PolyFoam™ XPS

ASSESSMENT AND CERTIFICATION OF INVERTED ROOF SYSTEMS

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Introduction

An inverted flat roof features the waterproofing installed directly to the structural deck. Above the waterproofed deck, an inverted roof system, or 'kit', is loose laid and secured by ballast. The system is the combination of thermal insulation and a membrane, called a water flow reducing layer (WFRL). The ballast is typically gravel or paving slabs.

This arrangement allows a roof to be waterproofed sooner, and protects the waterproofing layer from UV exposure and freeze thaw actions.

An inverted roof drains at two levels: the WFRL and the waterproofed deck. The WFRL significantly reduces the passage of rain water to the waterproofed deck, and so the majority of drainage takes place at the WFRL level.

Provision must still be made for the drainage that takes place at the waterproofing layer. This means that the insulation is not kept dry, as is the case in a conventional warm roof construction, and the material is therefore likely to be exposed to some moisture.

That moisture can adversely affect the insulation's thermal performance, so inverted roof kits use materials that can tolerate moisture, with any change in performance being a known and measurable behaviour.

NOTE: Achieving correct falls and flat roof drainage is not the subject of this white paper. It is assumed that relevant industry guidance is followed in the design and construction of inverted flat roofs with respect to rainwater drainage.

When calculating the thermal transmittance (U-value) of an inverted flat roof, the effect of moisture is taken into account through two corrections. The first is any change to the insulation's thermal conductivity due to moisture absorption. The second is the cooling effect of rainwater running over the waterproofing layer.

Inverted roof system manufacturers and suppliers obtain third party assessment and certification in order to provide customers with reliable information about how these corrections are applied and their effect on the system's performance. This document also looks at how different certification bodies approach the assessment of inverted roof systems.

Regulations and standards

Building regulations

National building regulations set a minimum standard that must be achieved to safeguard the health and welfare of people in and around buildings. They also set out requirements for conserving water and, most relevant to this document, energy.

The way in which the conservation of energy is demonstrated varies slightly by the regulations of each country of the UK. Broadly, however, the proposed building must demonstrate that it meets or betters defined limits for carbon dioxide emissions and energy consumption. The following regulations and supporting guidance apply:

- Part L of Schedule 1 and Regulation 26 in England, supported by Approved Documents L1A, L1B, L2A, L2B.
- Part L of Schedule 1 and Regulation 26 in Wales, also supported by Approved Documents L1A, L1B, L2A, L2B.
- Section 6 of the Domestic and Non-domestic Technical Handbooks 2019 in Scotland.
- Part F 2012 in Northern Ireland, supported by Technical Booklets F1 and F2.

The calculation software used to establish whole-building performance takes into account many and various aspects of building design, including heat loss through building elements (floors, walls and roofs, as well as glazed elements such as windows and rooflights).

Building fabric heat loss

Thermal transmittance is the measure of the rate of movement of heat energy through elements of the building fabric. It is expressed in terms of the transfer of heat energy in Watts (W) per square metre of building fabric (m2), per degree of temperature difference between inside and outside (K, for degrees Kelvin). This gives the units W/m2K, and is more usually called a U-value.

U-values can be established by laboratory testing (which is expensive and time consuming) or on-site measurement (which requires the building to have been built). Mathematical calculation methods are therefore most commonly used.

Thermal modelling can be used for all forms of construction, and is best suited to complex construction forms. A simplified form of calculation, known as the combined method, can be used for many constructions featuring defined layers of consistent thickness and thermal properties. This describes most common construction types, including inverted flat roofs.

The combined method is defined in the international standard BS EN ISO 6946.

Calculation of U-values by the combined method

Within a combined method U-value calculation, material layers are built up to reflect the composition of the building element as designed and/or constructed.

A typical material layer comprises the thickness and the thermal conductivity (or lambda value) of the construction product. Thickness is divided by thermal conductivity to give a thermal resistance for each layer. The thermal resistances of the complete construction are then totalled, and a reciprocal taken to work out the U-value.

Additional calculations are made where a layer is bridged by a material of different conductivity.

BS EN ISO 6946 details a number of corrections that can be applied to a U-value to reflect how the element will be constructed. These corrections make the end result more accurate and a better reflection of how the building element will perform in service, over the life of the building.

