THE EQUIVALENT THERMAL CONDUCTIVITY OF A PERFORATED METAL PLATE

Introduction and problem description

A method for calculating the equivalent thermal conductivity of a perforated metal plate is explained and validated.

The heat transfer through building components including perforated metal plates is 3D. The programs TRISCO and SOLIDO can be used to simulate this 3D heat transfer. In some cases it is helpful to replace the perforated plate by a homogeneous plate, for example

- because a 2D simulation is preferred,
- because the 3D component is relatively complex.

For the example shown in Figure 1 the equivalent thermal conductivity of the homogeneous plate will be derived.

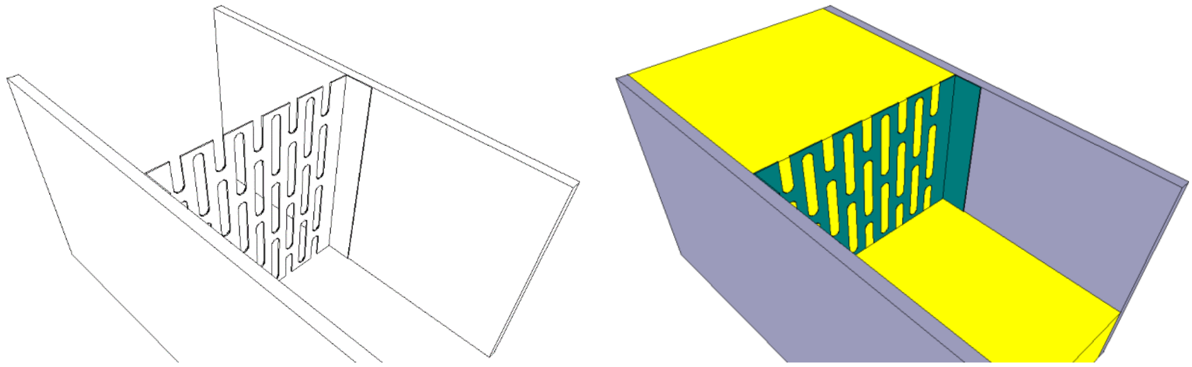

Figure 1. Insulated wall including a perforated steel frame.

<u>Example data.</u>

- internal and external board, thickness 10 mm, thermal conductivity 0.43 W/mK
- thermal insulation, thickness 212 mm, thermal conductivity 0.035 W/mK
- steel frame, height 212 mm, width 30 mm, thickness 1 mm, thermal conductivity 50 W/mK
- frame centre-to-centre distance 400 mm
- perforation geometrical data: Figure 2
- outdoors: temperature 0 °C, surface heat transfer coefficient 25 W/m2K
- indoors: temperature 20 °C, surface heat transfer coefficient 7.7 W/m2K.

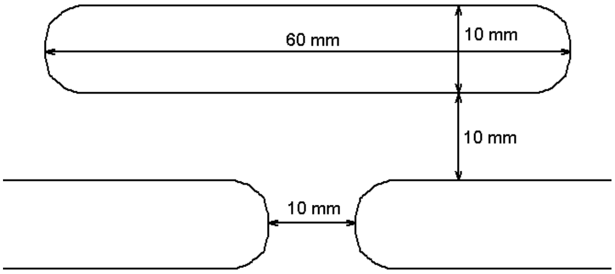

Figure 2. Perforation geometrical data.

