TECHNICAL REPORT

Calculation of heat flow, linear thermal transmittance of thermal bridges and mould growth risk assessment.

SUBJECT: Restructuring of a two-storey house.
Attic renovation works.

PROJECT SECTION: Thermal Bridge Assessment

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CLIENT: Restructura SpA

Designer/Surveyor

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TECHNICAL REPORT

Numerical calculation of the energy transmitted through building structures affected by thermal bridges and mould growth risk assessment.

The evaluation derives from a numerical finite element simulation; with this method heat transfers for each item are calculated and listed together with the total heat flow, the internal temperatures and surface temperatures, the thermal transmittance of individual elements, the thermal coupling coefficient and the thermal transmittance of thermal bridge. The mould growth risk assessment highlights the minimum surface temperature on the inner face, the critical temperature, the critical temperature factor, $\mathbf{f_{RSi,max}}$ and critical moisture conditions on monthly basis. At the end of the calculation, the thermal bridge is subject to an overall composition check and verified for against the risk of mould formation.

Methods of calculation

The finite element method, as specified in the provisions included in the EN ISO 10211 technical standard, lays out a series of indications for calculating the linear thermal transmittance and surface temperatures.

It is based on the following assumptions:

- All the physical properties are independent of temperature;

- There are no heat sources inside the building.

The numerical method used is valid in accordance with Appendix A of the standard itself, because:

a) it supplies temperatures and heat flows;

b) it allows to calculate temperatures and heat flows in different positions from those indicated by the standard by node subdivision;

c) it calculates the sum of absolute values of all heat flows twice, for n nodes (or cells) and for 2n nodes (r cells). The difference between these two results shall not exceed 1%;

d) it also iterates the calculation until the sum of all heat flows (positive or negative) entering the object, divided by half the sum of the absolute values of all heat flows, is less than 0,0001.

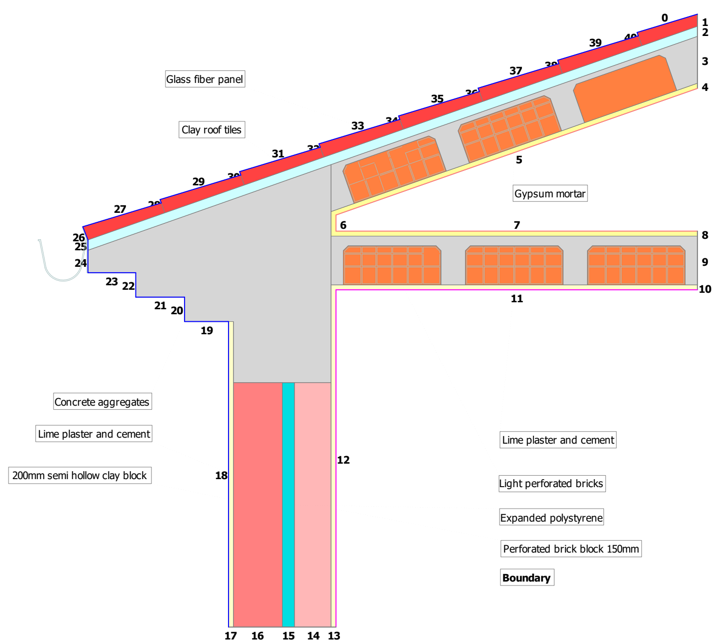
The Mould Growth Risk Assessment is conducted according to the ***EN ISO 13788***.

DATA and CALCULATION RESULTS

Geometrical Dimensions

The following figure shows the geometric pattern of the thermal bridge in which the size, the shape and the material layer composition are represented; each different boundary segment is marked by a numbered label. The table to the right shows size, expressed in meters, of all boundary sections marked by the labels.