In many construction elements, including inverted flat roofs, thermal insulation makes up the bulk of the thermal resistance, and therefore makes the greatest contribution to the final U-value. Thermal insulation materials are essential to meeting the energy efficiency requirements of national building regulations while retaining relatively thin, buildable constructions.

In the UK, BRE Report (BR) 443 supports construction professionals working with U-values by describing conventions that should be followed when calculating them. These conventions give more detail about material data that should be used, and how to apply the calculation method as described in BS EN ISO 6946 to different construction types.

Manufacturing standards

For some materials it is enough to use generic thermal conductivity values in U-value calculations, obtained from one of a number of standards (such as BS EN ISO 10456 or BS 5250). Generic values exist for thermal insulation, but the market is competitive and manufacturers work to specific product standards, declaring their performance characteristic accordingly.

A harmonised standard sets out an agreed method for assessing and testing products, and declaring their performance characteristics, across all EU member states. The harmonised standard for extruded polystyrene insulation (XPS), for example, is EN 13164.

Harmonised standards also allow products to be CE marked under the Construction Products Regulation. For a manufacturer to CE mark construction products, they must also issue a Declaration of Performance (DoP). A DoP declares the product's performance for its essential characteristics.

A DoP can be used as source of information for a product's thermal conductivity and/or thermal resistance, for use in U-value calculations. The DoP for an insulation product gives its declared thermal conductivity, or the thermal performance of the product upon leaving the factory.

The thermal conductivity used in a U-value calculation should reflect the conditions in which the product will be used. Sometimes, such as in the case of an inverted roof, this necessitates a change to the lambda value. We will explore this in more detail later.

Third-party assessment and verification

Another aspect of national building regulations is that construction materials and products should be fit for purpose. In both England and Wales, for example, Building Regulation 7 requires that "materials perform the functions for which they are designed".

Approved Document 7 supports the regulation by giving guidance on how to meet this requirement. Compliance can be established in a number of ways including following British or international standards, or through independent certification schemes.

An Agrément certificate is a document issued by an independent third party confirming that a product is fit for purpose, having been tested and assessed in relation to its intended application. Assessment involves laboratory testing of products and checks on the manufacturer's quality management systems. After issue, a comprehensive product review is carried out every few years to keep the certificate current.

In the UK, the British Board of Agrément (BBA) is the most well-established independent certification body in the UK. Agrément certificates are also issued by Kiwa BDA.

As part of their role in construction product testing and certification, the BBA publishes advice notes. One of these, BBA Information No.4, relates specifically to the performance of inverted flat roofs.

ETAG 031

While harmonised standards exist for insulation materials used in inverted flat roofs, one does not exist for inverted roof systems comprising insulation and WFRL.

Another route to CE marking is through European Technical Assessment (ETA). European Technical Approval Guidelines (ETAGs) provide a framework for assessing and testing construction products that do not have a harmonised standard. One such ETAG is ETAG 031, which deals with inverted roof 'kits'.

For an inverted roof system, therefore, the insulation component has a harmonised standard while the WFRL does not. When a system manufacturer/supplier seeks an Agrément certificate, the certification body uses relevant parts of ETAG 031 to help them assess performance characteristics of the system not covered by the insulation component's harmonised standard. A relevant example of this is explored in the next section of this document.

BS 6229:2018

Published in October 2018, BS 6229:2018 represented a significant update to the code of practice that covers the design, construction and maintenance of flat roofs with a fully supported, flexible waterproofing layer.

As part of its guidance, it describes the calculation of U-values in accordance with BS EN ISO 6946, supported by ETAG 031-1, BR 443, and BBA Information No. 4.

It also includes a section on the thermal performance of inverted roofs specifically, which will be addressed in the course of this white paper.

