

HEAT LEAKAGE AREAS (THERMAL BRIDGES)

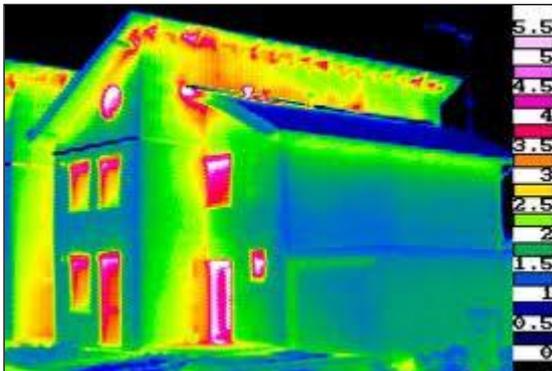
When insulating the outside shell of a building, the technical details of the construction must be known in order to determine possible heat leakage areas (thermal bridges). Warm air passes through such locations faster than the surrounding materials. Cold is the absence of heat. It is not the cold air coming inside, but rather the heat flowing outside.

Door and window openings are obvious heat leakage areas as these are usually less insulated than the walls. Other heat leakage areas can be:

1. The solid construction of an inside cross or shear wall with the outside supporting wall.
2. The connection of a concrete floor or roof that is supported on the cold outside wall.
3. The construction of a reinforced concrete or steel frame balcony from which the supports are connected to the inside wall.
4. Reinforced concrete or steel profile lintels over doors and windows.
5. Reinforced concrete or steel profile columns inside the wall construction.
6. Reinforced concrete or steel profile beams or columns supporting the roof and supported on the outside walls.

Reinforced concrete constructions or steel profiles that are connected to both the outside and inside of the shell construction have a low insulation value compared with other building materials and a very low insulation value compared to insulation materials.

Heat leakage areas (thermal bridges) can be made visible with an Infra Red camera placed outside during the winter when the house is heated.¹ Reducing heat leakage areas will reduce heat loss and save energy. The pictures below are only indicative.



The colour range shows to what extent heat is lost to the outside. In the first photo, the highest temperature (light pink) is seen at the windows. Yellow and green are the middle ranges.

The entire house is heated, but more heat loss occurs in the inside corner of the walls. Blue is a lower temperature, therefore less heat leakage.

The inclined roof is well insulated because the colour is dark blue.

The insulation under the roof line of the higher roof is poor, shown by the red colour. Here the cavity wall insulation apparently has settled down, creating a heat leak.

In the second photo, the low insulation value of the large window on the ground floor can be seen.

The warmth in the building rises and heats the first floor construction (ceiling of the ground floor).

Because the first floor construction is supported against/on the outside wall, that area shows a high heat loss to the outside.

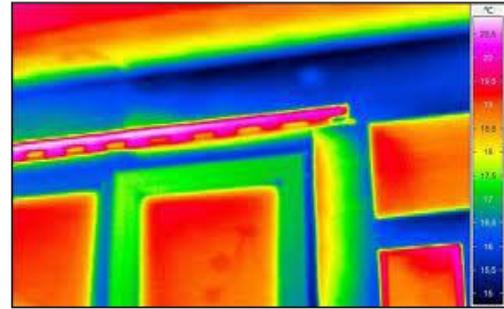
The inclined roof construction is insulated, but the area around the chimney and roof ridge is a heat leak, shown by the red colour.



¹ IR photography should be done perpendicular to the measured surface, without sun or wind (early morning), and with a temperature just above freezing point. The background temperature and material emissivity must be correctly entered.

