the sustainable building association

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Building Fabric – Why engineers should be involved

An article for the AECB by Sally Godber

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Low carbon new buildings are often designed to have minimal heat loss, but real performance is frequently disappointing. Sally Godber looks at some key Passivhaus principles that can help bridge the gap between design & reality.

As building services engineers, we should be able to accurately predict the variables in heating loads. Almost all of the calculations involved in this process are in our hands. And yet, it seems, we often fail to achieve this basic function. A study of the heat losses of dwellings[1], shows just how wide the gap is between the original design assumptions and the actual performance of buildings (see Figure 1).

This discrepancy was exactly what interested Wolfgang Feist, the co-creator of Passivhaus, 20 years ago: "I was working as a physicist. I read that the construction industry had experimented with adding insulation to new buildings and that energy consumption had failed to reduce. This offended me – it was counter to the basic laws of physics. I knew that they must be doing something wrong. So I made it my mission to find out what, and to establish what was needed to do it right."

The major underlying cause of the 'reality gap' is a lack of appreciation of the less obvious heat loss mechanisms. This article looks at some key Passivhaus design principles and gives examples of where the building may fail to live up to expectations.

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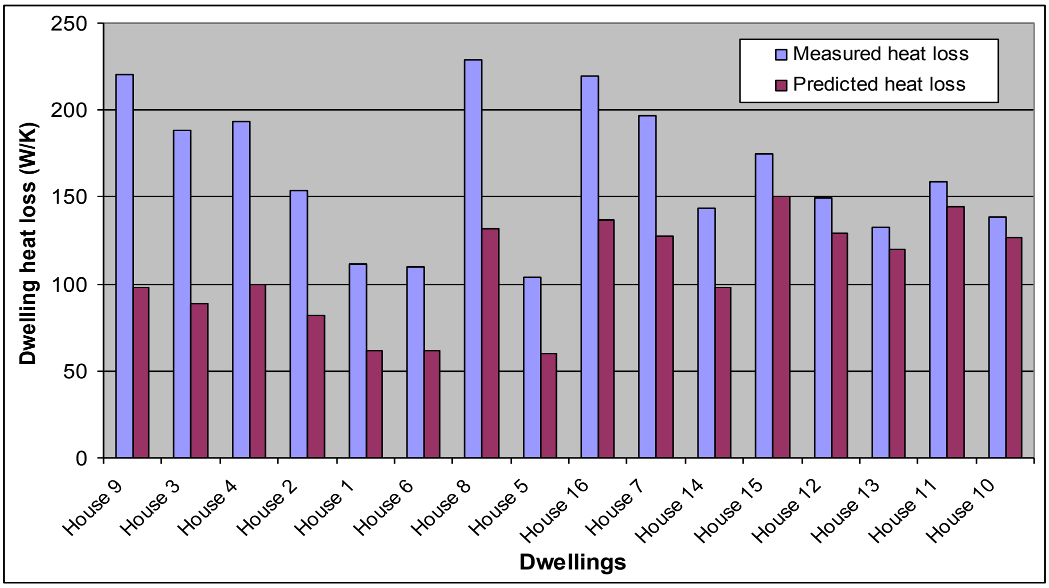

[1]Leeds metropolitan Centre for Built Environment http://www.lmu.ac.uk/as/cebe/

Modelling

Heat demand is calculated as the balance of heat losses and gains. The two charts in Figure 2 show typical annual energy values per square metre of floor area, for housing in the 1980s and for a modern low energy building. The balance of loss and gains gives the annual heating demand – shown in yellow

The two charts demonstrate how the dominating factors have altered over the past 30 years. Previously the fabric and infiltration losses dominated. Now solar gains, internal gains, window losses and thermal bridges have become much more critical.

This is why the Passivhaus design principles have been developed with a much more stringent interrogation of these factors. This means for modern buildings Passivhaus should provide a more accurate estimate of the heating requirement, a fact that has been borne out in the European CEPHUS study[1]

[1] http://www.passivehouse.com/07_eng/news/CEPHEUS_final_long.pdf

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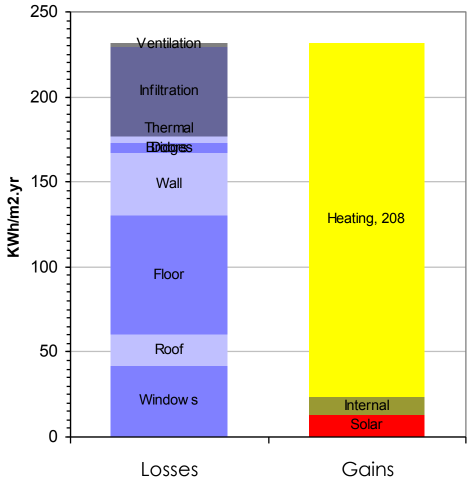
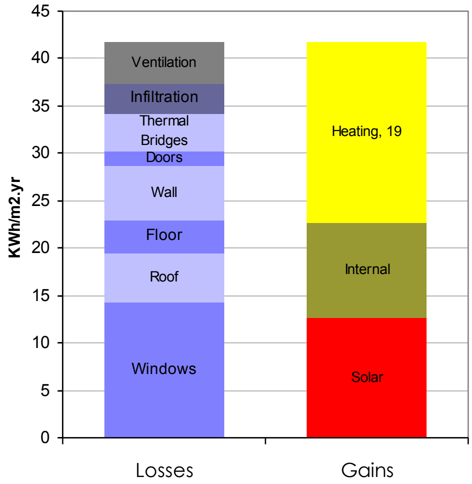
Figure 2:



