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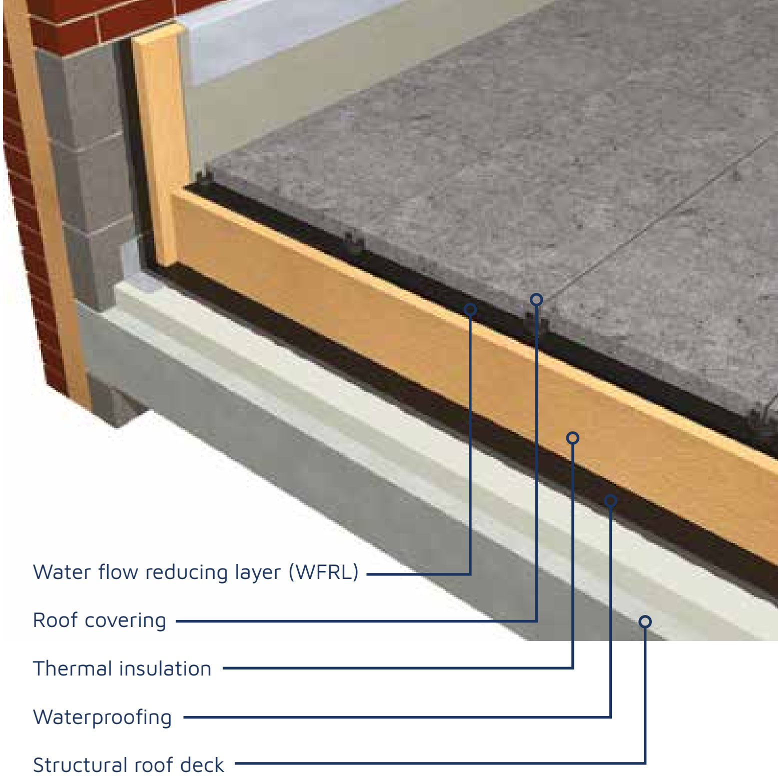
Calculating U-values for inverted roofs



The thermal transmittance (U-value) of an inverted flat roof can be calculated as for any straightforward floor, wall, pitched roof or flat roof construction. It can be done using U-value calculation software widely used within the construction industry, by a person with the appropriate knowledge of calculation standards and conventions.

Calculations are carried out using the 'combined method', a simplified form of calculation described in BS EN ISO 6946:2017. The construction element is built up in a series of layers, each being of uniform thickness and performance. The calculation method is able to take account of bridged layers, such as where an insulation material is installed between timber joists.

Inverted flat roofs are characterised by the positioning of the thermal insulation above the waterproofing layer, rather than below it as is the case with a 'conventional warm roof. This imposes two unique requirements on U-value calculations for inverted roofs, which are the subject of this technical bulletin.

Anybody regularly working with inverted roof constructions - designers, specifiers and contractors - should have an understanding of these issues to ensure that U-value calculations are accurate, and that the intended performance is achieved once the roof is in service.

SECTION 1: DECLARED AND DESIGN THERMAL CONDUCTIVITY

What is thermal conductivity?

Each material layer in a U-value calculation has a thermal conductivity, or the amount of heat energy it conducts (in Watts) for each metre of thickness, and each degree of temperature difference between one side of the material and the other in the direction of the heat flow.

Thermal conductivity, or lambda value, is expressed in the units W/mK.

Thermal conductivity is a general property of the material. The thermal performance of a specific thickness of a material is found by dividing the thickness by the thermal conductivity to give a thermal resistance. Combining the different thermal resistance values of the materials helps to calculate the U-value of a build-up.

Because thermal insulation materials have such low thermal conductivities, they typically make up the bulk of the thermal resistance in a given construction. This is certainly true of inverted roofs. Thermal insulation needs to be properly accounted for in U-value calculations, and the material itself needs to be installed correctly on site to achieve that performance.

What is declared thermal conductivity / declared lambda?

When an insulation material is manufactured, its properties are declared based on factory conditions. The thermal conductivity of the material is known as the 'declared thermal conductivity' or 'declared lambda'.

