Three-dimensional
heat flow simulation
for the determination of

heat bridge loss coefficients of installation housings in composite thermal insulation systems

On behalf of the company

KAISER GmbH & Co. KG

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Germany

Brief expert report on the simulation

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March 2017

1 Introduction

On behalf of Kaiser GmbH & Co. KG, the Passivhaus Institut Dr Wolfgang Feist determined the heat bridge loss coefficients and the room-side surface temperatures of installation housings in external composite thermal insulation systems. A composite thermal insulation system served as a reference wall structure for determining the heat losses. The reference model used represents a system structure to be found for the installation housing type. The client provided the necessary documents for this purpose.

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-rule	Name	Pat.	Mesh	λ [W/mK]	ε [-]	θ [°C]	h [W/m²K]
	MATERIAL		HIPS		100.00	0.220			
	MATERIAL		Heat insulation		100.00	0.032			
	MATERIAL		Glass		100.00	1.000			
	MATERIAL		Screw		100.00	17.000			
	MATERIAL		Interior plaster		100.00	0.510			
	MATERIAL		Exterior plaster		100.00	0.700			
	MATERIAL		Screed		100.00	1.400			
	MATERIAL		Impact sound insulation		100.00	0.060			
	MATERIAL		Reinforced concrete		100.00	2.300			
	MATERIAL		Cable_eq		100.00	15.000			
	MATERIAL		Wood		100.00	0.130			
	MATERIAL		NEOPOR		100.00	0.032			
	BC_SIMPL	NIHIL	BCE		100.00			-10.0	25.00
	BC_SIMPL	NIHIL	BCI - HFhorizontal		100.00			20.0	7.69
	BC_SIMPL	NIHIL	BCI - HFvertical		100.00			20.0	6.00
	MATERIAL		Dowel		100.00	0.270			
	MATERIAL		Air		100.00	0.100			
	MATERIAL		Air		100.00	0.040			
	MATERIAL		EQ		100.00	5.000			

Table 1: Materials used, heat conductivities and colour coding

The following boundary conditions were applied:

Outdoor temperature:	-10 °C
External heat resistance:	0.04 m²K/W
Indoor temperature:	20 °C
Internal heat resistance:	0.13 m²K/W
Vertical heat resistance:	0.17 m²K/W

3 Modelling

The installation housings in composite thermal insulation systems were converted into a calculation model required for the FEM heat flow simulation using a three-dimensional drawing model provided and inserted into the model of a façade structure with an composite thermal insulation system.

Bauteil Nr. 1 – Bauteil-Bezeichnung: Standard-WDVS

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

	Teilfläche 1	λ [W/(mK)]	Teilfläche 2 (optional)	λ [W/(mK)]	Teilfläche 3 (optional)	λ [W/(mK)]	Summe Breite Dicke [mm]
1.	Innenputz	0,600					15
2.	Stahlbeton	2,300					175
3.	Dämmung	0,032					160
4.	Außenputz	0,700					15
5.							
6.							
7.							
8.							

Flächenanteil Teilfläche 2: – Flächenanteil Teilfläche 3: – Summe: 36,5 cm

U-Wert: 0,18912 W/(m²K)

Bauteil Nr. 2 – Bauteil-Bezeichnung: Standard-WDVS

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

	Teilfläche 1	λ [W/(mK)]	Teilfläche 2 (optional)	λ [W/(mK)]	Teilfläche 3 (optional)	λ [W/(mK)]	Summe Breite Dicke [mm]
1.	Innenputz	0,600					15
2.	Stahlbeton	2,300					175
3.	Dämmung	0,032					100
4.	Außenputz	0,700					15
5.							
6.							
7.							
8.							

Flächenanteil Teilfläche 2: – Flächenanteil Teilfläche 3: – Summe: 30,5 cm

U-Wert: 0,29304 W/(m²K)

Figure 1: ETICS wall constructions – determination of the one-dimensional heat transfer

Bauteil Nr.	Bauteil-Bezeichnung
3	Standard-WDVS Deckenaufbau

Wärmeübergangswiderstand [m²K/W] innen R_{si}: 0,16 | außen R_{se}: 0,04

	Teilfläche 1	λ [W/(mK)]	Teilfläche 2 (optional)	λ [W/(mK)]	Teilfläche 3 (optional)	λ [W/(mK)]	Summe Breite Dicke [mm]
1.	Holzboden	0,130					25
2.	Estrich	1,400					60
3.	Trittschalldämmung	0,060					30
4.	Stahlbeton	2,300					175
5.	Dämmung	0,032					160
6.	Außenputz	0,700					15
7.							
8.							

Flächenanteil Teilfläche 2: – | Flächenanteil Teilfläche 3: – | Summe: 46,5 cm

U-Wert: 0,16576 W/(m²K)

Bauteil Nr.	Bauteil-Bezeichnung
4	Standard-WDVS Deckenaufbau

Wärmeübergangswiderstand [m²K/W] innen R_{si}: 0,16 | außen R_{se}: 0,04

	Teilfläche 1	λ [W/(mK)]	Teilfläche 2 (optional)	λ [W/(mK)]	Teilfläche 3 (optional)	λ [W/(mK)]	Summe Breite Dicke [mm]
1.	Holzboden	0,130					25
2.	Estrich	1,400					60
3.	Trittschalldämmung	0,060					30
4.	Stahlbeton	2,300					175
5.	Dämmung	0,032					100
6.	Außenputz	0,700					15
7.							
8.							