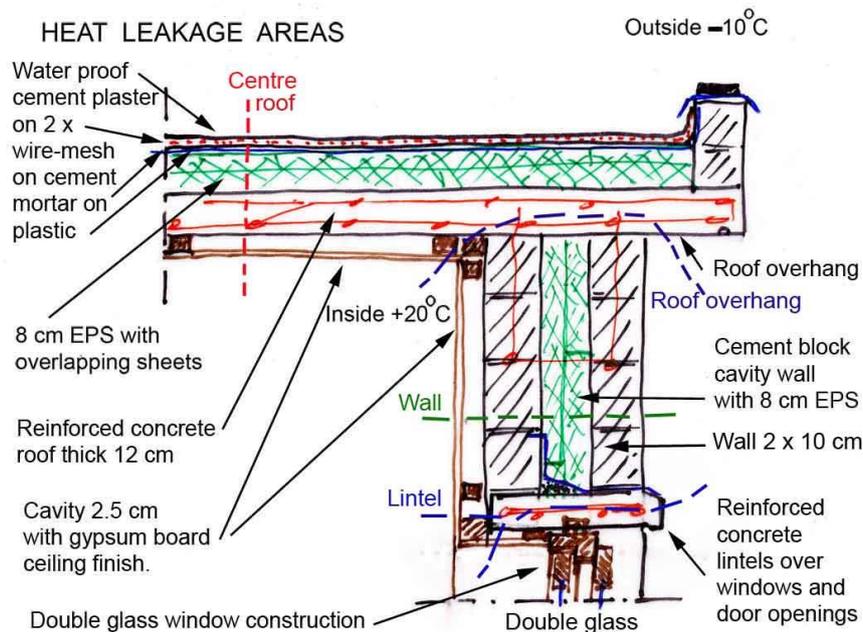
The wall (blue) and window frame (blue) with window construction shows the glass frame (green) being better insulated than the glass surface (red-orange).

Above the window, the supporting concrete or steel lintel construction is not insulated and the heat loss in this area is very large (pink). In this case, condensation can occur on the lintel above the window.



The same can be calculated before the construction is made. By calculating the possible heat loss areas, it can be avoided that condensation occurs inside the house. Condensation inside the construction may cause structural damage and reduce further the insulation value, while cold inner surfaces can be the cause of mould growing on the walls, ceilings and floors.

To illustrate the different temperature flows inside a construction, the following example has been analysed and calculation tables made for the various sections over the wall and roof.



Roof Centre (Red Line): Wire-mesh cement plaster (2 cm), EPS (8 cm), reinforced concrete (12 cm), cavity (2.5 cm), gypsum board (1 cm).					New Value	The humidity condensation point is determined with the Mollier diagram.		
Thickness x R _M = R _C						Temp from -10°C	Temperature Difference = R _C / TR _C x ΔT	Condensation with 60% Humidity
#	Description of the Existing Construction Layers	Thick Meter	R _M	R _C	Temp from -10°C	Temperature Difference = R _C / TR _C x ΔT	Condensation with 60% Humidity	With 90% Humidity
1	Outside transmission factor	-	-	0.04	-9.51	0.49		
2	Ferro-cement (wet)	0.02	0.6	0.012	-9.36	0.15	At 12°C	
3	EPS medium density	0.08	25	2.00	15.23	24.59		At 15°C
4	Reinforced concrete (dry)	0.12	0.6	0.072	16.11	0.88		
5	Cavity GBM-GBM	0.025	Black	0.16	18.08	1.96		
6	Gypsum board	0.01	6	0.06	18.81	0.74		
7	Inside transmission factor	-	-	0.10		1.23		
Value Total R_C				2.44	-20°C	ΔT=30°C		

Heat flow $\Lambda = 0.41 \text{ W/m}^2 \cdot \text{K} = 12.3 \text{ W/m}^2$ for 30°K.

Roof Overhang (Blue Line): Reinforced concrete (trajectory 35 cm), timber (2.5 cm), Gypsum board (1 cm). Thickness x $R_M = R_c$					New Value	The humidity condensation point is determined with the Mollier diagram.		
#	Description of the Existing Construction Layers	Thick Meter	R_M	R_c	Temp from -10°C	Temperature Difference= $R_c / TR_c \times \Delta T$	Condensation with 60% Humidity	With 90% Humidity
1	Outside transmission factor	-	-	0.04	-7.76	2.24		
2	Reinforced concrete (dry)	0.35	0.6	0.21	4.01	11.77		
3	Timber	0.025	5	0.125	11.02	7.01	At 12°C	
4	Gypsum board	0.01	6	0.06	14.38	3.36		At 15°C
5	Inside transmission factor	-	-	0.10		5.61		
Value Total R_c				0.535	-20°C	$\Delta T=30^\circ\text{C}$		

Heat flow $\Lambda = 1.87 \text{ W/m}^2.\text{K} = 56 \text{ W/m}^2$ for 30°K.