Most of the time, the material goes on to be installed in conditions where this performance is unaffected. Datasheets and product certification are likely to refer to it simply as 'thermal conductivity', because this is the value that should be used in U-value calculations.

What is the difference between declared and design lambda?

In some applications, however, thermal insulation is exposed to conditions that alter its performance beyond the 'factory settings'. An inverted roof is one of those applications, because of the positioning of the insulation above the waterproofing.

Rainwater drains from an inverted roof at two levels. The first is just below the permeable roof covering, at the membrane layer known as a water flow reducing layer (or WFRL). Rainwater can also reach the waterproofed deck, and drain from that level.

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The thermal insulation is therefore exposed to some rainwater, which the material is capable of absorbing. Water absorption has a negative impact on the thermal conductivity of an insulation material, depending how much water is absorbed. For situations where water absorption is expected, like inverted roofs, the declared lambda must be adjusted to account for water absorption, giving a design thermal conductivity, or design lambda.

Any manufacturer offering thermal insulation for inverted roofs should therefore provide both a declared and a design lambda for their product.

What is the water absorption of inverted roof insulation?

The thermal insulation layer on an inverted roof is usually extruded polystyrene (XPS), although expanded polystyrene (EPS) is also popular. XPS has the longer history of use in the application, but technical guidance for inverted roofs generally mentions both materials.

Water absorption is established by testing. The results vary depending on the foam structure of the material. Two types of absorption are tested: by immersion and by diffusion. The Polyfoam XPS blog features more information on the differences between the two.

How does water absorption relate to design lambda?

To arrive at a design lambda, the declared lambda is multiplied by a moisture correction factor. The moisture correction factor for EPS is greater than for XPS, because the more open structure of EPS allows more water into the material than the closed cell structure of XPS insulation.

The design lambda of XPS insulation has relatively little impact on the overall thickness of thermal insulation required.

Polyfoam XPS products have a moisture absorption of just 0.7%. That means an insulation board with a thickness greater than 100mm has its declared lambda of 0.033 W/mK adjusted to a design lambda of just 0.034 W/mK.

Can declared thermal conductivity be used in inverted roof U-value calculations?

The short answer to this question is: no. Design lambda should always be used for the insulation layer in an inverted roof U-value calculation.

This is because some rainwater is always expected to reach the waterproofing layer, regardless of the presence of a water flow reducing layer, or WFRL. It is not appropriate to assume that the insulation will be completely unaffected by moisture.

If a U-value calculation uses an insulation material's declared thermal conductivity, the calculation result is an unrealistic impression of the performance of the roof. If the chosen insulation product has a relatively high water absorption value, when it is installed and exposed to rainwater the rate of heat loss from the roof will be much higher than originally calculated.

Since U-values for construction elements form an essential part of compliance calculations, it's not impossible to imagine that the as-built performance would differ from the as-designed performance to the extent that the project risks failing to meet national building regulations.

SECTION 2: WFRLs AND RAINWATER COOLING CORRECTION

What is a water flow reducing layer (WFRL)?

The diagram of a typical inverted roof build-up shows a membrane layer called a water flow reducing layer, or WFRL. A WFRL is installed in conjunction with the thermal insulation, and together they form what is known as an inverted roof 'kit'.

The WFRL is a synthetic, non-woven, loose laid membrane that is a barrier to rainwater, reducing the volume of water that can reach the waterproofing layer. It also stops fines from entering the roof system. The properties of the membrane are defined in the technical guidance document ETAG 031, which says a WFRL should be water resistant, diffusion open, UV stable and rot resistant.

Is a water flow reducing layer (WFRL) waterproof?

A WFRL is water resistant, not waterproof, and technical guidance for flat roofing consistently reinforces that position. It is why design lambda values should be used rather than declared values, and it is why this second section of the technical bulletin talks about something called the rainwater cooling correction.

