IMPACT OF FENESTRATION ON THE OVERALL THERMAL PERFORMANCE OF THE BUILDING ENVELOPE

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ABSTRACT

The thermal performance of the building envelope influences how comfortable people are inside buildings, and how much money is spent to maintain that comfort level. Historically, there has been a tremendous focus on how much insulation is incorporated in the roof and opaque wall systems comprising a building envelope, and the level of insulation incorporated in these systems has been steadily increasing in the pursuit of improved energy performance. In contrast, there has been far less emphasis on the thermal performance of fenestration in terms of how it influences the overall thermal performance of the building envelope. Recent codes are now bringing a new focus on thermal characteristics of fenestration, and this paper is intended to establish/explain why this is so appropriate.

Our built environment includes more and more fenestration, as designers and developers respond to the increasing demand for sleek and clean building facades, natural lighting and the provision of spectacular views from our buildings. This response involves fenestration in many different forms from punched window openings to horizontal strip windows to complex, custom curtain wall. However, while the market demand for fenestration seems to be increasing, there are also an increasing number of professionals expressing very negative views about the amount of fenestration in our cities and the level of awareness regarding how this contradicts an interest in green buildings.

Indeed, the construction industry has been slow to appreciate the significance of the thermal performance of fenestration. A tremendous amount of time and effort is now appropriately being spent on performance testing of envelope assemblies. From individual windows to large, custom curtain wall systems, there is interest in evaluating full-scale mock-ups to understand how fenestration can be expected to perform in-service. This evaluation regularly involves assessment of structural capacity as well as resistance to air and moisture flow and, increasingly, condensation potential is being assessed. Testing to evaluate the thermal characteristics of fenestration is limited to relatively small assemblies, and is simply impossible for large assemblies due to equipment limitations. However, this does not and should not mean that the thermal characteristics of fenestration are ignored when we produce and evaluate new designs.

Fortunately, there is a means of determining the overall thermal transmittance of fenestration when physical testing is not an option. Although the pink panther has been effective in making most people think of thermal resistance (R-value) when considering heat flow, it is properly the thermal transmittance (U-value) that is used to characterize fenestration. Thermal transmittance is a measure of the rate at which heat is transferred through a building assembly subject to a temperature difference. The parallel path heat flow method is a simple mathematical procedure by which the overall thermal transmittance of an assembly is calculated as the area-weighted average of the thermal transmittance of the individual components of that assembly. The equation for thermal transmittance of an assembly is therefore:

$$U_{Overall} = (A_1 \times U_1 + A_2 \times U_2 + A_3 \times U_3 + \ldots)/A_{Overall}$$

Where:

A_1, A_2, A_3, … = the face area of the components of differing cross section
U_1, U_2, U_3, … = the cross-sectional U-value of the different components

The U-value input to a parallel path heat flow calculation can be based on physical test results, for example when considering windows for incorporation in punched or strip window wall configurations. The input can also be based on the results of thermal simulation undertaken with models of component cross-sections.

The presentation includes sample parallel path heat flow calculations for an example wall including brick-clad opaque areas and horizontal strip, commercial window areas with a fenestration to wall ratio of 0.50, and demonstrates the substantial difference between average thermal resistance and effective thermal resistance of the wall. The presentation then continues with a short, simple parametric study that highlights how the overall thermal performance of an envelope will be dominated by the significantly weaker thermal performance of the fenestration, even when the fenestration to wall ratio is as low as 0.10.

The presentation concludes with sample parallel path heat flow calculations for an example unitized curtain wall system with insulated spandrel panels. The calculations highlight the very considerable influence of the weak thermal performance of framing elements in both the vision and spandrel regions of the system, and how the overall thermal transmittance of the system is considerably higher than would be predicted by the use of high performance glazing units and heavily insulated spandrels, and considerably higher than is desired and required for energy efficient design.

CONCLUSION

Notwithstanding the popularity of fenestration in our built environment, it is the weak link in the chain in terms of thermal performance of the envelope and, due to parallel path heat flow, it can result in extremely low performance even when the amount of fenestration is minimized and the adjacent, opaque envelope assemblies are heavily insulated.

Whenever there is limited budget available for improvement of the thermal performance of a building envelope, it should always be directed to fenestration for maximum impact. Even so, if we want to be serious about saving energy in our built environment, we need to reduce the prevalence of fenestration.