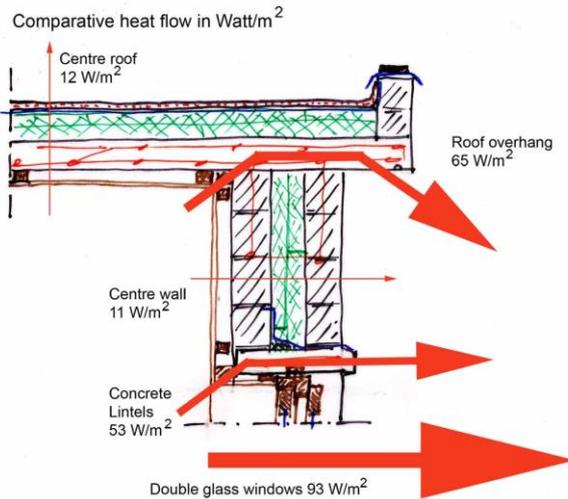
Wall (Green Line): Cement blocks (10 cm), EPS (8 cm) cement blocks (10 cm), cavity (2.5 cm), gypsum board (1 cm). Thickness x $R_M = R_c$					New Value	The humidity condensation point is determined with the Mollier diagram.		
#	Description of the Existing Construction Layers	Thick Meter	R_M	R_c	Temp from -10°C	Temperature Difference= $R_c / TR_c \times \Delta T$	Condensation with 60% Humidity	With 90% Humidity
1	Outside transmission factor	-	-	0.04	-9.53	0.47		
2	Cement block wall (moist)	0.10	0.6	0.06	-8.82	0.71	At 12°C	
3	EPS	0.08	25	2.00	14.80	23.62		At 15°C
4	Cement block wall (dry)	0.10	0.7	0.07	15.63	0.83		
5	Cavity GBM-GBM	0.025	Black	0.18	17.76	2.13		
6	Gypsum board	0.01	6	0.06	18.47	0.71		
7	Inside transmission factor	-	-	0.13		1.54		
Value Total R_c				2.54	-20°C	$\Delta T=30^\circ\text{C}$		

Heat flow $\Lambda = 0.39 \text{ W/m}^2.\text{K} = 11.8 \text{ W/m}^2$ for 30°K.

Lintel Window (Blue Line): Reinforced concrete (trajectory 30 cm), timber (2.5 cm), gypsum board (1 cm). Thickness x $R_M = R_c$					New Value	The humidity condensation point is determined with the Mollier diagram.		
#	Description of the Existing Construction Layers	Thick Meter	R_M	R_c	Temp from -10°C	Temperature Difference= $R_c / TR_c \times \Delta T$	Condensation with 60% Humidity	With 90% Humidity
1	Outside transmission factor	-	-	0.04	-7.86	2.14		
2	Reinforced concrete (dry)	0.30	0.6	0.18	1.87	9.64		
3	Cavity GBM-GBM	0.025	Black	0.18	11.42	9.64	At 12°C	
4	Gypsum board	0.01	6	0.06	14.63	3.21		At 15°C
5	Inside transmission factor	-	-	0.10		5.36		
Value Total R_c				0.56	-20°C	$\Delta T=30^\circ\text{C}$		

Heat flow $\Lambda = 1.79 \text{ W/m}^2.\text{K} = 53.7 \text{ W/m}^2$ for 30°K.

Double glass window $R_C = 0.32 \text{ m}^2 \cdot \text{K}/\text{W}$ with heat flow $3.125 \text{ W}/\text{m}^2 \cdot \text{K} = 93 \text{ W}/\text{m}^2$ for 30°K .