Flächenanteil Teilfläche 2: – | Flächenanteil Teilfläche 3: – | Summe: 40,5 cm

U-Wert: 0,24052 W/(m²K)

Figure 2: ETICS ceiling structures – determination of the one-dimensional heat transfer

For the three-dimensional heat flow calculation, the model was divided into finite elements using a three-dimensional mesh. In the area of the installation housing, 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. 6,100,000 nodes.

The various installation housings are modelled with the reference wall structures and their point heat bridge loss coefficient (X_{WB} in W/K) is calculated. 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 - ETICS), or the heat flow from the undisturbed model, and the simulated heat flow of the composite thermal insulation system with installation housing Φ_{3D}.

Figure 3 shows the housing model as a modelled FEM simulation model.

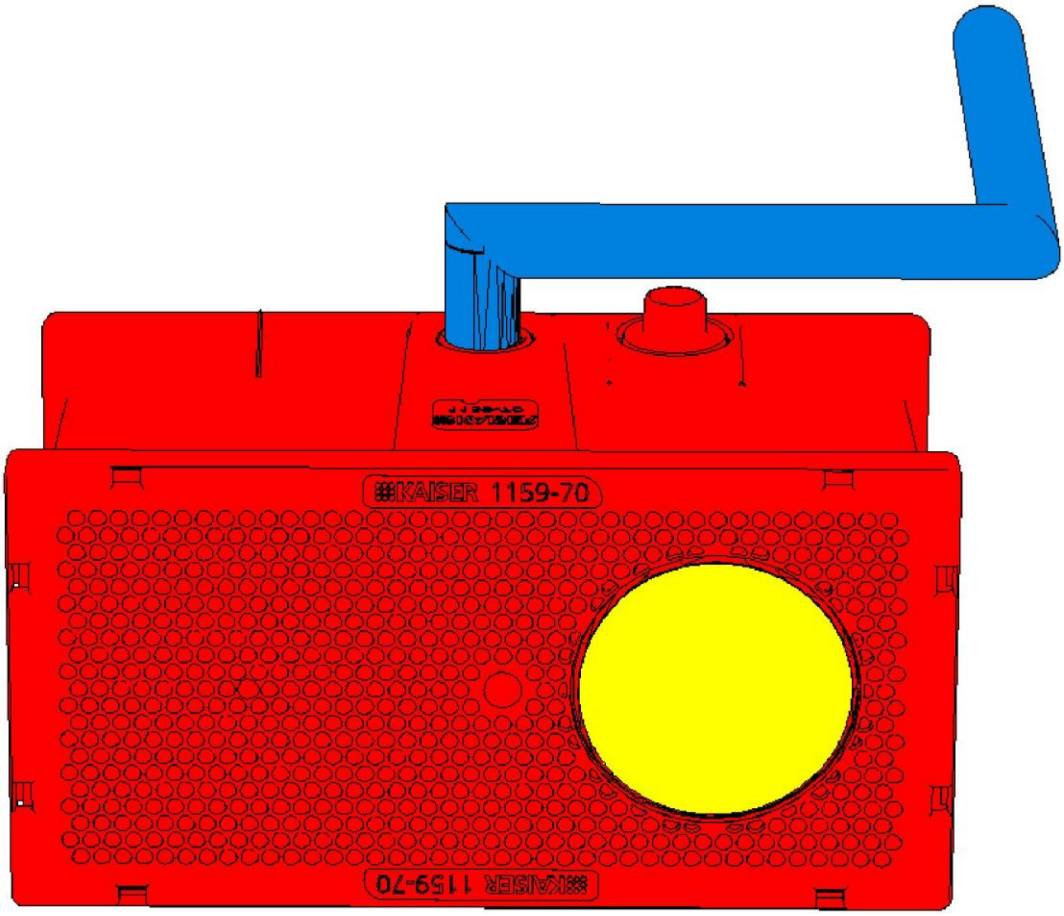

Figure 3: Calculation model for installation housing in composite thermal insulation system

4 Results

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 operative room temperature.

If the light is used in the installation housing in accordance with the manufacturer's instructions, condensation or an increased risk of mould on the room-side surface can be ruled out. Using the FEM simulation, an f_{Rsi} value of 0.97 was determined for an insulation thickness of 160 mm. With 100 mm insulation thickness of the regular insulation, the f_{Rsi} value is 0.96.

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

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

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

The heat bridge loss coefficients were determined in a thermal insulation composite system with an insulation layer that has a heat conductivity of 0.032 W/mK. If the heat conductivity of the regular insulation layer is lower, the heat bridge loss coefficients increase.

