The thermal performance of multi-foil insulation

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Summary

This paper reports the results of *in-situ* measurement of the U-values of some constructions incorporating a multi-foil insulation product. The results are compared with values that have been reported elsewhere for the thermal performance of the product. The *in-situ* results are generally in good agreement with the result of a hot-box test.

Introduction

There are a number of insulation products currently used in the UK that are generally described in the industry as multi-foil or multi-layer insulation products. One such product, TRI-ISO SUPER 9®, is illustrated in Figure 1. It has a nominal thickness of 25 mm thick and comprises fourteen separate layers, the second seven layers being a reversed repeat of the first seven. The separate layers are then stitched through to form a quilt-like sheet, the sheet then being supplied in roll form.

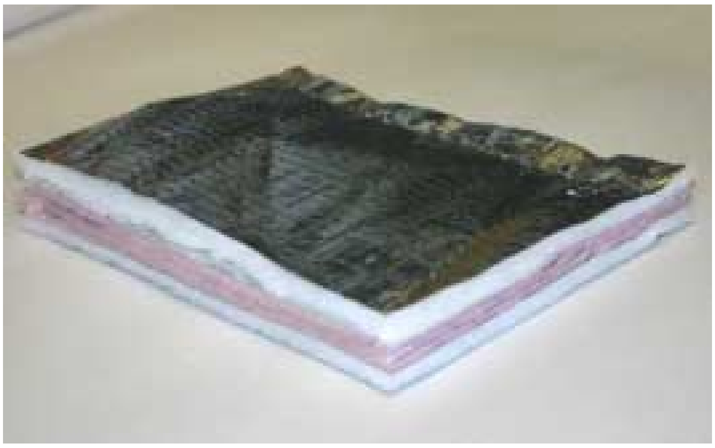

Figure 1 : Multi-foil insulation product

Widely differing values have been given for the thermal performance of this product. The manufacturer commissioned a report from TRADA Technology Ltd [1], which states "*"…TRI-ISO SUPER 9 had insulating properties equivalent to mineral wool (glass) of 200 mm. This provides thermal performance to the equivalent of an overall thermal resistance (R_T) of 5 m^2K/W based on a recognised international thermal conductivity value for standard glass wool insulation of 0.04 W/m·K.*" While this comparative test contrasted two insulation systems it did not provide any actual U-values.

In 2004 Celotex Ltd commissioned NPL to undertake a hot-box test [2], which gave a measured thermal resistance of 1.71 m^2K/W, about one-third of that indicated by TRADA.

This paper reports on some *in-situ* U-value measurements that have been carried out on wall, floor and roof constructions that contained TRI-ISO SUPER 9® as the principal insulation layer, the results of which add to the knowledge and understanding of the thermal performance of this product.

Testing techniques

The thermal properties of insulation materials are commonly tested by measuring samples of the product in a hot-plate apparatus conforming to BS EN 12667 [3]. The performance of products with foil facings, however, includes the effect of the surfaces on the thermal resistance of adjacent air spaces. These effects will not be allowed for in a normal hot-plate test where the surfaces of the test sample are adjacent to the hot and cold plates of the apparatus. Also, if the surface of the material is not flat, as is often the case with multi-foil insulation products, parts of the surface will be in contact with the hot and cold plates while other parts will have air pockets between the product surface and the surface of the hot and cold plates. This combination of direct contact areas and areas with air pockets make any test result difficult to interpret and apply to the product and its intended application.

A hot box test, on the other hand, can be done on a larger scale and in particular the test sample can consist of a more complete construction. The test method is defined in BS EN ISO 8990 [4]. In the test conducted by NPL the multi-foil insulation was placed between two plywood sheets, and had an airspace on either side of it, as would be the case in normal use of this product. The reported result is the thermal resistance of the product itself plus the two adjacent airspaces.

In-situ U-value measurements

In-situ U-value measurements were carried out on some wall and floor constructions that incorporated TRI-ISO SUPER 9® as the primary insulating layer. The measurements were carried out by the techniques given in ISO 9869 [5] using heat flow meters 100 mm in diameter. One location was in Torry, Aberdeen, where the walls of two Victorian flats had been improved by using the multi-foil insulation as part of an insulated dry-lining. The second location was a temporary classroom at a school in Alloa, Clackmannanshire, where the multi-foil insulation was used in the roof and ground floor construction. The form of these constructions, starting from the inside, were as follows:-

- **External wall construction, Torry**
  12.5 mm Plasterboard/25 mm unventilated cavity/ TRI-ISO SUPER 9®/25 mm unventilated cavity/Granite

