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# Thermo-humidity parameters of the thermal bridge of external partitions made in traditional and frame technology

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**ABSTRACT:**
In Poland, the construction of single-family houses based on brick technology is dominant. The investor, faced with the choice between traditional and frame technology, should carry out, inter alia, an analysis of the needs, the expected way of using the building and meeting the requirements regarding the physics of the building. The paper compares the thermal and humidity parameters of the thermal bridge of the wall corner made in both technologies. Computer simulations based on the finite element method were used to perform the calculations.

**KEYWORDS:**
wooden skeleton; brick technology; FEM; thermal and humidity parameters

## 1. Introduction

In Poland, the construction of single-family houses based on brick technology is dominant. Nevertheless, there is a growing interest in frame technology, in particular based on a wooden structure. When faced with the choice between brick and frame technology, the investor should analyze the needs, the expected way of using the building and meet the requirements for the building physics. The article focuses on the comparison of the hygrothermal parameters of the external wall corner rope bridge made in the brick and wooden skeleton technology. The occurrence of thermal bridges causes increased heat transfer, and hence increases in heat loss from the building, which in turn generates an increase in operating costs. Additionally, from the inside of the wall, there may be a risk of the formation of water vapor condensation, which if maintained for a longer period of time may lead to destructive processes of the partition.

## 2. Characteristics of analyzed thermal bridges

The aim of the study was to determine and compare the thermal protection characteristics of the outer wall corner as well as to check the occurrence of water vapor condensation and mold development on the inner surface of the partition through a wall made of concrete blocks and wooden skeleton technology.

The scope of the work included the performance of a hygrothermal analysis with the use of numerical calculations of the corner of a vertical partition based on a brick structure and a wooden structure (Fig. 1). The considered partitions are characterized by a similar heat transfer coefficient U [W/(m$^2\cdot$K)].

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a) b)

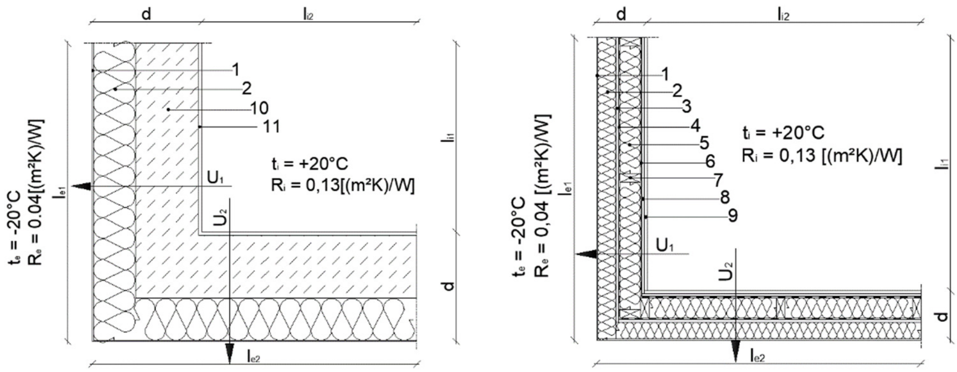


**Fig. 1.** Calculation models of the corners of a vertical wall made in the technology of: a) brick made of cellular concrete, b) wooden skeleton; 1 – thin-layer plaster, 2 – mineral wool, 3 – OSB board, 4 – vapor-permeable foil, 5 – mineral wool, 6 – vapor barrier foil, 7 – wooden profile 140, 8 – OSB board, 9 – plasterboard, 10 – concrete blocks cellular, 11 – gypsum plaster

Table 1 presents the thermal conductivity coefficients λ [W/(m · K)] of the materials forming the walls of the analyzed corner solutions. Due to the negligible influence in the calculations, the data on the vapor-permeable and vapor-barrier foil were omitted.

**Table 1**
Material data of the analyzed thermal bridges

| Type of material | Thickness | Thermal conductivity coefficient λ [W/(m · K)] |
|---|---|---|
| | d [m] | |
| Thin-layer plaster | 0.0045 | 0.7 |
| Mineral wool | 0.12[1)], 0,14[2)] 0,20[3)] | 0.035 |
| OSB | 0.012 | 0.18 |
| Breathable film | – | – |
| Wooden post | 0.14 | 0.16 |
| Vapor barrier foil | – | – |
| OSB | 0.012 | 0.18 |
| Plasterboard | 0.0125 | 0.25 |
| Aerated concrete blocks | 0.3 | 0.21 |
| Gypsum plaster | 0.015 | 0.4 |
| Structure insulation thickness: [1)] wooden – external insulation, [2)] wooden – internal insulation, [3)] brick | | |

According to the course of action presented below, the heat transfer coefficients U [W/(m² · K)] were calculated using FEM calculations for the adopted solutions of external partitions [1, 2]. Numerical analysis, assuming homogeneity and isotropy of the materials from which the individual layers are made, was performed using the ANSYS program based on the finite element method [2-4].