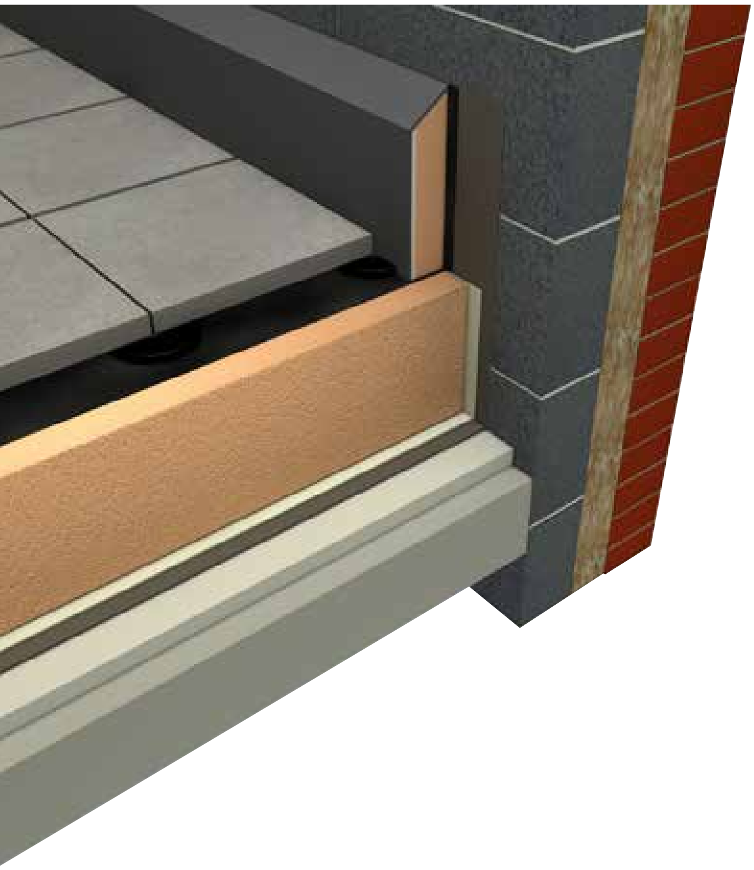
Unique characteristics of inverted roofs

Suitable insulation materials

Inverted roofs present a unique environment for thermal insulation material, being positioned above the waterproofing layer and therefore likely to be exposed to rainwater. For the insulation material to be effective as a thermal insulator it must be able to withstand the rigours of that environment, and therefore needs to demonstrate low water absorption and resistance to freeze thaw.

Extruded polystyrene (XPS) and expanded polystyrene (EPS) have the longest track record as insulation materials offered for inverted roof applications. This document focuses on those XPS and EPS solutions.

Alternative solutions featuring vacuum insulated panels (VIPs) or cellular glass (CG) are starting to be seen on the market. While they are not specifically addressed here, increasing choice for specifiers and contractors only serves to demonstrate the importance of understanding the factors that affect inverted roof design and construction, and how the performance of those solutions is assessed and communicated.



Correction factors

The introduction briefly described two corrections that are applied to inverted roof designs to more accurately assess their in-service thermal performance. At this point, we can explore both in more detail.

- **Moisture correction**

In the previous section we said that "the value for thermal conductivity used in a U-value calculation should reflect the conditions in which the product will be used".

Different insulation materials demonstrate different moisture absorption characteristics. Moisture is an effective conductor of heat, so moisture absorption has the effect of worsening the thermal conductivity of an insulation material. Due to the unique installation conditions for inverted roof insulation, it is important that a suitable insulation material is used where the effect of moisture will be minimised.

The effect of moisture on inverted roof insulation is established by applying a moisture conversion factor. Section 5.6.1.2 of ETAG 031 describes the procedure for correcting the insulation's thermal conductivity for use in U-value calculations, by multiplying the declared thermal conductivity by a moisture conversion factor to give a design thermal conductivity.

The factor is derived from an insulation's moisture conversion coefficient given in BS EN ISO 10456, and a calculation value for moisture content depending on whether the freeze thaw resistance of the insulation is critical. The calculation uses the average tested value for long term water absorption by diffusion (EN 12088, recently replaced by EN ISO 16536: 2019) and freeze thaw (EN 12091).

Section 4.6.2.2 of BS 6229:2018 says: "Calculations of the thermal transmittance (U-value) of specific roof constructions should be carried out … using design thermal conductivity (including moisture conversion factor Fm)."

• Rainwater cooling correction

Annex F of BS EN ISO 6946:2017 includes corrections that should be applied to U-value calculations. F.4.1 gives a correction procedure for inverted roofs "due to rainwater flowing between the insulation and the waterproofing membrane." The rainwater absorbs heat energy from the structure and increases the rate of heat loss from the roof.

It is important to remember that this correction is completely separate to the moisture conversion factor, which is applied to the thermal insulation separately. Rainwater cooling is calculated as a correction to the U-value for the roof build-up as a whole.

