Three-dimensional
Heat flow simulation
for the determination of

heat bridge loss coefficients of installation boxes in timber frame walls in studding construction

On behalf of the company

Kaiser GmbH & Co. KG

Ramsloh 4

D-58579 Schalksmühle

Documentation of the simulations

Note: This document is a third party translation.
Only the original German version of this document is legally valid.

1159-55 One-gang junction box ECON® Iso +

Author:
Adrian Muskatewitz, M.Eng.

June 2018

1 Introduction

On behalf of Kaiser GmbH & Co KG, the Passivhaus Institut Dr Wolfgang Feist determined the heat bridge loss coefficients of external sockets in timber frame walls in studding construction and the room-side surface temperatures. The exemplary wall structures provided by the client served as a reference wall structure for determining the heat losses. The client provided the necessary documents for this (see Annex).

Due to the possibility of dispensing with a separate heating system, passive houses place high demands on the quality of the components used. In addition to excellent heat insulation, high air tightness, highly efficient heat recovery and passive house windows, the absence of heat bridges in the thermal envelope is of outstanding importance for the function of the passive house.

2 Specifications for heat flow calculation

The calculations were carried out using the SOLIDO software from Physibel, Belgium. Table 1 lists the materials used in the calculation and their heat conductivities in conjunction with the colours selected for the illustration. Sources for the heat conductivities are the relevant standards and the data sheets provided by the manufacturer.

	Type	CEN-mle	Name	Rat.	Mesh [mm]	Grid	λ [W/mK]
	MATERIAL		Stainless steel		100.00	NORMAL	17000
	MATERIAL		Wood 500 kg/m³		100.00	NORMAL	0130
	MATERIAL		Plasterboard		100.00	NORMAL	0250
	MATERIAL		Exterior plaster		100.00	NORMAL	0700
	MATERIAL		Cable - Replacement material		100.00	NORMAL	15000
	MATERIAL		Thermoplastic		100.00	NORMAL	0250
	MATERIAL		Thermowall		100.00	NORMAL	0042
	MATERIAL		Thermoflex		100.00	NORMAL	0033

Table 1- Materials used, heat conductivities and colour assignment

The following boundary conditions were applied:

Outdoor temperature: -10 °C
External heat resistance: 0.04 m^2K/W
Indoor temperature: 20 °C)
Internal heat resistance: 0.13 m^2K/W

Note: This document is a third party translation. Only the original German version of this document is legally valid.

3 Modelling

The system structures were modelled using three-dimensional models and working drawings provided by the manufacturer and translated into an FEM heat flow model. The different variants for the reference structure of the external wall were specified by the manufacturer. A total of three reference wall structures were analysed. These differ in terms of the insulation thickness of the regular insulation layer and the associated dimensional change of the stud frame, as well as the layer thickness of the soft wood fibreboard. These models have dimensions of h*w of 0.50 m * 1.20 m – the depth varies depending on the thickness of the insulation.

Bauteil Nr.	Bauteil-Bezeichnung
1	Holzständerwand

Wärmeübergangswiderstand [m²K/W]	
innen R_{si}:	0,13
außen R_{sa}:	0,04

	Teilfläche 1	λ [W/(mK)]	Teilfläche 2 (optional)	λ [W/(mK)]	Teilfläche 3 (optional)	λ [W/(mK)]	Summe Breite Dicke [mm]
1.	Gipskartonplatte	0,250					13
2.	Gutex Thermoflex	0,038	Fichte	0,130			200
3.	Gutex Thermowall	0,042					80
4.	Außenputz	0,700					10
5.							
6.							
7.							
8.							