Water penetration of inverted roof kits is tested using a method described in ETAG 031. Test results often suggest that water does not penetrate the system, but industry guidance makes clear that achieving a standard of installation on site that replicates what is achieved on a small test rig should not be assumed.

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As the relevant code of practice for inverted roof design and construction, BS 6229:2018 carries weight. Publication of the revised standard in late 2018 has led to the inverted roofing sector working together to review and enhance the ETAG 031 test method, in conjunction with the British Board of Agrément (BBA).

At the time of writing (March 2020) that work is ongoing. In the meantime, the industry continues to act on the guidance of BS 6229:2018, which references a document called BBA Information Bulletin No.4.

What is BBA Information Bulletin No. 4?

The contents of Information Bulletin No.4 describe the drainage of inverted roofs, and how to accurately calculate a rainwater cooling correction factor for U-value calculations. For the purposes of this Polyfoam XPS technical bulletin, it is the latter we are most interested in.

BBA Information Bulletin No.4 sets out industry-standard guidance on the correct application of rainwater cooling correction factors in U-value calculations for inverted roofs. It describes the values that should be used, and emphasises that a WFRL is not a waterproof layer.

What is the rainwater cooling correction?

Rainwater that flows over the waterproofing layer of an inverted roof creates a cooling effect that must be applied to a U-value calculation to simulate the additional heat loss. BS EN ISO 6946:2017 does this through the application of a rainwater cooling correction

The correction is calculated using three values, all of which are also described in BBA Information Bulletin No.4:

- p, which is the average rate of precipitation during the heating season.

When carrying out a U-value calculation, knowing the project's location allows an accurate value of p to be established, ensuring the accuracy of the calculation. It should be based on location-specific data from the Met Office.

Inputting accurate rainfall data for the location improves the accuracy of an inverted roof U-value calculation. For example, a building in the south-west of England experiences a much lower average rainfall than one in the Outer Hebrides.

- f, a drainage factor expressing the fraction of p that reaches the waterproofing.

This is based on the result of the ETAG 031 test, following the guidance of BS 6229:2018 and BBA Information Bulletin No. 4. To ensure that the WFRL is not assumed to be waterproof, the BBA's document says a minimum fraction (and therefore f value) of 0.025 should be used to represent 2.5% of the rainwater reaching the waterproofing layer.

- x, a standard value of 0.040 that is the factor for increased heat loss caused by rainwater flowing over the waterproofing layer.

f and x are often multiplied together and described as an fx value. When an inverted roof kit achieves no water penetration in the ETAG 031 test, applying the minimum value for f of 0.025 and the standard value of x of 0.040 generates an fx value of 0.001, rather than 0 (zero).

CONCLUSION

Without a WFRL, more water reaches the waterproofing layer and increases the effect of rainwater cooling on the roof U-value calculation. Inverted roofs can be constructed without a WFRL, but they would not be economical. A significantly thicker layer of insulation would be required to compensate, increasing the depth of the roof build up and the cost of the inverted roof system.

Specifying WFRLs, and accounting for them accurately in U-value calculations for inverted roofs, is an essential part of ensuring that buildings achieve their intended performance once occupied and in service.

Even with a WFRL, a minimum value for f should be used in rainwater cooling corrections, and the design lambda should always be used for insulation layers in an inverted roof build-up. It is not appropriate to assume that the insulation will be exposed to no water, or that no rainwater cooling correction needs to be applied.

At Polyfoam XPS, we pride ourselves on applying the correct and most up-to-date guidance on U-value calculations for inverted roofs, ensuring we provide accurate results for each project.

We have also been at the forefront of industry efforts to improve guidance around WFRLs and their installation, and our contribution to the Liquid Roofing and Waterproofing Association's (LRWA) insulation committee has led to the creation of LRWA Guidance Notes 14 and 15.

Our inverted roof solutions feature Roofboard Extra and Roofboard Super extruded polystyrene insulation boards, and Polyfoam Slimline Zero membrane for the WFRL. For any technical queries or U-value calculations relating to inverted roofs, use our website to contact us or email technical@polyfoamxps.co.uk.

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