Technical Note No 49

U-values of curtain walls

This Technical Note is one of four on the effect of building envelope performance on energy use in buildings. The series comprises:

TN 46 Introduction to building envelope energy transfer
TN 47 Overall building envelope U-values
TN 48 U-values of windows
TN 49 U-values of curtain walls

Introduction

This Technical Note gives the background to the calculation of U-values for curtain walls. It refers to 'The thermal assessment of window assemblies, curtain walling and non-traditional building envelopes' published by CWCT.

It gives guidance on the calculation of U-values and describes how curtain walls may be improved to reduce their U-values.

Curtain wall types

This Technical Note relates to the following construction types. A fuller description of each is given in TN 14.

Stick curtain walling

Stick curtain walling comprises a frame of mullions and transoms with infill of glass and insulated panels. The U-value is dominated by the glass and the frame, particularly if it is an aluminium frame. Modifications to the insulated infill panels or fit out have limited effect on the overall U-value.

Stick curtain walls are commonly largely glazed constructions. The overall U-value will be greatly affected by the ratio of glazing area to area of opaque infill panels, which is called the glazing ratio.

Unitised walling

Unitised walling is similar to stick curtain walling but assembled into units prior to installation. Its thermal performance is similar to that of stick curtain walling. Framing members are generally wider than for stick curtain walling so have lower frame U-values. However, the overall U-value is similar for the same glazing ratio.

Panelised walls

Panelised walls are constructed as prefabricated storey height panels spanning bays of the main structural frame of the building. They are generally based on a structural steel frame or precast concrete panels and are less commonly used than stick and unitised walls. Panelised walls are fundamentally different from stick and unitised walls both in their construction and calculation of thermal performance and are not considered in this Technical note.

Rainscreen

A rainscreen is an outer layer of panels with a ventilated cavity behind. They may be used as a decorative finish hung in front of the opaque areas of stick or unitised curtain walls. The panels make no contribution to thermal insulation and are omitted from U-value calculations. However, the panel support rails and brackets may form linear and point thermal bridges and must be included in U-value calculations.

Energy transfer

The total energy transfer through a building envelope is due to:

- Temperature difference between the warm and cold environments;
- Solar radiation;
- Air leakage.

This Technical Note only deals with the heat transfer due to temperature difference, which is expressed in terms of U values.

Energy transfer due to solar radiation is covered in TN 50 'Solar gain and shading' and TN 51 'Environmental control glass'.

Energy transfer through a building envelope by mass transfer is covered in TN 46 'Introduction of building envelope energy transfer'.

U-value

The overall U-value depends on the U-values of the frame, glazing, infill panels, backing walls and any penetrations through or partially through the insulation, such as the brackets for brise soleil.

Centre panel U-values

Centre panel U-values for glazing and infill panels are used by manufacturers. They represent the uniform heat transfer through the panel neglecting the non-linear heat transfer at the edge of the glazing unit or the infill panel.

When calculating U-values of walls it is necessary to consider the size of the panel. Generally, smaller panels of identical construction have higher U-values.

Thermal bridges

A thermal bridge is a part of the building envelope where the otherwise uniform thermal resistance is significantly changed by:

- Full or partial penetration of the building envelope by materials with a different thermal conductivity, and/or;
- A change in the thickness of the fabric, and/or;
- A difference between internal and external areas, such as occur at corners.

The consequences of thermal bridges are extra heat transfer, lower surface temperature at the warm side, and a lower temperature gradient across the building envelope at the point where the thermal bridge is present.

The extra heat transfer due to the presence of a thermal bridge is represented either by a linear or point thermal transmittance.

Linear thermal bridge (ψ-value)

A linear thermal bridge is a thermal bridge where the geometry and thermal properties are uniform in one direction. It can be represented by its cross-section, which provides the basis for a two-dimensional geometrical model for computer simulation. Linear thermal bridges often occur at junctions between different building components, corners and interfaces between different types of cladding.

The linear thermal transmittance, ψ-value, in W/m·K, represents the heat transfer through the linear thermal bridge. It is necessary to state the dimension (width of the linear thermal bridge) used because the ψ-value of the linear thermal bridge depends on this choice.

$$\psi = L^{2D} - \sum_{j=1}^{N} U_j l_j \,, \qquad L^{2D} = \frac{Q^{2D}}{\Delta T}$$

Where

ψ	is the thermal transmittance the linear thermal bridge, in W/mK;
Q^{2D}	is the heat transfer through the 2D geometrical model, in W/m;
L^{2D}	is the 2D linear thermal coupling coefficient, in W/mK;
ΔT	is the environmental temperature difference, in K;
U_j	is the one-dimensional thermal transmittance of j-th component, in W/m²K;
l_j	is the width of component included in the 2-D simulation model where U_j applies, in m.

