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# Modelling Thermal Bridging at Interface Conditions. Analysis of Solutions for Reducing Thermal Bridges Effects on Building Energy Consumption

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**Introduction**: Advanced architectural developments require an integrated approach to evaluate interaction between heating, lighting, ventilation and acoustics in the building thermophysical behaviour. External building claddings, traditional or multilayer walls with high thermal capacity, are usually used to reduce the indoor temperature surface. The acoustic resistance of a façade can be estimated through the acoustical mass law. Elements without high thermal mass and with low thermal capacity, usually provides lower acoustic performances. The aim of this study is to analyze an usual thermal bridge, a structural connection between a concrete beam and a balcony, investigating the thermal and acoustic effects of different insulation solutions whit and without a Thermal Break Element (TBE):

1. Balcony without TBE and thermal insulation beam surface;
2. Balcony with TBE and thermal insulation on beam surface;
3. Balcony with TBE and thermal coat (thickness 10 cm);
4. Balcony without TBE and thermal coat on the wall;
5. Balcony without TBE and complete thermal coat (thickness 10 cm on the external wall and 5 cm under the balcony);

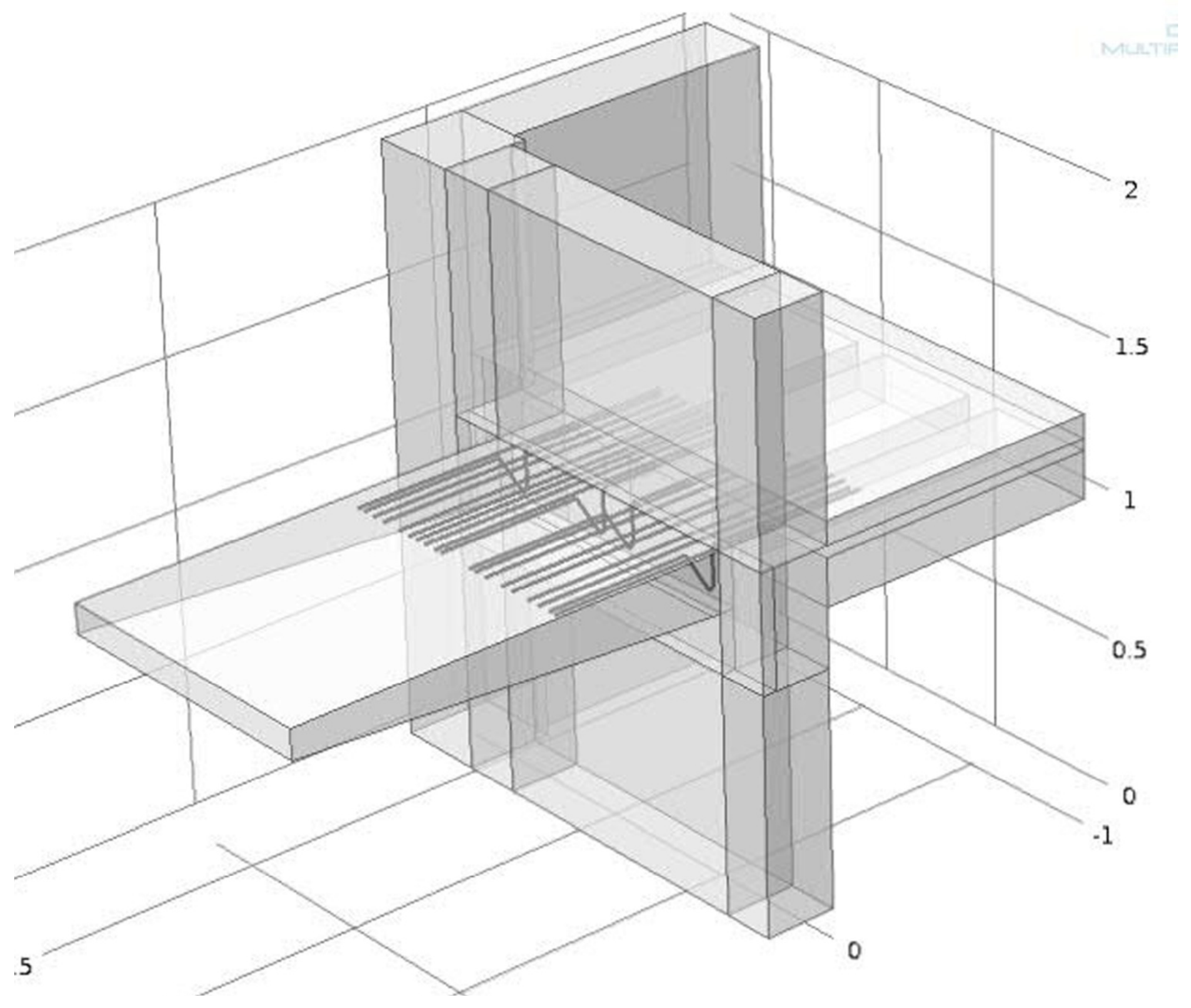

**Figure 1**. 3D detailed model for thermal analysis

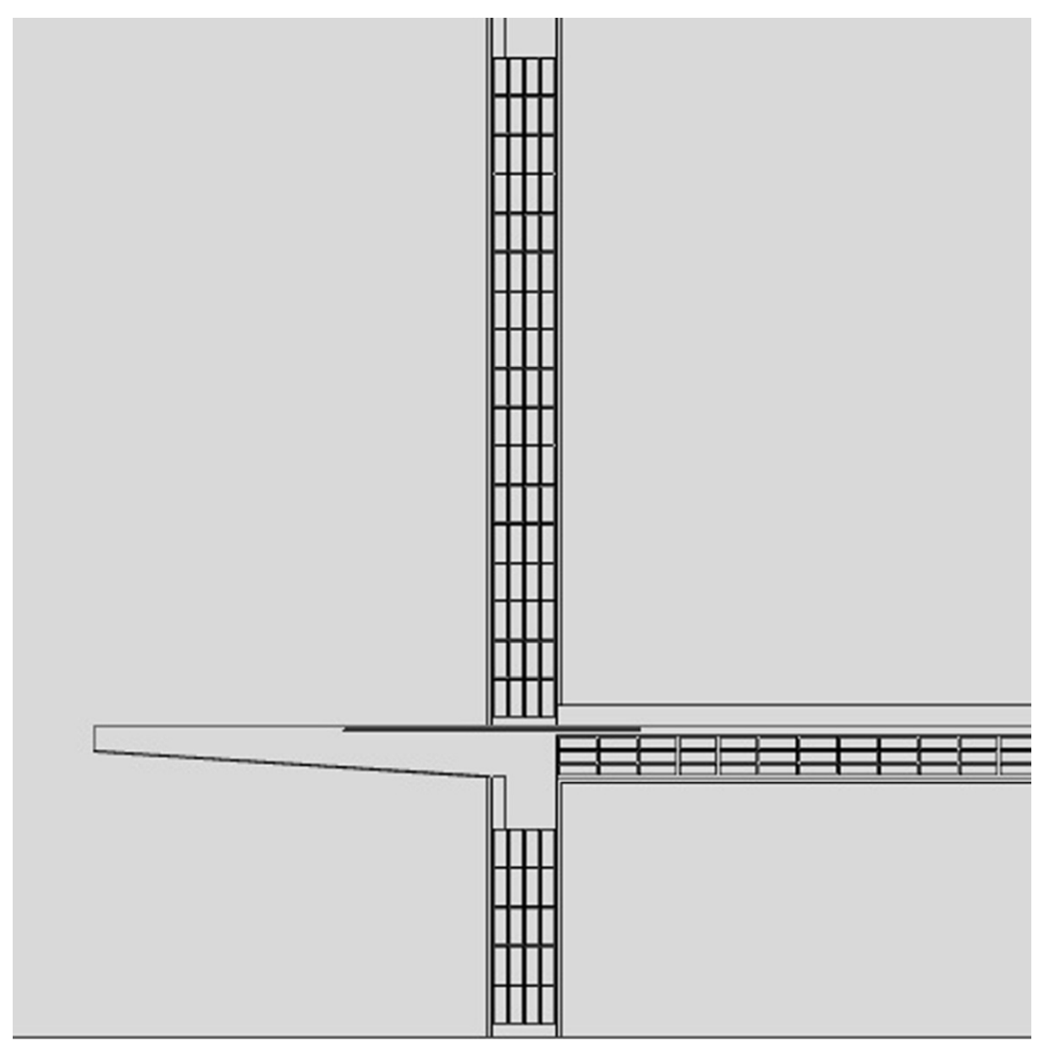

**Figure 2**. 2D detailed model for acoustic analysis

**Computational Methods:** Thermal and acoustic behaviour of the balcony with TBE (thickness 8 cm high 20 cm containing structural steel rods (22 steel element with diameter 12 mm and length 1140 mm), was evaluated using COMSOL Multiphysics 4.2a. The iterative solver FGMRES was used.

**Thermal analysis:** Boundary condition for the 3D models studied were assumed at uniform temperature for exposed (0°C) and indoor surfaces (internal air and floor at 20°C).

**Acoustic analysis:** The acoustic resistance of the external façade was investigated a 2D models. A stationary frequency domain analysis fixed at 500 Hz, reference frequency for building elements analysis, was applied. A cylindrical wave radiation was applied at 2 m from the external wall with an incident pressure of 2 Pa, corresponding at 100 dB.