Figure 1



Dimensions

Table 1

Segment	size [m]
0	0.26
1	0.05
2	0.04
3	0.19
4	0.02
5	1.57
6	0.07
7	1.48
8	0.02
9	0.20
10	0.02
11	1.48
12	1.38
13	0.02
14	0.15
15	0.05
16	0.20
17	0.02
18	1.25
19	0.18
20	0.10
21	0.20
22	0.10
23	0.20
24	0.09
25	0.04
26	0.06
27	0.34
28	0.01
29	0.35
30	0.01
31	0.35
32	0.01
33	0.35
34	0.01
35	0.35
36	0.01
37	0.35
38	0.01
39	0.35
40	0.01

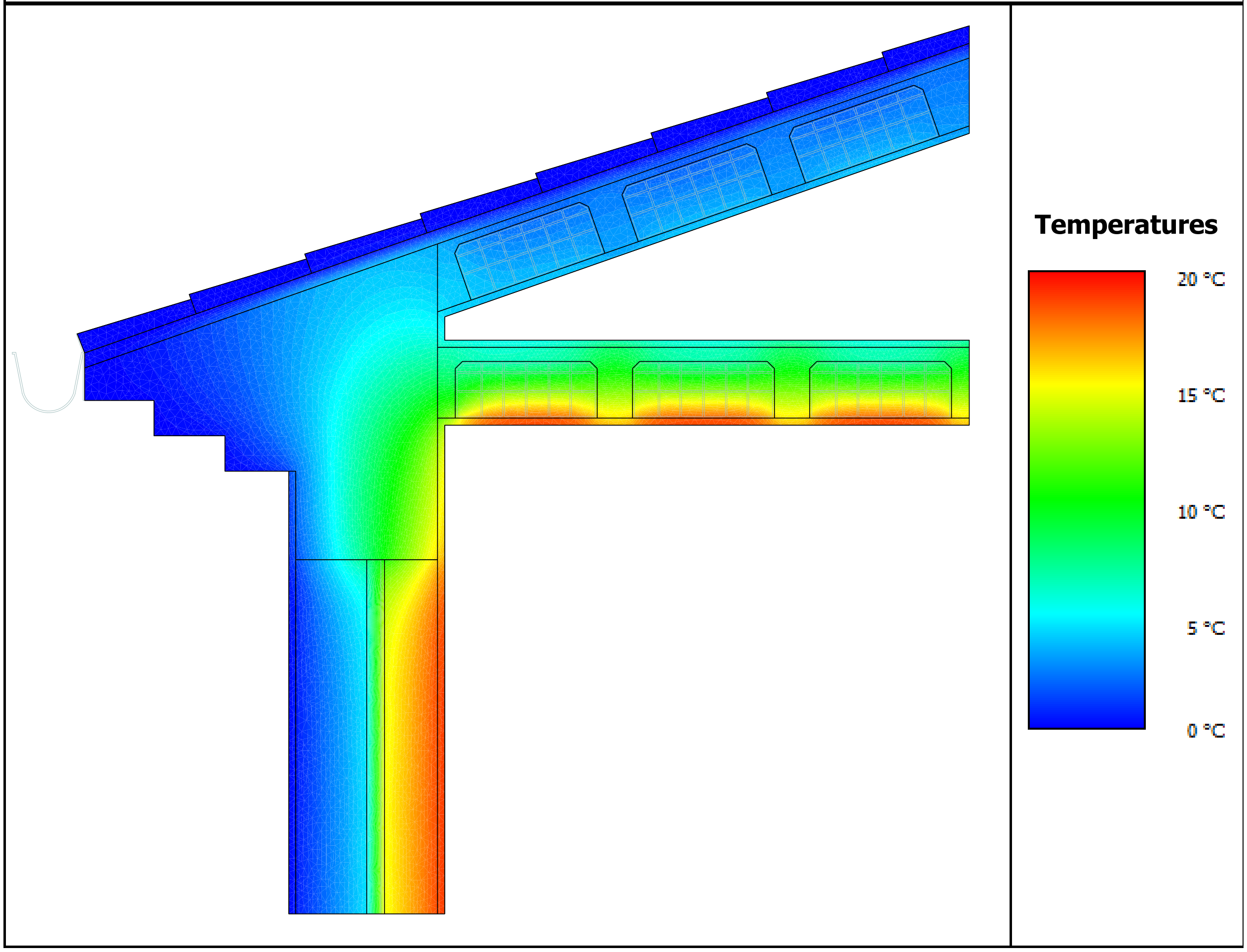
Temperature Curves

Figure 2, shows the representation of the contour lines (iso-lines) of the calculated thermal bridge.