Calculating the rainwater cooling correction requires three values:

- p (measured in mm/day) is the average rate of rainfall during the heating season. It is based on location-specific data and varies significantly across the UK. Both BS EN ISO 6946 and BBA Information No.4 explain where this data can be derived from.

- f is a drainage factor. It expresses the percentage of the rainfall (p) that reaches the waterproofing membrane. We will discuss this in more detail shortly.

- x (measured in W.day/m2.K.mm) is the factor for increased heat loss. It is a standard value of 0.040 W.day/m2.K.mm, as given in BE EN ISO 6946.

Rainwater cooling is a fundamental part of the combined method for calculating U-values. The overall U-value correction, and its subsequent impact on insulation thickness, is strongly dependent on these values.

All of the documents we have highlighted so far – ETAG 031, BR 443, BS 6229:2018 and BBA Information No.4 – point to BS EN ISO 6946 and the rainwater cooling correction as an essential part of inverted roof U-value calculations.

Water flow reducing layer (WFRL)

WFRLs were developed as a way to limit the ingress of moisture into the roof system. The membrane is loose laid over the thermal insulation layer (guidance on installation, including laps, can be found in LRWA Guidance Note 14) and acts as a barrier to significantly reduce the volume of rainwater reaching the waterproofing.

A WFRL should be resistant to liquid water, but permeable to water vapour because it allows the dispersal of any moisture vapour that builds up within the inverted roof system. In that sense, it shares characteristics with vapour permeable membranes (or 'breather' membranes) that are often installed on pitched roofs. ETAG 031 and BBA Information No.4 describe performance characteristics that a membrane acting as a WFRL should possess.

It is important to remember that a WFRL is not a waterproof layer, and none of the standards or guidance documents referred to in this white paper suggest otherwise. Some moisture is still expected to reach the waterproofing layer, and the application of a moisture conversion factor to the insulation material is unaffected.

Where a WFRL has a significant impact is in the application of the rainwater cooling correction. By reducing the volume of rainwater flowing between the insulation and the waterproofing, the effect of the correction is reduced and a thinner insulation solution can be used. An inverted roof can be constructed without a WFRL, but the effect of the rainwater cooling correction becomes much more significant.

ETAG 031 Annex C test

The drainage factor, f, used in the rainwater cooling correction calculation is directly influenced by the presence of a WFRL.

Annex C of ETAG 031 describes a "test method for determining water flow through an inverted roof kit". Agrément certificate providers use this test to establish the effectiveness of an inverted roof system, incorporating the result into the manufacturer/system supplier's third-party verification.

The test rig is set up to measure the volume of water that reaches the waterproofing layer, as a percentage of the total volume that the rig is subjected to. Despite the industry-wide acceptance that the WFRL is not a waterproof layer, test results often yield a result of zero water penetration through the loose laid membrane.

ETAG 031 was published in 2010, and experience over the last decade has shown that the test method is not necessarily representative of in-service performance. BS 6229:2018 and BBA Information No.4 both reflect that even where a test shows no rainfall penetration, the effect of some water entering the system should be included.

BS 6229:2018 does this in section 4.6.2.2. It includes a note suggesting that the calculated thickness of insulation to achieve a target U-value be increased by 10% to allow for imperfections in the WFRL. For example, where the insulation thickness is calculated to be 180mm, the actual thickness used on site would be 200mm (rounded up from 198mm, which is 180mm + 18mm increase).

This insulation thickness increase is offered as a suggestion, "until further research and test evidence is made available and included as part of a future update" of BS 6229.

The note in BS 6229 is relevant to the final section and the conclusion of this document. LRWA Guidance Note No. 15 also describes issues with the suggestion of increasing the insulation thickness by 10%, and explains work being carried out by the inverted roofing sector with the BBA.

The aim of the industry work is to establish a revised test method that will generate more representative results. The intention is for the value of f generated by this new test to be used in BBA certificates for inverted roof systems, giving greater confidence about the real-world performance of inverted roofs and allowing BS 6229 to be updated.

Assessment and certification of inverted roof systems

The role of Agrément certificates

An Agrément certificate is an authoritative document that helps to answer questions that specifiers and installers may have about established construction products. For products that are CE marked, an Agrément certificate demonstrates fitness for purpose and suitability of application, and how the product can contribute to compliance with national building regulations.

