A review of recent guidance on inverted roof construction

The authors

JOHN POTTER is an architect, based in Newcastle on Tyne, with extensive experience of a wide range of building types, from housing, hospitals and schools to nuclear power stations. He represents the RIBA on British Standards Technical Committees and is a Director of JPA Technical Literature Ltd., producing technical documentation and software for the construction industry.

HUW EVANS has a post-graduate degree in Technical Authorship from Sheffield Hallam University. He has a particular interest in building physics and the energy efficiency of buildings and, in collaboration with JPA Technical Literature Ltd., provides training in Part L of the Building Regulations and the use of software to assess energy performance and produce Energy Performance Certificates.

1. Introduction

New guidance on inverted warm roofs is contained in European Technical Approval Guidance 031 (ETAG 031) which has been issued in order to ensure consistent standards of assessment of inverted roof systems throughout Europe. An inverted roof is defined in ETAG 031 as one with a slope not exceeding 8.5°, with thermal insulation installed above the waterproof covering and restrained by a surface protection layer.

This Technical Paper considers ETAG 031 together with two recent publications by the British Board of Agrément (BBA):

- BBA Information Bulletin No. 4, which emphasises the importance of correct drainage and the need to adjust calculated U-values to take account of the cooling effect of any rainwater which drains through the system.
- BBA DataSheet No. 40/10, which describes the methodology to be adopted when analysing the results of thermal conductivity testing of insulation materials to determine a declared thermal conductivity value (λ_D).

2. ETAG 031 – Inverted roof kits

ETAG 031 is the basis for preparing European Technical Approvals (ETAs) for inverted roof kits (systems) in accordance with the European Union's Construction Products Directive (CPD). It specifies:

- methods of verification;
- assessment criteria;
- presumed conditions for design and execution.

An inverted roof kit with an ETA prepared in accordance with ETAG 031 will be deemed to satisfy the Essential Requirements of the CPD.

2.1 ETAG 031-1 General

ETAG 031-1 considers inverted roof kits (or systems), which consist of:

- an insulant together with one or more of;
- a filter layer, a separation layer or a water-flow reducing layer.

Such roof kits are used with other components to form complete systems (excluding the waterproof covering).

Environmental conditions on inverted roofs subject the insulation to high levels of moisture. In some climatic zones, including the UK, the insulation is also subjected to repeated cycles of freezing and thawing. In order to obtain a U-value which takes account of such conditions, ETAG 031-1 requires the declared thermal conductivity of the insulant (λ_D) be corrected for the effect of water absorption by diffusion and by freeze-thaw cycling. The U-value calculation must also be corrected to allow for the additional heat loss which results from rainwater passing through the inverted roof kit and flowing across the waterproof layer.

2.2 ETAG 031-2 Insulation with protective finishing

ETAG 031-2 contains specific requirements for insulants with an integral surface protection layer.

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3. Insulation

ETAG 031-1 considers two families of insulation:

- XPS - Extruded polystyrene foam to BS EN 13164:2008.
- EPS - Expanded polystyrene to BS EN 13163:2008.

Table 1 - Suitability of insulants for inverted roof categories

Inverted roof category	XPS	EPS
Untrafficked	✔	✔
Pedestrian	✔	✔
Green roof	✔	–
Roof garden	✔	–
Parking deck	✔	–

Source: ETAG 031-1: page 7.

3.1 Lambda 90/90

During manufacture of an insulant its conductivity (lambda value, λ) will be affected by variations in the production process. Its value in use will be affected by ageing, compression and the presence of moisture.

To ensure design U-values calculations are robust the product standards referred to above require that manufacturers state declared lambda values (λ_D) for their products. Declared values are arrived at by statistical analysis which ensures that 90% of production achieves the quoted conductivity value with a 90% confidence level (hence the term lambda 90/90, $\lambda_{90/90}$, as referred to in BBA DataSheet No. 40/10).

3.2 Thermal conductivity corrections

Any thermal insulant used in an inverted warm roof will absorb moisture by diffusion: in climates such as that of the UK, those insulants will be subject to repeated cycles of freezing and thawing which can have the effect of increasing the amount of water absorbed. The efficiency of a thermal insulant is directly affected by the amount of moisture it contains.

