CZASOPISMO INŻYNIERII LĄDOWEJ, ŚRODOWISKA I ARCHITEKTURY
JOURNAL OF CIVIL ENGINEERING, ENVIRONMENT AND ARCHITECTURE
JCEEA, t. XXXVI, z. 66 (1/19), styczeń-marzec 2019, s. 37-44, DOI:10.7862/rb.2019.4

**Daniel TOKARSKI**[1]
**Wioletta ŻUKIEWICZ-SOBCZAK**[2]
**Marta CHODYKA**[3]
**Tomasz GRUDNIEWSKI**[4]
**Jerzy Antoni NITYCHORUK**[5]
**Robert TOMASZEWSKI**[6]

# COMPUTER SIMULATION OF HEATING PROPERTIES IN WALL PARTITION WITH BUILT-IN ELEMENTS THAT IMITATE THERMAL BRIDGES

The article aimed at presenting of the design assumptions of the wall partition built anda results of computer simulation of thermal properties in a heterogeneous wall partition in THERM. Display of the isotherms' distribution, heat flux vectors and temperature distribution in the area of thermal bridges and beyond. The tested partition on the basis of which simulations were created, was equipped with elements imitating thermal bridges, used in construction, to show their influence on the thermal properties of building structures. Thermal bridges can take the form of linear and point bridges. The example described in the article concerns the problem of thermal bridges occurring in wall partitions. The simulation is a preliminary pilot action before the start of non-invasive tests, ie measurement and calculation of the heat transfer coefficient, thermovision measurements on the surface of the barrier.

**Keywords:** 2D modeling, thermal permeability, thermal flows, point and linear thermal bridges

[1] Corresponding author: Daniel Tokarski, Państwowa Szkoła Wyższa im. Papieża Jana Pawła II w Białej Podlaskiej, Wydział Nauk Ekonomicznych i Technicznych, ul. Sidorska 95/97, 21-500 Biała Podlaska; tel. 833446921; d.tokarski@pswbp.pl
[2] Wioletta Żukiewicz-Sobczak, Państwowa Szkoła Wyższa im. Papieża Jana Pawła II w Białej Podlaskiej, Wydział Nauk Ekonomicznych i Technicznych, ul. Sidorska 95/97, 21-500 Biała Podlaska; wiola.zukiewiczsobczak@gmail.com
[3] Marta Chodyka, Państwowa Szkoła Wyższa im. Papieża Jana Pawła II w Białej Podlaskiej, Wydział Nauk Ekonomicznych i Technicznych, ul. Sidorska 95/97, 21-500 Biała Podlaska; m.chodyka@dydaktyka.pswbp.pl
[4] Tomasz Grudniewski, Państwowa Szkoła Wyższa im. Papieża Jana Pawła II w Białej Podlaskiej, Wydział Nauk Ekonomicznych i Technicznych, ul. Sidorska 95/97, 21-500 Biała Podlaska; gisbourne2@gmail.com
[5] Jerzy Antoni Nitychoruk, Państwowa Szkoła Wyższa im. Papieża Jana Pawła II w Białej Podlaskiej, Wydział Nauk Ekonomicznych i Technicznych, ul. Sidorska 95/97, 21-500 Biała Podlaska; wnet.dziekan@pswbp.pl
[6] Robert Tomaszewski, Państwowa Szkoła Wyższa im. Papieża Jana Pawła II w Białej Podlaskiej, Wydział Nauk Ekonomicznych i Technicznych, ul. Sidorska 95/97, 21-500 Biała Podlaska; r.tomaszewski@dydaktyka.pswbp.pl

# 1. Introduction

Computer simulation is a simulation using a mathematical model, saved in the form of a computer program. Simulation techniques are particularly useful where the analytical determination of the solution would be too labor-intensive, and sometimes even impossible, which often takes place in complex systems.

