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SELECTED PROBLEMS OF THERMAL BRIDGES IN CONTEMPORARY MULTI-OCCUPANCY BUILDINGS

WYBRANE PROBLEMY MOSTKÓW TERMICZNYCH WE WSPÓŁCZESNYCH WIELORODZINNYCH BUDYNKACH MIESZKALNYCH

A b s t r a c t

In contemporary multi-occupancy buildings, each architecture studio has its own uniform and trademarked design for the external appearance of the structure. Façade features such as breaks, bays, balconies and cornices often generate energy and humidity problems. These require detailed analysis, both in terms of construction as well as physical aspects, so that elements are appropriately designed.

Keywords: *thermal bridge*, *thermal quality*, *architectural detail*

S t r e s z c z e n i e

We współczesnych budynkach wielorodzinnych stosowane detale elewacji urozmaicające monotonię bryły stają się wizytówką określonej pracowni architektonicznej. Wychodzące z płaszczyzny elewacji ryzality, wykusze, balkony i gzymsy często stwarzają problemy cieplno-wilgotnościowe. Prawidłowe zaprojektowanie tych elementów wymaga szczegółowej analizy detalu zarówno pod względem konstrukcyjnym, jak i fizykalnym.

Słowa kluczowe: *mostek termiczny*, *jakość cieplna*, *detal architektoniczny*

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Denotations

$\upsilon_{i,\min}$ – minimum internal surface temperature [°C]
t_s – point temperature [°C]
f_{Rsi} – temperature factor at the internal surface [–]
$f_{Rsi,\mathrm{kryt}}$ – critical value of temperature factor at the internal surface [–]
$\Theta_{si,\min}$ – minimum acceptable surface temperature of the joint [°C]
Ψ_i – linear heat transport coefficient for internal dimensions [W/mK]

1. Introduction

The move away from uniform and prefabricated techniques for the construction of multi--occupancy buildings properties has allowed architects to experiment with individual and distinctive building facades which acquire considerable value as trademarked designs. A wide availability of building materials allows for the creation of more refined architectural details: balconies, cornices, breaks, bays, roofs and screens [7]. On the other hand, proven partition methods and solutions have remained in use: two-layered external walls, ventilated two-sectional ceilings [2] and rooves. Linking traditional solutions and developing new concepts can have unexpected consequences [1, 3]. Instead of enhancing comfort levels, problems arise with maintaining proper temperatures in a room and mould growth can result. Highly sensitive points for concern are the roof joints, ceilings and outer walls as well as the cornices.

In the photograph and cross section diagrams of a joint (Fig. 1, 2) we can see examples of solutions to this problem. Occupants in upper floors often report problems with maintaining proper internal temperatures even where controls are set at maximum level. In some apartments, tell-tale signs of mould growth appear on internal surfaces of the joint and on parts of the wall, and along the length of the cornice (Fig. 3).

In most cases, the problem is attributed to improper exploitation more precisely through excessive attempts to save on heating costs. Apartment users are often blamed for limiting the amount of ventilation and switching off heating for long periods. However, an analysis of heating costs in these particular apartments indicates otherwise. The cost of heating a 1 m^2 area can be as much as 50% higher than for a flat on the floor below.


Fig. 1. Examples of building facades erected after 2000

In order to establish the reasons for the problem occurring, it was necessary to examine the design, application and construction stages. Inspections of a group of buildings (Fig. 1, 2a) highlighted discrepancies between execution and design. Although the basic internal partition layers were constructed and fitted to the design, the construction firm used a more traditional set of materials for the wall, ceiling and roof joint, as shown in Fig. 4.

