of windows.

European standards

The principle standard to calculate the required heating energy EN 832 is based on a number of further standards. Among them EN ISO 6946 [3] and EN ISO 10211 [4] are used for the calculation and evaluation of thermal bridges. Preferably, thermal bridges are considered today as follows:

$$L = \sum A \cdot U + \sum l \cdot \psi + \sum \zeta \qquad (2)$$

The thermal conductance L corresponds to the past product of the thermal transmittance U and the area A, see equation (1), but now includes thermal bridge effects given by these additional addenda. Linear extended thermal bridges, such as building edges, or the link zone of the glass to the frame, are characterised by the linear thermal transmittance◊y (psi-value), given in the unit W/mK. Often it is allowed, e.g. in the case of windows, to neglect punctual cold bridges denoted with the symbol ζ. In this case the conductance will be denoted L^{2D}, since only two-dimensional effects are considered.

The transfer of this concept to windows is done by the WG7 of CEN TC89. The work on the standard EN ISO 10077-1 [5] for the simplified determination of the thermal transmittance of windows based on equation (2) was completed in 1999. The formal vote was positive and the standard will be published soon. It will contain rules to determine U-values for different window constructions in a simpler way. Some substantial modifications are:

- For frames made of metal the developed surface area is considered according to EN ISO 6946, i.e. the surface resistance is reduced and the U-value will increase.
- The link between glass and frame, i.e. the edge of the glass, is considered to be the 'cold bridge coefficient' linear thermal transmittance Ψ or psi-value according to equation (2).

It applies to the thermal transmittance of a window according to EN 10077-1:

$$Uw = \frac{A_g \cdot U_g + A_f \cdot U_f + l_{fg} \cdot \Psi_{fg}}{A_g + A_f} \qquad (3)$$

To apply equation (3), the size of the window is important as well as the thermal transmittances of frame and glass and the linear thermal transmittance. (See example in Figure 1). A table will be given to read out the U-value of standard sized windows. An excerpt is shown in Table 1. The example is highlighted, see figure 1.

The thermal transmittance U_f of the frame may be determined by a measurement according to EN ISO 12412 [6], but this takes time and money, assuming that a test profile already exists. Fortunately the progress of computer engineering and software development has made it possible to execute thermal calculations with sufficient precision [7]. The draft standard prEN 10077-2 describes the necessary details and boundary conditions. The cross section of the frame profile is modelled by a two-dimensional computation method .The quantity L^{2D}, i.e. the thermal conductance of the section, is determined by calculation. The thermal transmittance of the frame is given by:

$$Uf = \frac{L^{2}D - U_p \cdot l_p}{l_f} \qquad (4)$$

The symbols are explained in figure 2. Likewise the linear thermal transmittance y of the link (or chaining zone) between frame and