There is now one program available in Polish on the Polish market - SAT supporting the calculation of two-dimensional elements in accordance with the norm 10211: 2008 [8]. The program is quite complicated to use, especially for less-competent computer engineers. On the Internet you can find a lot of computing tools available commercially or free of charge, including eg DAVID 32, HAM-lab, Unorm, Champs-bes, or the THERM program. Programs dedicated to construction are primarily a classic electronic catalog of heat bridges "EUROKOBRA" [3]. The "Unorm" version 2012 and "David 32" are an intermediate version between the catalog and the calculation program. The programs do not give the designer full possibilities of independent modeling of any architectural detail, but they will be useful in engineering practice for typical solutions used mainly in frame building.

THERM is a computer program operating in the Microsoft Windows operating system. Developed at the Lavrence Berkeley National Laboratory, designed for architects, construction engineers, academic teachers, students of building departments, architecture, and other people interested in heat exchange problems in architectural details. Using the THERM 7.4 program. it is possible to model two-dimensional heat flow in building details such as: windows, walls, roofs, foundations and others in which thermal bridges are a significant problem. Analyzes made using THERM allow correct calculation of the heat flux density and temperature field in the cross-section. Two-dimensional heat flow calculations are based on the finite element method (FEM) [1], which enables modeling of geometrically complex architectural and building sections with 1 mm accuracy.

Completed calculations for practically any detail while maintaining the requirements as to its geometry as in the standard [9], allows to determine partial (edge) heat transfer coefficients UX and UY, and consequently to determine the linear heat transfer coefficient [W/mK]. Determining the temperature at any point of the nodes of the two-dimensional element, including anywhere on the inner edge, allows you to calculate the temperature factor fRsi, which is required in the construction project. The graphical interface allows you to plot cross-sections of the analyzed elements with known dimensions or import ready-made drawings in the form of dxf files. or bmp graphic files.

The results of calculations are obtained in the form of: 1) graphic, including: - isothermal distribution in the cross-section of the modeled element, - a colored temperature field in the cross-section, - a colored heat flux density field. 2) textual, including: - heat transfer coefficients U [W/(m$^2$K)], - heat flux value [W/m], - flux density [W/m$^2$]. Obtained results in the form of colored drawings can be easily transferred to any graphic program or text editor. Additionally, you can generate a MES grid with node numbering [2].

The example described in the article concerns the problem of thermal bridges occurring in wall partitions. Unfortunately, thermal bridges can not be removed, but only reduce their impact. The negative effects of thermal bridges, apart from the increased loss of heat, are also the lowering of temperature on the surface of the existing bridge, condensation of water vapor, excessive settling of the dust and the possibility of mold fungi. The bridge is usually created by the presence of materials in these places, which have a higher thermal conductivity coefficient $\lambda$ [W/(m·K)] than the remaining part of the barrier [5,7].

The existence of thermal bridges are easy to locate using the thermal image of the external and internal walls of the building. Bridges increase energy losses because the local temperature value in certain areas of the building envelope is greater. In this place, the heat escapes into the environment due to the increase in temperature, which causes an increase in radiation and convective flow [4].

## 2. Methodology of the research

The study was conducted in two similarly constructed rooms and the laboratory which was established in the premises of the Student Dormitory in the PSW in Biala Podlaska.

To install the research partition, the laboratory room was divided into two parts, i.e. the transmitting and receiving rooms (figure 1). The transmitting room was heated while the receiving one was cooled to obtain the highest possible temperature difference on both sides of the partition [6]. Next, thermal bridges were located in the partition in the form of elements of different heat transfer coefficient (linear and point) distributed as shown in the figure 2 and 3.

