Forschungsinstitut für Wärmeschutz e.V.
München

TEST REPORT

Applicant: Hilti Aktiengesellschaft
Feldkircher Straße 100
9494 Schaan
Liechtenstein

Subject: Numerical analysis, assessment and classification
of point thermal transmittance of mechanical fastener
Hilti X-IE 6 and Hilti X-IE 9
for fixing of perimeter insulation
and external wall insulation behind rainscreen claddings.

English version of German test report B3-2016/15

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1. Conceptual formulation

For Hilti Aktiengesellschaft in Schaan (Liechtenstein), the correction to thermal transmittance U, due to thermal bridging effect of mechanical fastener Hilti X-IE 6 and Hilti X-IE 9 is analysed numerically by means of "Finite-Element"-method and classified as belonging to a fastener class.

According to ISO 6946, corrections shall be applied to the thermal transmittance if corrections are ≥ 3 % of the U-value. According to TR 0-25, if the thermal bridging effect of the anchor is smaller than 0.0005 W/K, the nominal value of point thermal transmittance is 0 W/K and the anchors may therefore be neglected in the U-value calculation.

The thermal bridging effect of plastic anchors for external thermal insulation composite systems is considered by means of a correction value $n \cdot \chi$ to the thermal transmittance U (U-value), according to the formula

$$U_c = U + n \cdot \chi$$

where U_c is the corrected U-value, n is the number of anchors per m² and χ is the point thermal transmittance (correction per anchor). The maximum number of plastic anchors per unit area whose effect on thermal transmittance does not need to be considered in the design U-value for the wall depends on the thickness of the insulation layer. According to the Technical Report the calculations shall be carried out for the lowest insulation layer thickness (in this case 60 mm) further for a medium thickness (around 150 mm) and finally for the highest insulation layer thickness allowed for this particular anchor (in this case 200 mm). The calculation for the highest insulation layer thickness may be omitted, if the χ-value for the medium insulation layer thickness is lower than the χ-value for the lowest insulation layer thickness.

2. Fundamentals for numerical analysis

The calculation is conducted according to DIN EN ISO 10211:2015-06 and based on the technical report EOTA TR-025 "Technical Report – χ" for ETAG 014[1)] but with modified model and boundary conditions for the application in perimeter insulation and insulation behind curtain walling.

2.1. Thermal quantities

The used thermal quantities are described in the table below.

Table 1: Thermal quantities

Name	Sign	Unit
Temperature	θ	°C
thermal conductivity	λ	W/(m·K)
thermal resistance	R	m²·K/W
surface resistance	R_s	m²·K/W
density of heat flow rate	q	W/m²
thermal transmittance	U	W/(m²·K)
heat flow rate	Q	W
thermal coupling coefficient for 3-dim calculation	L^{3d}	W/K
correction (per fastener) to U-value = point thermal transmittance	$U_p = \chi$	W/K

[1] Technical Report No. 025 for ETAG 004 and 014– TR025: Determination of point thermal transmittance of plastic anchors for the anchorage of external thermal insulation composite systems (ETICS)

2.2. Product specifications

The fastener consists of a sleeve with disc made of high density polyethylene (HDPE). The powder-actuated fastener consists of carbon steel (HRC 58). The fastener is mounted 1 mm countersunk with the outside surface of the insulation. The fastener is sold for application in perimeter insulation in soil and insulation in curtain walling.