3D simulation TRISCO data **perforated_plate_3D.trc**

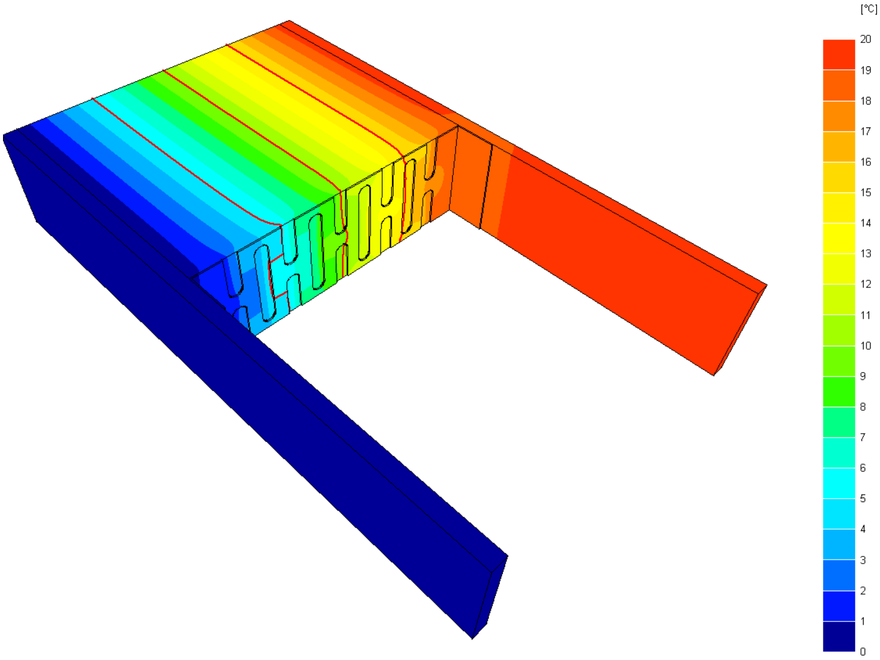

Figure 3. Isotherms (colour increment 1 °C, line increment 5 °C) (insulation partially omitted).

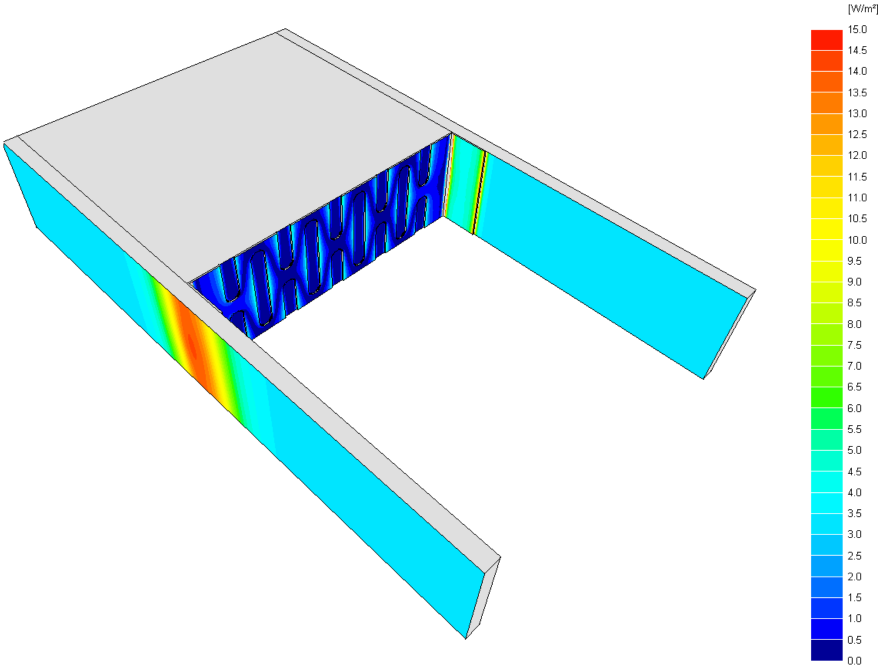

Figure 4. Heat flow densities (insulation partially omitted).

Figure 3 and Figure 4 show the isotherms and the heat flow densities in the wall. The thermal insulation is partially omitted in the graphic (not in the calculation).

The thermal transmittance of the wall is

U_{wall} = 0.229 W/m²K.

This is 44 % higher than the thermal transmittance of the undisturbed wall

U_0 = 0.159 W/m2K.

In case of a non-perforated steel plate, the thermal transmittance of the wall is

$U_0 = 0.47\ W/m^2K$

showing the effectiveness of the perforations.