So far in this document, we have outlined the factors that affect the performance of inverted roof insulation systems. We have also shown the network of standards and guidance documents that set out how to assess inverted roof system performance.

For inverted roof systems, the BBA and its Agrément certificates are the most widely used third-party assessment and verification service in the UK. The introduction of a new certificate to the marketplace, issued by Kiwa BDA, has demonstrated an alternative interpretation of those standards and guidance documents.

While alternative interpretation and competition is healthy for the inverted roof sector, and the construction industry generally, it is important that specifiers and installers are presented with all of the facts in order to be able to make informed decisions about how a system will perform.

As we saw at the start of this document, compliance with national building regulations rests on the accurate calculation of U-values. This section describes the interpretations used by both the BBA and Kiwa BDA.

British Board of Agrément

The BBA's interpretation of inverted roof system performance and assessment is evidenced in its certificates issued to insulation manufacturers and roofing system suppliers. It is further supported by their BBA Information No. 4, which is cited in BS 6229:2018.

A moisture conversion factor is applied to the declared thermal conductivity of the insulation material, as described in ETAG 031, to give a design thermal conductivity.

ETAG 031 defines two levels for the effect of moisture on the thermal conductivity of the insulation. For warmer Mediterranean countries, freeze thaw is not a significant design issue. Design lambda can therefore be calculated taking into account only the effects of water absorption by diffusion (level 2).

For northern European countries, including the UK, freeze thaw is an issue. The water absorption caused by diffusion and subsequent freeze thaw must be taken into account, and the BBA's calculation of the moisture conversion factor reflects that.

When calculating the rainwater cooling correction, the BBA chooses to adopt a minimum drainage factor (f) of 2.5%, even if the ETAG 031 Annex C test result suggests no water penetration through the WFRL. When multiplied by the standard value of x, this yields a value for fx of 0.001.

No other corrections or adjustments are advised.

Kiwa BDA

In February 2020 KIWA BDA issued an Agrément certificate for an inverted roof system. The certificate takes a different approach to all others available in the UK. Some key points from the certificate, relevant to the subjects discussed in this white paper, are as follows.

Section 2.1.3 says that "roofs incorporating the system should be designed in accordance with BS 6229".

Section 2.1.10 says that the WFRL will "prevent the potential for water ingress" from direct precipitation. Ambient temperature fluctuations may result in some condensation, which will drain away. Any water ingress "will not affect the performance of the system" – suggesting that freeze thaw is not an issue either.

Section 2.1.11 says that the drainage factor (f) for the system is 0 (zero). For conventionally ballasted inverted roofs, the moisture conversion factor for the purposes of establishing design lambda equals 1. There is also no rainwater cooling correction to be applied.

Where Fm = 1, this means that design lambda is the same as declared lambda. With no rainwater cooling correction applied either, the Kiwa BDA certificate is essentially declaring that moisture does not affect the system, despite its position above the roof waterproofing.

Correspondence with Kiwa

Polyfoam XPS has contacted Kiwa to discuss the reasoning behind the statements made. Within individual correspondence, Kiwa acknowledged the following.

- That the WFRL is not a waterproof layer.
- That water reaching the waterproof layer will alter the thermal performance of an inverted flat roof.
- That effective roof falls should mean that any water drains promptly from the waterproofing layer, thereby meaning it is not in the roof system for long enough to have an effect.
- That they consider the note in section 4.6.2.2 of BS 6229:2018, describing the 10% increase in insulation thickness, to be a "comprehensive requirement".

The Kiwa BDA certificate makes no mention of the BS 6229 note or the 10% increase. The view has only been expressed by Kiwa in correspondence with individual parties.

Conclusion

Established standards clearly set out calculation processes for the performance of inverted roofs. For many years, the inverted roofing sector in the UK has followed one interpretation in conjunction with the assessment and verification processes of the BBA.

The issuing of a certificate from an alternative Agrément certificate provider, using a different interpretation, is to be welcomed. It encourages debate and an assessment of whether established practice is as accurate as it can be.

However, alternative interpretations should be stated clearly and unambiguously, in order to allow all parties involved in the design, specification and installation of inverted roofs the opportunity to make informed decisions. Otherwise, there is a risk of confusion among designers, specifiers, contractors and manufacturers alike.

