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What is the "correct" *U*-Value?
Evaluation and limits of the measurement and calculation results

1 Introduction

The elements of the envelope of a building, such as the masonry, the facade or even the window are being continuously improved with respect to their thermal performance. If the thermal behaviour is to be assessed, then there are various methods available for obtaining the thermal transmittance U for each construction product. However, not every verification method leads to the same results for the same products. With this, the question of a correct U value is answered in a simple manner. The U value cannot be "correct".

2 Methods for determining the thermal transmittance *U*

In order to somewhat narrow the scope of the spectrum of construction products, the following sections deal only with the product window.

For the verification of U_W of a complete window, the manufacturer has various methods available based on the European standards.

- Table F1 to F4 of EN ISO 10077-1
- Calculation according to EN ISO 10077-1
- Measurement according to EN 12567-2

For the procedure using tables as well as with the calculation procedure, the input parameters U_g, U_f and ? must be known. Even here, there are different methods to determine the input parameters. As a rule, the thermal transmittance of the glazing U_g can be read off directly from the table C2 of DIN EN 10077-1 simply on the basis of the glass construction, the surface coating and the glass pane. In the case of other construction systems, the calculation procedure based on DIN 673 or even a measurement based on DIN 674 must be used.

For the verification of the thermal transmittance U_f of the frame, there are tables or diagrams of EN ISO 10077-1 available for various materials. However, these have been only been made on a very global basis and do not cover all possible constructions.

The verification for the linear thermal transmittance ? can simply be done using the tables E.1 based on EN ISO 10077-1. For typical spacers made of aluminium and steel or for spacers made of materials having a better thermal performance, there are tabular values available depending on the construction of the glazing. To be able to judge the thermal performance better, it is recommended to perform a calculation based on EN ISO 10077-2.

3 Comparison of the assessment methods of U_f for various frame materials

As mentioned at the beginning, the assessed of the thermal transmittance U_f can be done using tables, calculations or measurements. However, these assessmnet methods differ substantially

Figure 1 Test facility to obtain the thermal transfer coefficient as per EN 12412 at **ift** Rosenheim

from each other in details. For this purpose, the following frame materials are considered more closely.

3.1 Wood frame profile

If, for example, a frame profile cross-section IV 68 based on DIN 68121 needs to be assessed, then this can be done using Fig. D2 of EN ISO 10077-1 based on the defined depth of 68 mm (refer to Fig. 2). If the raw material of the frame is made out of softwood (fir), then the global value of U_f = 1.8 W/(m²K) can be read off the table. Differences between the side and lower frame cross-sections are not taken into account.

If one wishes to perform the asessment, using the calculation based on EN ISO 10077-2, on the same frame cross-section, then one gets the value U_f = 1,4 W/(m²K) for the side cross-section or U_f = 1,8 W/(m²K) for the lower cross-section. A measurement based on EN 12412-2 can lead to a value, better by about 0.2 W/(m²K), as compared to the calculated value.

Fig. 2 illustrates the diagram D2 of EN ISO 10077-1. In the diagram other calculation results based on EN ISO 10077-2 for an IV 68 (side and lower cross-section) have been shown.

3.2 Plastic Frame Profiles

Using the table procedure based on EN ISO 10077-1, the cross-sections of plastic frames can be assessed depending on the number of chambers. In this connection, globally the values considered are U_f = 2.2 W/(m²K) for a profile with two hollow chambers or U_f = 2.0 W/(m²K) for a profile with three hollow chambers. Other parameters affecting the thermal properties such as the depth, type of reinforcement and sealing system are not taken into consideration. These parameters, crucial for plastic frame profiles, can be taken into consideration using only the calculation or the measurement procedure.

Fig. 3 displays the table value of U_f = 2.0 W/(m²K) and other calculation or measurement results for the 3 chamber profile with a blocksealing system. Thereby, there is an average improvement of about 0.2 W/(m²K) respectively for the above-mentioned system between the tabular procedure, calculation procedure as well as calculation procedure and measurement procedure.

3.3 Metal Frame Profile

For the assessment of the metal frame profile the calculation or the measurement procedure should be used. Only when no values are available using these procedures can the assessment of metal profiles be done using the tabular procedure from diagram D4 based on EN ISO 10077-1. At first, the thermal transmittance must be de-

termined depending on the distance of the metallic layers. Finally, U_f must be determined with the help of the developed surfaces.

The tabular procedure leads to very unreasonable values and should be used, as already mentioned, only in exceptional cases. Between the calculation and measurement procedures, only slight differences of about 0.1 W/(m²K) are observed.

4 Limitations of the Tabular, Calculation and Measurement Procedures

Depending on the assessment method and the frame material, one gets different results for the input parameter U_f for the same product.

