8. How to avoid thermal bridges

8.1. What is thermal bridge

A thermal bridge is formed when there is a low thermal insulation between the external and internal faces of a wall, which encourages the formation of condensation. This can be a consequence of the geometric form, the structural junction or when materials with different coefficients of heat transmittance installed in non-parallel layers. Most frequently thermal bridge zones are at foundations, parapets, reinforced - concrete columns, corners, window openings, etc. (figures 1 and 2). Having low thermal insulation properties, concrete parts in the masonry as integrated beams, window and door lintels represent thermal bridges where condensation can occur and lead to the growth of moisture.

In order to ensure the safety requirements for earthquakes, reinforced concrete beams (figure 2) support the walls made of hollow bricks or of small blocks of autoclaved cellular concrete. These beams are very favourable for thermal bridges, which increases the heat losses with 25 – 40%, even in the case of an well-insulated building. The humidity generated by the condensate has an opposite effect to the room comfort. The low temperature of the internal surface of the wall and the local development of a relatively high degree of humidity lead to formation of condensation.

Almost 40% of the wall area damages and aesthetical problems are consequences of thermal bridges. So it is necessary:

- To ensure an uniform thermal protection degree on the entire surface of the wall by a supplementary thermal insulation;
- To avoid the condensation phenomenon on the surface and in the thickness of the wall;
- To prevent degradation at the external wall surface under the influence of climatic factors.

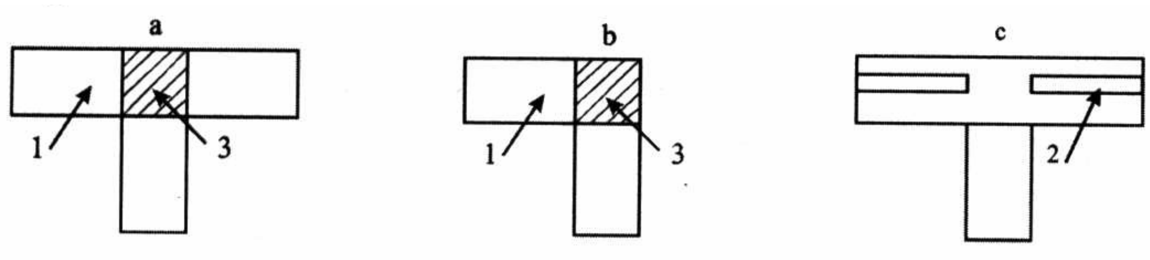

Fig. 1 Thermal bridges at the intersection of transversal and longitudinal walls

a, c – at the intersection with a transversal wall

b – at the corner

1. Masonry (hollow bricks or autoclaved cellular concrete)
2. Sandwich wall (prefabricated or cast-in-situ reinforced concrete)
3. Reinforced concrete beam.

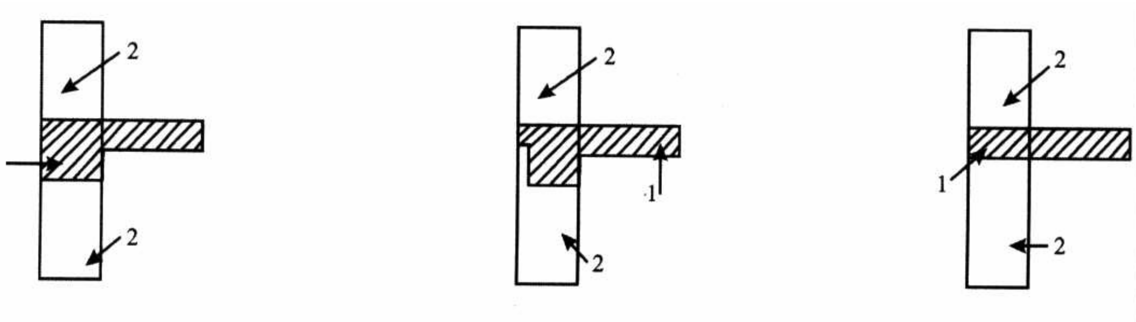

Fig. 2 Thermal bridges at the intersection of external walls and floors

1. Reinforced concrete slab
2. Masonry

8.2. Measures to avoiding thermal bridges

Thermal bridges can be avoided through an adequate structural composition and through insulation of the existing thermal bridges. These issues are important not only for energy saving and costs reductions, but also for the increase of the building's lifetime.