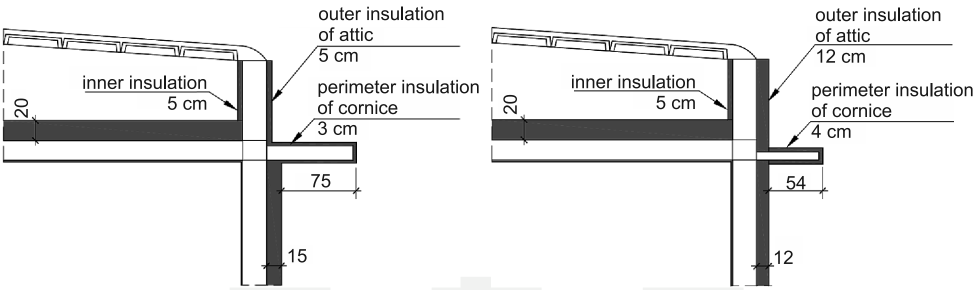


Fig. 2. Solutions for joints

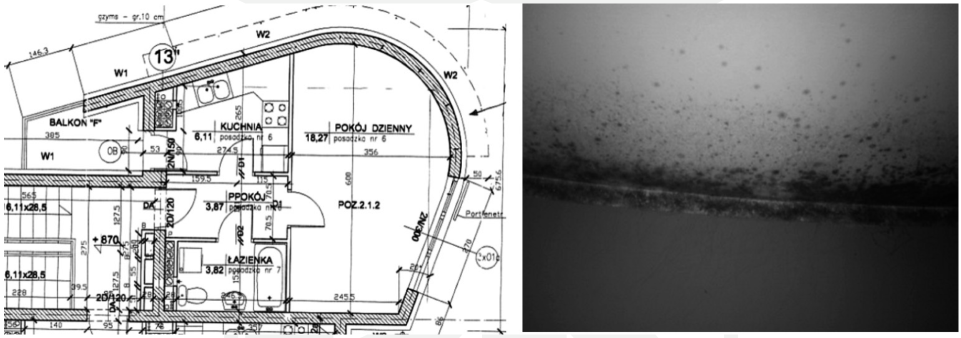


Fig. 3. A diagrammatic and photographic view of the surface of a ceiling in the section of the building

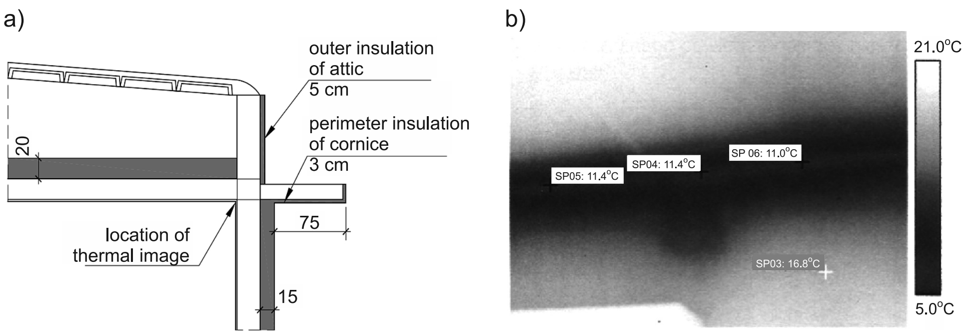


Fig. 4. The outside wall, ceiling and roof as currently configured: a) diagram showing materials, b) thermal image where the outside temperature was –11°C

After intervention of owners of apartments in summer period an additional layer of mineral wool was added in the roofspace against the outside walls, with thicknesses of 10 cm, and 25 cm on the attic wall.

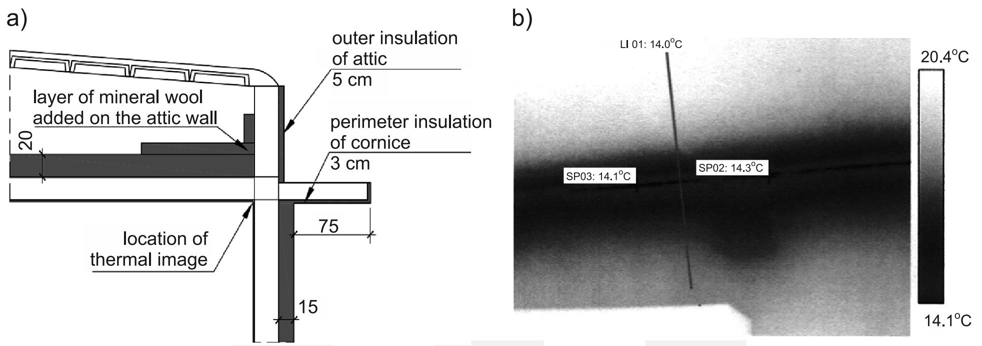


Fig. 5. Insulating the roof and ceiling: a) diagram showing materials, b) thermal image with the insulation in place, where the outside temperature was –10°C

This remedial work only partially limited this thermal bridge effect – the junction of outside wall with the ceiling and roof continued to experience heat losses from the apartment. Therefore, it was necessary to perform a more detailed analysis of the problematic structure.