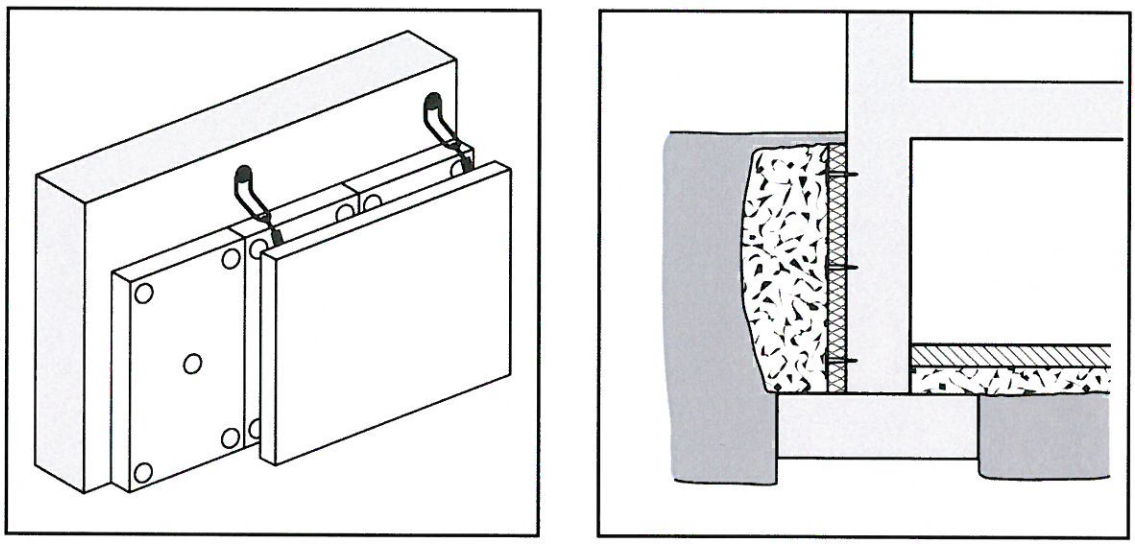

Figure 1: Draft of use cases of the Hilti X-IE Fastener (Left: curtain walling; Right: perimeter)

The lengths of the sleeve are variable depending on the insulation thickness. The length of the powder-actuated fastener is constant at 62 mm. The diameter of the disc is 60 mm for the X-IE 6 and 90 mm for the X-IE 9. The study looks at Hilti X-IE 6 and X-IE 9 fasteners for insulation thicknesses from 60 mm to 200 mm.

Annex 1 shows details of the sleeve and fastener.

2.3. Boundary conditions and model for analysis

The boundary conditions are adjusted to application in perimeter insulation in soil and the application in insulation of curtain walling, adhering the regulations of ISO 6946[2]:

Boundary conditions for perimeter application:

θ_i = 20°C R_{si} = 0.13 m²K/W (model boundary to interior)

θ_e = 5°C R_{se} = 0 m²K/W (model boundary to exterior)

Boundary conditions for curtain walling application:

θ_i = 20°C R_{si} = 0.13 m²K/W (model boundary to interior)

θ_e = -5°C R_{se} = 0.13 m²K/W (model boundary to exterior)

The numerical analysis is done by solving the three-dimensional temperature field by means of finite elements method. A representative part of the system is considered for the modelling.

In the 3D-model, the fastener is attached in a construction deviating from the reference construction in EOTA TR 0-25 to match the fields of application of the Hilti X-IE:

The insulation layer of varying thickness on a 175 mm concrete wall substrate with 10 mm interior plaster and is not furnished with exterior plaster.

[2] DIN EN ISO 6946:2008-04 „Thermal resistance and thermal transmittance – calculation method"

2.4. Material properties

The thermal design values used are taken from DIN EN ISO 6946 and DIN EN ISO 10456.[3)4)] Thermal properties of air cavities are determined acc. to DIN EN ISO 6946.

Thermal conductivities used are listed in Table 2.