A radical, efficient and safe solution is to cover the entire external wall (figure 3) with a continuous layer of thermal insulation of expanded polystyrene or mineral felt, protected by a thin plastering reinforced with a dense glass fiber net, steel or polymeric wires (ETICS system – External Thermal Insulation Composite System). There are various alternatives of this system on the market. The type of the mortar and the net should be durable and compatible with each other and this makes the difference between these alternatives.

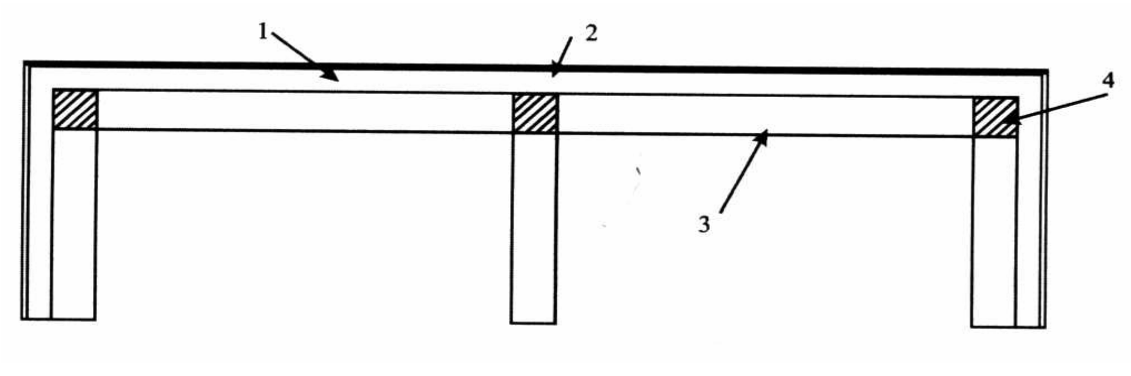

Fig. 3 continuous external thermal insulation

1. Expanded polystyrene or mineral wool
2. Protection layer
3. Brick masonry or autoclaved cellular concrete
4. Reinforced concrete.

Expanded polystyrene gives efficient solutions for thermal bridges preventing as insulation of foundation and walls surfaces. Its advantages are:

- High insulating degree, small insulation thickness;
- Humidity resistance;
- Very good compression resistance;
- Adhesion force of the insulating plates to the concrete surface;
- Easy cutting with simple tools.

8.3. Local insulation of thermal bridges

When it is not possible to execute a general thermal insulation of a building, local insulation of the thermal bridges can be applied (fig.4). To this purpose expanded polystyrene boards, mineral felts or autoclaved cellular concrete are suitable (fig.5).