- **Flat (low-pitch) Roof construction, Alloa**
  Plasterboard/430 mm unventilated roof void/ TRI-ISO SUPER 9®/15 mm slightly ventilated airspace/Plywood/Marleydek roof membrane

- **Floor construction, Alloa**
  Chipboard/15 mm unventilated airspace/TRI-ISO SUPER 9®/ventilated underfloor space

Results of the in-situ U-value measurements

The results of the measurements are summarised in Table 1, which shows the measured U-values (U_m) compared with the corresponding U-value (U_c) calculated according to BS EN ISO 6946 [6], with the thermal resistance of the multi-foil together with the two adjacent airspaces taken as 5.0 m²K/W (see Table 2).

Table 1: Comparison of Measured and Calculated U-values

Location	**Insulation**	**Measured U_m** (W/m²K)	**Estimated error in U_m** (W/m²K)	**Calculated U_c** using R=5.0 m²K/W (W/m²K)	**Ratio U_m/U_c**
	Torry				
Wall 1	TRI-ISO SUPER 9® multi-foil insulation with adjacent airspace to each side	0.49	± 0.07	0.19	2.58
Wall 2		0.52	± 0.08	0.19	2.74
Wall 3		0.50	± 0.08	0.19	2.63
Wall 4		0.45	± 0.07	0.19	2.37
	Alloa				
Roof 1	TRI-ISO SUPER 9® multi-foil insulation with adjacent airspace to each side	0.85	± 0.13	0.19	4.47
Roof 2		0.76	± 0.11	0.19	4.00
Floor 1	TRI-ISO SUPER 9® multi-foil insulation with unventilated adjacent airspace to warm side and ventilated underfloor space to cold side	0.43	± 0.06	0.19	2.26
Floor 2		0.48	± 0.07	0.19	2.53

Measurements from Torry, Aberdeen

The measurements were of the walls of two flats (two measurements per flat) where the multi-foil insulation was used as an integral part of the dry-lining refurbishment of the existing solid (granite) walls. The four measured values were all very similar ranging from 0.45 to 0.52 W/m²K.

Based on a thermal resistance of 5 m²K/W for the multi-foil insulation inclusive of the air spaces on either side of it, the U-value calculation is set out in Table 2:

Table 2: U-value calculation

Layer	**Thickness** (mm)	**Thermal conductivity** (W/m·K)	**Thermal resistance** (m^2K /W)
R_{si}			0.130
Plasterboard	12.1	0.21	0.058
25 mm cavity + TRI ISO SUPER 9 + 100 mm cavity			5.000
Aberdeenshire granite	220	2.5	0.088
R_{se}			0.040
Total resistance, R_T			5.316
		$U = 1/R_T =$	0.19 (W/m^2K)

The measured values were some 2.5 times higher than the calculated value of 0.19 W/m²K, The multi-foil insulation was stapled to 100 mm battens with 25 mm counter battens to which the plasterboard is fixed. The thermal performance of the multi-foil insulation comprises the thermal resistance of the 25 mm thick product plus the thermal resistance of the low-emissivity airspaces on either side of the multi-foil insulation.

At the time of the *in*-situ measurement there was no opportunity to make a visual inspection of the installation of the multi-foil insulation. However, subsequent to the *in*-situ U-value measurements being carried out, one of the flats was revisited in February 2005 when the plasterboard lining was removed at the site of the U-value measurements and the installation of the TRI-ISO SUPER 9® examined. The multi-foil insulation was found to have been installed correctly and the outer foils were clean (Figure 1 is a section of the sample taken from the wall). The conclusion therefore is that the thermal resistance *in-situ* of the multi-foil insulation is significantly less than would be indicated by a thermal resistance of 5.0 m²K/W. Using the average U-value for the four measurements, i.e. 0.49 W/m²K, and working backwards through the U-value calculation indicates an R-value for TRI-ISO SUPER 9® (inclusive of the airspaces on either side of it) of 1.72 m²K/W. This value is in agreement with the NPL hot-box measurements on TRI-ISO SUPER 9® which gave an R-value of 1.71 m²K/W.

Measurements from Alloa, Clackmannanshire

The U-values of the flat roof and the floor construction, both of which incorporated multi-foil insulation, were measured.