Table 2: Design values of thermal conductivity

Item	Material	Design value of thermal conductivity λ W/(m·K)
Expansion pin	Carbon steel	50
Fastener / plug (variable in length)	High density polyethylene	0.50
Insulation layer	thermal insulation material	0.035
Interior plaster	gypsum based plaster	0.57
Wall substrate	concrete (use category A)	2.3

[3] DIN EN ISO 10456:2010-05 „ Hygrothermal properties – Tabulated design values and procedures for determining declared and design thermal values "
[4] DIN EN ISO 6946:2008-04 „Thermal resistance and thermal transmittance – calculation method"

3. Conduction of numerical analysis

The calculations is conducted for the Hilti X-IE 9 fastener in 6 different in lengths / insulation thicknesses. The items and associated Hilti drawing numbers are given in the table below:

Table 3: Item and drawing numbers for Hilti X-IE 9

item designation	item number	assembly drawing	plastic part drawing	pin drawing
X-IE 9-60 BK	2041746	5077325/04	5129933/03	324473/08
X-IE 9-70 BK	*	5077325/04	5129933/03	324473/08
X-IE 9-100 BK	2041749	5077325/04	5077183/04	324473/08
X-IE 9-120 BK	2041750	5077325/04	5077183/04	324473/08
X-IE 9-140 BK	2041751	5073703/04	5073630/03	324473/08
X-IE 9-200 BK	2041754	5073703/04	5073630/03	324473/08

*) *currently not sold*

Because of geometric equalities of the fasteners Hilti X-IE 6 and Hilti X-IE 9, the results of calculation of Hilti X-IE 9 can also be applied for the Hilti X-IE 6. The corresponding items and drawing numbers are shown in the table below:

Table 4: Item and drawing numbers for Hilti X-IE 6

item designation	item number	assembly drawing	plastic part drawing	pin drawing
X-IE 6-60	2041719	5077325/04	5129673/02	324473/08
X-IE 6-70	2041740	5077325/04	5129673/02	324473/08
X-IE 6-100	2041744	5077325/04	5030806/06	324473/08
X-IE 6-120	2041745	5077325/04	5030806/06	324473/08
X-IE 6-140	2041393	5073701/04	5067128/05	324473/08
X-IE 6-200	2041396	5073701/04	5067128/05	324473/08

The correction values χ per plastic anchor (= point thermal transmittance) are calculated from the comparison of thermal transmittance for the whole system with and without plastic anchor.

$$\chi = \frac{U_c - U}{n} \quad [W/K] \quad \text{and} \quad U_c = \frac{L^{3d}}{A} \; [W/(m^2 \cdot K)]$$

The substrates (wall materials) for anchors are described in ETAG 014 by five use categories (A to E). The point thermal transmittance has to be determined for the most unfavourable substrate (usually concrete) covered by the ETA of that anchor. Alternatively, the χ-value can be determined for each use category separately and is then denoted by an index (A to E) for the individual use category. Each use category covers all use categories with a lower thermal conductivity of the wall material. With normal weight concrete as substrate (use category A), the determined χ-value covers all use categories.

Note:

Within the scope of calculation procedures for the heating energy demand of buildings (e.g. according to ISO 13790), the determination of the transmission heat loss of building parts in contact with soil (external basement wall with perimeter insulation) a temperature correction factor is used to accommodate for the minor temperature difference of the external building elements in contact with soil. As usually these factors have to be applied to the thermal transmittance U and the linear thermal transmittance ψ and as well to the determined point thermal transmittance χ, because the calculations in this report do not include the thermal effects of the surrounding soil.

4. Results

The table below shows the results of calculation for the Hilti X-IE 6 and Hilti X-IE 9 with substrate of use category A as described in ETAG 014 (175 mm concrete wall) for the application in perimeter insulation and insulation in curtain wallings.

Table 5: Results of calculation for Hilti X-IE 6 and Hilti X-IE 9

insulation thickness h [mm]	χ [W/K]	
	perimeter	curtain walling
60	0.00212	0.00152
70	0.00171	0.00128
100	0.00113	0.00091
120	0.00096	0.00079
140	0.00084	0.00072
200	0.00067	0.00059