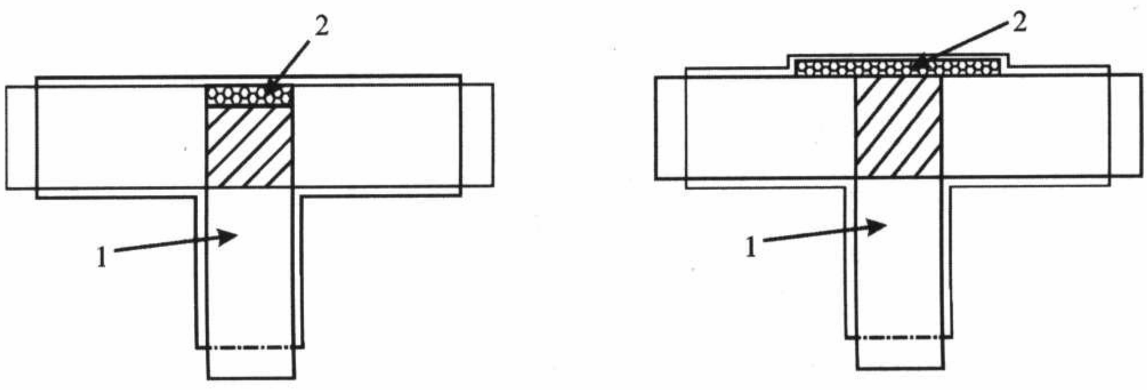

Fig. 4 Thermal bridges with local thermal insulation on the internal and on the external sides of the wall

1. Brick masonry or autoclaved cellular concrete
2. Thermal insulation min. 6cm thick with expanded polystyrene, mineral wool or cellular concrete

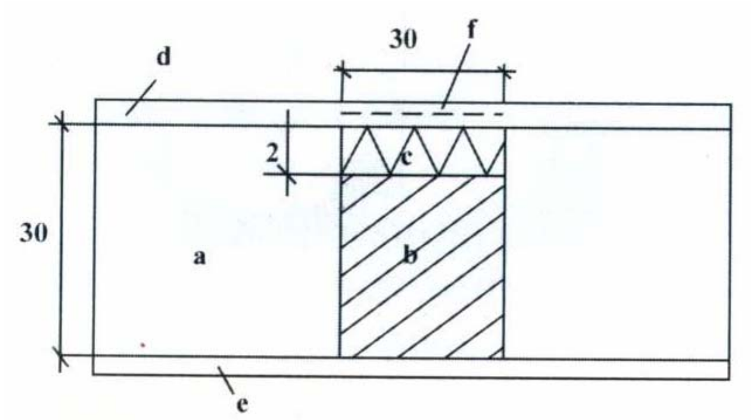

Fig. 5 Thermal bridge locally insulated

a. Masonry with autoclaved cellular concrete blocks
b. Reinforced concrete column
c. Local thermal insulation of expanded polystyrene (board 30cm width and 6cm thick)
d,e. Plastering
f. Welded net and plastering on wire mesh

Analyzing the thermal field at an external temperature of T_e = -18°C and an internal temperature of T_i = 20°C, one can come to the conclusion that on the internal side of the wall appears a minimum temperature of T_{si} = 11.8°C (figure 6). The risk of condensation exists (p_s = 1385 P_a < pV = 1403 P_a) when the relative air humidity in the room is 60%. To avoid this risk, the expanded polystyrene plate should be 60cm wide.

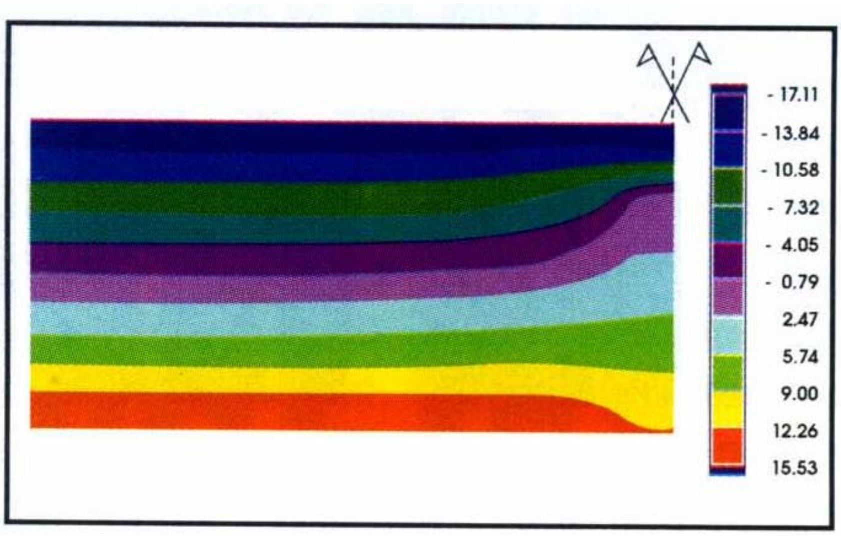

Fig. 6 Thermal field in the thermal bridge area using the symmetry line

The minimal temperature is off the reinforced concrete beam line.

