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Impact of the position of the window in the reveal of a cavity wall on the heat loss and the internal surface temperature of the head of an opening with a steel lintel

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A B S T R A C T

The interface between the head of the window and the wall represents one of the largest thermal bridges of a building and one of the areas with the highest risk of surface condensation. This paper confirmed the importance, and investigated the impact, of the location of the window in the reveal of a cavity wall on the Ψ_{lintel} and surface temperature of the area. Additionally, it studied the reliability and accuracy of assessing this thermal bridge using an adiabatic surface instead the actual window. Two possible construction details that meet PARTL 2013 were modelled and assessed with HEAT2D software, following two different methods: the standard and commonly used (adiabatic surface) method and the detailed one (including the actual window). The outputs revealed that the adiabatic surface prevents the software to account the heat transfer that in reality occurs between the window frame and the highly conductive steel lintel. Therefore, the current simplified method could underestimates the heat losses up to 33% and the surface temperature by over 4 °C for certain locations. Additionally, it locates the optimal area for the frame between overlapping 70 mm the cavity to align with the insulation layer of the cavity. Finally, it concluded that under current trends of extremely low Ψ_{lintel} the adiabatic surface has a greater impact than before, producing less accurate outputs, enough to start to think on the necessity of including the actual window during the assessment of the thermal performance of top hat lintels without base plate in low/zero carbon projects.

Contents

1. Introduction

A thermal bridge represents an area of least resistance to the heat flux through the building envelope. One of the most significant thermal bridges in cavity wall constructions is located at the head of openings, due to the sudden change in materials and geometry and the presence of steel lintels [1]. The side effects associated with a thermal bridge are greater heat loss and a subsequent reduction of

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the internal surface temperature in comparison with the surrounding area. This temperature gradient is naturally higher in corners and lintels [2–4]. Therefore, the lintel area is one of the most likely location for condensation and mould growth to occur.

Traditionally frames are fixed into the external leaf of the wall overlapping the cavity by a minimum of 30 mm, following the recommendation of the Robust Details catalogue [5]. However, well insulated walls are relatively thick, so the window can be placed at several locations in the reveal of the window opening. As energy heat loss associated with a thermal bridge is a result of the component performances as well as the way that components are interconnected [6], the location of the window in the reveal of a cavity wall also has an impact on the Ψ_{lintel} [4,6–8]. The linear thermal transmittance [Ψ-value] measures the extra two-dimensional heat loss of the fabric through linear thermal bridges expressed as [W/mK] [9].

The window is part of the thermal envelope. The main design aim is to secure the continuity of this envelope. Therefore, in terms of thermal performance, the frame should be aligned with the layer of lower conductivity in the wall, the insulation layer. Roberts et al. [7] pointed out the importance of the location of the window with respect to the insulation layer of the wall, on the magnitude of the $\Psi_{lintel.}$ In their study the alignment of the window with the insulation of the cavity resulted in a significant reduction of the Ψ_{lintel} with respect to the extreme outer and inner locations. In the same line of thoughts, the Zero Carbon Hub [8] concluded that in traditional brick and block cavity walls the deeper the window is moved into the cavity the better Ψ-value is achieved.

Additionally, there is another important issue to investigate related with the location of the frame of the window. The impact in terms of heat loss of the current conventions used in the UK to assess thermal bridging at openings, which allow the substitution of the window with adiabatic boundary layers [9]. Therefore, Ψ-value is taken as independent of the window, and depends only on the location and geometry of the junction [9]. In terms of condensation risk, Ward [9] recommends that window should be included in the model, when known, to calculate the temperature factor.

1.1. Theory of heat loss calculations

A linear thermal bridge such as the steel lintel junction, is defined by its linear thermal transmittance [ψ-value] and its temperature factor [*f*-value] [10].