Flächenanteil Teilfläche 2	Flächenanteil Teilfläche 3	Summe
14,0%		30,3 cm

U-Wert: 0,15946 W/(m²K)

Figure 1: Wall construction wooden wallboard - determination of the one-dimensional heat transfer coefficients (model 1)

Bauteil Nr.	Bauteil-Bezeichnung
2	Holzständerwand

Wärmeübergangswiderstand [m²K/W]	
innen R_{si}:	0,13
außen R_{sa}:	0,04

	Teilfläche 1	λ [W/(mK)]	Teilfläche 2 (optional)	λ [W/(mK)]	Teilfläche 3 (optional)	λ [W/(mK)]	Summe Breite Dicke [mm]
1.	Gipskartonplatte	0,250					13
2.	Gutex Thermoflex	0,038	Fichte	0,130			200
3.	Gutex Thermowall	0,042					60
4.	Außenputz	0,700					10
5.							
6.							
7.							
8.							

Flächenanteil Teilfläche 2	Flächenanteil Teilfläche 3	Summe
14,0%		28,3 cm

U-Wert: 0,17333 W/(m²K)

Figure 2: Wall construction timber stud wall - determination of the one-dimensional heat transfer coefficients (model 2)

3	Holzständerwand
Bauteil Nr.	Bauteil-Bezeichnung

Wärmeübergangswiderstand [m²K/W] innen R_{si}: 0,13
außen R_{sa}: 0,04

	Teilfläche 1	λ [W/(mK)]	Teilfläche 2 (optional)	λ [W/(mK)]	Teilfläche 3 (optional)	λ [W/(mK)]	Summe Breite Dicke [mm]
1.	Gipskartonplatte	0,250					13
2.	Gutex Thermoflex	0,038	Fichte	0,130			160
3.	Gutex Thermowall	0,042					60
4.	Außenputz	0,700					10
5.							
6.							
7.							
8.							

Flächenanteil Teilfläche 2: 14,0%
Flächenanteil Teilfläche 3:
Summe: 24,3 cm

U-Wert: 0,20140 W/(m²K)

Figure 3: Wall construction timber stud wall - determination of the one-dimensional heat transfer coefficients (model 3)

For the three-dimensional heat flow calculation, the model was divided into finite elements using a three-dimensional mesh. In the area of the penetrations, the mesh size of the net is 0.5 x 0.5 x 0.5 mm. It increases towards the edges of the model. The model comprises a total of approx. 685,000 nodes.

The heat bridge loss coefficients are calculated from the difference between the one-dimensional heat transfer Φ_{1D} of the undisturbed model (see Fig. 1 - 3) and the simulated heat flow of the wooden stand system with external socket Φ_{3D}.

Figure 4 shows the exemplary system structure as a modelled FEM simulation model.