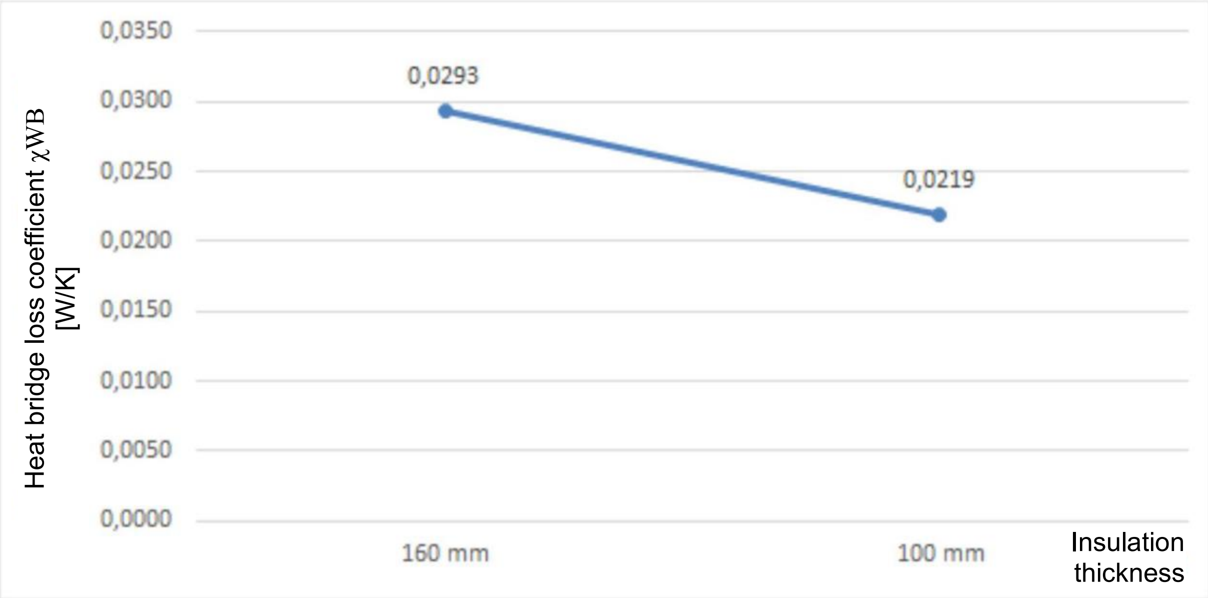

Diagram 1: Overview of the results of the FEM simulation

Note: Heat bridge loss coefficients for insulation thicknesses between 100 mm and 160 mm can be roughly taken from the diagram.

SOLIDO - Calculation Results

SOLIDO data file: 160_opt.sld

Number of nodes = 3635602
Heat flow divergence for total object = 6.27527e-009
Heat flow divergence for worst node = 200

Col.	Type	Name	tmin [°C]	Node	tmax [°C]	Node
4	MATERIAL	HIPS	-10.04366	263396	16.57837	187188
6	MATERIAL	Heat insulation	-9.71980	63457	18.69229	18386
7	MATERIAL	Glass	-8.24220	2723634	-7.53927	2237817
11	MATERIAL	Screw	15.41272	1759340	16.30406	1778739
20	MATERIAL	Interior plaster	19.00848	2347370	19.53744	19218
44	MATERIAL	Exterior plaster	-9.83452	64308	-7.49681	1624377
79	MATERIAL	Screed	18.49609	2194071	19.65599	19242
101	MATERIAL	Impact sound insulation	16.55509	2097867	19.62175	19241
104	MATERIAL	Reinforced concrete	15.80685	1797405	19.42998	19230
106	MATERIAL	Cable_eq	13.76520	1860978	17.17819	3556685
159	MATERIAL	Wood	18.65913	2174841	19.84227	19243
165	MATERIAL	NEOPOR	-3.69348	1334262	16.11366	166943
171	BC_SIMPL	BCE	-10.04366	263396	-7.76893	2547337
174	BC_SIMPL	BCI - HFhorizon	19.20445	2347508	19.53744	19218

175	BC_SIMPL	BCI - HFvertika	19.37693	2136356	19.84227	19243
181	MATERIAL	Dowel	15.80304	1778305	16.34549	1797983
192	MATERIAL	Air	-9.41695	116891	16.69784	1229982
193	MATERIAL	Air	-4.00652	1277104	16.60755	129459
200	MATERIAL	EQ	-6.01031	253236	-2.56476	3359203