The floor construction had a well ventilated underfloor space, such that this ground floor was essentially an exposed floor where the ground would have only a small effect on the resultant U-value. Again the measured U-values of 0.43 and 0.48 W/m²K were significantly higher than the calculated value of 0.19 W/m²K, indicating that, similar to the conclusion from the wall construction at Torry, the effective R-value of the multi-foil insulation in the classroom floor construction is substantially less than the 5.0 m²K/W. The implied R-value for the multi-foil insulation (plus adjacent airspaces) based on a measured average U-value of 0.46 W/m²K is 1.85 m²K/W, again (within the errors of the measurements) in agreement with the NPL hot-box result of 1.71 m²K/W.

The flat roof construction also incorporated multi-foil insulation, where this was laid on top of the timber joists prior to the roof-deck being laid.   The drawings show a degree of draping of the multi-foil insulation, thus creating a small variable airspace (average thickness of approximately 15 mm) between the upper surface of the multi-foil insulation and the roof deck. The underside of the multi-foil insulation faced the unventilated roof void, which was 430 mm deep. The measured U-values were 0.85 and 0.76 W/m^2K. The implied R-value from the average U-value of 0.81 W/m^2K is 0.96 m^2K/W. This is somewhat smaller than the implied R-values of 1.72 and 1.85 m^2K/W of the other two constructions examined. There was no opportunity in this instance to inspect the installation of the multi-foil insulation and so the reasons why this installation performed even less well compared to the other two constructions is not clear (although a reduced thermal resistance would be expected if the multi-foil insulation were adjacent to the roof decking so losing the benefit of the airspace).

Discussion of *in-situ* results

If the calculated U-value is based on the NPL test result of resistance of 1.71 m²K/W the comparison of calculated and measured U-values are those given in Table 3. Figure 2 shows the measured U-values plotted against both the originally calculated U-value and against the re-calculated U-values for the multi-foil insulation based on thermal resistances of 5.0 and 1.71 m²K/W respectively. The measured and calculated U-values are in much better agreement, particularly for the wall and floor constructions, when the calculated U-value is based on the thermal resistance as measured by NPL.

The discussion has not considered the effect of heat flow direction. Convection in airspaces does depend on the direction of heat flow, but these results are not readily analysed in terms of the effect of convection because the measurements provide the total resistance of the product and the adjacent airspaces as a single value. The NPL measurement was done with the heat flow upwards at an angle of 45°. The overall thermal resistance would be expected to be reduced for upwards heat flow in a flat roof, but it should be, if anything, greater for horizontal heat flow in a wall or downwards heat flow in a floor.

Table 3: Measured U-values and re-calculated U-values based on a thermal resistance of 1.71 m²K/W for the multi-foil insulation and adjacent airspaces

Location	Insulation	Um (W/m²K)	Error (W/m²K)	Uc (W/m²K)	Um/Uc
	Torry				
Wall 1	TRI-ISO SUPER 9® multi-foil insulation with adjacent airspace to each side	0.49	± 0.07	0.49	1.00
Wall 2		0.52	± 0.08	0.49	1.06
Wall 3		0.50	± 0.08	0.49	1.02
Wall 4		0.45	± 0.07	0.49	0.92
	Alloa				
Roof 1	TRI-ISO SUPER 9® multi-foil insulation with adjacent airspace to each side	0.85	± 0.13	0.50	1.70
Roof 2		0.76	± 0.11	0.50	1.52
Floor 1	TRI-ISO SUPER 9® multi-foil insulation with unventilated adjacent airspace to warm side and ventilated underfloor space to cold side	0.43	± 0.06	0.49	0.88
Floor 2		0.48	± 0.07	0.49	0.98