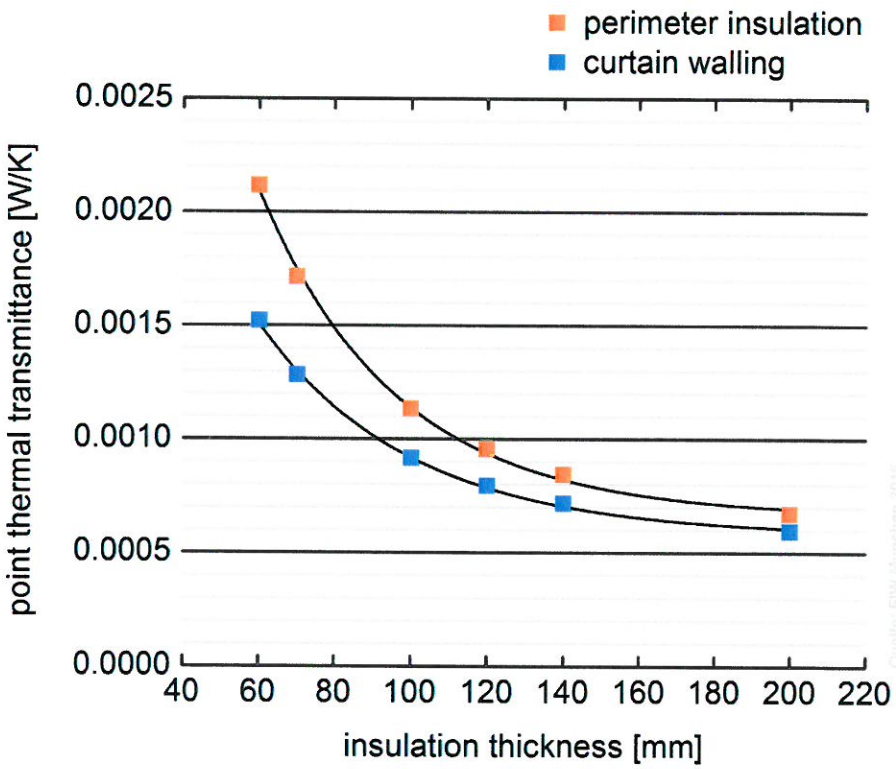

Figure 2: point thermal transmittance – results of calculation for Hilti X-IE 9

For comparative purposes, the thermal transmittance χ is additionally calculated for the Hilti X-IE 60 with boundary conditions strictly according to EOTA TR 025 (for application in external thermal insulation composite systems (ETICS)).

This calculation returns a value for χ of 0.00173 W/K.

In the case of 60 mm insulation thickness, the calculation with the modified boundary conditions for perimeter insulation gives 20 % higher values of thermal transmittance because of the omitted outdoor plaster and the increased heat transfer on the outer surface. The reduction of the heat flow due to the soil is taken into account by temperature correction factors. The calculation with boundary conditions for curtain wallings on the other hand results in ~ 10 % lower values, because of the increased surface resistance on the exterior surface of 0.13 $(m^2 \cdot K)/W$.

5. Classification

Adhering to the regulations of EOTA TR 025, the Hilti X-IE 9 and Hilti X-IE 6 the following nominal values of point thermal transmittance are determined as shown in Table 6 and Table 7.

Table 6: nominal value of point thermal transmittance for application in perimeter insulation

Product / application	Nominal value of point thermal transmittance
Hilti X-IE 6 and Hilti X-IE 9 in perimeter insulation	χ (60 mm) 0.003
	χ (70 mm – 100 mm) 0.002
	χ (120 mm – 200 mm) 0.001

Table 7: nominal value of point thermal transmittance for application in curtain wallings

Product / application	Nominal value of point thermal transmittance
Hilti X-IE 6 and Hilti X-IE 9 in insulation of curtain walling	χ (60 mm – 90 mm) 0.002
	χ (100 mm – 200 mm) 0.001

6. Liability

The calculation results are valid only for the listed materials, properties and dimensions. The aforementioned analysis is based on the current knowledge from research in thermal transport. Liability can only be accepted within the scope of this knowledge. Warranty for analysis results and expert opinions of FIW München e.V. is limited to the limitations of claim in § 634a BGB for buildings.