The KIWA BDA clearly indicates that moisture will not be present in the roof or, if it is, that it will not be present for long enough to negatively impact the thermal performance. This is contrary to the established view of inverted roofs and, for a BDA certified system, means that:

- a moisture conversion factor does not need to be applied to the declared lambda of the insulation product; and
- for a conventionally ballasted inverted roof, the rainwater cooling correction will be calculated as zero.

Separate to the published certificate, Kiwa advise that the note in section 4.6.2.2 of BS 6229:2018 is a comprehensive requirement. The foreword to the British Standard is clear that notes in the text constitute additional information that do not form part of the recommendations.

Polyfoam XPS have received and seen other correspondence indicating that KIWA view the correction factors applied in BBA certification as not required, and advocating the 10% correction factor suggested in BS6229:2018.

The Kiwa BDA Agrément certificate, however, contains nothing to encourage its users to adopt the note. It only says that BS 6229 should be followed in the design of a roof. A user of the Kiwa BDA Agrément certificate could read BS 6229 and choose to disregard the contents of the note, unaware that the body issuing the certificate expects them to account for the note in their specification.

This effectively creates a ‘two tier’ system within Kiwa’s own interpretation, in addition to the obvious differences with the BBA’s established interpretation. Table 1 illustrates the differences in approach, using the following scenarios.

- A generic XPS insulation system certified by the BBA.
- A generic EPS insulation system certified by the BBA.
- The same generic EPS certified by Kiwa, and using their publicly available interpretation.
- The same generic EPS certified by Kiwa, but where the note in section 4.6.2.2 of BS 6229:2018 has been applied.

Table 1: Comparison of insulation thicknesses following different interpretations

Insulation type	XPS	EPS		
Certification body	BBA	BBA	Kiwa (as per certificate - calculated insulation thickness not increased by 10%)	Kiwa (as per correspondence - calculated insulation thickness increased by 10%)
Declared thermal conductivity of insulation	0.033 W/mK	0.033 W/mK	0.033 W/mK	0.033 W/mK
Design thermal conductivity of insulation	0.034 W/mK	0.038 W/mK	n/a – declared lambda is used	n/a – declared lambda is used
Rainwater cooling	Rainwater cooling calculated as per BS EN ISO 6946	Rainwater cooling calculated as per BS EN ISO 6946	No rainwater cooling correction	No rainwater cooling correction
Target U-value (W/m^2K)	Insulation thickness (mm)			
0.25	130	145	125	140
0.20	160	180	155	175
0.18	180	200	175	195
0.15	215	240	210	235
0.13	245	275	240	265

Assumed roof build-up (inside to outside):
150mm concrete deck (2.50 W/m·K), 7.5mm hot melt waterproofing, thermal insulation, WFRL, gravel or paving slabs ballast layer.

Rainwater cooling correction values (where applicable):
p = 3.000; f = 0.025; x = 0.040

Table 1 shows how removing the moisture conversion factor and avoiding a change from declared to design lambda potentially creates a substantial saving in insulation thickness.