ETAG 031-1 therefore requires the declared thermal conductivity of any insulant to be used in an inverted warm roof be corrected by the moisture conversion factor, F_m, which is calculated according to BS EN ISO 10456 and ETAG 031-1 section 5.6.1.2. F_m is derived from:

- f_ψ – the moisture conversion coefficient by volume (2.5 for XPS and 4.0 for EPS).
- ψ_{cor} - the moisture content by volume (m^3/m^3), which for the UK includes the moisture absorbed by diffusion (ψ_{diff}) and the additional absorption resulting from freeze-thaw cycling (ψ_{FT}).

The declared lambda value of the insulant (λ_D) is multiplied by Fm in order to arrive at the corrected lambda value (λ_{corr}) which is then used in determining the U-value of the construction. Figure 1 shows the relationship between F_m and the quantity of moisture absorbed by the insulant.

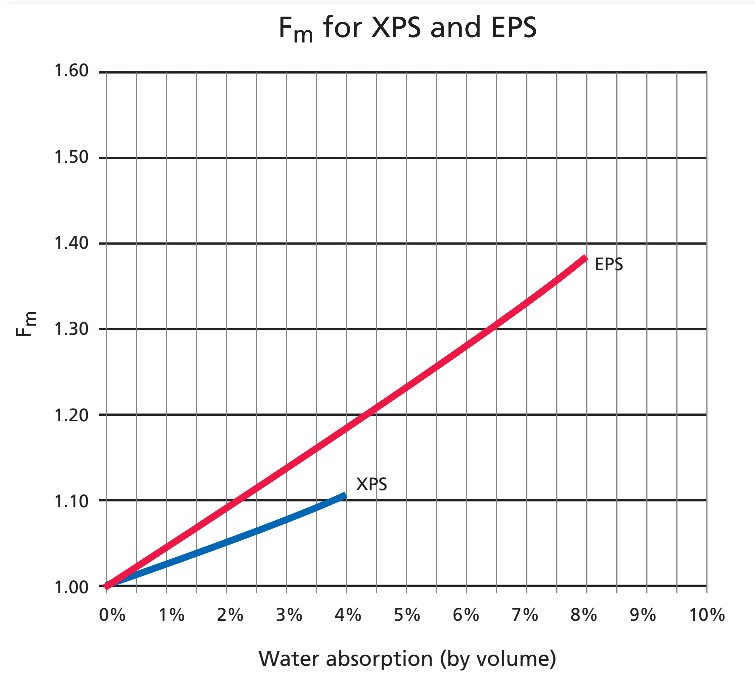

Figure 1: F_m for XPS and EPS. Plots terminated at maximum permitted absorption level for XPS and EPS.

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4. Rainwater cooling

Any rainwater which is able to penetrate the inverted roof system and reach the waterproof layer will absorb heat from the underlying structure and so affect the thermal performance of the construction as a whole. The extent of that heat absorption depends upon the daily average rainfall during the heating season and the proportion of that rainfall which reaches the waterproof layer.

In order to take account of that additional heat loss the initial U-value of the roof must be corrected by adding to it a rainwater correction factor, ΔU_r (determined using the method described in BS EN ISO 6946:2007 section 7 and Annex D.4).[1]

ΔU_r is derived from:

- the proportion of the thermal resistance of the total construction which is provided by insulation above the waterproof layer;
- the average rate of rainfall (mm/day) for the site during the heating season[2] (**p**);
- the increased rate of heat loss caused by that portion of the average rainfall which reaches the waterproof layer (**f.x**).

The corrected U-value of an inverted roof is therefore dependent on its location and the proportion of rainwater which reaches the waterproof layer. The average daily rainfall in the UK ranges from 1 mm/day in South East England to more than 8 mm/day in Western Scotland: therefore it is essential to consider the project location when determining the amount of insulation required to achieve the design U-value. The lower the uncorrected U-value of the roof, the greater will be the effect of applying the rainwater cooling correction.

The proportion of rainwater which reaches the waterproof layer can be substantially reduced by incorporating in the system a water-flow reducing layer directly above the insulation, to drain rainwater off the roof before it reaches the waterproof layer (see figure 2). A water-flow reducing layer must be rot-resistant, UV-stable, and impermeable to liquid water but permeable to water vapour. The drainage factor (**f**) for a water-flow reducing layer should be established using the test method described in ETAG 031-1 Annex C, or taken from relevant BBA certificates.