Gräfelfing, 23 November 2016

Dipl.-Ing. Christoph Sprengard

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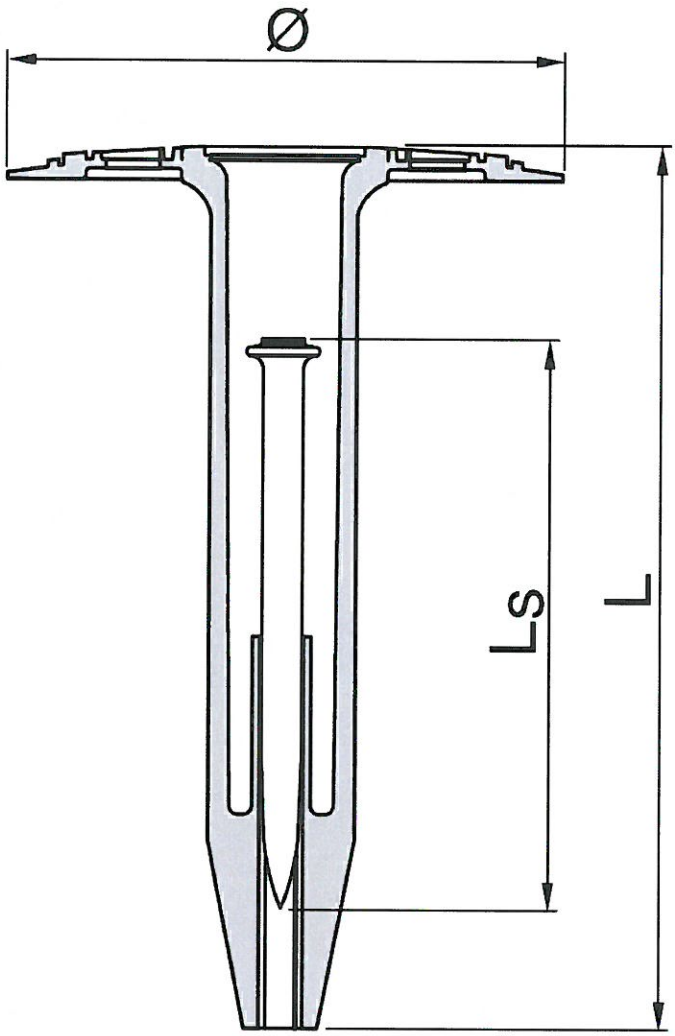
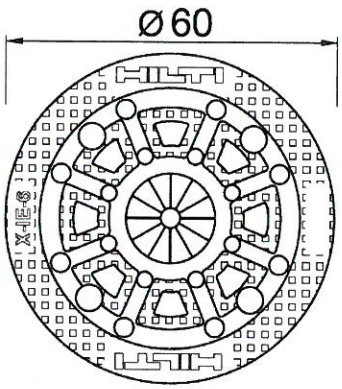
Max Engelhardt B.Eng.

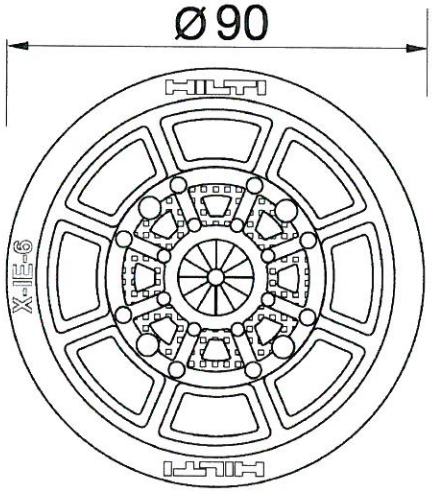
Annex 1: Drawing of the Hilti X-IE 6 and X-IE 9 fixing element with carbon steel powder-actuated fastener.