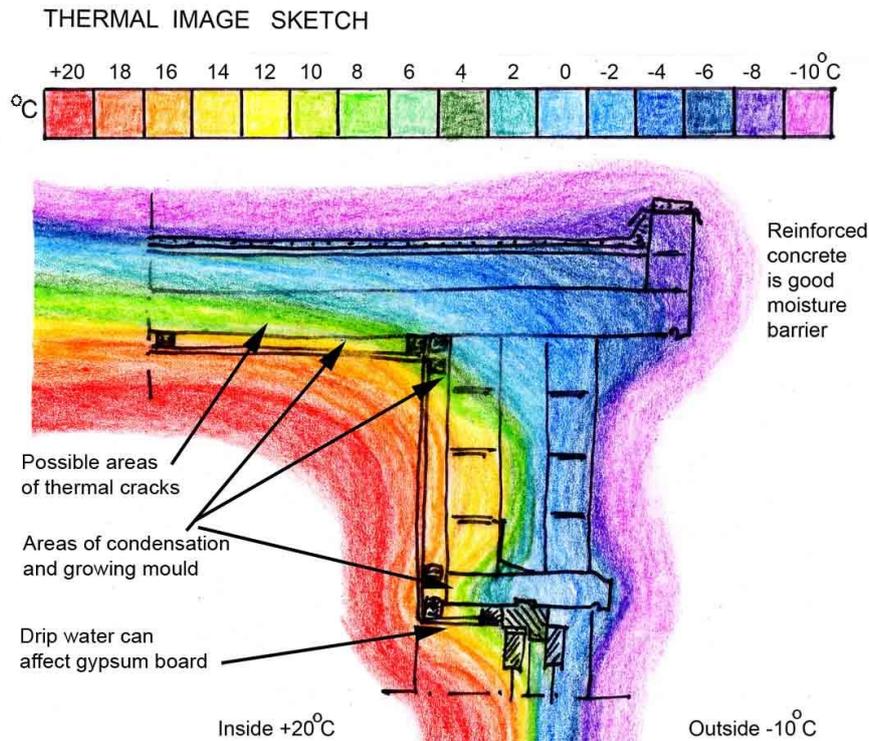


The following sketches give an impression of the comparative heat flow for each of these sections and the rainbow thermal image.

The calculations above show that the largest heat loss in Watt per m^2 is through the window. The lintels above the doors and windows have about half the heat loss per m^2 surface than the windows, but also their surface is much smaller than that of the window.

The roof overhang area, however, is over the entire length of the roof with the largest heat leakage in the corner.

Condensation of the inside humidity will occur foremost on the glass window, as well as near the lintels and the wall-roof corner. Given this large surface, it is important to design the thermal insulation of the roof-wall connection differently.

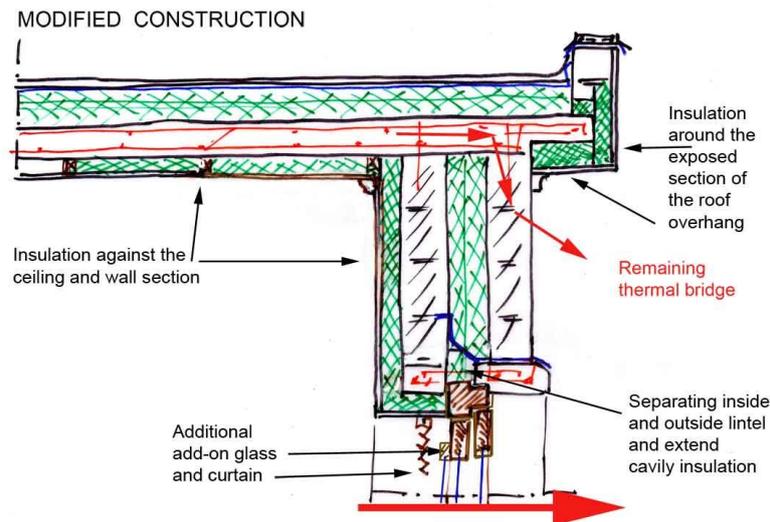


Both glass windows need easy drainage for the condensation water to go outside

The approximate effect of the inside-outside connecting reinforced concrete roof construction is made visible in the above sketch. Because the central concrete section of the roof structure will be $+10^\circ\text{C}$ (warm) and the outside rim of the roof -6°C (cold), thermal cracks can occur over the wall support.