Node	X	Y	Z
263396	400.00	546.25	562.20
187188	395.10	553.41	750.00
63457	300.00	482.50	590.00
18386	0.00	825.00	607.31
2723634	559.99	531.18	582.50
2237817	528.75	480.00	585.00
1759340	497.79	501.13	740.29
1778739	498.75	502.50	780.44
2347370	535.00	1000.00	747.82
19218	0.00	1250.00	735.00
64308	300.00	490.00	575.00
1624377	488.75	500.00	583.83
2194071	526.25	0.00	955.00
19242	0.00	1250.00	1015.00
2097867	520.00	0.00	925.00
19241	0.00	1250.00	955.00
1797405	500.00	497.50	750.00
19230	0.00	1250.00	750.00
1860978	503.61	548.75	726.83
3556685	636.36	584.62	884.73
2174841	525.00	0.00	1015.00
19243	0.00	1250.00	1040.00
1334262	470.00	486.25	720.22
166943	393.89	545.00	748.50
263396	400.00	546.25	562.20
2547337	548.75	500.00	582.50
2347508	535.00	1015.00	722.73
19218	0.00	1250.00	735.00
2136356	522.50	0.00	1040.00
19243	0.00	1250.00	1040.00
1778305	498.17	498.31	750.00
1797983	499.97	502.70	781.69
116891	390.76	445.31	584.14
1229982	462.76	588.75	750.00
1277104	466.25	491.25	719.04
129459	390.76	553.75	750.00
253236	400.27	457.91	589.11
3359203	600.77	541.25	719.04

Col.	Type	Name	ta [°C]	Flow in [W]	Flow out [W]
171	BC_SIMPL	BCE		0.00056	8.33197
174	BC_SIMPL	BCI - HFhorizon		5.22744	0.00000
175	BC_SIMPL	BCI - HFvertika		3.10390	0.00000

SOLIDO - Calculation Results

SOLIDO data file: 100_opt.sld

Number of nodes = 2644232
Heat flow divergence for total object = 0.000237157
Heat flow divergence for worst node = 0.996053

Col.	Type	Name	tmin [°C]	Node	tmax [°C]	Node

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4	MATERIAL	HIPS	-9.39332	96533	15.25927	159837
6	MATERIAL	Heat insulation	-9.53849	1474601	17.91506	12899
7	MATERIAL	Glass	-8.39476	1938965	-7.87590	1860251
11	MATERIAL	Screw	14.07774	1275013	14.95761	1288772
20	MATERIAL	Interior plaster	18.45705	1881656	19.28205	13623
44	MATERIAL	Exterior plaster	-9.69848	1365295	-7.63889	12809
79	MATERIAL	Screed	17.83644	1746460	19.46983	13649
101	MATERIAL	Impact sound insulation	15.04251	1651459	19.41676	13648
104	MATERIAL	Reinforced concrete	14.47414	1302027	19.11523	13635
106	MATERIAL	Cable_eq	12.22923	1346976	15.95936	2560633
159	MATERIAL	Wood	18.07104	1719333	19.75684	13650
165	MATERIAL	NEOPOR	-5.11733	973521	14.74434	145500
171	BC_SIMPL	BCE	-9.69848	1365295	-8.02552	1860249
174	BC_SIMPL	BCI - HFhorizon	18.75510	1922414	19.28205	13623
175	BC_SIMPL	BCI - HFvertika	19.10353	1732898	19.75684	13650
181	MATERIAL	Dowel	14.47156	1288475	14.99624	1302423
192	MATERIAL	Air	-9.32825	110282	15.41055	899289
193	MATERIAL	Air	-5.43949	810406	15.28575	118887
200	MATERIAL	EQ	-6.44100	206816	-4.05965	2407214

Node	X	Y	Z
96533	390.00	443.74	642.43
159837	395.10	553.41	750.00
1474601	516.25	362.00	650.00
12899	0.00	825.00	0.00
1938965	558.67	468.03	642.50
1860251	551.25	501.25	645.50
1275013	497.79	501.13	740.29
1288772	498.75	502.50	780.44
1881656	552.50	1000.00	746.56
13623	0.00	1250.00	735.00
1365295	506.25	346.00	635.00
12809	0.00	725.00	649.96
1746460	541.25	0.00	955.00
13649	0.00	1250.00	1015.00
1651459	532.50	0.00	925.00
13648	0.00	1250.00	955.00
1302027	500.00	497.50	750.00
13635	0.00	1250.00	750.00
1346976	503.61	548.75	726.83
2560633	632.99	586.67	884.73
1719333	538.75	0.00	1015.00
13650	0.00	1250.00	1040.00
973521	470.00	486.25	720.22
145500	393.89	545.00	748.50
1365295	506.25	346.00	635.00
1860249	551.25	501.25	642.50
1922414	556.25	1015.00	716.46
13623	0.00	1250.00	735.00
1732898	540.00	0.00	1040.00
13650	0.00	1250.00	1040.00
1288475	498.17	498.31	750.00
1302423	499.97	502.70	781.69
110282	390.76	445.26	644.16
899289	462.76	588.75	750.00
810406	455.00	495.00	719.04
118887	390.76	553.75	750.00
206816	400.27	457.91	649.11
2407214	600.77	541.25	719.04

Col.	Type	Name	ta [°C]	Flow in [W]	Flow out [W]
171	BC_SIMPL	BCE		0.00000	12.78671
174	BC_SIMPL	BCI - HFhorizon		8.24496	0.00000
175	BC_SIMPL	BCI - HFvertika		4.54145	0.00000

The following page shows the calculation models and the associated isotherm representations and temperature curves.

