ENVELOPING ISSUE

MASTERCLASS
Professor
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This month's article questions whether simple, steady-state heat loss calculations will continue to be of use in a world of high-performance buildings

The design of building envelopes presently falls into an unhappy void between the responsibilities of the architect and of the engineer. I believe that, as guardians of building carbon performance, building services engineers should be responsible for the performance of the building envelope. However, to the architect the envelope is the means of sculpting the form of the building and generating its outward appearance. We must therefore be prepared to collaborate more closely and develop a clear understanding of envelope thermal performance issues in order to be able to communicate these with our architectural colleagues.

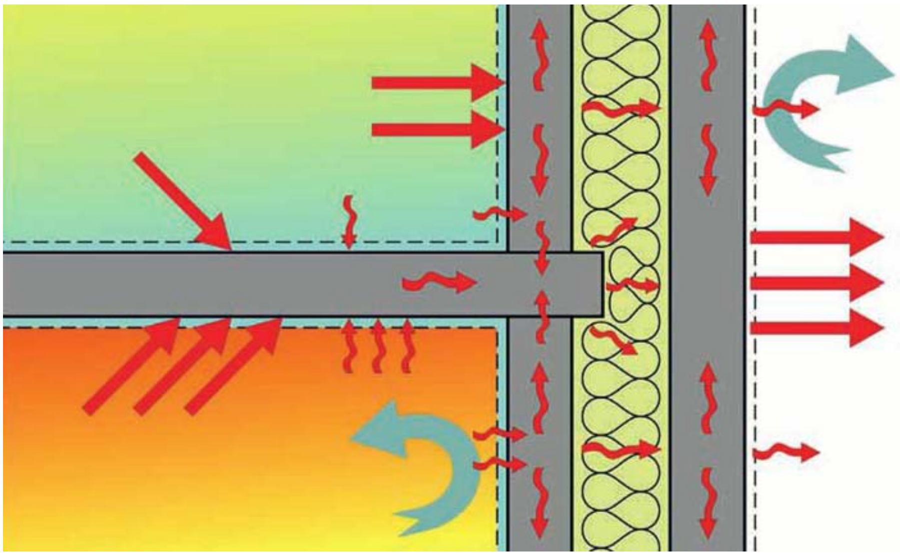
As we approach the limit of efficiency gains in equipment and systems, we need to achieve a step change in our understanding of building envelopes. The building physics that underlie thermal performance is well developed and we have sophisticated software to help us. Nevertheless, it is still essential for engineers to have a good understanding of the principles of heat transfer and storage, so that they can validate or challenge the veracity of the results generated from software.

When I started my career in building services, the building envelope was entirely the architect's responsibility and calculating heat losses was a simple business. Everybody assumed that construction was homogeneous and the Building Regulations had prescriptive standards for insulation. All the engineer had to do was choose the design temperatures and undertake steady state heat loss calculations using the U-values prescribed. This is far from the case in the present day.

Insulation standards have increased dramatically and it is simply not the case that you can go on adding insulation to a wall or roof and things will keep getting better. Adding insulation to traditional constructions changes the temperature gradient and thus introduces the risk of interstitial condensation. So, as we increase the insulation and air tightness of our buildings, we must also attend to the transit of moisture vapour through the construction, or provide means to exclude it.

From 1985 the Building Regulations required us to account for repetitive thermal bridging (construction elements that spanned the insulation thickness, such as framing in the walls of timber housing). This meant the steady-state calculation had to be expanded to include the linear conduction of thermal bridges represented by the psi-value.

As insulation requirements increased in subsequent revisions to the Building Regulations, it became necessary to insulate overstuds and rafters to reduce the conduction at thermal bridges, but this made calculations almost impossible without finite element analysis software to calculate the three-dimensional heat flows. The notional building used in Part L 2010 includes psi-values for all the common



The traditional U-value calculation models a simple, linear flow of energy from the internal air to the external air by conduction alone (accounting for the resistance of a stagnant air boundary layer). In fact, to represent the true picture, we ought to account for absorption and emission of energy by radiation, differential conduction into the internal face at high and low levels due to stratification, and for three dimensional flows within the construction thermal bridging conditions but still falls short in some cases.

As we continue to increase insulation levels, thermal bridges assume increasing significance as a proportion of the overall heat loss. They can also create problems due to condensation at local cold spots. Yet, despite all this, thermal bridges do not appear to feature highly in the consideration of those designing external walls.

A study by the Joseph Rowntree Foundation on sustainable housing at Elm Tree Mews (*Journal*, December 2010, pages 7 and 23), found that the design calculations seriously underestimated the extent of thermal bridging, resulting in heat loss of 50% higher than expected. This appears to have been partly due to the assumptions included in the calculations not having been checked against the actual construction details.

It is essential that those taking responsibility for building performance calculations are fully involved in the design of the building envelope. There is a danger that any disconnection between those who detail the construction and those who understand the thermal performance could lead to serious consequences, possibly even failure of a structure due to condensation damage.