2. Thermal protection requirements

According to the binding regulations (WT 2008) [6] concerning thermal insulation of building partitions (in force until the end of 2013), there is a requirement to provide maximal value of heat permeation at a value of factor *U*. The effects of thermal bridges were not taken into account in the heat demand calculations, and the required thermal quality levels for a solid structure were instead defined according to a moisture point (Eq. 1). It is necessary to calculate the temperature of the internal surface of the partition where a thermal bridge occurs, through experimentation or by using a numeric program.

$$\upsilon_{i,\min} \geq t_s + 1 \tag{1}$$

In 1997, this condition was incorporated into a regulation on the technical requirements of buildings and their locations [6] which remained in effect until the end of 2008. According to this calculation procedure, the dew point temperature value used to assess the humidity levels (Eq. 1) changed depending on how the room was used. In domestic properties, a room with a temperature of +20°C and φ_i = 55% gives a reading (Eq. 1) of

$$\upsilon_{i,\min} \geq 11,7\,^{\circ}\mathrm{C} \tag{2}$$

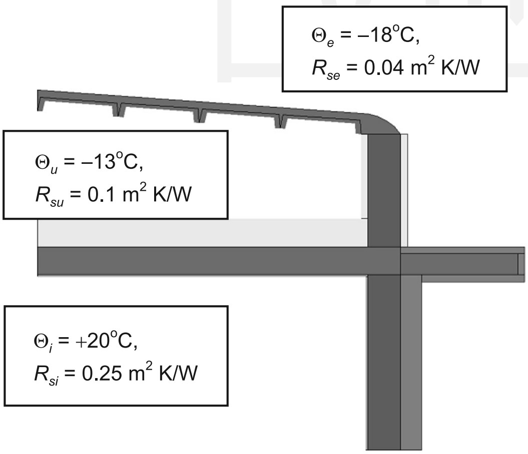
In the subsequent re-drafting of this regulation in November 2008, conditions giving rise to surface vapour condensation were modified – ‘on an internal surface of a non-transparent internal partition, there can be no condensation of vapour allowing for the development of mould growth'. Checks to ensure that this condition is adhered to are carried out using temperature factor f_{Rsi}, as defined in the PN-EN ISO 13788 standard [1]. In regard to external partitions of housing blocks, communal group buildings, civic and industrial buildings, the following approach should be taken in relation to external partitions and the main part of the building. The temperature factor f_{Rsi} should not be less than the required critical value, calculated according to the PN-EN ISO 13788 standard.

The required value should be calculated according to section 5 of the standard, and it is within acceptable parameters to fix the required value of the factor at the level of 0.72.

3. Analysis of the solution for the selected construction's joint

3.1. Pre-calculation values

The wall is constructed of 24 cm thick SILKA E blocks. The wall insulation is 15 cm thick foamed polystyrene. The walls are covered with gypsum plaster – assumed to be 2 cm thick. The ventilated ceiling and roof have the following layers: 2 cm thick gypsum plaster, 20 cm steel-concrete Filigran plates, vapour insulating foil, mineral wool mats, 2 cm × 10 cm × 10 cm height, width and length, roof space at 60 to 136 cm pitched height (the height of the ceiling to the roof at the point of analysis is 60 cm). Assumptions were made in terms of edge of area conditions and thermal properties of materials, according to [1, 4] as shown in Fig. 6.



Material	λ [W/mK]
Reinforced concrete	2.30
SILKA E	0.53
Foamed polystyrene EPS79-040	0.040
Gypsum plaster	0.57
Mineral wool mats	0.039
Mineral wool boards	0.039

Fig. 6. Calculations assumed for the cross section of the joint

Insulation at this joint was examined under three different conditions:

- Following the work: lack of edge-to-edge insulation of the attic walls and lack of insulation on the upper surface of the cornice,
- Thermal insulation work carried out – laying of additional, horizontal edge-to-edge insulation of the roofspace with 25 cm overlaying on the attic wall,

– Bringing the joint up to its design specifications – filling missing spaces with additional, edge-to-edge thermal insulation on the attic wall using 5 cm thick mineral wool layers, and 3 cm thick foamed polystyrene on the upper surface of a cornice.

3.2. Calculation results and discussion

Measurements were taken for minimum temperatures in the joint ($\theta_{si,\mathrm{min}}$) and the thermal factor f_{Rsi}. The results are shown in Table 1.