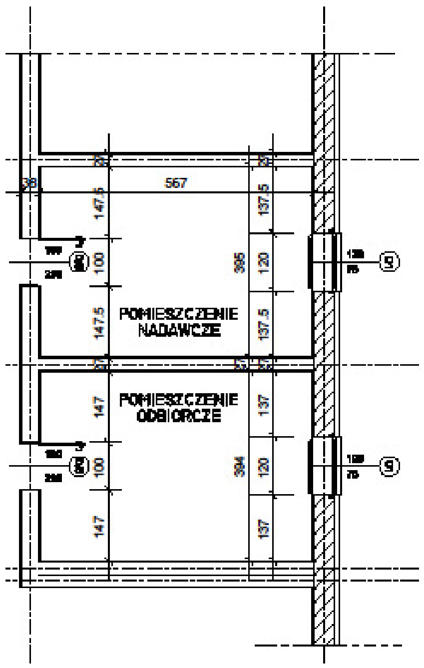


Fig. 1. Projection of rooms

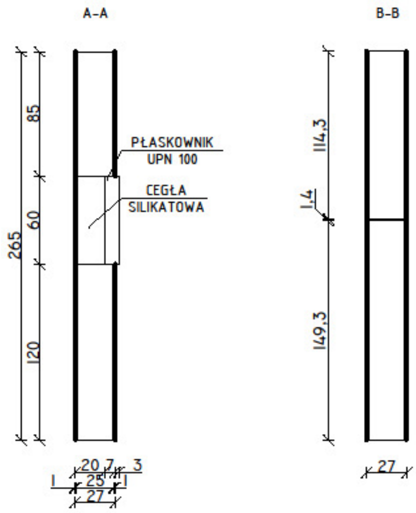


Fig. 2. Sections in the partition

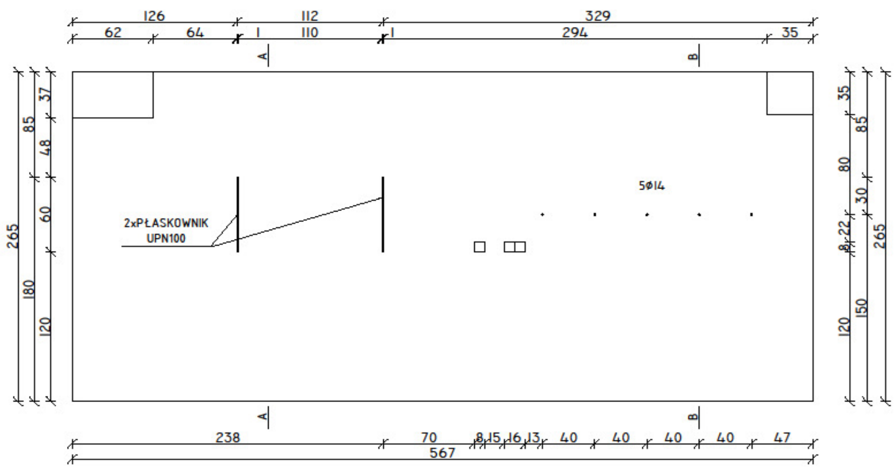


Fig. 3. View of the partition from the reception room

To make the bridges, the following elements were used: 2 UPN 100 flat bars (heat transfer coefficient $\lambda = 58{,}00$ W/(m·K); weight 10,6 kg/m), steel bars 5 x $\Phi$ 14 mm (coefficient of thermal conductivity $\lambda = 58{,}00$ W/(m·K); each 30 cm long), gypsum internal plaster (thermal conductivity coefficient $\lambda = 0{,}40$ W/(m·K);

density $\rho$ = 1000 kg/m$^3$). Five drillings of $\Phi$ 14 mm were made, in which steel rods were located. The next step was to cut out furrows with an angle grinder measuring 10 × 60 cm into the two UPN 100 flat bars. Before placing the linear bridges in the proper place, the holes were adapted to the dimensions of the flat bar by forging.

## 3. Computer simulation of the thermal properties of the partition

THERM has created a simulation of an exemplary homogeneous partition model with vertical and horizontal cross-sections running through the partition with the following boundary conditions:

- External: temperature 6.3°C, heat transfer coefficient $\lambda$= 9 W/(K·m$^2$),
- Internal: temperature 23°C, heat transfer coefficient $\lambda$= 29,7 W/(K·m$^2$).