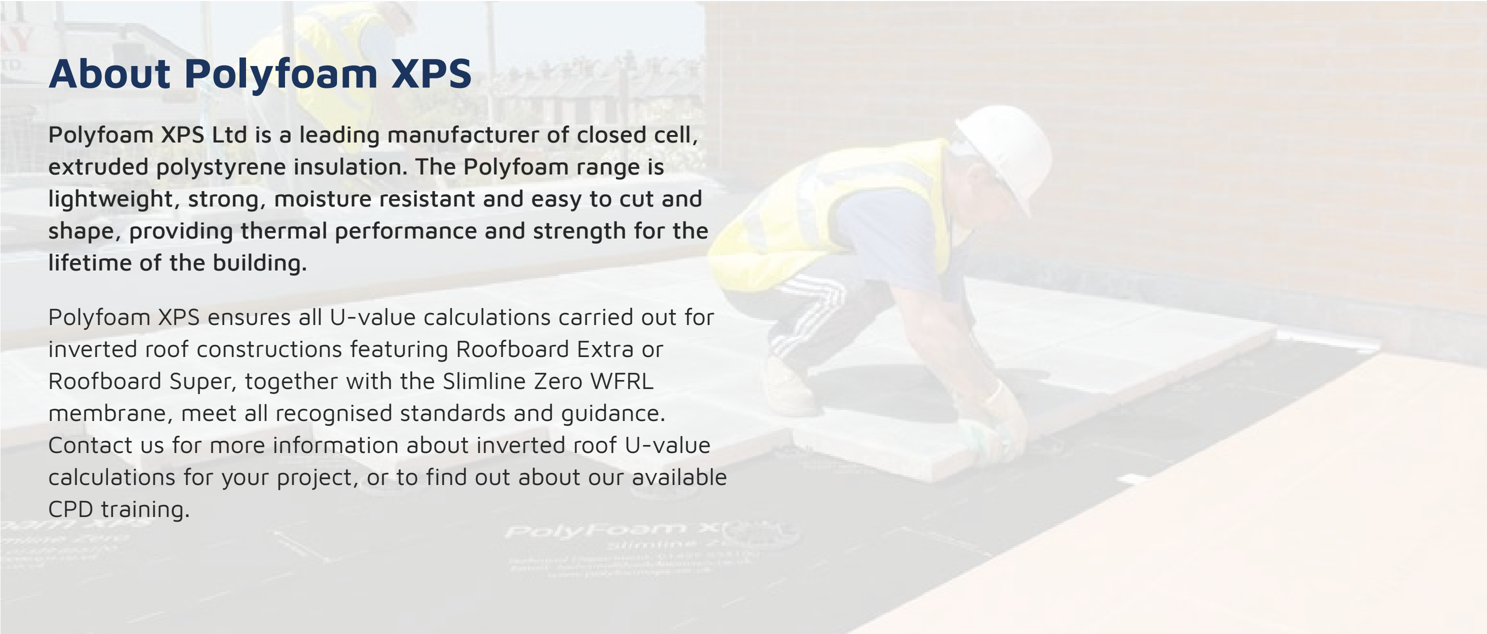
The effect of applying the 10% insulation thickness increase results in a product thickness on site almost identical to that calculated by the 'traditional' interpretation of standards. It can therefore be said that the interpretations of the two certifying bodies are not vastly different – as long as the 10% insulation thickness increase is applied.

This is reassuring for all involved with inverted roofing, but clear communication is required.

By failing to publicise the expectation that the 10% insulation thickness increase should be applied, inverted roofs designed and installed as publicised in the Kiwa BDA Agrément certificate risk having too little insulation.

For systems certified by the BBA, there is no clear evidence that a 10% increase in insulation thickness needs to be applied as a further correction. The thermal conductivity of the insulation material and the overall thermal performance of the roof is already adjusted as outlined in this document.

Polyfoam XPS urges designers of inverted flat roofs to consider these issues, as specifications could be accepted with insulation thicknesses inadequate to meet the thermal performance targets for the building.



About Polyfoam XPS

Polyfoam XPS Ltd is a leading manufacturer of closed cell, extruded polystyrene insulation. The Polyfoam range is lightweight, strong, moisture resistant and easy to cut and shape, providing thermal performance and strength for the lifetime of the building.

Polyfoam XPS ensures all U-value calculations carried out for inverted roof constructions featuring Roofboard Extra or Roofboard Super, together with the Slimline Zero WFRL membrane, meet all recognised standards and guidance. Contact us for more information about inverted roof U-value calculations for your project, or to find out about our available CPD training.

References

BS 6229:2018 Flat roofs with continuously supported coverings – Code of practice

BS EN ISO 6946:2017 Building components and building elements – Thermal resistance and thermal transmittance – Calculation methods

BS EN ISO 10456:2007 Building materials and products – Hygrothermal properties – Tabulated design values and procedures for determining declared and design thermal values

BS EN 12088 Thermal insulating products for building applications. Determination of long term water absorption by diffusion

Recently replaced by BS EN ISO 16536: 2019 of the same title.

BS EN 12091 Thermal insulating products for building applications. Determination of freeze-thaw resistance

ETAG 031-1 Guideline for European technical approval of inverted roof insulation kits

BRE Report BR 443 Conventions for U-value calculations

BBA Information No. 4 Inverted roofs – Drainage and U-value corrections

LRWA Guidance Note No. 14 Best Practice for the Installation of Water Flow Reducing Layers in Inverted Roofs

LRWA Guidance Note No. 15 Clarification of BS6229:2018 regarding the thermal performance of inverted roofs and inverted blue roofs

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