The tabular procedure is a simple and cost-effective method for assessing the thermal transmittance for standard cross-sections. However, for optimisation purposes, for example, it is totally unsuitable, since no details regarding the respective construction are taken into consideration. This is possible only with the calculation or measurement procedures. With the calculation procedure, the details of the profile cross-section are taken over exactly in the calculation model. In this connection, not only does the construction affect the result, but even the characteristic data of the material used play a decisive role. The advantage of the calculation procedure lies clearly in the possibility of quickly changing input parameters. With this, there is a simple way to optimise the product. However, it must always be borne in mind that with optimisation tasks, the characteristic data of the material must be in line with the rules layed down in the standards.

EN ISO 10077-2 itself as well as DIN 4108-4 and EN 12524 yield information about the characteristic data of the materials for the calculation-based verification. The design values mentioned there for the thermal conductivity have been listed for most materials. If, however, other materials are

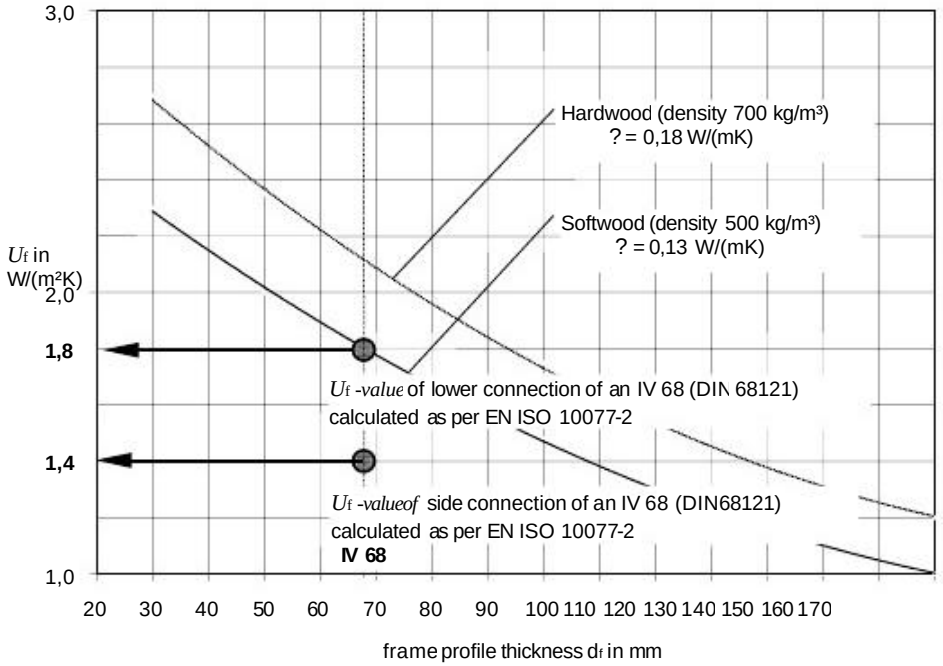

Figure 2
Table D 2 of EN ISO 10077-1: Comparison of the results of different frame connections as per EN ISO 10077-2

used, then the only way is to specially verify the thermal conductivity of the material. Based on the measured value obtained for the thermal conductivity, or also known as declared value, finally the calculated value or design value can be determined. prEN ISO 10456 as well as DIN 52612 form the basis for determining the thermal nominal and design values of construction materials and products and also the calculation coefficients for the temperature and humidity.

The procedures are, however, until today not workable for all materials – nor are they clearly defined. Thus, for example, in various countries, there could be different demands on the moisture content of the materials, which, ultimately can lead to different design values. Thus, in the context of the CE marking, theoretically, different design values for the thermal conductivity of the materials, and, thus, different thermal transmittance for the frame profiles are possible. The most time-consuming procedure, which, however, yields the best results, is the verification method using measurements. The limitations here are primarily related to the dimensions of the test sample. In case of verification using measurements, it must be noted that the test sample on which measurements are made must match the actual product to be used in the construction as far as possible. Ideally, the test sample used should be taken from the running production line. Thus, owing to the test being carried out on a real test sample, the measurement yields realistic values, but, however, is not suitable for optimisation tasks owing to the high level of effort required for carrying out the measurement.

5 Summary and Outlook

If the methods of assessment for determining the U_w of a complete window are known, then the U-value can be obtained in line with the requirements. The input parameters can then either be obtained in a simple and cost-effective manner using the tabular procedure or alternatively, with higher cost and effort using calculations or measurements, which, however, gives the best values.

