Energy conservation

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Introduction
Heat loss from a building as a result of different indoor and outdoor temperatures is measured as a U-value, which is the heat lost (in Watts, W) per unit area (in metres squared, m2) per degree temperature difference (in Kelvin, or K). The U-value (in W/m2K) can be expressed as an average for the building envelope as a whole, or for a specific component such as a door or window.

Analysis
For Portland Stone cladding systems U-values may be determined by a simple thermal resistance calculation method (see BS EN ISO 6946). This method is suitable for systems that comprise several uniform layers.

It is possible to analyse layers which incorporate elements with a different thermal conductivity, but only if the thermal conductivities of the different elements are similar and not if one of the elements is metal, such as a fixing.

The U-value is the inverse of the overall thermal resistance:

$$U = \frac{1}{\sum R} \ \mathrm{W/m^2K}$$

For a layered construction the overall thermal resistance is the sum of the thermal resistances of each layer, plus two surface resistances to account for heat flow from the indoor environment to the internal surface, and from the external surface to the outdoor environment. The surface resistances are defined in BS EN ISO 6946, and for a vertical wall the design values are:

R_{SI} = 0.13 m^2K/W for indoor surfaces, and
R_{SE} = 0.04 m^2K/W for outdoor surfaces

For a new building the U-value of a vertical wall is required to average 0.25 W/m2K, giving an overall thermal resistance of 4.00 m^2K/W. Subtracting the surface resistances gives a target for the cladding system thermal resistance of 3.83 m^2K/W.

The thermal resistance R (in m^2K/W) of a uniform layer, with a thickness d (in metres, m) and a thermal conductivity Ï (in W/mK), is:

$$R = \frac{d}{\lambda} \ \mathrm{m^2K/W}$$

The thermal conductivity of a material can sometimes be obtained from the material supplier (for example for insulation materials), but in most cases it has to be established from generic data (see BS EN 12524). BS EN 12524 includes tables of thermal conductivity which have been compiled from measured values and analysed statistically to give a likely upper (safe) value for design purposes.

For limestone, the thermal conductivity depends upon the density of the stone. For a typical Portland Stone density of 2,200 kg/m^3 (5% moisture content) the design value of thermal conductivity is 1.7 W/mK. For a 100 mm thick Portland Stone panel the thermal resistance is therefore:

$$R = \frac{0.1}{1.7} = 0.059 \ \mathrm{m^2K/W}$$

This only contributes about 1.5% of the thermal resistance of the cladding system, and all stone cladding systems must rely heavily on a layer of insulation material to achieve the desired thermal performance.

For thinner Portland Stone panels the thermal resistance values are:

40 mm R = 0.024 m^2K/W
50 mm R = 0.029 m^2K/W
75 mm R = 0.044 m^2K/W

These low thermal resistances are beneficial when Portland Stone flooring is used with underfloor heating - the low resistance permits heat to be conducted up to the surface more rapidly.

There are several insulation materials which may be used in a cladding system, each of which has a different thermal conductivity For the 100 mm panels considered above, the target thermal resistance, allowing for the surface resistances and the Portland Stone panels, is around 3.24 m^2K/W. For a mineral wool or expanded polystyrene insulation a typical thermal conductivity is 0.037 W/mK. The required thickness of insulation is therefore at least:

$d = R\lambda = 3.24 \times 0.037 = 0.120$ m, or 120 mm

assuming none of the other layers has an appreciable thermal resistance and that there are no thermal bridges through the insulation layer.

For a high performance phenolic insulation a thermal conductivity of 0.023 W/mK is readily achievable, and the required thickness of insuation is:

$d = R\lambda = 3.24 \times 0.023 = 0.075$ m, or 75 mm

The designer must therefore choose a suitable insulation product, and the required thickness will then depend upon the thermal conductivity of the insulation.

The position of the insulation within the construction will depend upon the type of cladding system. For a precast concrete cladding system the insulation may be applied to the inside face of the precast unit, with minimum thermal bridging, and this arrangement can usually be analysed using the simple approach above. For a built-up or hand-set cladding system, however, the insulation will often be placed immediately behind the cladding panels, perhaps with a small air-gap to control water ingress, and the cladding fixings will pass through the insulation layer, causing localised thermal bridging.

If the Portland Stone fixings penetrate the insulation layer then a more detailed analysis is required to establish the degree of thermal bridging. This requires the designer to use detailed numerical calculation, typically in the form of computer simulation. There are many software packages which are suitable for this type of analysis, including the two-dimensional analysis software 'Therm', which is freely available (http://windows.lbl.gov/software). Guidance on the use of such software is given in BS EN ISO 10211-1 and BS EN ISO 10077-2, both of which include 'benchmark' analyses which may be used to test both the software and the skills of the analyst.

For a simple, continuous, component such as a corbel plate, it is possible to analyse a two-dimensional cross-section through the bracket, as shown in Plate 1. From this analysis the designer can predict the excess heat loss due to the thermal bridging effect of the bracket, and it is then possible for the designer to determine how much additional insulation is required to compensate for this heat loss.

For a localised (point) fixing such as a cramp-and-dowel or a wire tie it is necessary to use three-dimensional analysis, but this only needs to be done once for each type of fixing. An example is shown in Plate 2. The additional heat loss due to a single fixing can then be multiplied up by the number of fixings per square metre, and the required extra thickness of insulation then calculated.

With regard to fixings it is worth noting that stainless steel offers a lower thermal conductivity than mild steel, and mild steel in turn is much better than aluminium. BS EN 12524 gives the thermal conductivity of these materials as:

Stainless steel	17	W/mK
Mild steel	50	W/mK
Aluminium alloy	160	W/mK

Steel also has the advantage of being much stronger than aluminium, and the consequent reduction in cross-section to give the same stiffness/strength has further benefits in reducing thermal bridging.

For rainscreen cladding, where Portland Stone panels are used with open joints, a further refinement is required. Rainscreen systems permit air to circulate behind the cladding panels, and BS EN ISO 6946 requires that for such systems the thermal resistance of the cladding panels and the air gap must be ignored, and the outer face of the insulation (if present) or backing wall be treated as the external surface of the cladding system. The external surface resistance is then increased to RSE = 0.13 W/m^2K, to allow for the fact that air movement behind the panels is restricted. It is important however that thermal bridges through the insulation layer are still accounted for.

Finally, the designer must consider the effect of thermal bridging around openings such as doors and windows. Reveal and return details inevitably lead to greater heat loss, and this can be calculated by reference to BRE Information Paper IP 1/06. This paper defines the allowable heat loss at details such as window jambs, sills and lintels.

Referenced documents

BRE Information Paper IP 1/06 Assessing the effects of thermal bridging at junctions and around openings

BS EN ISO 6946:1997 Building components and building elements - Thermal resistance and thermal transmittance - Calculation method

BS EN ISO 10077-2:2003 Thermal performance of windows, doors and shutters - Calculation of thermal transmittance - Part 2: Numerical method for frames

BS EN ISO 10211-1:1996 Thermal bridges in building construction - Heat flows and surface temperatures - Part 1 General calculation methods

BS EN 12524:2000 Building materials and products - Hygrothermal properties - Tabulated design values

BS EN ISO 13370:1998 Thermal performance of buildings - Heat transfer via the ground - Calculation methods