The values of the average horizontal component of the heat flux density, read out by means of numerical analysis, for the parts of the $q_1$ and $q_2$ joints, respectively [W/m$^2$], were used to calculate the heat transfer coefficients of the individual joints of the external partition (Fig. 1):

$$U_1 = \frac{q_1}{(t_i - t_e)} \left[\frac{W}{m^2K}\right], \tag{1}$$

$$U_2 = \frac{q_2}{(t_i - t_e)} \left[\frac{W}{m^2K}\right], \tag{2}$$

where:
$q_1$, $q_2$ – heat flux density [W/m$^2$],
$t_i$, $t_e$ – internal and external temperature [°C].

The design's internal and external temperatures were assumed to be $t_i$ = +20°C and $t_e$ = –20°C, respectively, according to [5, 6]. In the numerical calculations, the heat transfer coefficients were additionally declared for the horizontal flow on the inner side $h_i$ = 7.69 W/(m$^2$ · K) and on the outer side $h_e$ = 25 W/(m$^2$ · K), which are the inverse of the resistance $R_{si}$, $R_{se}$ [(m$^2$ · K)/W] [7, 8]. The boundary conditions according to [9], were $R_{si}$ = 0.25 (m$^2$ · K)/W.

## 3. Results of analytical-numerical analysis

When calculating the linear heat transfer coefficient Ψ [W/(m · K)], a corner height of one meter was assumed. The value of the heat flux Φ [W] flowing through the joint for the considered variants was obtained using numerical methods and was, respectively, 15.23 W and 14.19 W for the brick technology [W] for the frame technology. Then, by means of analytical calculations, the remaining thermal and humidity parameters were determined (Table 2). The conducted analysis showed that both the corner joint of the wooden skeleton structure and the brick technology meet the conditions relating to thermal and humidity parameters. Thanks to numerical calculations, the minimum values of the temperature $t_{min}$ [°C] (Fig. 2) on the inner surface of the thermal bridge partition were obtained, which allowed for the calculation of the temperature coefficient $f_{Rsi}$, obl based on the equation:

$$f_{R_{si},obl} = \frac{t_{si,min} - t_e}{t_i - t_e} \tag{3}$$

where:
$t_{si,\,min}$ – minimum temperature on the inner surface of the thermal bridge [°C],
$t_e$ – outside air temperature [°C],
$t_i$ – internal air temperature [°C].

The value of the temperature factor for the analyzed structures is summarized in Table 2. According to [7] the critical value of the temperature coefficient $f_{Rsi}$, critical. is 0.72. Thanks to the numerical analysis from the inside, the minimum temperature was read at the corners of the analyzed partitions. In a brick partition, $t_{min}$ is 17.649°C, while in a wooden partition, it is 17.897°C. The determined values of the temperature coefficient $f_{R_{si},obl}$ are greater than the critical value of $f_{R_{si}}$, critical. This means that in the analyzed partitions there is no risk of condensation on the inner surface of the wall.

**Table 2**
Thermal parameters of the analyzed thermal bridges

| **Thermal parameters of the analyzed corners of the outer wall** | | | |
|---|---|---|---|
| The heat transfer coefficient U [W / (m2 · K)] of the individual parts of the joint | Brick technology | $U_1$; $U_2$ | 0,137 |
| | Wireframe technology | $U_1$; $U_2$ | 0,141 |
| Linear thermal coupling coefficient $L^{2D}$ **[W/(m·K)]** $L^{2D} = \frac{\Phi}{l \cdot (t_i - t_e)}$ | Brick technology | $L^{2D}$ | 0,381 |
| | Wireframe technology | $L^{2D}$ | 0,308 |
| Linear heat transfer coefficient (on external dimensions) $\Psi_e$ **[W/(m·K)]** $\Psi_e = L^{2D} - (l_{e1} \cdot U_1 + l_{e2} \cdot U_2)$ | Brick technology | $\Psi_e$ | -0,030 |
| | Wireframe technology | $\Psi_e$ | -0,049 |
| Temperature coefficient $f_{Rsi,obl}$ $f_{Rsi,obl} = \frac{t_{s,min} - t_e}{t_e - t_i}$ | Brick technology | | 0,941 |
| | Wireframe technology | | 0,947 |
| Where: φ - heat flux flowing through the junction; $t_i$, $t_e$ - internal and external temperature [$^o$C]; $l_{e1}$, $l_{e2}$ - external dimensions [m]; $t_{s,\,min}$ - min. temperature for the corner [$^o$C]. | | | |