We may have accounted for non-homogeneous construction, but there are still more factors that we must consider in order to completely understand the steady-state heat loss. The calculations traditionally use a single temperature point to represent internal and external conditions, typically the air temperature. Yet in modern low-energy buildings it is not uncommon to find a mixture of radiant and air heating sources.

We often choose radiant heating systems for their ability to transfer energy to surrounding surfaces, without significant effect on the air temperature. Radiant heating therefore could create greater heat loss, due to the increased absorption at the internal surface, than would be indicated by simple conduction of heat from the air. The CIBSE heat loss calculations now include a heat source factor to account for the differential heat loss by fabric and ventilation conduction due to the balance of radiant and air heating.

Similarly we should also account for heat loss or gain by radiation from the external surface of the building. In an urban situation the heat loss from the roof to a cold night sky may be much more significant than heat loss from the walls which are surrounded by other buildings also radiating heat. Conversely the absorption of solar energy during the day may in fact be greater than the notional heat loss.

There is no simple way of analysing the radiant contribution to building heat loss but nevertheless it should still be considered when making choices about the materials used in building envelopes. In particular this might start to inform choices about the use of materials with high emissivity or those which are highly transparent to radiation such as glass curtain walls.

For the complete picture we should also consider the dynamic thermal response of a building, not just the steady-state condition. A proportion of the heat flowing through the envelope, in either direction, will heat up the construction materials. It is only when the temperature of the material has been raised that onward transmission takes place. This introduces both attenuation and a time delay, fundamentally changing the envelope's response to diurnal variations in temperatures and solar radiation. The attenuation is known as 'decrement' and the time lag as the 'decrement delay'.

Decrement is used when calculating summertime cooling loads but, as we continue to drive for improved

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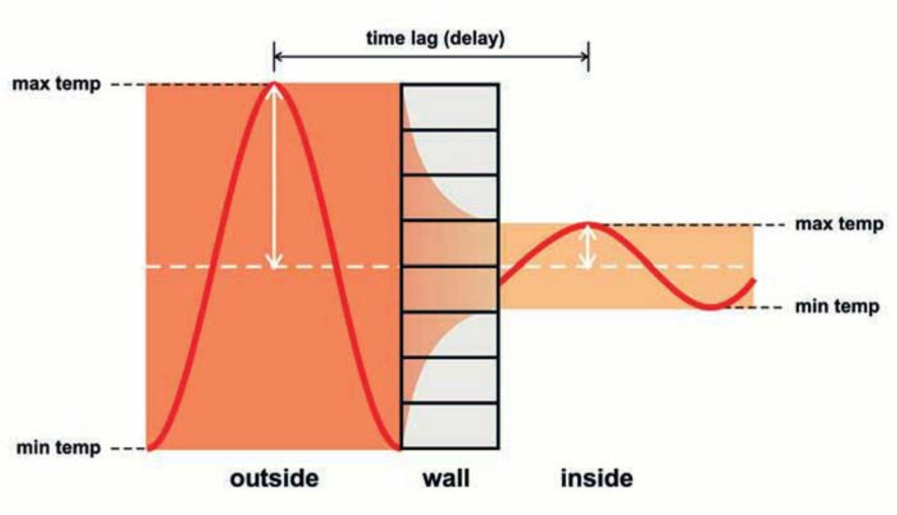
This display of corks in a restaurant window indicates the problems that can be created by simply adding more insulation to an envelope construction without considering the vapour permeability. The corks act as an insulant, changing the temperature gradient, but they do not inhibit the passage of water vapour. Condensation occurs outside the insulation where the temperature drops below the dewpoint



Diurnal variations in external temperature are attenuated by building envelopes to the extent that they contain thermal mass to partially absorb the energy flow. This results in a dynamic insulation property known as decrement

performance, we will also need to account for it in the heating condition. Consider a traditional brick wall with insulated cavity. The decrement factor from exterior to interior is 0.26, with a decrement delay of about 10 hours. The decrement factor is applied to the steady state U-value heat transfer. Thus the heat absorbed at the exterior during the day is only transmitted to the interior at a fraction of the intensity during the night. Conversely, during the daytime, the interior experiences passive cooling as a result of the heat loss from the previous night. Consider now that the construction is symmetrical inside to outside as it is outside to inside. The same decrement factor and delay must therefore also apply to heat flowing outwards in the winter. So, we must now consider the insulation of conventional masonry construction as being dynamic over the diurnal cycle. The same applies, to a greater or lesser extent, to any form of envelope construction, and this must surely be an essential part of our understanding of building envelopes. The building envelope is the primary means of creating a comfortable and stable internal environment yet, outside academia, it is one of the least rigorously analysed aspects of the building services design. As we move forward we will need a concerted effort to refine our understanding of building envelope performance and to ensure that building services engineers are in a position to lead on this fundamental aspect of carbon performance. **CJ**

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