The table on the right shows the chromatic scale relative to the temperature range as defined on the boundary. The minimum and maximum temperatures refer to the temperature calculated on the faces, on the border with the internal and external environment, taking into account the convective heat transfer.

Each contour line is defined with a step of 0.25 °Celsius.

Figure 2



External boundary conditions – Climate data

The following table shows the climate data in relation to relative humidity and temperatures, in order to perform an evaluation of the critical temperatures on a monthly basis, for a mould growth risk assessment on the inner wall surfaces.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Set	Oct	Nov	Dec
T[°C]	1.2	3.1	8.3	11.9	18.0	22.1	23.6	22.6	19.1	12.3	6.8	2.6
UR[%]	83.2	80.4	80.6	66.6	65.3	60.4	54.1	72.6	74.6	82.0	93.0	88.2

Internal boundary conditions - Transmittance calculation

The following table lists all the boundary areas with the relating temperatures and convective coefficient.
In order to perform the calculation you must define at least one INTERNAL and one EXTERNAL environment: the calculation of the linear thermal transmittance is accomplished starting from the INTERNAL environment.

Table 2

Zones	btr	Temperature [°C]
EXTERNAL	-	0.00
Attic	0.80	4.00
INTERNAL (in relation to which the TB is calculated)	-	20.00

Internal boundary conditions - Mould growth risk assessment

The following table shows the temperatures and relative humidity values relating to the internal zone.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Set	Oct	Nov	Dec
T[°C]	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
UR[%]	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0

Thermal properties of building materials

The following table proposes a list of all the materials used for the structure of the bridge with its thermal conductivity value.

Table 3

Material	Thermal conductivity [W/mK]
Perforated brick block 150mm	0.3330
200mm semi hollow clay block	0.4250
Expanded polystyrene	0.0400
Lime plaster and cement	0.7000
Concrete aggregates	1.0100
Light perforated bricks	0.1300
Clay roof tiles	0.9900
Glass fiber panel	0.0420
Gypsum mortar	0.2900

Soil characteristics

The following table shows the SOIL characteristics, if any.
The evaluation of the heat exchange coefficient of the slab on ground is made in accordance with EN ISO 13370.

Table 4

Descrition	Symbol	Value	Unit of measurement

Table 4

Thermal conductivity	k	1.5000	[W/mK]
Characteristic dimension of floor	B’	0.00	[m]
Equivalent thickness	dt	0.00	[m]
Ground equivalent transmittance	Ug	0.00	[W/m²K]

Characteristic dimension B' = (2 * Floor Area)/Floor Perimeter

Heat flows

The table below shows the heat flow values for each thermal bridge boundary together with the boundary area and the relating convective coeff. for each face.

Table 5

Facade	Associated zone	Thermal Flux [W/m]	Convective coefficient [W/m²K]
0	EXTERNAL	-0.49	25.0
5	Attic	2.83	7.7
6	Attic	-0.44	7.7
7	Attic	-21.67	7.7
11	INTERNAL (in relation to which the TB is calculated)	24.22	7.7
12	INTERNAL (in relation to which the TB is calculated)	23.40	7.7
18	EXTERNAL	-16.81	25.0
19	EXTERNAL	-2.67	25.0
20	EXTERNAL	-0.85	25.0
21	EXTERNAL	-1.23	25.0
22	EXTERNAL	-0.36	25.0
23	EXTERNAL	-0.47	25.0
24	EXTERNAL	-0.09	25.0
25	EXTERNAL	-0.01	25.0
26	EXTERNAL	-0.01	25.0
27	EXTERNAL	-0.19	25.0
28	EXTERNAL	-0.02	25.0
29	EXTERNAL	-0.79	25.0
30	EXTERNAL	-0.04	25.0
31	EXTERNAL	-1.20	25.0
32	EXTERNAL	-0.04	25.0
33	EXTERNAL	-0.88	25.0
34	EXTERNAL	-0.03	25.0
35	EXTERNAL	-0.73	25.0
36	EXTERNAL	-0.03	25.0
37	EXTERNAL	-0.70	25.0
38	EXTERNAL	-0.03	25.0
39	EXTERNAL	-0.67	25.0
40	EXTERNAL	-0.02	25.0