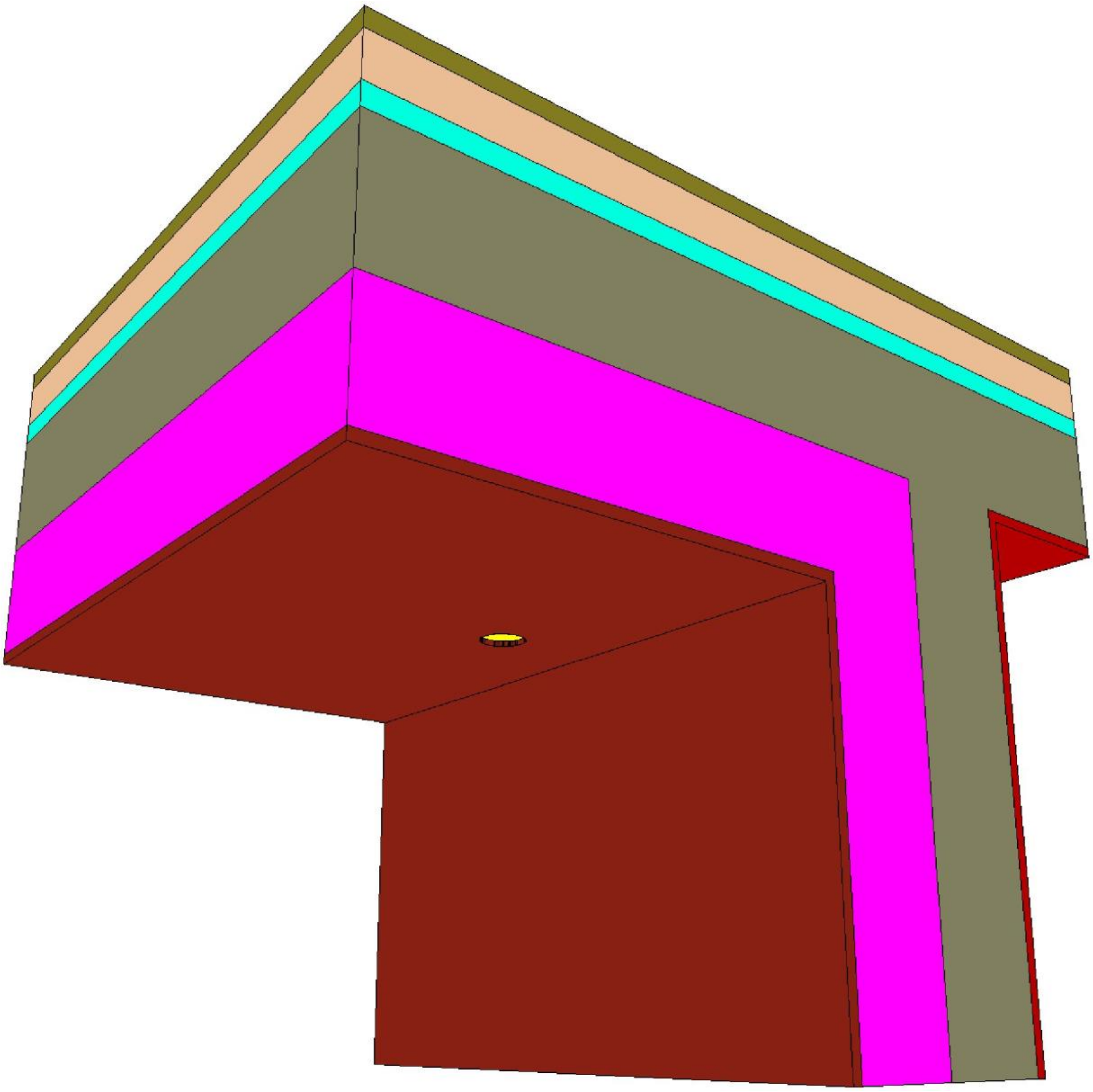