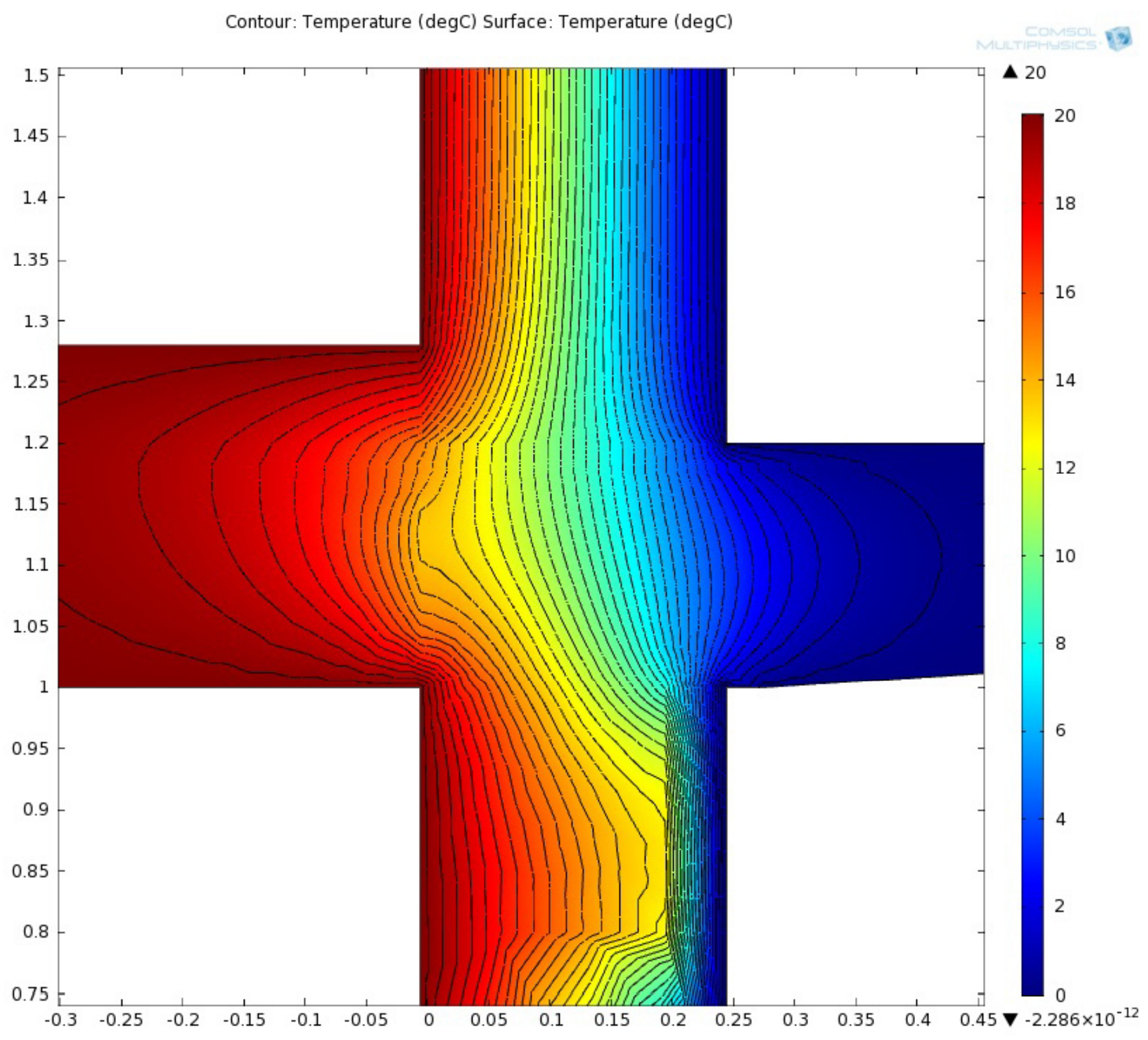

**Figure 3.** Thermal analysis, Case 1: Temperature distribution and Isothermal lines

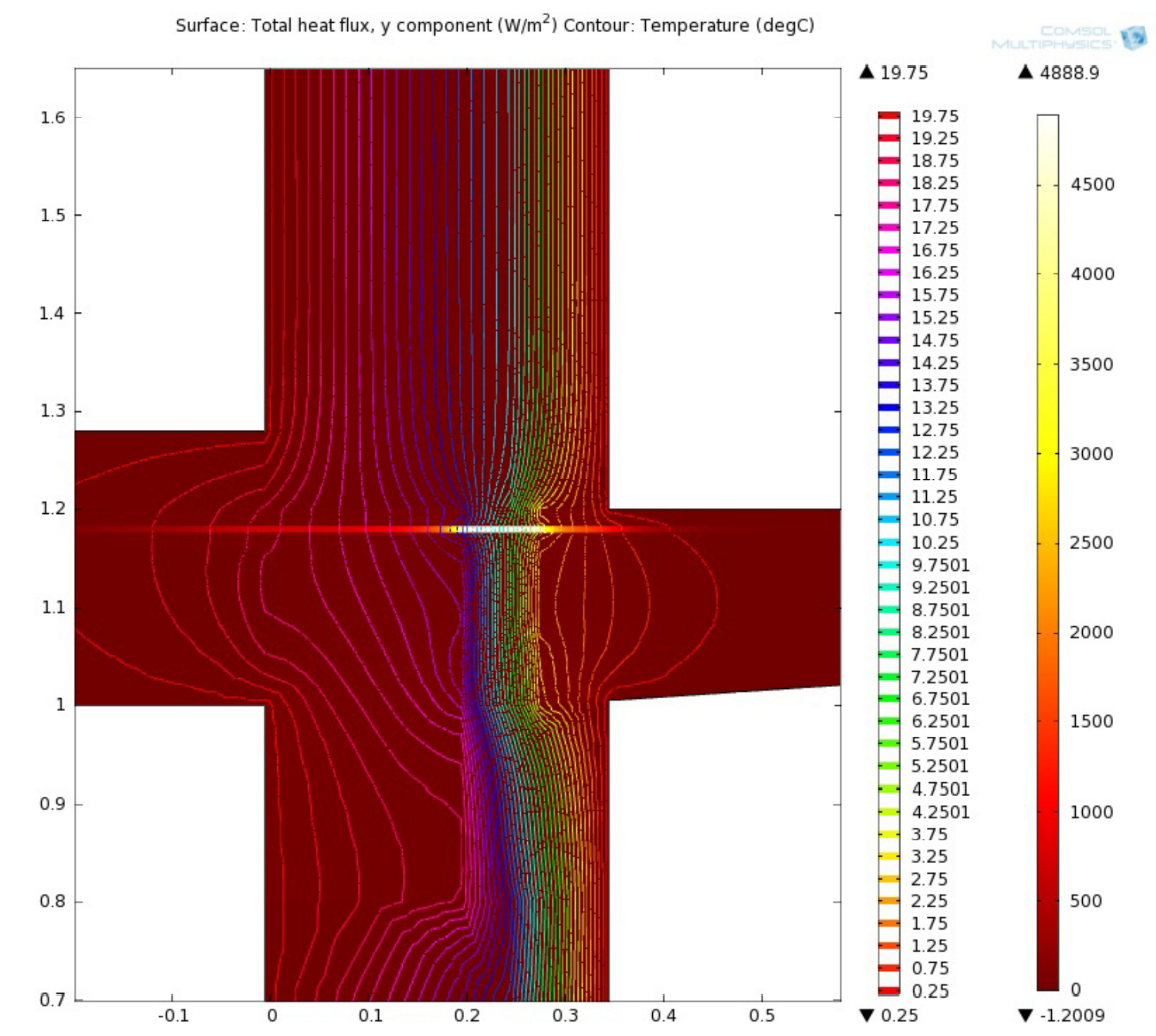

**Figure 4.** Thermal analysis, Case 2: Total heat flux (thermal light colour) Steel rood heat transfer.

**Thermal Analysis:** using a surface representation of temperature and heat flux distribution the best thermal insulation was evaluated. The reinforcement rod, that crosses the TBE component, produces an higher thermal bridge effect (Fig.3,4). In accordance with UNI EN ISO 10211:2008, the 2D models of the same nodes were