When the thermal protection is made of autoclaved cellular-expanded concrete 6 cm thick, T_{si} = 10.6°C, and p_s = 1279 p_a < p_v = 1403 P_a, the risk of condensation is higher. The situation could be worse on other sides of the façade (lintels, belts, pedestals, embrasures).

The application of a local thermal insulation leads to other behaviour problems with the time. The expanded polystyrene layer represents an obstacle for the heat flows and for the capillary migration of water. Due to this, the external plastering will be exposed to thermal shocks and humidity variations different than these on the rest of the facade. This is the reason why the external plastering must be locally reinforced with rabitz plastering and welded net. The welded net must be covered with several centimeters of plaster against corrosion, otherwise at the plastering surface cracks will appear that will keep the rainwater. Due to the low temperatures influence, the cracks will get bigger and bigger and finally degradation will be a fact.

Pursuant to the temperature drops, humidity and rigidity between the reinforced external plastering area and the not reinforced one, there is a fissuring risk on the contact line and the two areas will have different colors after time.

For this reason it is recommended that the plastering reinforced with welded net and rabitz plastering is replaced with thin plastering reinforced with a dense net, just as at the ETICS system, which should surpass the expanded polystyrene plate width.

In conclusion it can be said that the optimal solution to avoid the effect of reinforced concrete thermal bridges is to cover the entire façade with a continuous thermal insulation made of expanded polystyrene, mineral felt or autoclaved cellular concrete. The optimum thickness for the thermal insulation is of minimum 6 cm.

In cases when this solution cannot be applied, it is necessary to ensure a local thermal insulation made of expanded polystyrene protected with a thin plastering reinforced with a dense net, which will reduce the risk of condensation. In order to avoid the appearance of cracks at the edge of the insulated area, it is recommended that the reinforcement surpass the expanded polystyrene plate, penetrating into the rest of the external plastering.

Mineral fiber quilt insulation is a slightly more expensive method of loft space insulation but can be more appropriate if loft is going to be used or converted as an extra room. Mineral fiber quilt is available in 60mm, 80mm, 100mm, 150mm, and 200mm thickness and in widths that suit to all joist spaces. The material is rolled between the joists and then applied in a second layer across the joists to prevent the “thermal bridge”, which is created by the ceiling plasterboard and each of the joists.

APPENDIX 1. Density, estimating value of the coefficient of thermal conductivity and of the number of diffusion resistance on water vapour of different building materials.

N°	Material	Density ρ *kg/m³*	Estimating value	
			Coefficient of thermal conductivity λR *W/mK*	figure of diffusion resistance on water vapour μ
1	**2**	**3**	**4**	**5**
1. Natural stones				
1.1	Marble, granite, basalt	2 800	3,49	67,74
1.2	Sandstone, quartz	2400	2,04	21
1.3	Limestone	2000	1,16	12,35
2. Concrete				
2.1	Reinforced concrete	2500	1,63	26,25
2.2	Ordinary concrete	2400	1,45	26,25
2.3	Concrete with crushed bricks	2400	1,02	14
2.4	No-fines concrete	1900	1,02	14
2.5	Haydite-perlite concrete	1100	0,38	6,36
2.6	Haydite concrete	1500	0,58	8,4
2.7	Perlite concrete (insulating)	800	0,26	2,87
2.8	Foam concrete (autoclave)	800	0,26	5,67
2.9	Gas concrete (autoclave)	800	0,26	5,67
2.10	Ash concrete	1250	0,49	-
3. Plasters and mortars				
3.1	Cement-sand mortar	1800	0,93	8,4
3.2	Lime- cement-sand mortar	1700	0,87	7,77
3.3	Lime-sand mortar	1600	0,81	6,36
3.4	Lime-perlite plaster	550	0,16	2,53
3.5	Lime-sand plaster (external)	1600	0,87	5,67
3.6	Lime-sand plaster (internal)	1600	0,70	5,67
3.7	Thermal insulating external plasters with expandable polystyrene granules	400	0,12	-