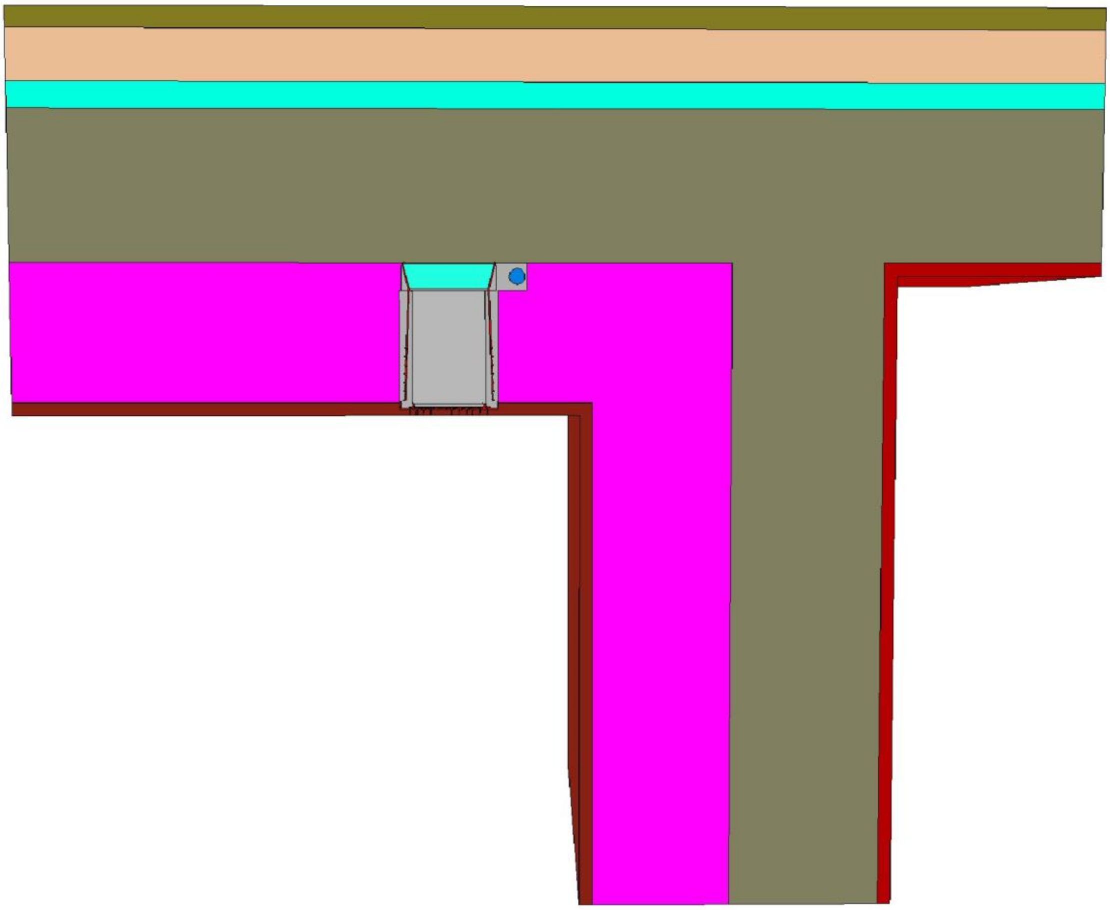