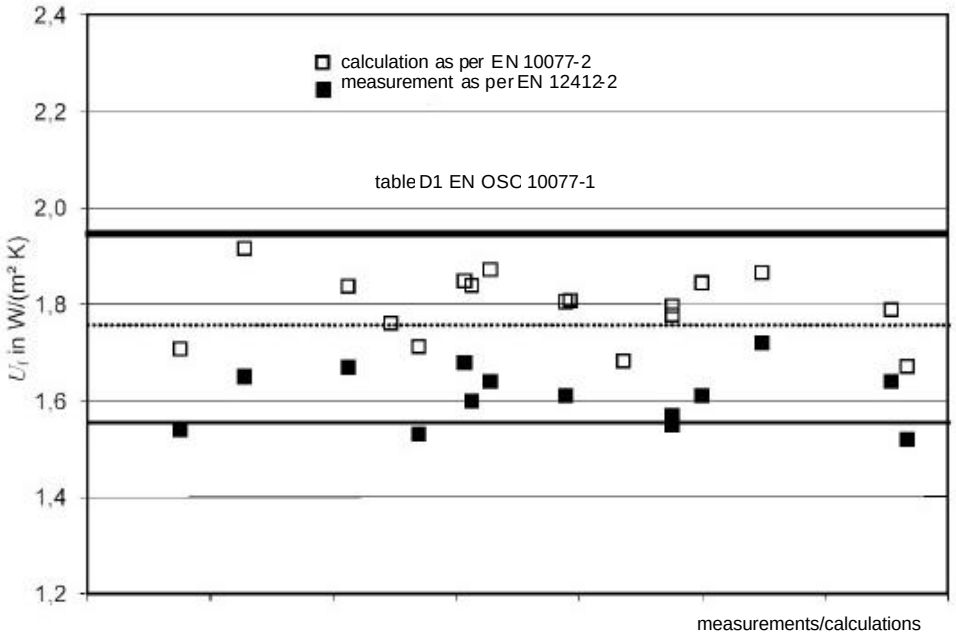

Figure 3
Diagram of the thermal transmittance of plastic frame profiles Comparison of the results obtained as per Table D1 of EN ISO 10077-1 and calculation as per EN ISO 10077-2 or measurement as per EN 12412-2 for triple chamber profiles

To ensure that even in future the values of the thermal transmittance obtained using the various assessment methods are comparable, it is indispensable to carry out the verification using "honest" product or material data.

In the context of the CE marking, the thermal transmittance U_w is a mandatory characteristic, and, thus, to be specified by the manufacturer. The type test of the product, thus, is done by an approved body. Manufacturers can draw upon the verified thermal transmittance for the CE marking at their own responsibility. They must then ensure the conformance to the declared values by means of an independent production control in their manufacturing premises.

Literature

[1] DIN EN 673 : 2003-06
Glas im Bauwesen – Bestimmung des Wärmedurchgangskoeffizienten (U-Wert) – Berechnungsverfahren
Berlin: Beuth Verlag GmbH

[2] DIN V 4108-4 : 2004-07
Wärmeschutz und Energie-Einsparung in Gebäuden – Teil 4: Wärme- und feuchteschutztechnische Bemessungswerte
Berlin: Beuth Verlag GmbH

[3] EN ISO 7345 : 1996-01
Wärmeschutz – Physikalische Größen und Definitionen (ISO 734 : 1987)
Berlin: Beuth Verlag GmbH

[4] (Norm-Entwurf) DIN EN ISO 10456 : 2005-06
Baustoffe und -produkte – Wärme- und feuchtetechnische Eigenschaften - Tabellierte Bemessungswerte und Verfahren zur Bestimmung der wärmeschutztechnischen Nenn - und Bemessungswerte
Berlin: Beuth Verlag GmbH

[5] (Norm-Entwurf) DIN EN ISO 10077-1 : 2004-08
Berechnung des Wärmedurchgangskoeffizienten – Teil 1: Vereinfachtes Verfahren
Berlin: Beuth Verlag GmbH

[6] DIN EN ISO 10077-2 : 2003-10
Wärmetechnisches Verhalten von Fenstern, Türen und Abschlüssen; Berechnung des Wärmedurchgangskoeffizienten – Teil 2: Numerisches Verfahren für Rahmen
Berlin: Beuth Verlag GmbH

[7] DIN EN 12412-2 : 2003-11
Fenster, Türen und Abschlüsse; Bestimmung des Wärmedurchgangskoeffizienten mittels des Heizkastenverfahrens – Teil 2: Rahmen
Berlin: Beuth Verlag GmbH

[8] DIN EN 12524 : 2000-07
Baustoffe und -produkte – Wärme- und feuchteschutztechnische Eigenschaften - Tabellierte Bemessungswerte
Berlin: Beuth Verlag GmbH

[9] DIN EN ISO 12567-1 : 2000-09
Fenster, Türen und Abschlüsse; Bestimmung des Wärmedurchgangskoeffizienten mittels des Heizkastenverfahrens – Teil 1: Komplette Fenster und Türen
Berlin: Beuth Verlag GmbH

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