Table 1

Thermal quality of the analyzed joint

Joint insulation conditions	$\theta_{si,\,\mathrm{min}}$ °C	Adherence to the dew point condition	f_{Rsi}	Adherence to the WT2008 standard	
				$f_{\mathrm{Rsi,\,kryt}}$=0,72	$f_{Rsi,\mathrm{kryt}}$, for class 3 humidity conditions
After-work state	7.7	No	0.676	No	No
Insulation work completed	8.0	No	0.684	No	No
At design specifications	9.9	No	0.734	Yes	No

These readings show that the joint is at risk of internal condensation, according to the requirements for humidity protection which are binding up to 2008, but that the WT2008 standards give cause to dispute that outcome. Adherence to the requirement standard depends on the assumed critical value of $f_{Rsi,\mathrm{crit}}$.

In view of this, the thermal quality of the joint should be improved to avoid any conceivable risk of mould growth.

4. Proposals for improving the joint's thermal quality

For internal partitions with high thermal insulation parameters, the effect of a thermal bridge generated by a solid structure is very great. Changes need to be made to the joint and two options should be considered:

– Proper thermal insulation of the existing thermal bridge, without the need for expensive construction solutions
– A design-based solution to the problem.

In the case of a joint in the existing building, there is a need to increase the thickness of edge-to-edge insulation including the attic walls. The best results are obtained by supplementing the external insulation of the attic and the upper and lower surface of a cornice (Fig. 7)

Such action will partially limit the effect of the thermal bridge – the minimum temperature will increase by 12°C. The linear heat transport coefficient ψ_i will also decrease (Table 2).

Significant improvement is only possible through construction intervention – at the building design stage. Isothermal connectors should be used as brackets and the typical solution used for the foundations of houses – ie: spacer layer of foamed dark glass (Fig. 8) – should be applied to the attic wall.

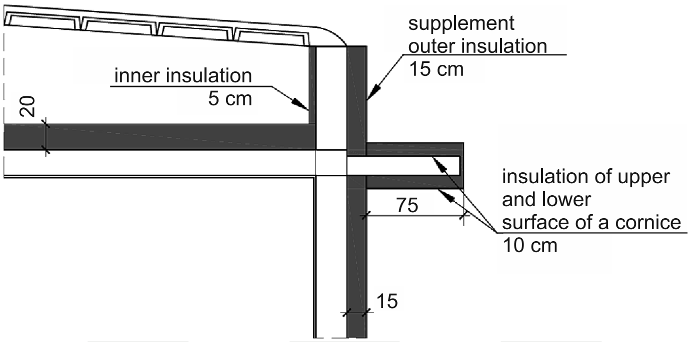


Fig. 7. Proposal for insulation the existing joint

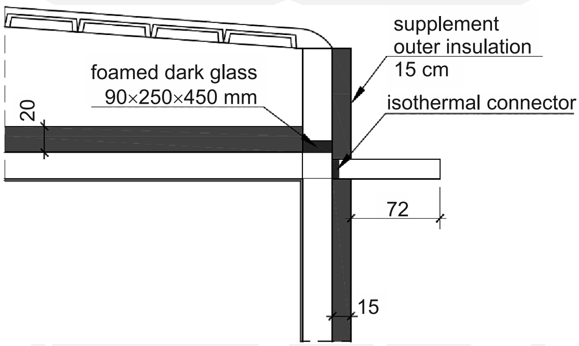


Fig. 8. Proposal for a construction solution

Table 2

Thermal characteristics of the modified joint

Variant of joint solution	Design solution Used	Proposed joint insulation	Proposed change of joint construction
$\theta_{si,\,\min}$ [°C]	9.9	12.0	14.5
Ψ_i [W/mK]	0.419	0.284	0.123

5. Conclusions

In the light of the thermal and humidity conditions of rooms surveyed in the housing blocks, for ventilated ceilings and attics are necessary – possibly double-sectional. In such a construction, the connection between the exterior walls with features such as cornices need special attention. The geometry of the structure examined in this paper is especially unfavourable – there is an attic and a supported cornice at the juncture of the ceiling and the roof. Both act as cooling elements – removing heat from the structure. Consequently, the temperature is significantly lower on the internal surface and the heat permeation factor is high for such a thermal bridge. In the case of a building in situ, it is only possible to insulate particular surfaces of the thermal bridge, but at the project design stage it is worthwhile considering changes in the construction of the structure, leading to an increase in the thermal quality of the building shell. This action is necessary from the perspective of consecutive regulations which restrict the permitted thermal protection ranges.

Attention should be paid to an evaluation of the quality of thermal bridges where the only parameter is the thermal factor, f_{Rsi}. According to technical and binding conditions [6], the critical value can be assumed to be 0.72. This has led to the adoption of solutions which were judged to be unfavourable or even defective, in terms of the physics – as well as the art and design – of building construction.

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