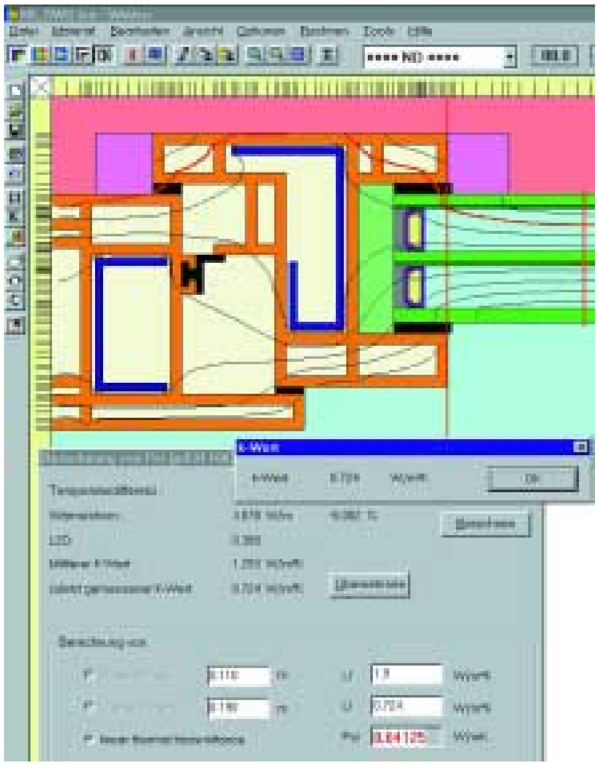

Figure 4: Screen shot of a typical calculation with the program WINISO®

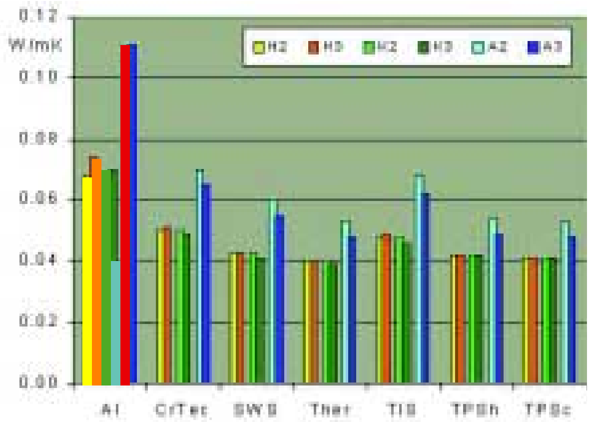

Figure 5: Linear thermal transmittance of a conventional spacer system and warm edge systems used in six different frame-glazing combinations

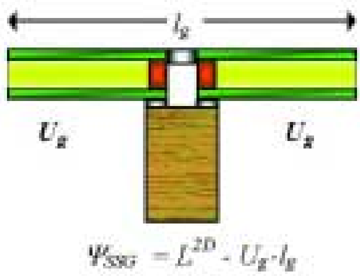

Figure 6: Definition of the linear thermal transmittance applied to a structural sealant glazing system

Table 1 Thermal transmittance of windows according to EN 10077-1 (excerpt)

Type of glazing	Ug	Uf (frame area 30%) 1.0	1.4	1.8	2.2	2.6	3.0	3.4	3.8	7.0
Single	5.7	4.3	4.4	4.5	4.6	4.8	4.9	5.0	5.1	6.1
Double	3.1	2.6	2.7	2.8	2.9	3.1	3.2	3.3	3.5	4.3
	2.1	1.9	2.0	2.1	2.3	2.4	2.5	2.7	2.8	3.6
	1.7	1.6	1.8	1.9	2.0	2.2	2.3	2.4	2.5	3.3
	1.3	1.4	1.5	1.6	1.7	1.9	2.0	2.1	2.3	3.1
	1.1	1.2	1.4	1.5	1.6	1.8	1.9	2.0	2.1	2.9
Triple	2.1	1.9	2.0	2.1	2.2	2.4	2.5	2.6	2.8	3.6
	0.9	1.1	1.2	1.3	1.4	1.6	1.7	1.8	2.0	2.8
	0.7	0.9	1.1	1.2	1.3	1.5	1.6	1.7	1.8	2.7

glazing can be determined by the computer according to the following equation:

$$\Psi_{fg}=L^{2D}-U_f l_f-U_g l_g \quad (5)$$

This procedure is illustrated in figure 3. Special attention should be paid to the 'dividing line' between frame and glass. The ψ-value depends not only on the thermal characteristics of the edge of the insulating glass, but also on the geometry and the material of the frame profile and the thermal quality of the glass. In the case of low performance glass units or frame profiles the y -values are negligible, but high performance components will result in remarkably high values. That is why the ψ -value is of increasing importance today.

In summing up, the calculation of ψ for windows is based on equation (3). For façades this equation is extended and two further amendments take into account the panel and the edge of the panel. The ψ -values of the link glass-frame, and the link panel-frame respectively, influence strongly the U-value of the element. Therefore all attempts to reduce thermal bridges in high performance building components should be encouraged and consequentially improve the ψ -values.

THE WARM EDGE

The thermal transmittance of an insulating glass unit is defined as the 'centre-value' of the pane. The U_g-value is valid only at a certain distance from the edge of the glass pane. Near the edge, the edge seal and the type of the spacer, determine (besides other influences) the thermal performance of an insulating glass unit. A metallic spacer profile within the edge seal will build a severe cold bridge between both glass panes and will result in low surface temperatures and additional heat losses.

The elimination of condensation was the original intention of the development of thermal improved edge seal systems. The best way to do this is to increase the surface temperature at the glass edge and so reduce the risk of condensation forming. Consequently this technique was called 'warm edge' and different systems are available on the market today.