defined to evaluated the linear thermal bridges $\psi_{calc}$ whit UNI EN ISO 14683:2008. These results were compared with those obtained by COMSOL (Table 1).

**Table 1**. Thermal analysis results

| | HEAT FLUX | | | | | | THERMAL BRIDGE | | |
|---|---|---|---|---|---|---|---|---|---|
| | U-factor (W/m²K) | $L_{Tot}$ (m) | ΔT (K) | $\psi_{calc}$ (W) | COMSOL simulation (W) | Difference between $\psi_{calc}$ and simulated | $L_{2D}$ (W/mK) | UNI 14683:2008 | |
| case 1 | 0.4814 | 4.5 | 20 | 43.33 | 41.00 | -5.4% | 0.481 | 0.7 | -31.2% |
| case 2 | 0.3591 | 4.4 | 20 | 31.60 | 29.73 | -5.9% | 0.359 | 0.7 | -48.7% |
| case 3 | 0.1942 | 4.3 | 20 | 16.70 | 15.63 | -6.4% | 0.194 | 0.95 | -79.6% |
| case 4 | 0.2242 | 4.8 | 20 | 24.69 | 23.51 | -4.8% | 0.224 | 0.95 | -76.4% |
| case 5 | 0.1865 | 4.4 | 20 | 17.11 | 15.94 | -6.8% | 0.187 | 0 | - |

**Acoustic Analysis**: The acoustic resistance of façade was carried out and results compared whit standards. Acoustic resistance of building thermal bridges increases only in the presence of a uniform and continuum treatment of the building envelope. The presence of steel rods produces an important reduction of acoustic performances (Fig.5,6).