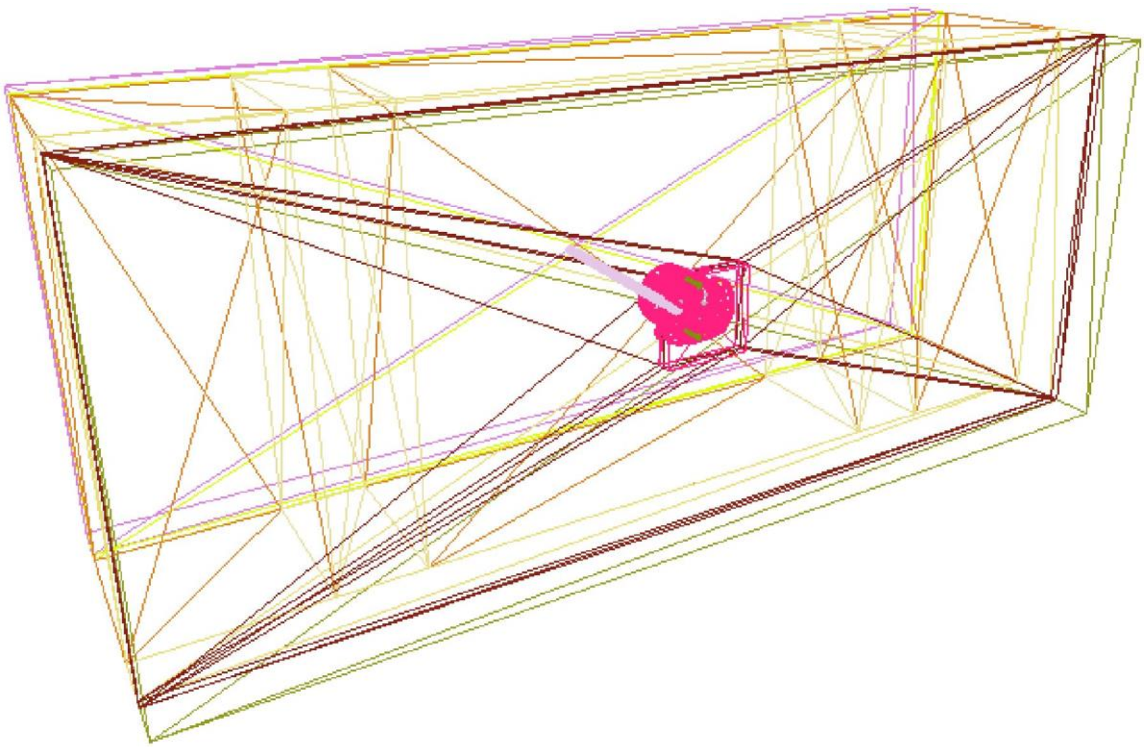


Figure 4 - Exemplary model structure

Note: This document is a third party translation. Only the original German version of this document is legally valid.

4 Results of the heat flow simulation

The results of the heat flow simulation are documented below. In addition to the heat bridge loss coefficients, the minimum surface temperatures T_{min} were also determined. These are determined at -10°C outside temperature and 20°C room temperature.

When using the ECON® Iso + one-gang junction box in accordance with the manufacturer's instructions, condensation on the room-side wall surface can be ruled out. Using the FEM simulation, an f_{Rsi} value of:

- 0.89 (16.71 °C) with an insulation thickness of 200 mm and a soft wood fibreboard thickness of 80 mm
- 0.89 (16.69 °C) with an insulation thickness of 200 mm and a soft wood fibreboard thickness of 60 mm
- 0.87 (16.27 °C) with an insulation thickness of 160 mm and a soft wood fibreboard thickness of 80 mm

are determined.

$$f_{Rsi} = \frac{\theta_{si} - \theta_e}{\theta_i - \theta_e}$$

With θ_{si}: Min. internal surface temperature from heat flow simulation [°C]

θ_e: Outdoor temperature from heat flow simulation [°C]

θ_i: Internal temperature from heat flow simulation [°C]

To determine the point heat bridge loss coefficients (χ_{WB}), the heat flow determined from the simulation models is compared with the one-dimensional specific transmission heat loss. The difference between the specific heat flows, including the temperature difference, results in the point heat bridge loss coefficient X_{WB} in W/K.

The following applies: $(U * A - \Phi_{3D}) / \Delta_T$

With:

- U = Heat transfer coefficient of the outer wall [W/(m^{2}K)]
- A = Reference area [m^2]
- Φ_{3D} = Heat flow simulation [W/K]
- Δ_T = Temperature difference [K]

200 mm insulation thickness + 80 mm HWFP	hsi = 7.69, hse = 25
T_i [°C]	20.0
T_a [°C]	-10.0
Model height [m]	0.50
Model width [m]	1.20
$\Phi_{Solido, WB}$ [W/K]	3.03044
$T_{min, WB}$ [°C]	16.71
U_{Wall} [W/(m²K)]	0.1595
χ_{WB} [W/K]	0.00534
Φ0 [W/K]	2.87028

Table 2 - Overview of results for model 1

200 mm insulation thickness + 60 mm HWFP	hsi = 7.69, hse = 25
T_i [°C]	20.0
T_a [°C]	-10.0
Model height [m]	0.50
Model width [m]	1.20
$\Phi_{Solido, WB}$ [W/K]	3.28462
$T_{min, WB}$ [°C]	16.69
U_{Wall} [W/(m²K)]	0.1733
χ_{WB} [W/K]	0.00549
Φ0 [W/K]	3.11994