In the case of a building element with framing members, the frame including the interaction between the frame and the glazing units or opaque panels can be treated as a linear thermal bridge and the heat transfer through the frame including the edge effect is represented by the linear thermal transmittance ψ defined as above.

In practice, this heat transfer is more often represented by a frame U-value excluding the edge effect and a linear thermal transmittance ψ* that only represents the extra heat transfer due to the interaction between the frame and the glazing units and /or the opaque panels. The relation between them is as follows:

$$\psi = U_f b_f + \psi^* \times n$$

Where

U_f is the frame U-value excluding edge effect, in W/m²K;
b_f is the projected width of the frame viewed from inside, in m;
Ψ^* is the linear thermal transmittance at the edge of the glazing unit/opaque panel, in W/mK;
n is the number of panels supported by the framing member, i.e 1 for glazing on one side only and 2 for glazing on both sides.

Point thermal transmittance

A point thermal bridge is caused by highly localised full or partial penetration of the building envelope, such as a bracket supporting brise soleil.

The point thermal transmittance, χ-value in W/K, represents the heat transfer through the point thermal bridge.

$$\chi = L^{3D} - \sum_{j=1}^{N} U_j l_j - \sum_{k=1}^{M} \psi_k l_k , \quad L^{3D} = \frac{Q^{3D}}{\Delta T}$$

Where

Q^{3D} is the heat loss through the 3D geometrical model, in W;
L^{3D} is the 3D linear thermal coupling coefficient, in W/mK;
ΔT is the environmental temperature difference, in K;
ψ_k is the linear thermal transmittance of k-th linear thermal bridge, in W/mK;
l_k is the length of linear thermal bridge where the ψ_k applies, in m.

A repeating point thermal bridge can be treated as a virtual linear thermal bridge. Draft standard pr EN 13947 Annex A specifies the method of dealing with repeating point thermal bridges.

U-value of a typical element

The U-value of a curtain wall element is area weighted according to:

$$A_{element} U_{element} = \sum_{element} AU + \sum_{element} \psi P + \sum_{element} \chi$$

Where

A is the area element to which the 1-D U-value U applies;
P is the length of the thermal bridge to which ψ applies.

U-value of a curtain wall zone

A curtain wall zone may comprise different types of cladding connected by junctions. The heat transfer through the junctions shall be included in the overall U–value calculation of the zone according to:

$$A_{zone} U_{zone} = \sum_{zone} A_{element} U_{element} + \sum_{zone} \Psi_{junction} P_{junction} + \sum_{zone} \chi_{junction}$$

Where

$P_{junction}$ is the length of the linear thermal bridge at the interface to which ψijunction applies.

Environmental conditions

The U-value of a curtain wall is assessed under typical environmental conditions, as set out in TN 48.

U-value of components/assemblies

U-values of components/assemblies are measured or calculated according to the relevant standards.

The core standards for measurement are:

- BS EN ISO 12567-1;
- BS EN ISO 12567-2;
- BS EN ISO 125412-2.

The core standards for calculating centre pane U-values are:

- BS EN 673;
- BS 6946;

The core standards for calculating the two dimensional thermal transmittance are:

- BS EN ISO 10077-2;
- BS EN ISO 10211-2;

- BS EN ISO 10211-1;
- pr EN 13947.

BS EN ISO 10077-2 is only applicable to curtain walling with infill entirely composed of glazing units.

pr EN 13947 also gives a simplified method of calculating the overall U-value of curtain walling by using default frame U-values, and linear thermal transmittances.

Specialist or general software is used to simulate the heat transfer through the profiles and to calculate the U-Value, ψ-value, and χ-value as appropriate.

Specialist software commonly used in the UK includes:

- THERM
- BISCO, TRISCO, SOLIDO, CAPSUL
- FLIXO

There is also general software that can be used to carry out thermal analysis, such as ANSYS.

The overall U-value of the curtain wall can be calculated according to the formulae given above. Detailed formulae for different types of non-load bearing walls can be found in 'The thermal assessment of window assemblies, curtain walling and non-traditional building envelopes' published by CWCT, which includes worked examples of calculations of the overall U-value in Annex B.