The linear thermal transmittance of the steel lintel junction [Ψ_{lintel}] measures the extra two-dimensional heat flow associated with the junction which is not accounted for by the U-values of the plane elements of the junction. The Ψ_{lintel} is calculated using the following equation in accordance with Ward and Sanders [10] and its units are W/mK:

$$\Psi = L^{2D} - l_w \cdot U'_w \quad (1)$$

Where, L^{2D} is the thermal coupling coefficient or the two-dimensional heat transfer coefficient between the inside and outside conditions, expressed in W/mK. U'_w is the thermal transmittance or U-value of the flanking wall, expressed in W/m^2 K. l_w is the length in metres over which the U_w value applies.

Additionally, the temperature factor at the internal surface [f_{Rsi}] is used to determine whether certain surfaces inside a building present potential for condensation because of their low surface temperature [9]. It is calculated under steady-state conditions by the following equation [9]:

$$f_{Rsi} = \frac{T_{si} - T_e}{T_i - T_e} \quad (2)$$

Where T_{si} is the minimum temperature of the internal surface and typically $T_e = 0\,^{\circ}C$ and $T_i = 20\,^{\circ}C$ are the external and internal air temperatures respectively, used for calculations for residential buildings in the UK [9]. If humid air contacts an internal surface with a temperature below dew point, for instance due to thermal bridging, condensation will occur [11]. For residential buildings in the UK T_{si} should be greater than, or equal to, 15 °C, as determined by $f_{CRsi} = 0.75$ the critical temperature to avoid risk of condensation in dwellings [9]. Since the lintel area is one of the most likely locations for condensation, it is important to accurately calculate the temperature factor to determine any potential for condensation.

"Assessing the effects of thermal bridging at junctions and around openings" [9] and the "Conventions for calculating linear thermal transmittance and temperature factors" [10] are the guides used in the UK to perform the calculations of the heat loss and surface temperature associated with this type of thermal bridges. According to these documents, when assessing heat loss, the frame does not need to be included in the model and can be substituted for an adiabatic surface [9]. The reason for this is that often in the first stages of the design, the window that will be used is not known.

Previous research by Sierra et al. [12] investigated the impact on the calculation of Ψ_{lintel} and surface temperature of using an adiabatic surface instead of a detailed frame. The study was only carried out for the standard position of the window, when the frame overlaps the outer face of the cavity by 30 mm. It concluded that, for this location, the use of an adiabatic surface could underestimate the heat losses by up to 9% in comparison with a detailed assessment of the thermal bridge when including the window. The use of an adiabatic surface involves assuming no heat exchange along the joint between the window frame and the wall. Therefore, the main reason to explain the difference in output between the two methods, is that substituting the frame by an adiabatic boundary ignores the heat transfer between window frame and wall/lintel area, while the detailed method takes account of it. Additionally, the adiabatic surface can increase by over 3 °C the actual internal surface temperature of the junction, which agrees with the recommendation suggested by Ward [9] to include the window when calculating the temperature factor. Otherwise, if the junction is not assessed correctly, it could hide possible risks of condensation which may show up once the building is finished.

Finally, it is also necessary to point out that the location of the window needs to balance thermal performance with other factors, especially when moving the frame to internal positions. For instance, Bloom [18] pointed out that deep reveals provide shade when glazing is positioned internally, giving reductions in daylight and solar gains. Deeper locations could also generate buildability and structural issues when fixing the window, requiring casing [8]. The main reason behind the extended use of the position recommended by the Robust Details catalogue [5] is structural. It gives stability, when installing and using windows and additionally it facilitates the sealing of the opening for airtightness.

The purpose of this research was to investigate the impact of the location of the window in the reveal of a cavity wall on the Ψ_{lintel} to determine the most efficient position in terms of minimizing the heat loss of the fabric. At the same time, the variation of the surface temperature was also studied. Finally, this research also analysed the effect of moving the adiabatic surface in the reveal of the opening on the Ψ_{lintel} and its internal surface temperature.

2. Methodology

2.1. Data collection and modelling assumptions

A parametric analysis was carried out to find out how Ψ_{lintel} and the internal surface temperature change depending on whether an adiabatic surface or the actual window is included in the model when moving the location of the frame in the reveal of the wall.