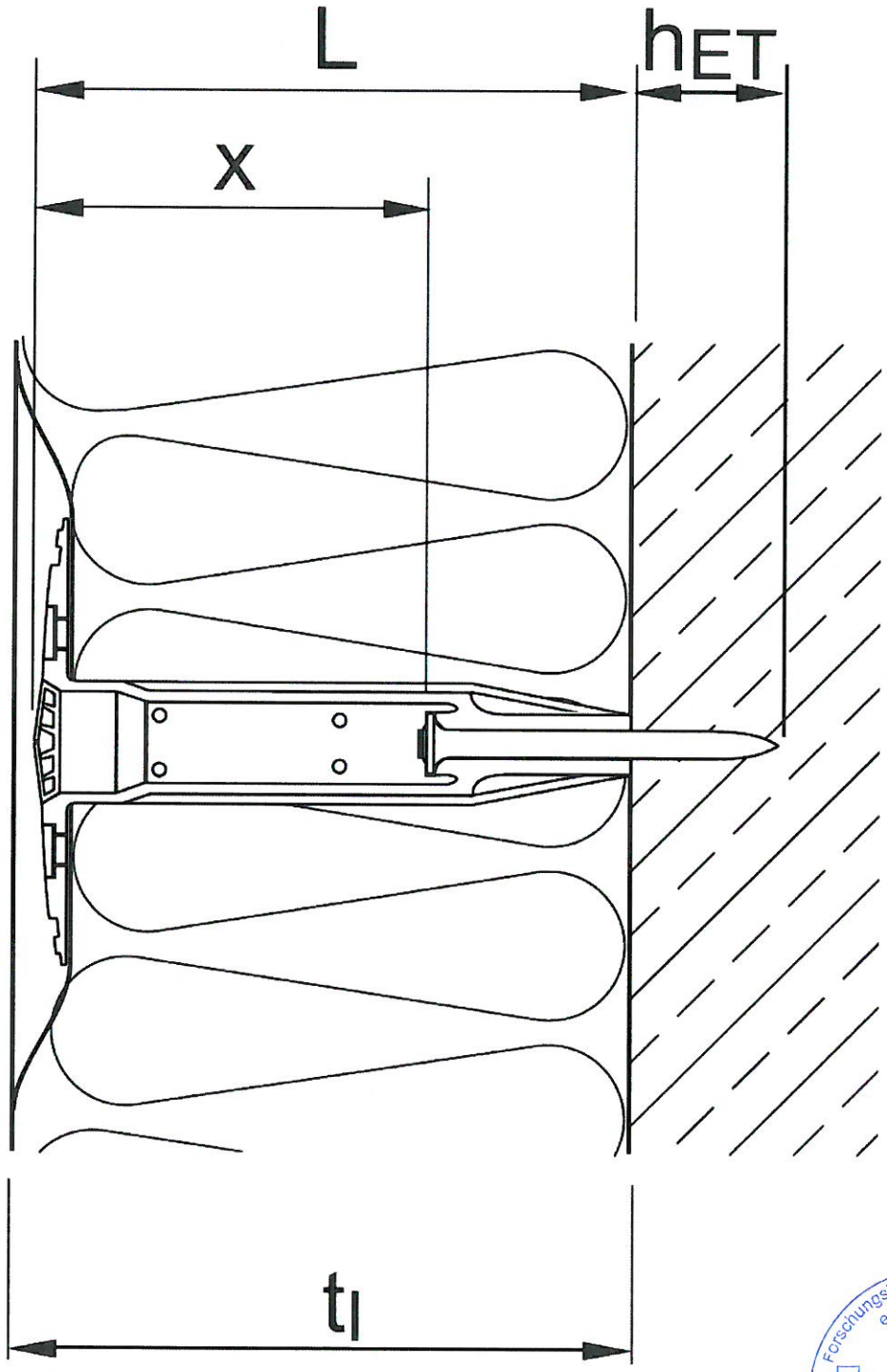
X-IE 6



X-IE 9



Annex 2: Assembly drawing of the Hilti X-IE 6.



Annex 3: Model view and heat flux density graphic of Hilti X-IE 9 fastener (axial section) in 140 mm insulation at boundary conditions and model modifications for application in perimeter insulation.