Table 3 - Overview of results for model 2

160 mm insulation thickness + 60 mm HWFP	hsi = 7.69, hse = 25
T_i [°C]	20.0
T_a [°C]	-10.0
Model height [m]	0.50
Model width [m]	1.20
$\Phi_{Solido, WB}$ [W/K]	3.79076
$T_{min, WB}$ [°C]	16.27
U_{Wall} [W/(m²K)]	0.2014
χ_{WB} [W/K]	0.00552
Φ0 [W/K]	3.6252

Table 4 - Overview of results for model 3

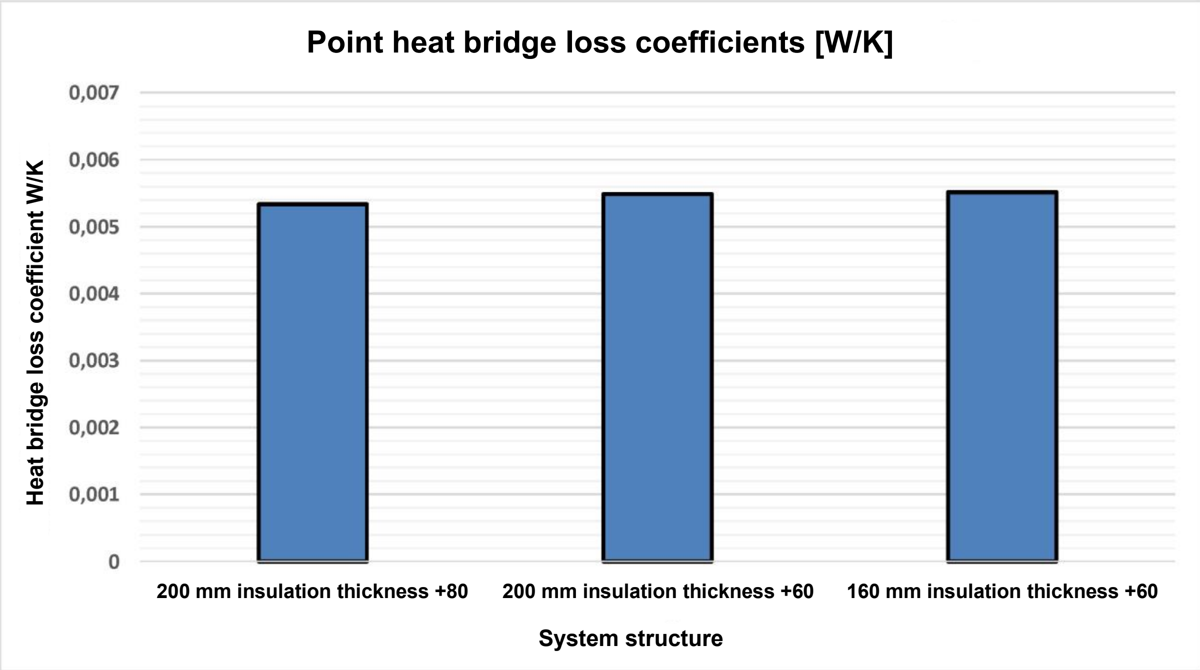


Figure 5 - Illustration of the point heat bridge loss coefficients

The isothermal representations and temperature curves are shown below.