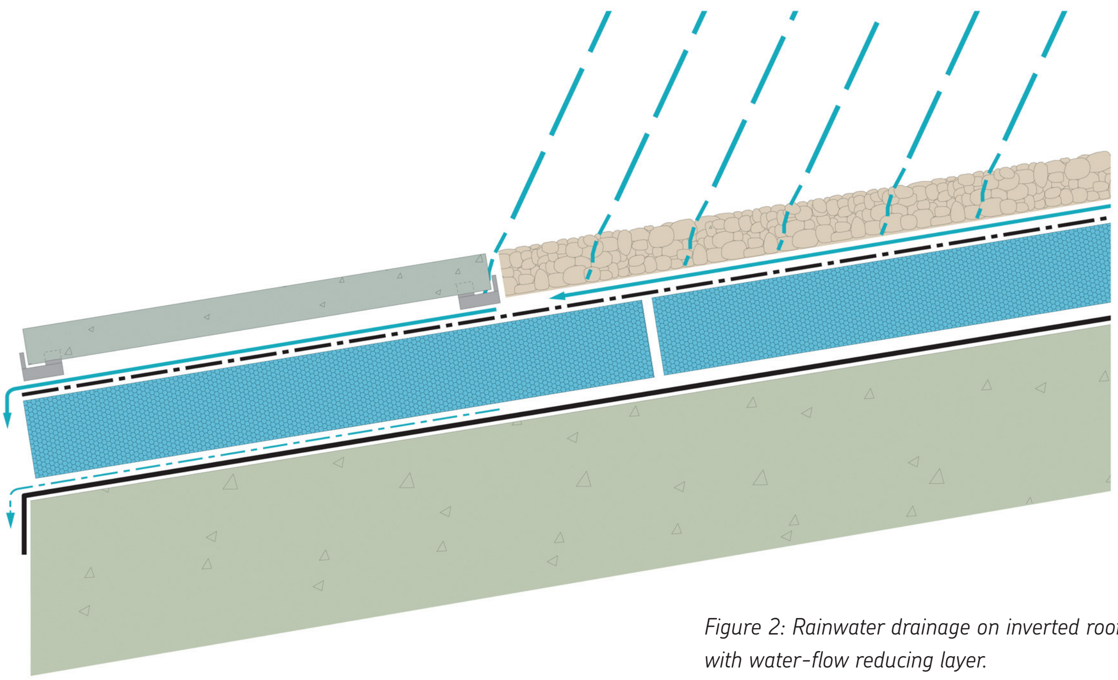

Figure 2: Rainwater drainage on inverted roofs with water-flow reducing layer.

1 If the total of all correction factors to the U-value calculation, including ΔU_r, is less than 3% of the uncorrected U-value, those corrections may be ignored.
2 The daily average rainfall rate may be determined from rainfall maps on the Met Office web site, taking the heating season as 182 days. http://www.metoffice.gov.uk/climate/uk/averages/19611990/images/RainOctMar6190.gif

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5. Drainage

In order to conform to the recommendations contained in BS 6229:2003 flat roofs should be designed to drain to outlets situated at low points, which are most likely to occur at the midpoint of spans. Effective drainage, designed to BS EN 12056-3, will avoid ponding, reduce silting and minimise stressing due to freeze-thaw cycling. It is good practice to provide drainage from the top of the insulation in addition to that from the waterproofing layer. In systems which incorporate a water-flow reducing layer it is essential to provide for drainage from the water-flow reducing layer.

Good practice would be to provide the minimum drainage falls listed in BS 6229:2003 Table 6. Where zero pitch roofs (described in BBA Information Bulletin No. 4 as having a slope not exceeding 0.7°) are specified, extra care is required to ensure correct drainage both at the waterproofing layer and at the water-flow reducing layer. Reference should be made to the BBA certificates for the selected insulation and waterproof layer.

6. References

ETAG 031. Inverted Roof Insulation Kits. EOTA.
-1. General. November 2010.
-2. Insulation with Protective Finishing. November 2010.

BBA Information Bulletin No. 4. Inverted roofs - Drainage and U value corrections.
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British Board of Agrément. Issue 3. October 2010.

BS EN ISO 6946:2007.
Building components and building elements. Thermal resistance and thermal transmittance. Calculation method.

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Building materials and products. Hygrothermal properties. Tabulated design values and procedures for determining declared and design thermal values.

BS EN 12056.
Gravity drainage systems inside buildings.
-3:2000. Roof drainage, layout and calculation.

BS EN 13163:2008.
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BS 6229:2003.
Flat roofs with continuously supported coverings.
Code of practice.

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