1	2	3	4	5
4. Bituminous and asphalt materials				
4.1	Bitumen	1050	0,16	-
4.2	Bituminous paper (waterproofing)	600	0,17	46,2
4.3	Poured asphalt	1800	0,76	92,59
4.4	Asphaltic concrete	2100	1,05	92,59
4.5	Bitumen perlite	5000	0,14	-
5. Masonry				
5.1	Brickwork of ordinary full bricks on lime-sand mortar	1800	0,79	7,24
5.2	Brickwork of lime-sand bricks on lime-sand mortar	1900	0,87	7,24
5.3	Brickwork of cork bricks ρ=1300 *kg/m³*	1350	0,58	5
5.4	Brickwork of hollow bricks (accord. BDS standard) on lime-sand mortar	1400	0,52	-
5.5	Brickwork of diatomite bricks on light mortar ρ=1400 *kg/m³*	900	0,29	4,038
5.6	Stonework of stones with regular shape and stone's density (*kg/m³*) -2800 -2000 -1200	 2680 1960 1260	 3,20 1,13 0,51	 3,62 11,73 5,76
5.7	Stonework of stones with irregular shape and stone's density (*kg/m³*) -2800 -1200	 2420 1380	 2,57 0,60	 19,09 6,23
6. Loose materials				
6.1	Dry sand	1600	0,58	4,56
6.2	Dry soil	1400	0,52	2,56
6.3	Diatomite	600	0,17	2,53
6.4	Perlite	150	0,06	-
6.5	Expanded clay	500	0,16	2,53
6.6	Cinder	1000	0,29	3,88

1	2	3	4	5
7. Soils and clay putty				
7.1	Vegetable soil under buildings	1800	0,16	-
7.2	Clay and sand putty	1800	0,70	7,77
7.3	Clay putty	1300	0,52	5
8. Metals, glass, asbestos-cement and gypsum products				
8.1	Steel	7850	58,15	Vapour impermeable
8.2	Cast iron	7200	50,01	
8.3	Windows' glass	2500	0,76	
8.4	Asbestos- cement tiles	1900	0,35	-
8.5	Gypsum tiles	1200	0,41	7,5
8.6	Striated gypsum tiles	1200	0,30	-
8.7	Gypsum cardboard	800	0,21	-
9. Wood and wooden products				
9.1	Pine and fir-tree across the fibres	550	0,17	12,28
9.2	Oak and beech across the fibres	800	0,23	13,46
9.3	Wooden shavings	250	0,09	2,87
9.4	Laminated wood	600	0,17	35
9.5	Compact cardboard	1000	0,23	-
9.6	Ordinary cardboard	700	0,17	-
9.7	Undulating thermal-insulating cardboard	150	0,07	-
10. Mineral wool and products				
10.1	Slag wool	200	0,058	1,55
10.2	Ditto	150	0,052	1,55
10.3	Glass wool	100	0,047	1,55
10.4	Ditto	80	0,044	1,55
10.5	Marl wool	100	0,047	1,55
10.6	Mats of glass or marl wool	120	0,049	2,23
10.7	Mats of slag wool	200	0,058	2,23
10.8	Tiles of marl wool	250	0,076	2,23
10.9	Ditto	150	0,058	2,23