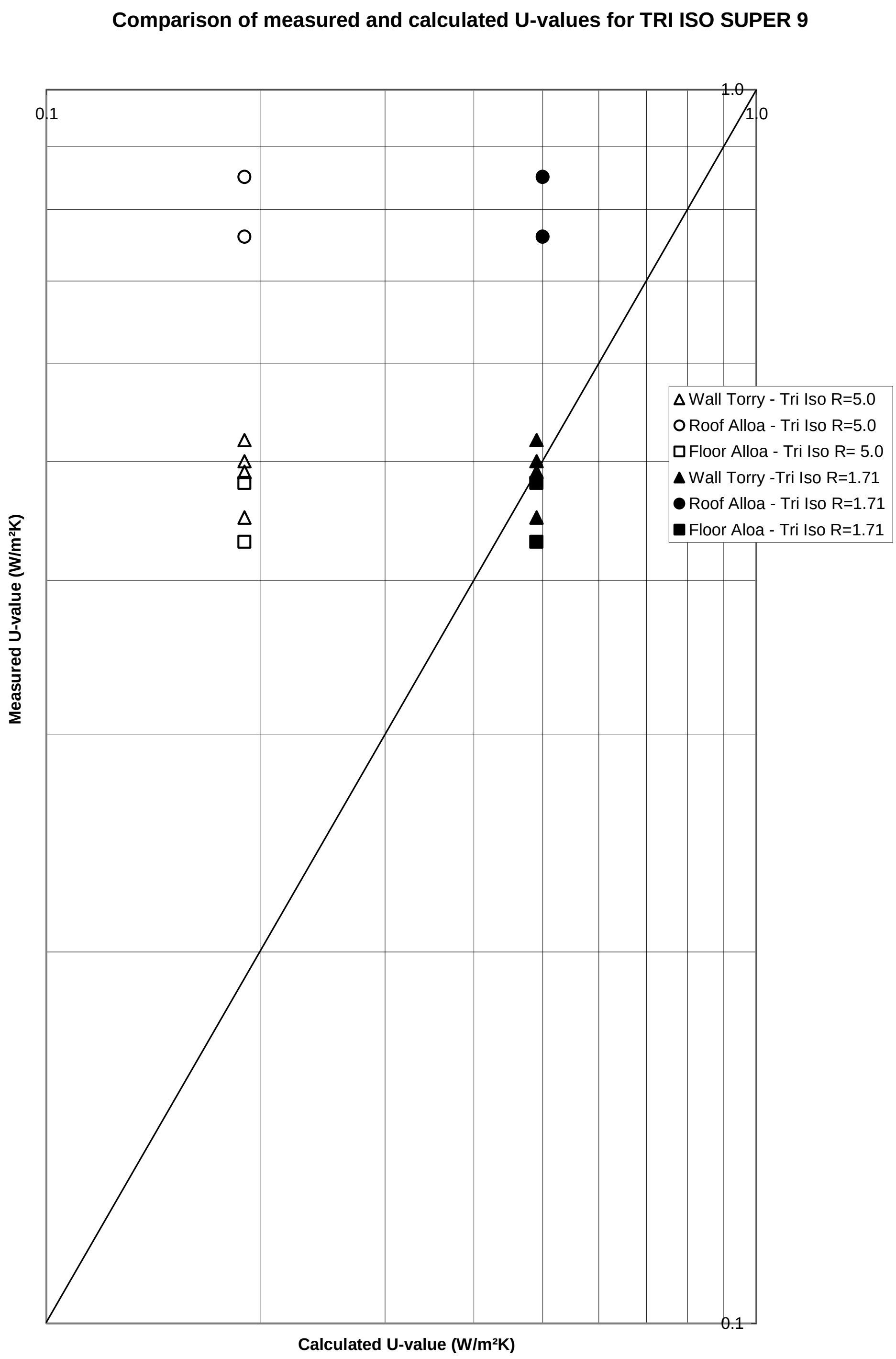

Figure 2: Comparison of measured and calculated U-values

The diagonal line in Figure 2 indicates the positions that the points would occupy if there were perfect agreement between the measured U-values and the calculated U-values. Points above the line indicate results where the measured U-value is higher than the calculated U-value, indicating that heat loss is higher than expected. Points below the line indicate results where the measured U-value is less than the calculated U-value. The graph shows that there is much better agreement when an R-value of 1.71 m²K/W is used than there is when an R-value of 5 m²K/W is used.

Conclusions

For these constructions incorporating a multi-foil insulation, the *in-situ* U-value measurements reported in this paper are in good agreement with the NPL guarded hot-box measurements for the same product, and are not consistent with a thermal resistance of 5.0 m^2K/W. For multi-foil insulation, the consistency here of the thermal performance measured *in*-situ with that measured in a hot-box suggests that either method provides a suitable means of establishing the thermal performance of such products to the accuracy delivered by the respective methods.

Acknowledgement

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References

[1] TRADA Certificate Number 0101
first issued in February 2001 and re-issued in February 2005 valid until February 2006.

[2] NPL Test Report, "Measurement of the thermal resistance of an air cavity insulated with ACTIS TRI-ISO SUPER 9 ®" Reference: PP31/E04060280
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[3] BS EN 12667:2001, Thermal resistance of building materials and products - Determination of thermal resistance by means of guarded hot plate and heat flow meter methods – Products of high and medium thermal resistance

[4] BS EN ISO 8990:1996, Thermal insulation – Determination of steady-state thermal transmission properties – Calibrated and guarded hot box

[5] ISO 9869:1994, Thermal Insulation – Building elements – *In-situ* measurement of thermal resistance and thermal transmittance

[6] BS EN ISO 6946:1997, Building components and building elements – Thermal resistance and thermal transmittance – Calculation Method.