Figure 4: Model representation 160 mm insulation thickness



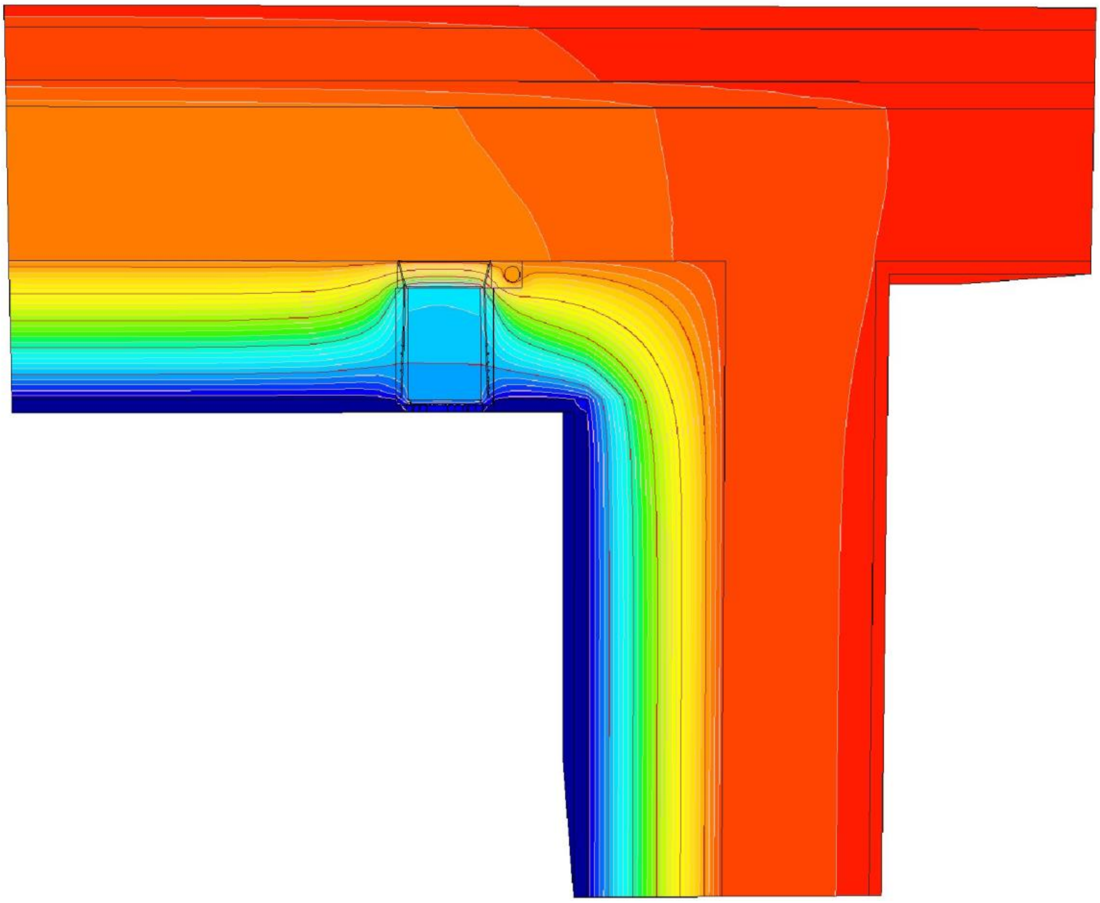


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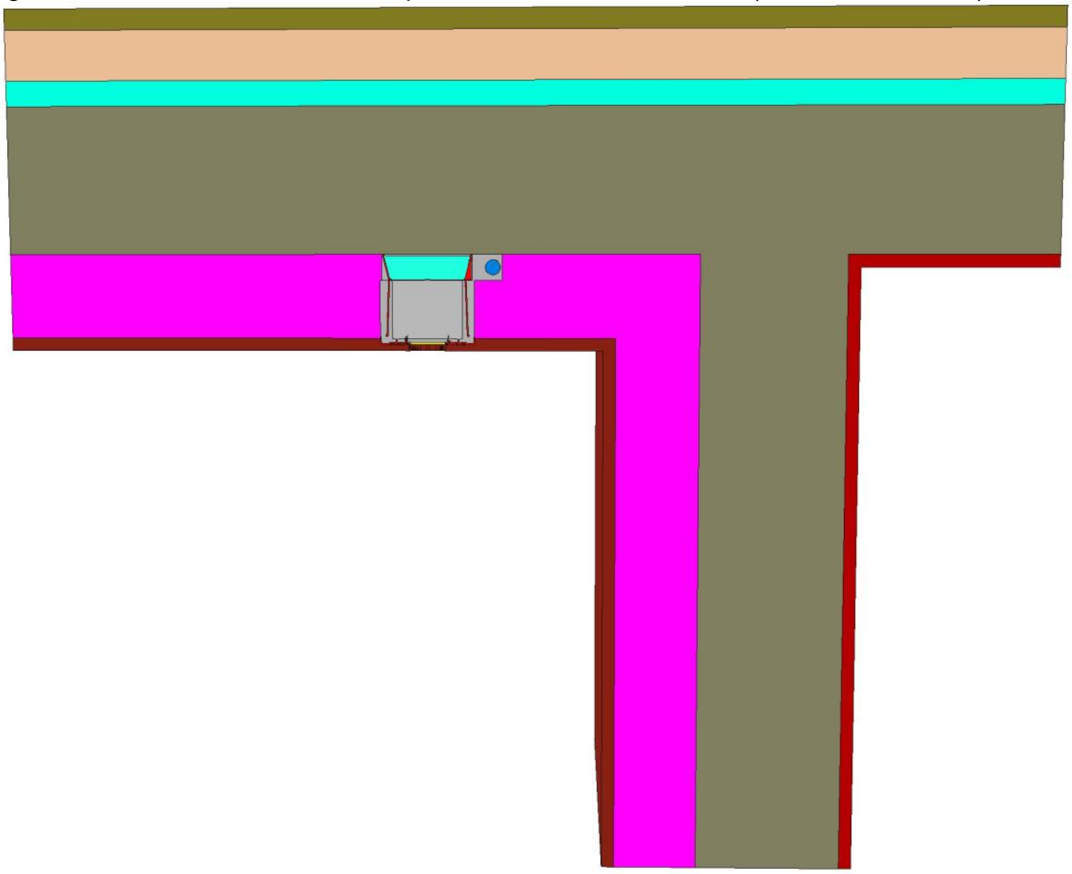
Figure 5: Material and isothermal representation, vertical section (160 mm insulation)