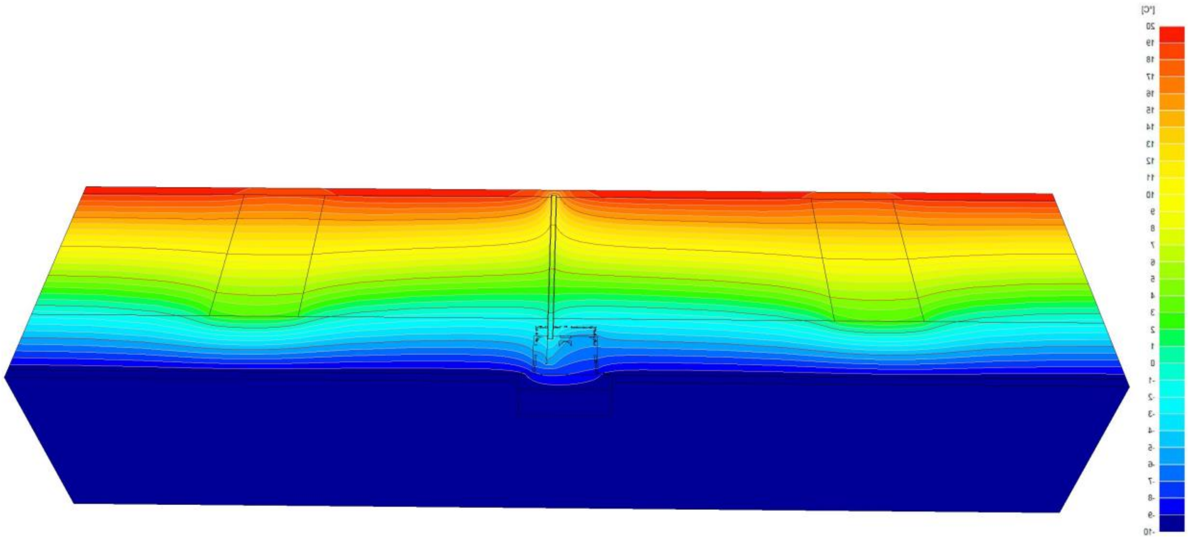


Figure 6 - Temperature curve and isotherm representation model 1

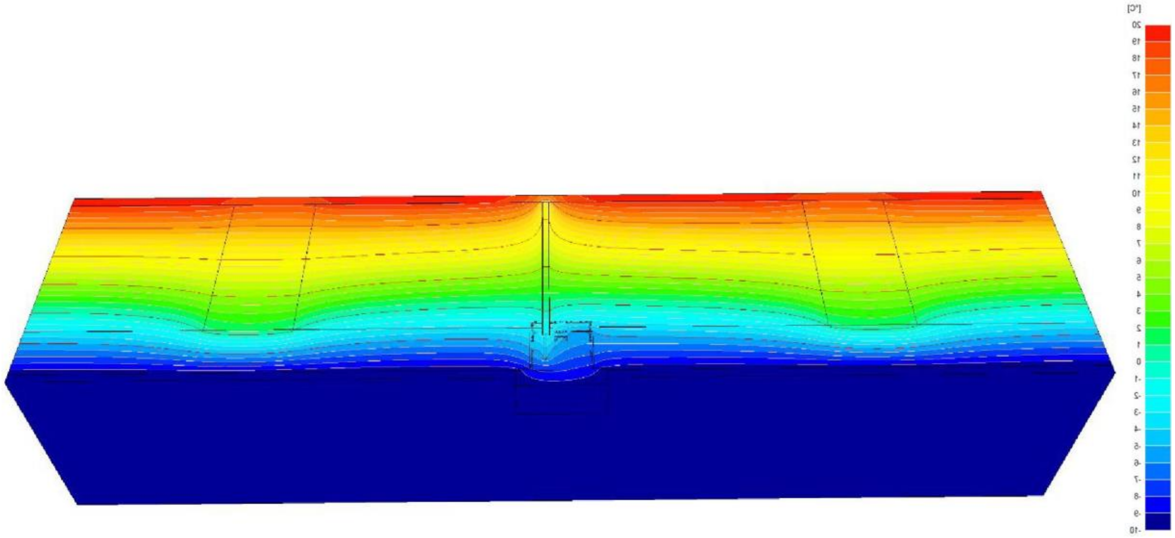


Figure 7 - Temperature curve and isotherm representation model 2

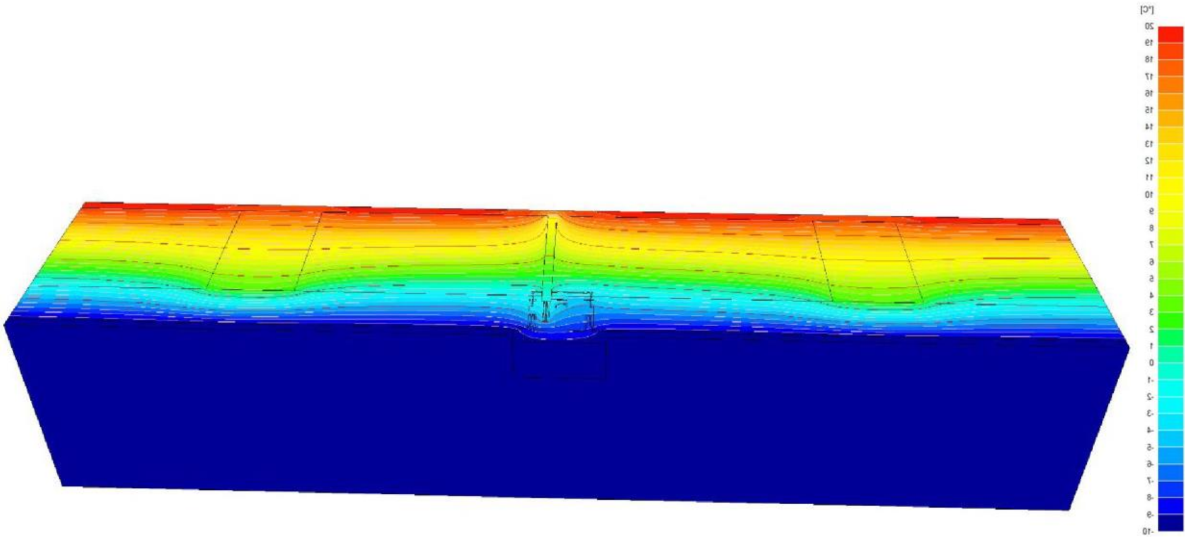


Figure 8 - Temperature curve and isotherm representation model 3

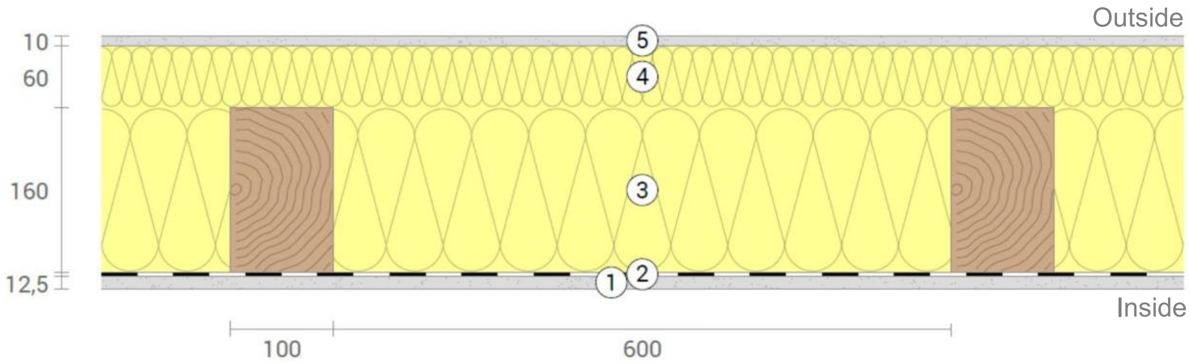
5 Summary

The ECON® Iso + one-gang junction box from Kaiser GmbH & Co. KG is a successful design with regard to the tested parameters. The additional heat losses due to the constructive heat bridge are negligible or can be compensated for in the order of approx. 0.005 W/K, even in the high-energy new building segment, and are also suitable for use in passive houses. The energy balance should be taken into account if a relatively high number of installation boxes are installed and if coupling effects are to be expected due to changes in cable routing. The heat bridge loss coefficients increase with reduced heat conductivity of the regular insulation level. Room-side surface condensation and cold air drop due to low surface temperatures can also be ruled out for the analysed structure. The surface temperatures at -10°C outside temperature are approx. 16.8 °C at the coldest point.

Note: This document is a third party translation. Only the original German version of this document is legally valid.