Final results

The final table shows the calculated values relating to the entire structure.

The result of the numerical simulation is the heat flow (**F**) which passes through the structure, expressed in W/m, due to the difference in temperature between the INTERNAL and EXTERNAL environments.

The equivalent heat flow (**F_wtb**), also expressed in W/m, relating to the structure without considering the thermal bridge, was assessed considering the same temperature difference between the inside and outside environments and the equivalent length (**L**) defined for the comparison.

From the difference between these two values, the linear thermal transmittance (**kl**) and the coupling coefficient (**L_{2D}**) are also calculated.

Table 6

U [W/mK]	**Associated Leng.** [mm]
1.80	1.48
0.42	1.38

Table 7

Descrition	**Symbol**	**Value**	**Unit of measurement**
Linear thermal transmittance	kl	-0.85	[W/mK]
Total heat flow	F	47.62	[W/m]
Thermal coupling coefficient	L2D	2.38	[W/mK]
Equivalent length	L	2.86	[m]
Heat flow (without thermal bridge)	F_wtb	54.01	[W/m]

Mould growth risk assessment

This final table shows the critical moisture levels on a monthly basis, the critical temperature factor and the critical temperature, in accordance with ***EN ISO 13788***.

Critical tempertaure factor	$f_{RSi,max}$	[-]	0.82
Mould formation temperature	T_{min}	[°C]	16.69

The assessment shows:
- critical month: **January**
- minimum temperature on the inner face: **13.66°C**

The thermal bridge is subject to the risk of mould formation.

	external conditions		***internal conditions***						
	T_e	φ_e	T_i	φ_i	$p_{sat}(\theta_i)$	p_i	$p_{sat}(\theta_{si})$	$T_{si,min}$	f_{RSi}
Jan	1.2	83.2%	20.0	65%	2337	1519	1519	16.69	0.82
Feb	3.1	80.4%	20.0	65%	2337	1519	1519	16.69	0.8

Mar	8.3	80.6%	20.0	65%	2337	1519	1519	16.69	0.72
Apr	11.9	66.6%	20.0	65%	2337	1519	1519	16.69	0.59
May	18.0	65.3%	20.0	65%	2337	1519	1519	16.69	-0.66
Jun	22.1	60.4%	20.0	65%	2337	1519	1519	16.69	2.58
Jul	23.6	54.1%	20.0	65%	2337	1519	1519	16.69	1.92
Aug	22.6	72.6%	20.0	65%	2337	1519	1519	16.69	2.27
Set	19.1	74.6%	20.0	65%	2337	1519	1519	16.69	-2.68
Oct	12.3	82%	20.0	65%	2337	1519	1519	16.69	0.57
Nov	6.8	93%	20.0	65%	2337	1519	1519	16.69	0.75
Dec	2.6	88.2%	20.0	65%	2337	1519	1519	16.69	0.81

LEGEND

T_e	Outside average monthly temperature	[°C]
φ_e	Average monthly external relative humidity	[%]
T_i	Inner average monthly temperature	[°C]
φ_i	Average monthly internal relative humidity	[%]
$p_{sat}(\theta_i)$	Inner saturation pressure	[Pa]
p_i	Inner vapour pressure	[Pa]
$p_{sat}(\theta_{si})$	the minimum acceptable internal saturation pressure	[Pa]
$T_{si,min}$	Minimum acceptable surface temperature	[°C]
f_{RSi}	Temperature factor	[-]

Designer/Surveyor

(signature & stamp)