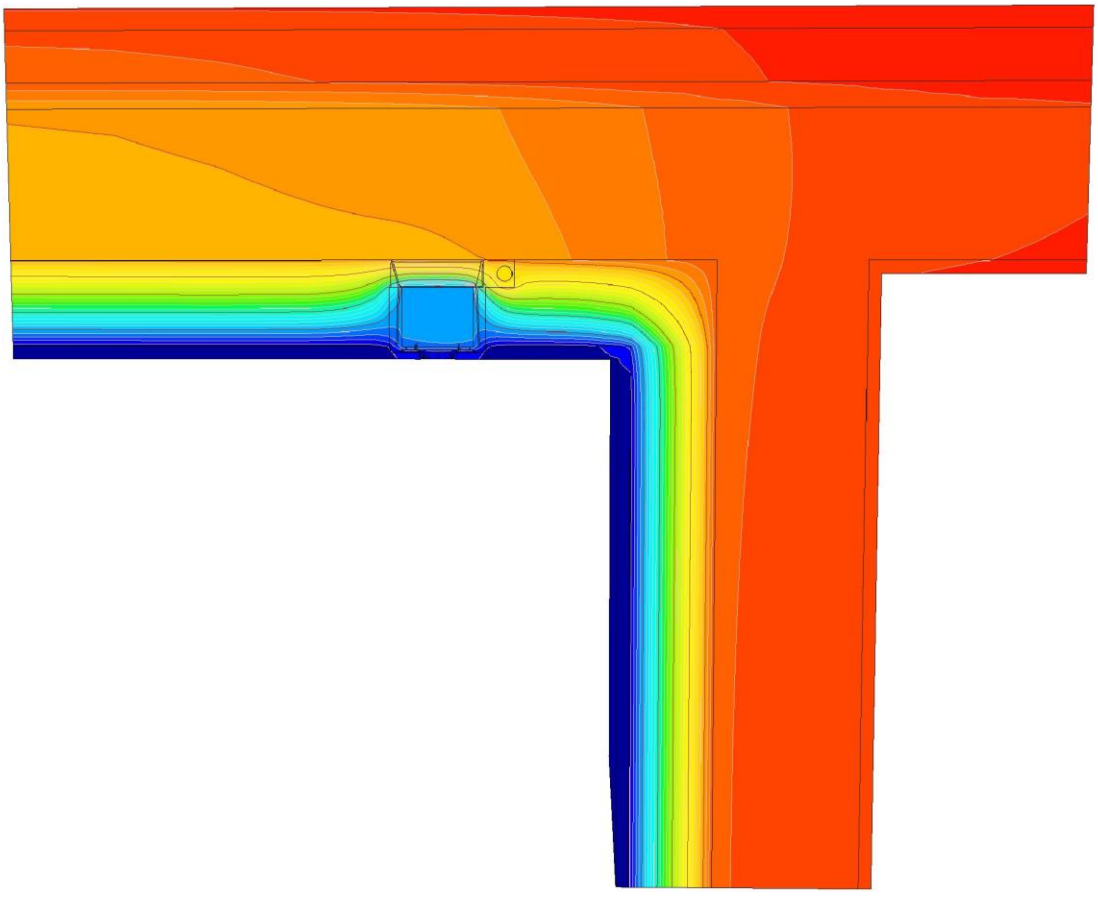


Figure 6: Material and isothermal representations, vertical section (100 mm insulation)

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KAISER 160 mm insulation thickness	**hsi = 7.69, hse = 25**
T_i [°C]	**20.0**
T_a [°C]	**-10.0**
$Q_{Solido, undisturbed}$ [W]	**7.45221**
$Q_{Solido, WB}$ [W]	**8.33197**
$T_{min, WB}$ [°C]	**19.20**
U_{Wall} [W/(m²K)]	**0.2484**
χ_{WB} [W/K]	**0.0293**
Ueq WB [W/(m²K)]	**0.2777**
Mod. 1 (end terraced house)	
Quantity	**60.00**
Σ additional losses [W/K]	**1.75952**
Area (AW to outside air) [m²]	**184.2**
ΔU [W/m²K]	**0.00955**
Limit value free of heat bridges [W/m²K]	**0.010**
Requirement fulfilled?	**Yes**
Mod. 2 (non-residential buildings)	
Quantity	**290.00**
Σ additional losses [W/K]	**8.504346667**
Area (AW to outside air) [m²]	**867.9**
ΔU [W/m²K]	**0.00980**
Limit value free of heat bridges [W/m²K]	**0.010**
Requirement fulfilled?	**Yes**

KAISER 100 mm insulation thickness	**hsi = 7.69, hse = 25**
T_i [°C]	**20.0**
T_a [°C]	**-10.0**
$Q_{Solido, undisturbed}$ [W]	**12.13059**
$Q_{Solido, WB}$ [W]	**12.78671**
$T_{min, WB}$ [°C]	**18.75**
U_{Wall} [W/(m²K)]	**0.4044**
χ_{WB} [W/K]	**0.0219**
Ueq WB [W/(m²K)]	**0.4262**
Mod. 1 (end terraced house)	
Quantity	**80.00**
Σ additional losses [W/K]	**1.749653333**
Area (AW to outside air) [m²]	**184.2**
ΔU [W/m²K]	**0.00950**
Limit value free of heat bridges [W/m²K]	**0.010**
Requirement fulfilled?	**Yes**
Mod. 2 (non-residential buildings)	
Quantity	**380.00**
Σ additional losses [W/K]	**8.310853333**
Area (AW to outside air) [m²]	**867.9**
ΔU [W/m²K]	**0.00958**
Limit value free of heat bridges [W/m²K]	**0.010**
Requirement fulfilled?	**Yes**

Table 1: Overview of the simulation results

5 Summary

The installation housing system from KAISER GmbH & Co. KG represents a successful design in terms of the tested parameters. The additional heat losses caused by the constructive heat bridge can also be compensated for in the high-energy new building segment and are also suitable for use in passive houses. They should nevertheless be taken into account in the energy balance, especially if a relatively large number of luminaires are installed. Room-side surface condensation and cold air drop due to low surface temperatures can also be ruled out according to the analysed structure. The surface temperatures are over 19 °C even at -10°C outside temperature. This almost corresponds to the surface temperature of the undisturbed wall.