A typical heating balance for a house built in the early 1980s



A typical heating balance for a low energy house

A very small and large window. In most models it would be assumed that these two would have the same overall U-value if the performance characteristics were the same, whereas in reality the window on the right will perform much better than the left because of the smaller proportion of frame.

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Correct U-value assessment.

Manufacturers should not be relied upon to calculate opaque U-values. Instead, this task should be undertaken by a member of the design team who understands the complexities of insulation performance. In general, a conservative approach is recommended, as changes during design development or construction rarely improve performance.

Particular care is needed when scrutinising insulation conductivities. Manufacturers are improving their products, but specifiers need to be somewhat sceptical about their claims. Insulation materials should always refer to the $\lambda_{90/90}$ value which ensures that a conservative value is used and an on-going sampling is in place to ensure quality. If in any doubt, take a conservative value from CIBSE guide A 2006.

The inclusion of regularly-repeating thermal bridges – particularly the extent of timber frame – within U-values also needs care. The default figures given in the standards for Building Regulations, BR497, are too generous: 15% is taken as the timber fraction of timber-framed structures; but various studies[2] have found typical values in excess of 25%. Ideally the structure should be removed from the insulation so the U-value is not dominated by the extent of bridging.

Some structures use cavities in the construction that are ventilated to outside. It is wishful thinking to say that any insulation between these cavities and the outside will do anything thermally, given the vagaries of on-site installation. It is generally best to exclude from the U-value calculation any material on the outside of ventilated cavities.

Bypass and blowthrough

Air movement through or around insulation significantly decreases the performance. There are two primary methods that this can happen; blowthrough and convective bypass.

Convective bypass occurs where there are gaps between and around insulation. Because of the temperature difference between the two sides of the insulation, convective air currents will move heat from the warm side of the insualtion to the cold side, bypassing it and reducing its performance. And the impact is significant: a 7.5 mm gap between wall insulation boards can cause a 200% increase in heat loss[3].

Figure 3 shows a classic case of a partially filled cavity which is ventilated to outside. The picture demonstrates particularly poor installation; the architect's drawing would have shown the insulation flush against the inner course of blocks on the right-hand side.

Because of the tolerances of rigid insulation, together with the uneven surface of the blockwork, it is almost impossible to construct this detail well; and, as it is covered up so quickly it is even harder to check. Where rigid insulation is used, then tongue-in-grove edges, or layers overlapping together should be used. Expanding foam can then be used in the odd case where gaps are present and then all joints taped to further mitigate air movement.

[2] http://www.jrf.org.uk/sites/files/jrf/low-carbon-housing-full.pdf - see page 31

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Figure 3:

Cold air can bypass the insulation, meaning its performance is substantially reduced. Note the level of insulation here ~50mm would be insufficient for most modern buildings.

[3] Hens 2002

A more thermally robust detail would be to replace this insulation with a mineral wool batt, which could closely follow the contours of the wall, and could butt up together with a tolerance fit. However, this causes another problem: blowthough, which occurs in open-cell insulation, such as a mineral wool in contact with a ventilated cavity. As the cold air moves through the cavity (primarily due to external pressure from the wind) there is nothing stop bulk air movement through the insulations itself - removing heat as it goes.

There is a very simple solution to this problem: avoid ventilated cavities next to insulation. There are two methods of achieving this in the cavity wall example: either use a wind-proof membrane between void and insulation; or fully fill the cavity and get rid of the ventilation. The latter is much easier to build well, but does rely on a quality to prevent moisture ingress (see Figure 4).

Figure 4:

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A fully-filled cavity wall using a compressible insulation. There are no gaps at all in the insulation. The inner face of the blockwork will be plastered to provide the airtight barrier, whilst the outer face will be rendered to prevent moisture penetration

Airtightness

Air tightness has come to the fore since 2006 with the Part L requirements. Good airtightness will improve occupant comfort and fabric durability as well as energy consumption. However, in order to achieve the best results it must always be coupled with a well-designed ventilation system; relying on a leaky building for ventilation is not a good idea for a low energy design.

Air and wind tightness are different: Air tightness means absolutely preventing air from penetrating through the shell, while wind tightness merely stops air movement through the insulation. Both are needed on a good construction.