Selected architectural details have been adopted for calculations the following material data and characterizing them heat conduction coefficients:

- UPN 100 flat bars, heat transfer coefficient $\lambda$= 58,00 W/(m·K),
- Steel bars $\Phi$ 14 mm, coefficient of thermal conductivity $\lambda$=58,00 W/(m·K),
- Gypsum internal plaster, thermal conductivity coefficient $\lambda$= 0,40 W/(m·K).

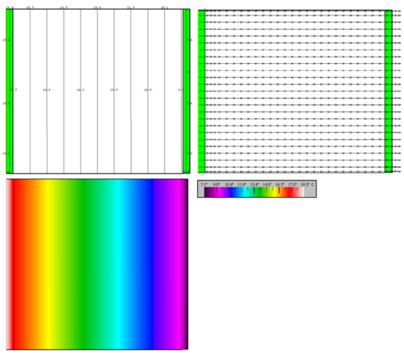

Fig. 4. Homogeneous partition as a case study of isothermal distribution, heat flow vectors and temperature distribution

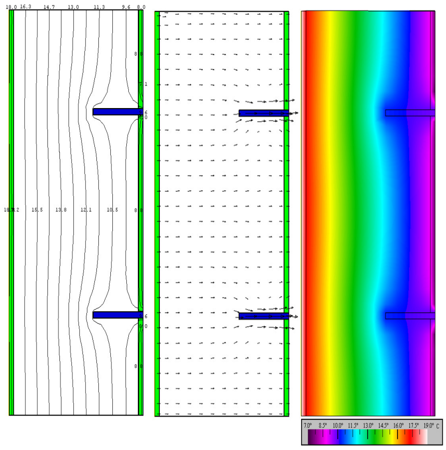

Fig. 5. Isothermal distribution, heat flux vectors and temperature distribution in the area of the partial linear bridge – a horizontal cross-section

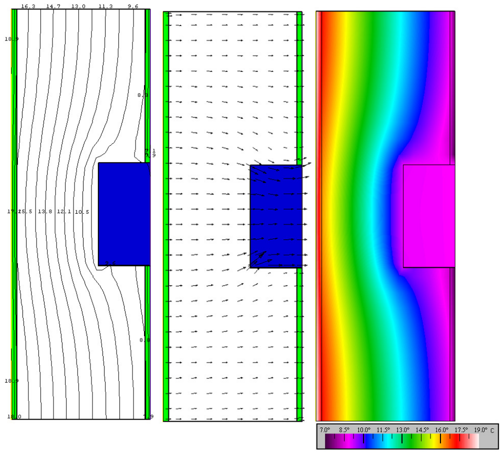

Fig. 6. Isothermal distribution, heat flux vectors and temperature distribution in the area of a partial linear bridge – vertical cross-section

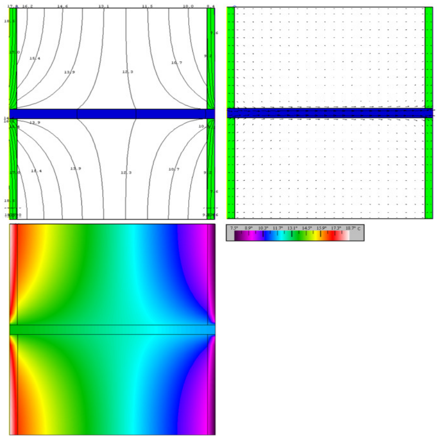

Fig. 7. Isothermal distribution, heat flux vectors and temperature distribution in the area of point bridge – a horizontal cross-section