1	2	3	4	5
11. Other materials				
11.1	Pressed rush-board	300	0,12	1,68
11.2	Expanded cork	120	0,041	19,09
11.3	Tiles of cork refuse	150	0,058	17
11.4	Linoleum	1100	0,19	525
11.5	Foamed polystyrene	35	0,043	12,35
11.6	Foamed glass	400	0,12	35
11.7	Tiles of rigid foamed polyurethane	50	0,035	-
11.8	Thermal insulating products with foamed polystyrene granules	600	0,18	-
11.9	Perlite tiles with water glass	450	0,11	-

APPENDIX 2. Coefficient of thermal conductivity of windows, doors and ceiling windows

N°	Windows, doors and ceiling windows	Coefficient of thermal conductivity *U (W/mK)*
1.	Single glazed wooden window	5,88
2.	Double glazed wooden window glazed with glass package	2,63
3.	Double glazed wooden window with two stuck leaves	2,63
4.	Single glazed wooden balcony door	5,88
5.	Double glazed wooden balcony door with glass package	2,63
6.	Double glazed wooden balcony door with two stuck leaves	2,63
7.	Double wooden window	2,32
8.	Double balcony door	2,32
9.	PVC windows and doors, double glazed with glass package	2,63
10.	Single window on metal frame	6,66
11.	Window on metal frame with two stuck leaves	3,57
12.	Single glazed ceiling window on metal frame	6,66
13.	Ceiling window on metal frame with two stuck leaves	3,57
14.	Hollow glass blocks 194/194/80 mm	3,12
15.	Profile glass, single (with [profile)	6,25
16.	Profile glass, double (with أ profile)	2,94

APPENDIX 3. Estimating temperatures for the winter season in different settlements in Bulgaria.

N°	Settlement	t °C	N°	Settlement	t °C
1.	Aitos	-13	37.	Pazardjik	-15
2.	Baltchik	-12	38.	Panagiurishte	-18
3.	Berkovitza	-17	39.	Pernik	-17
4.	Blagoevgrad	-14	40.	Petritch	-10
5.	Botevgrad	-20	41.	Peshtera	-14
6.	Bresnik	-20	42.	Pirdop	-18
7.	Burgas	-10	43.	Pleven	-17
8.	Biala Slatina	-20	44.	Plovdiv	-15
9.	Varna	-11	45.	Pomorie	-10
10.	Velingrad	-20	46.	Popovo	-18
11.	Vidin	-18	47.	Parvomay	-15
12.	Vratza	-17	48.	Radomir	-17
13.	Gabrovo	-18	49.	Razgrad	-19
14.	Gorna Oriahovitsa	-20	50.	Razlog	-15
15.	Gotse Deltchev	-15	51.	Russe	-17
16.	Dimitrovgrad	-14	52.	Samokov	-18
17.	Dobritch	-15	53.	Sandanski	-10
18.	Drianovo	-17	54.	Svilengrad	-13
19.	Dupnitza	-16	55.	Svishtov	-17
20.	Elena	-18	56.	Sevlievo	-18
21.	Elhovo	-14	57.	Silistra	-17
22.	Ivaylovgrad	-12	58.	Sliven	-13
23.	Isperih	-18	59.	Smolian	-16
24.	Ihtiman	-20	60.	Sofia	-16
25.	Kasanlak	-14	61.	Sozopol	-10
26.	Karlovo	-14	62.	Stara Zagora	-13
27.	Karnobat	-14	63.	Troyan	-18
28.	Kardjali	-15	64.	Tran	-20
29.	Kustendil	-16	65.	Targovishte	-17
30.	Lovetch	-17	66.	Tarnovo	-17
31.	Lom	-17	67.	Harmanli	-14
32.	Madan	-16	68.	Haskovo	-14
33.	Montana	-18	69.	Tsarevo	-10
34.	Nova Zagora	-13	70.	Tchirpan	-15
35.	Oriahovo	-17	71.	Shoumen	-17
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