Lacking standardisation in the past, different quantifying values for the 'warm edge' effect were used and a comparison was often hard to achieve. As the surface temperature is in correlation with the heat losses, the linear thermal transmittance will be the best choice for a characteristic value.

Warm edge development

In 1999 six manufactures of warm edge systems agreed to start a common investigation project. The aim was to define a basis for the evaluation of warm edge systems and to quantify the improvement compared to conventional edge systems with a spacer made of aluminium. The linear thermal transmittance is only definable in a framed-glazing system. Therefore two insulating glass units, a double and a triple glazing with low emissivity coating, and three types of frame profile according to EN ISO 10077 were selected. The details are shown in Table 2.

For each warm edge system the y -values of six glass frame combinations were calculated using the program WINISO® [7], figure 4 is a screen shot of a typical calculation. A summary of the results is given in figure 5. The ψ -values of the investigated warm edge systems are shown in a bar diagram together with a conventional edge system.

In general the influence of double or triple glazing on the ψ-values is negligible, but there is a remarkable increase in the surface temperature as further investigation proved. The warm edge systems give ψ-values of 0,05 to 0,06 W/mK for the frame profile made of aluminium with thermal break, whilst the conventional edge system results in 0,11 W/mK. Frames profiles made of wood or plastic show only a small difference between 0,04 to 0,05 W/mK for warm edge system and 0,07 for the conventional system.

Warm edge systems reduce the cold bright effect (characterised by the linear thermal transmittance) significantly

Table 2: Investigated glass frame combinations

Frame profile (EN ISO 10077)		Double glazing 1,2 W/m²K	Triple glazing 0,8 W/m²K
Wood	1,3 W/m²K	H2	H3
PVC (steel reinforced)	1,9 W/m²K	K2	K3
Aluminium	2,0 W/m²K	A2	A3

by between 30% to 50%. This results in a reduction of the thermal transmittance of a standard sized window of between 0,1 to 0,3 W/m²K. For small sized windows or crossbars the improvement is even more substantial.

STRUCTURAL SEALANT GLAZING

Conventional framework for windows or façades is characterised by the thermal transmittance U_f, see equation (4). Therefore it is necessary to define the width lf of the frame profile. In some modern constructions, e.g. structural sealant glazing systems, the definition of the width is not evident and the Uf -value loses its meaning, whilst the linear thermal transmittance (ψ -value) can easily be defined and understood, see figure 6. The mean average thermal transmittance of a façade U_F is then:

$$U_f = (A_F \Diamond U_g + l_{SSG} \cdot \psi_{SSG})/A_F \qquad (6)$$

The value yssg includes the glazing, as well as the glazing edge properties and framework. It is a characteristic value of the construction as a whole.

SUMMARY

The thermal performance of high insulating building components like modern insulating glass units is not determined by the thermal transmittance alone. It is necessary to take into account the link to the neighbouring elements. This link is characterised by a type of coupling coefficient, the linear thermal transmittance or the ψ -value. In the case of conventional window systems the risk of condensation and heat loss is increased along the glass edge. This effect can be reduced considerably by the use of thermally improved edge sealing systems known as warm edge.

The concept of linear thermal transmittance may be extended to window and façade systems where a thermal transmittance to the frame is not applicable. An example would be structural sealant glazing components, where the y -value would be a simple way to assess the efficiency of the system. ■

BIBLIOGRAPHY

[1] DIN 4108 Wormeschutz im Hochbau, 1981

[2] EN 832 Thermal performance of buildings – Calculation of energy use for heating – residential buildings, 1998

[3] EN ISO 6946-1 Building components and building elements – Thermal resistance and thermal transmittance – Calculation method. 1996

[4] EN ISO 10211 Thermal bridges in building constructions – Heat flows and surface temperatures, 1995

[5] prEN 10077-1 Thermal performance of windows, doors and shutters – Calculation of the thermal transmittance, part 1: Simplified method. part 2: Numerical calculation method for frames, 1998

[6] prEN 12412 Windows, doors and shutters – Determination of the thermal transmittance by the hot box method, 1998

[7] WINISO Calculation of 2- and 3-dimensional heat flow www.sommer-informatik.de

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