2D simulation for deriving equivalent λ

TRISCO data perforated_plate_equi_lambda_.trc
BISCO data perforated_plate_equi_lambda.bsc

In order to derive the equivalent thermal conductivity of the perforated plate, a representative part of the plate is considered (Figure 5, left). Fixed surface temperatures on top and at the bottom are applied as boundary conditions. This corresponds to the expected heat transfer direction in the 3D problem above.

Figure 5 (right) shows the isotherms and heat flows through the plate part. The isotherms in the centre of the perforations are almost horizontal, which justifies the boundary conditions assumed (constant temperature in the centre of the perforations).

The heat flow simulated amounts to Q_{2D} = 97.9 W/m.

The equivalent thermal conductivity of the homogeneous plate can now be derived:

$$\lambda_{eq} = \frac{dQ_{2D}}{b\Delta\theta_{ie}}$$

with	d	depth of the section considered = 0.08 m
	b	width of the section considered = 0.07 m
	Q_{2D}	simulated 2D heat loss = 97.9 W/m
	$\Delta\theta_{ie}$	temperature difference = 20 K

λ_{eq} = 5.6 W/mK

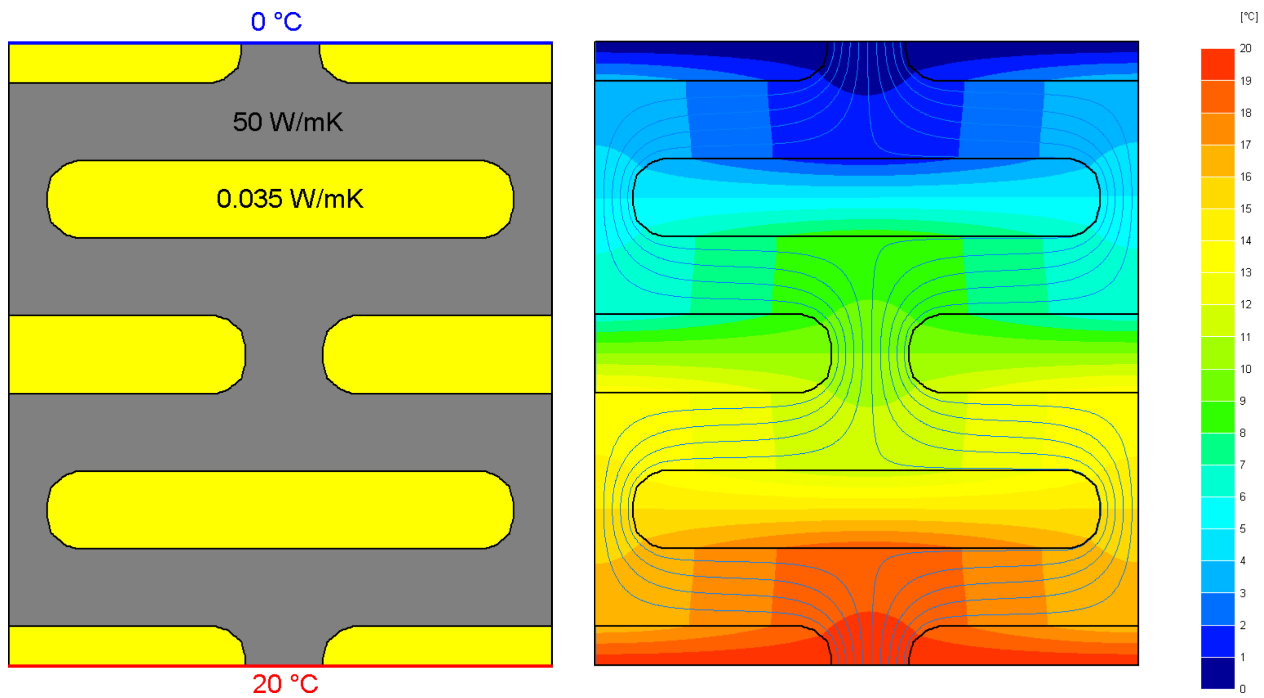

Figure 5. Equivalent λ simulation: data (left) and results (right): isotherms and heat flow lines (increment 10 W/m).