Without high efficiency insulation glass with Argon/Krypton and heat reflective coatings, a third glass window and roll curtains can improve the insulation value of the window area.

The thermal bridge is caused by the non-insulating concrete roof overhang and the connection between the concrete and the outside support wall. Insulation is needed over an extended length of the ceiling and the inside upper wall to insulated both the concrete and inside block wall. When the R_C of the 8 cm EPS = $2 \text{ m}^2 \cdot \text{K/W}$, and the R_M of concrete is $0.6 \text{ m}^2 \cdot \text{K/W}$, the maximum length of the thermal bridge is $2/0.6 = 3.3 \text{ m}$. This length can be reduced by insulating the outside overhang of the roof. A similar situation applies to the inside wall supporting the roof.



In the above sketch, the window lintel has been divided into two elements and the cavity insulation is continued downwards. In addition, the inside wall insulation has been improved.

The roof design has added insulation on the outside overhang, as well as on the inside against the roof and the wall. Although this will minimise condensation problems, a thermal bridge with the outside wall section under the roof overhang still remains. This outside wall stays cold and has full contact with the inside reinforced concrete floor.

The desired roof insulation value is $R_C = 2.44 \text{ m}^2 \cdot \text{K/W}$.

The insulation of the thermal roof bridge is $R_C = 0.53 \text{ m}^2 \cdot \text{K/W}$, a difference of $R_C = 1.91 \text{ m}^2 \cdot \text{K/W}$.

The insulation added to the ceiling and inside wall is 4 cm EPS = $R_C = 1.00 \text{ m}^2 \cdot \text{K/W}$.

With the concrete $R_C = 0.6 \text{ m}^2 \cdot \text{K/W}$, the insulation should extend 1.7 m from the outside wall or about 1.4 m from the inside wall surface.

The remaining insulation to reach the same insulation level of the central roof area or the wall construction is $R_C = 0.9 \text{ m}^2 \cdot \text{K/W}$. This would mean 8 cm EPS against the ceiling for 1.5 m from the wall support and a further 1.5 meter of 4 cm EPS, in total about 3 m.

The above calculation shows that although the concrete roof is well insulated on the outside, the thermal bridge at the supports requires application of another insulation layer below the ceiling, between 2 m and 3 m wide; practically under the entire roof. The most effective way to reduce such a thermal bridge is full insulation on the outside and on the outside supporting wall. This can be less expensive than adding a full layer of insulation to the whole ceiling.

A better solution is if the inside supporting construction, including the roof, is thermally not connected to the (cold) outside construction.

Many existing buildings with reinforced concrete roofs cannot easily be modified and inside thermal insulation is then the most economical or practical option. It must be ensured that any timber construction elements are not affected by moisture from condensation.

Resume

- With InfraRed (IR) photography, a reasonable indication can be obtained of the potential heat leakage areas (thermal bridges) during the winter situation. Photo's should be taken at night, cold dry weather (temperature difference between inside and outside > 15°C) and the building should be warmed up.
- With an IR measuring instrument, the same information can be obtained from either the inside of the building or from the outside, measuring many points under the same conditions.
- Knowing the construction details and making the temperature calculation for a winter situation gives a good indication of the thermal bridge areas.
- Insulating thermal bridges from the outside can avoid condensation on the inside and thermal cracks in reinforced concrete constructions.
- Insulating on the inside should be done with humidity blocking constructions located on the warm side to avoid condensation inside the construction of humidity that will travel from the inside to the outside. Joints in critical areas need to be taped with aluminium tape.