Thermally improved construction

A set of design curves is given in Appendix A of 'The thermal assessment of window assemblies, curtain walling and non-traditional building envelopes' published by CWCT.

The design curves indicate that the dominating factor affecting the overall U-value of a curtain wall are the fractional area of the glazing and the mullion spacing. The U-value of the frame has a secondary effect while the U-value of the infill panel shows little affect.

The design curves suggest various means of improving the U-value of a curtain wall.

Reduced glazing area
With a mullion spacing of 1200 mm, centre pane U-value of glazing of 1.2 W/m^{2}K, frame U-values ranging from 3.0~3.5W/m^{2}K, reducing the fractional area of the glazing from 100% to 30% can reduce the U-value of the curtain wall by around 36%. However, designers should beware of reducing daylight in the building.

Greater mullion spacing
By using as great a mullion spacing as is structurally allowed, the overall U-value of curtain wall can be reduced. For the same DGU unit and framing as described above with 50% glazing fractional area, increasing the mullion spacing can reduce the U-value of a curtain wall by around 6.5%.

Fewer transoms
Using fewer transoms or using structural silicone glazing to replace transoms as appropriate can reduce the overall U-value of a curtain wall. However, structural integrity should be taken into account.

Deeper thermal breaks
In general, deeper thermal breaks reduce heat transfer. However, consideration needs to be given to increased convection in the deepened air cavity.

The relevant position of thermal breaks in all components is very important. The rule is to locate all the thermal breaks, which are at or near a frame, at the same depth which should be as close to the cold side as possible.

Non-metal components
Non-metal components introduced at thermal bridges can reduce the effect of the thermal bridge significantly.

Possible choices include:

- Thermal breaks;
- Plastic pressure plates;
- Butyl tape incorporated with aluminium pressure plates;
- Plastic closers at the edges of infill panels;
- Moulded foam tube fitted onto mullion nosings to reduce convection.

Improved glazing units
Thermally improved glazing units can reduce heat loss through non-load bearing walls significantly.

These can employ:

- Low-E coating;
- Inert gas filling;
- Warm edge spacers.

Appropriate consideration also has to be given to avoiding over-heating due to solar gain.

Notation

A	Projected area	m^2
Q	Rate of 2D heat flow	W/m
Q	Rate of 3D heat flow	W
U	U-value	W/m^2K
Ψ	Linear thermal transmittance	W/mK
χ	Point thermal transmittance	W/K
P	Parameters of the edge of the frame/glazing/infill panel within a element	m
P	Parameter/length of linear thermal bridge at the interface	m
l	Length of linear thermal bridge in 3-D simulation model	m
l	Length of linear thermal bridge in the third direction in 2-D simulation model	m
l	Length of 1-D component in simulation models	m
ΔT	Temperature difference	°C

Subscription

zone	A curtain wall zone
element	A curtain wall element
junction	junction between different types of building elements
edge	Edge of the frame/glazing/opaque panel

Superscription

2D	2-dimensional
3D	3-dimensional
*	Interaction between frame and glazing/opaque panel

References

TN 14 Curtain wall types, CWCT 2000

TN 46 Introduction to building envelope energy transfer, CWCT 2005

TN 47 *Overall building envelope U-values,* CWCT 2005

TN 48 *U-values of windows,* CWCT 2006

TN50 Solar gain and solar shading, CWCT, in preparation

TN51 Environmental control glasses, CWCT in preparation

BS EN ISO 12567-1, *Thermal performance of windows and doors. Determination of thermal transmittance by hot box method. Complete windows and doors*

BS EN ISO 12567-2: *Thermal performance of windows and doors. Determination of thermal transmittance by hot box method. Roof windows and other projecting windows*
Standards for measure

BS EN ISO 12412-2: *Thermal performance of windows, doors and shutters. Determination of thermal transmittance by hot box method. Frames*

BS EN 673: *Glass in building. Determination of thermal transmittance (value). Calculation method*

BS 6946: *Specification for metal channel cable support systems for electrical installations*

BS EN ISO 10077-2: *Thermal performance of windows, doors and shutters. Calculation of thermal transmittance. Numerical method for frames*

BS EN ISO 10211-2: *Thermal bridges in building construction. Heat flows and surface temperatures. Linear thermal bridges*

BS EN ISO 10211-1: *Thermal bridges in building construction. Heat flows and surface temperatures. General calculation methods*

pr EN 13947: *Thermal performance of curtain walls – Evaluation of thermal transmittance*

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