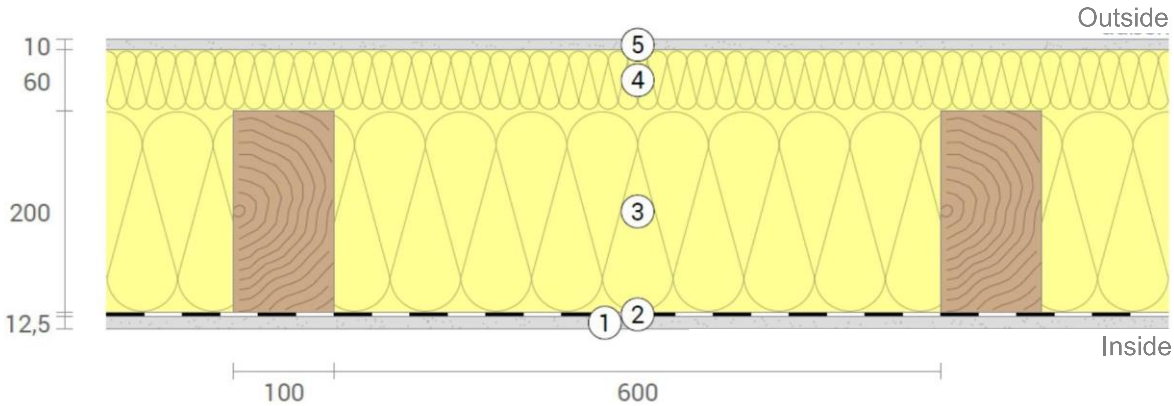
6 Annex

Reference wall constructions provided by the manufacturer:



① Plasterboard panel (12.5 mm)
② pro clima INTELLO®
③ Gutex Thermoflex (160 mm)
④ Gutex Thermowall (60 mm)
⑤ Exterior plaster (10 mm)

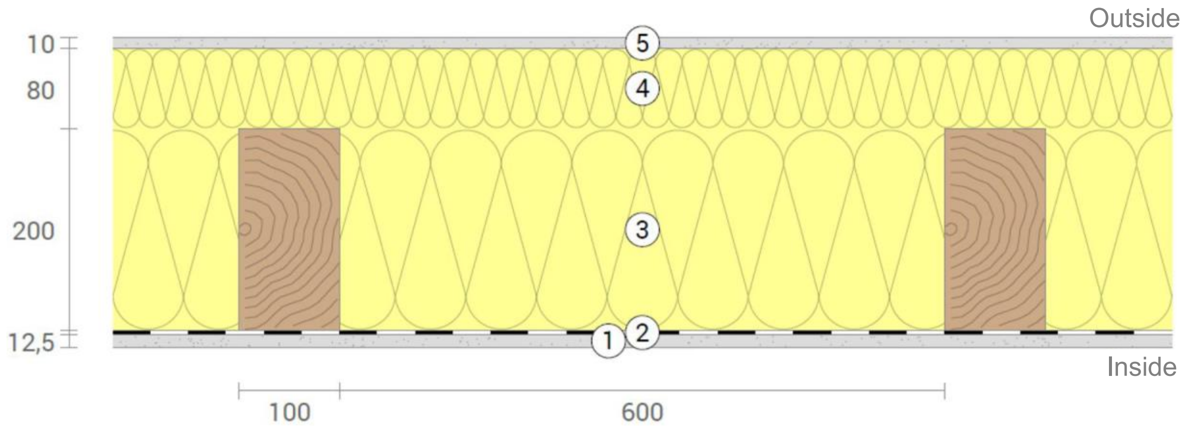
Figure 9 - Reference structure 1



① Plasterboard panel (12.5 mm)
② pro clima INTELLO®
③ Gutex Thermoflex (200 mm)
④ Gutex Thermowall (60 mm)
⑤ Exterior plaster (10 mm)

Figure 10 - Reference structure 2

Note: This document is a third party translation. Only the original German version of this document is legally valid.



① Plasterboard panel (12.5 mm)
② pro clima INTELLO®
③ Gutex Thermoflex (200 mm)
④ Gutex Thermowall (80 mm)
⑤ Exterior plaster (10 mm)

Figure 11 - Reference structure 3

Note: This document is a third party translation. Only the original German version of this document is legally valid.