Validation of the equivalent λ

TRISCO data perforated_plate_2D_simplified.trc

In order to validate the derived equivalent thermal conductivity a construction with a homogeneous instead of a perforated plate is considered as shown in Figure 6. The problem is a 2D heat transfer problem now.

Figure 7 and Figure 8 show the isotherms and the heat flow densities in the wall. The thermal insulation is partially omitted in the graphic (not in the calculation).

The thermal transmittance of the wall is

U_{wall} = 0.228 W/m²K.

This value is almost identical to the one obtained by the 3D simulation, which validates the method explained.

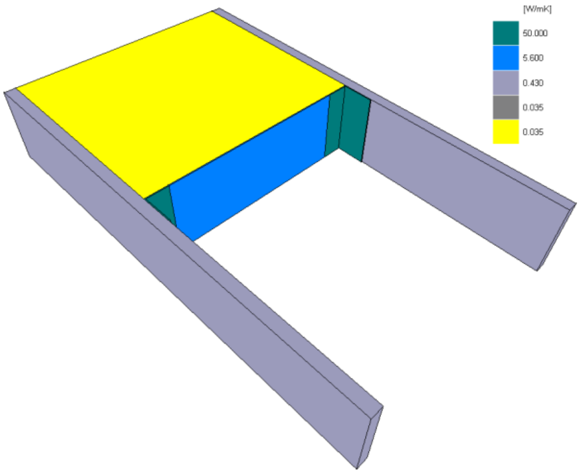

Figure 6. Insulated wall including a perforated steel frame.

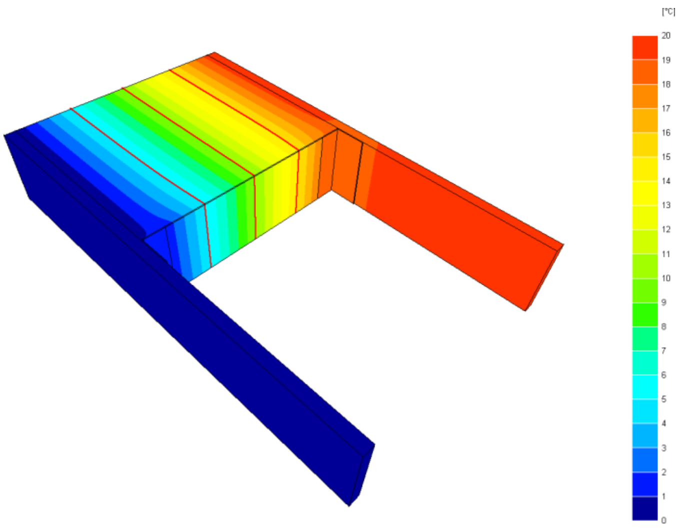

Figure 7. Isotherms (colour increment 1 °C, line increment 5 °C) (insulation partially omitted).

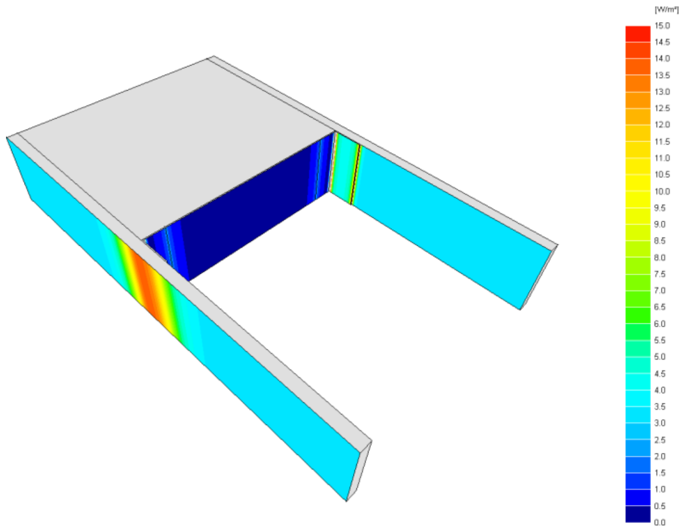

Figure 8. Heat flow densities (insulation partially omitted).