The easiest way to achieve a high standard of air tightness is to simplify the air-tight layer as much as possible – junctions will always be difficult, so minimising these is the first step.

An air-tightness strategy should then be discussed (preferably before planning) and fully developed as the construction is chosen. There are a number of air-tightness consultants and manufacturers that can provide advice, but a good basic understanding of these principles is needed within the design team.

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Complex shapes like these means that to achieve a good airtightness the contractor will have to be highly skilled, and even then it's a risk. A much better solution is to simplify the design of the airtight layer

Thermal bridges

Even though an understanding of what constitutes a thermal bridge is commonplace, a clear strategy to reduce its impact is not.

The most significant thermal bridges occur where there is a conflict between structural and thermal elements around complex junctions. The most successful way of reducing thermal bridging is to challenge the architect to make the thermal envelope as simple as possible. A construction method is needed that separates the structural elements (which generally have high conductivity) from the insulation as much as possible, preferably with the structure inside of the thermal envelope.

This strategy ensures that the thermal bridges are kept to a minimum. Where they do occur Thermal analysis software can be used to quantify their effect. However, the calculation should be undertaken with caution, as the result is primarily a small difference between two large numbers, and so is easy to get wrong.

Conclusion

By bringing an understanding of building physics to the table services engineers can undoubtedly change the way buildings are designed, creating thermal envelopes which are simpler, easier to build and better performing.

The wider field of building physics covers this topic in much more detail to include areas such as comfort and moisture transfer. The Passivhaus Designer course run by CarbonLite allows participants to fast track their understanding of this and other aspects of low energy design highlighted within this article see http://www.carbonlite.org.uk for more information.

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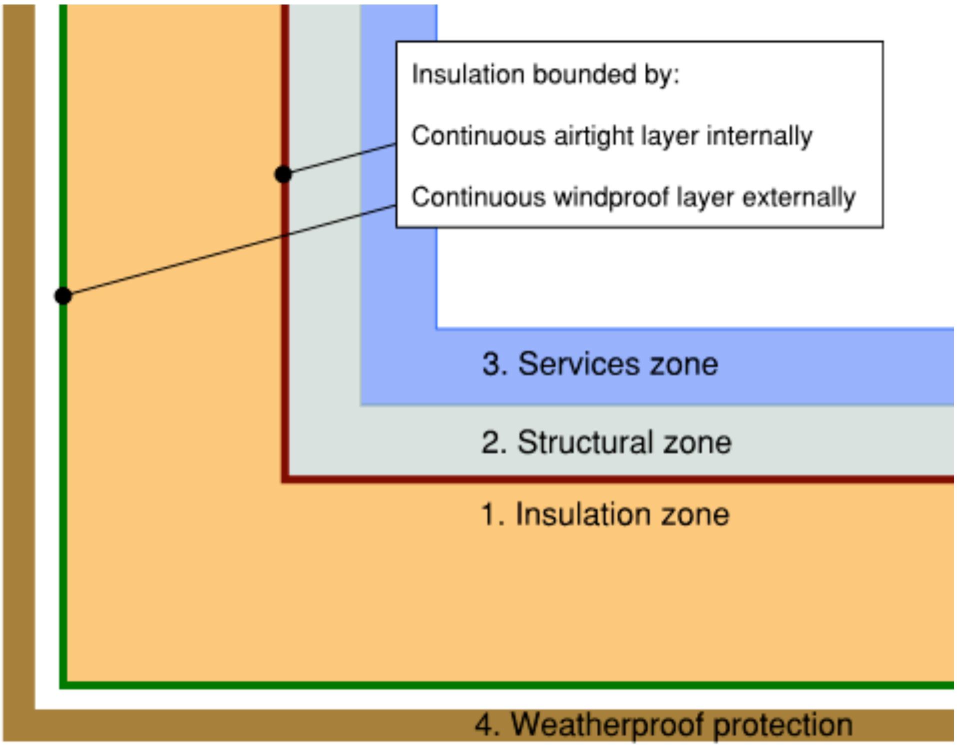
IN BOX OUT

These basic rules below will help to deliver better performing building fabric. A typical corner incorporating these elements is shown below:



1. Keep a separate insulation zone free from thermal bridges or cavities. Externally this is covered in a windproof layer to stop blow through. Internally an airtightness layer stops air movement through the fabric, and reduces moisture penetration, note that the airtightness membrane can also be located on the inside of the structural zone if it makes the construction simpler, but must be on the outside of the services zone.
2. A separate structural zone, which might be in-filled with insulation to improve the performance but is not the primary role.
3. All services should be kept clear of the insulation and airtightness layers, a services zone is the easiest way to achieve this
4. Weatherproof cladding to provide protection from water ingress & aesthetic, in some cases (such as fully filled brick cavity) the weatherproof protection and windproof layer may be the same thing.

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