Figure 2 shows the temperature distribution of the considered wall corner variants obtained by computer simulation. The performed numerical analysis allows, at the design stage, to evaluate technological and design solutions that are extremely important at the operational stage.

a) b)

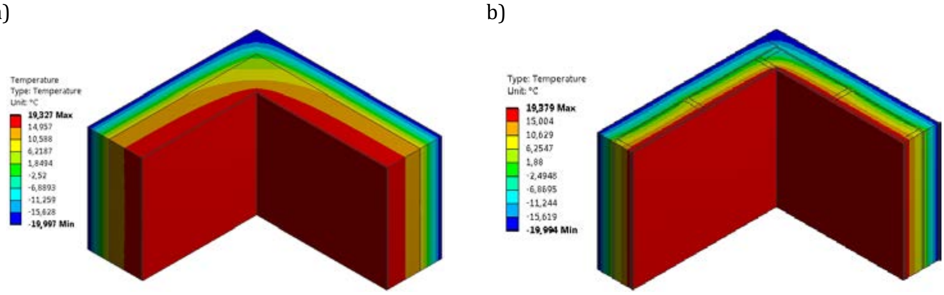


**Fig. 2.** Temperature distribution for the corner made in: a) brick technology, b) frame technology

## 4. Conclusion

In places where thermal bridges occur, one should try to limit their negative impact on heat loss and the risk of condensation. Particular attention should be paid to appropriately shaped material systems in a given joint and to prevent the formation of gaps between the thermal insulation and structural elements. The performed thermal and moisture analysis of the corners made in the brick and wooden technology showed that in both cases the conditions regarding the parameters of the building physics are met. Despite this, there is still a barrier to investors choosing structures based on a wooden skeleton. The reason for this may be the reluctance of investors to adopt alternative methods.

## References

[1] Gołaś A., Ryś M., Gajda R., Badanie własności termoizolacyjnych okien z wykorzystaniem metody elementów skończonych, Modelowanie Inżynierskie, Gliwice 2011.
[2] Major M., Kosiń M., Modelowanie rozkładu temperatur w przegrodach zewnętrznych wykonanych z użyciem lekkich konstrukcji stalowych, Budownictwo o Zoptymalizowanym Potencjale Energetycznym, 2016.
[3] Kenet L., ANSYS Tutorial Release 2020, SDC Publications.
[4] Major M., Kosiń M., Evaluation of Energy Efficiency of External Stud Partitions with Use of Numerical Analysis, IOP Conference Series: Earth and Environmental Science, 2019.
[5] Rozporządzenie Ministra Infrastruktury z dnia 12 kwietnia 2002 r. w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie, Dz.U. z 2002 r., Nr 75, poz. 690.
[6] PN-EN 12831:2006. Instalacje ogrzewcze w budynkach – Metoda obliczania projektowego obciążenia cieplnego.
[7] Pawłowski K., Projektowanie przegród zewnętrznych w świetle aktualnych warunków technicznych dotyczących budynków, Grupa Medium, Warszawa 2016.
[8] PN-EN ISO 6946:2008 Komponenty budowlane i elementy budynku – Opór cieplny i współczynnik przenikania ciepła – Metoda obliczania.
[9] PN-EN ISO 13788:2003 Cieplno-wilgotnościowe właściwości komponentów budowlanych i elementów budynku. Temperatura powierzchni wewnętrznej umożliwiająca uniknięcie krytycznej wilgotności powierzchni wewnętrznej kondensacji. Metody obliczania.

## Parametry cieplno-wilgotnościowe mostka termicznego przegród zewnętrznych wykonanych w technologii tradycyjnej i szkieletowej

**STRESZCZENIE:**
W Polsce dominuje budowa domów jednorodzinnych opartych na technologii murowanej. Inwestor, stając przed wyborem pomiędzy technologią tradycyjną a szkieletową, powinien przeprowadzić między innymi analizę potrzeb, przewidywanego sposobu eksploatacji budynku oraz spełnieniu wymagań odnośnie do fizyki budowli. W pracy podjęto się porównania parametrów cieplno-wilgotnościowych mostka cieplnego naroża ściany wykonanej w obu technologiach. Do przeprowadzenia obliczeń wykorzystano symulację komputerową opartą na metodzie elementów skończonych.

**SŁOWA KLUCZOWE:**
szkielet drewniany; technologia murowana; MES; parametry cieplno-wilgotnościowe