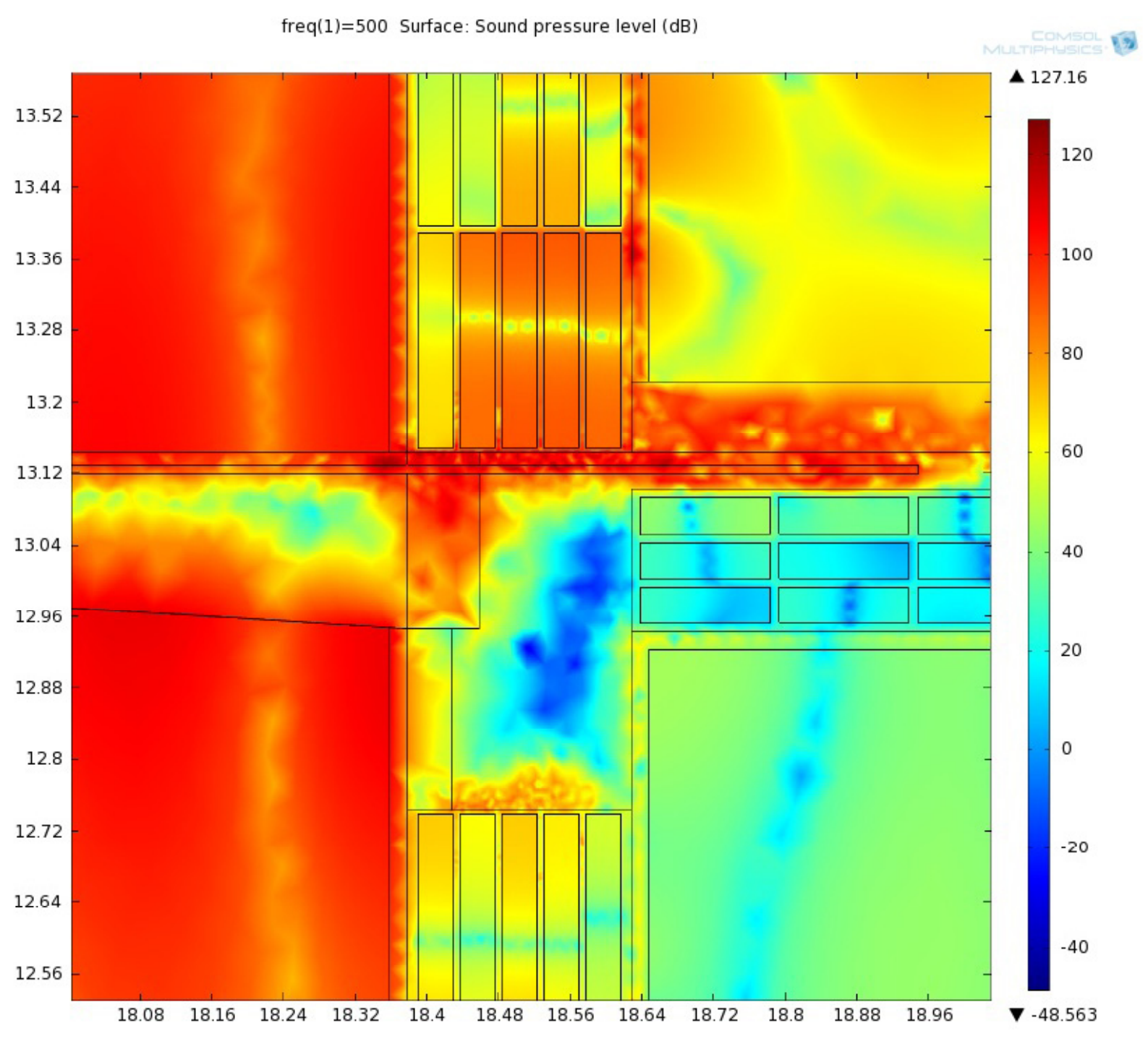

**Figure 5**. Acoustic analysis, Case 2: Sound transmission

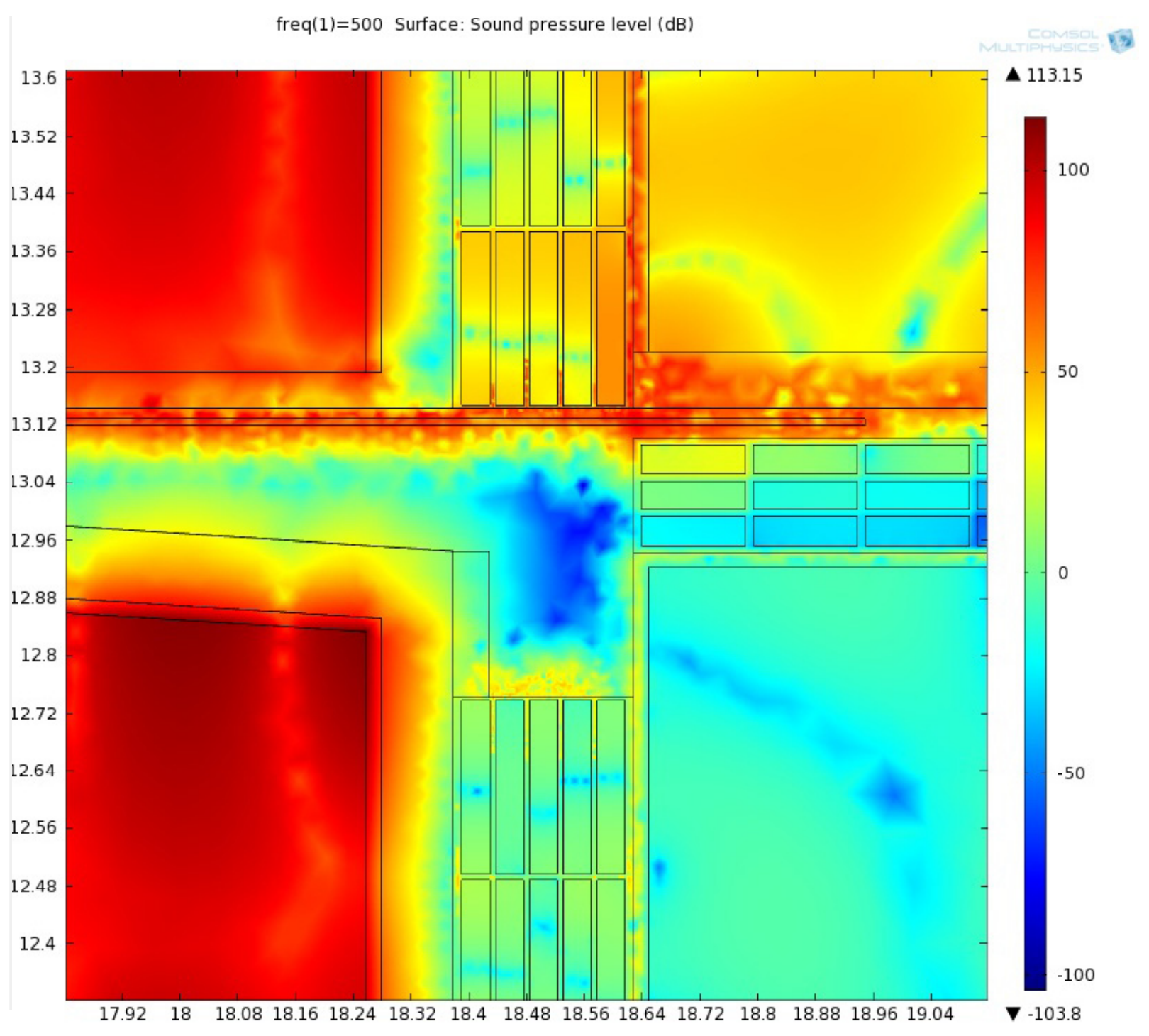

**Figure 6**. Acoustic analysis, Case 5: Sound transmission

**Conclusions:** An optimal solution for thermal insulation, does not always produce an optimal acoustic resistance. Multiphysics simulations allow the choice of the better solution in the