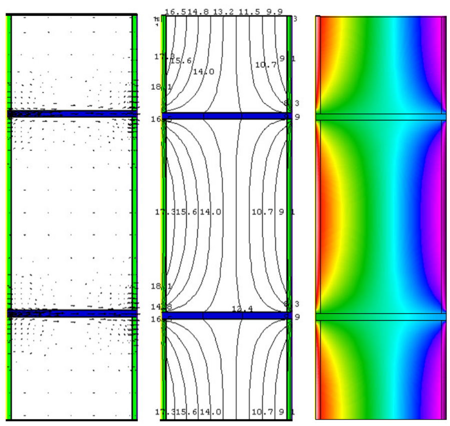

Fig. 8. Section of the baffle in the place where point bridges are located – horizontal cross-section (vectors of heat intensity, isothermal distribution, temperature distribution)

## 4. Conclusions

The presented results of a computer simulation of a building partition which was designed in accordance with the information provided by construction and thermal physics data, which is supposed to allow for explaining some selected problems, showed a clear negative effect of the built-in thermal bridges on the thermal properties of the partition.

In the case of the homogeneous partition, the isotherms are parallel, and the vectors of the heat flux intensity are perpendicular to the surface of the baffle, which is in line with the theory of heat flow (figure 4).

In the case of the area in which the partial linear heat bridges are located, the isotherms cease to be parallel to the surface of the partition. Then, two-way heat flow is visible, as indicated by the heat flow vectors. The vectors are no longer perpendicular to the surface of the baffle in the area of the linear bridge, which means that the heat flows not only from one surface to the other but in this case also vertically (figure 5,6).

In the case of the area in which point thermal bridges are located, the isotherms cease to be parallel to the surface of the partition. Then, two-way heat flow is visible, as indicated by the heat flow vectors. The vectors are no longer perpendicular to the surface of the baffle in the area of the point bridge, which means that the heat flows not only from one surface to the other, but also, as in this case, vertically (figure 7,8).

The building divider was designed based on the information collected in the field of construction and thermal physics, so that it is possible to explain selected issues in a simple way. To sum up, in order that the bulkhead can be used as a teaching aid in laboratory exercises in thermal physics of buildings, rooms should be adequately cooled or heated in order to increase the temperature difference around 15–20°C.

The simulation is a preliminary pilot action before the start of non-invasive tests, ie measurement and calculation of the heat transfer coefficient, thermovision measurements on the surface of the barrier. The results thermographic analysis wall partition with built-in elements that imitate thermal bridges are presented in the next article in the series.

### References

[1] Gawin D., Komputerowa Fizyka Budowli, komputerowa symulacja procesów wymiany masy i energii w budynkach, KFBiMB, Łódź 1998.

[2] Grabarczyk S., Komputerowe wspomaganie projektowania budownictwa energo-oszczędnego, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 2005.

[3] Heim D., Błaszczyk E., Ocena możliwości wykorzystania energii odnawialnej w oparciu o analizy statystyczne i symulacje komputerowe, Budownictwo

i inżynieria środowiska, Zeszyty Naukowe Politechniki Rzeszowskiej, nr 252 z. 47, Rzeszów 2008.

[4] Kisilewicz T., Królak E., Pieniążek Z., Fizyka cieplna budowli, Wydawnictwo Politechniki Krakowskiej, Kraków 1998.

[5] Klemm P., Budownictwo ogólne, tom 2, Fizyka budowli, Wydawnictwo Arkady, Warszawa 2006.

[6] Krause P., Steidl T., Orlik-Kożdoń B. Cieplnowilgotnościowe projektowanie ścian z betonu komórkowego. Zeszyt 3 Część 2 Mostki termiczne. SPB. Warszawa 2016.

[7] Norma, PN-EN ISO 10211-1: 1998 Mostki cieplne w budynkach. Strumień cieplny i temperatura powierzchni. Ogólne metody obliczania.

[8] PN-EN ISO 10211:2008, Mostki cieplne w budynkach. Strumienie ciepła i temperatury powierzchni. Obliczenia szczegółowe.

[9] PN-EN ISO 14683:2008, Mostki cieplne w budynkach, Liniowy współczynnik przenikania ciepła, Metody uproszczone i wartości orientacyjne.

*Przesłano do redakcji: 20.07.2018 r.*