designing phase: the use simplified analysis approach to evaluate heat flux values not consider the steel rood presence. This can provide errors, over 50% compared to the effective heat transmission values obtained by COMSOL. Besides, in the acoustic field the rods become the main points of sound transmission. Only an homogeneous building cladding allows an acoustic improvement of the façade. This integrated approach can be an useful tool to determine the best design solution for the heat transfer reduction and acoustic behaviour optimization of the building envelope.

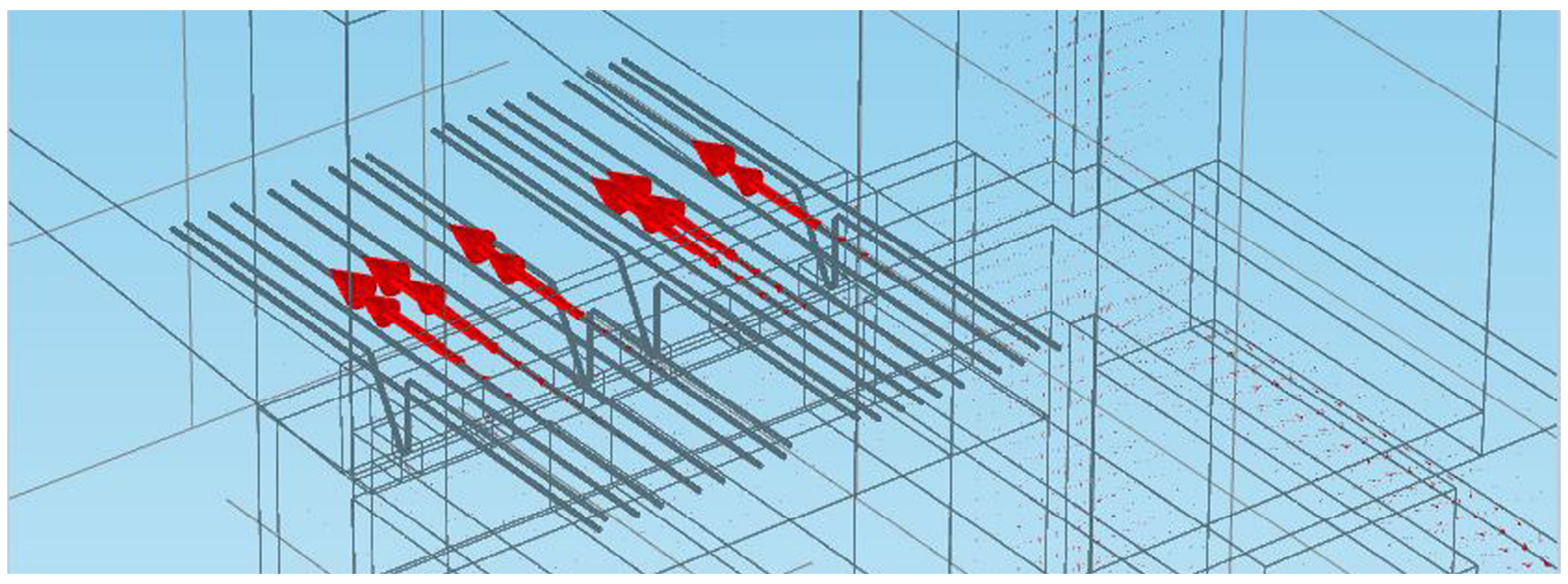

**Figure 7.** Case 2: Total Heat Flux (red harrow) thought concrete beam (right) and TBE with steel roods (left).

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