VALIDATION OF SIMPLIFYING THE THERMAL SIMULATION OF AN OBJECT WITH A 3D SLOPED METAL BAR

1. Introduction

Objects containing sloped metal bars can be simulated thermally using the Physibel program SOLIDO. Because of the sloped shape a dense grid is required for a precise thermal simulation. Therefore, when simulating complex details containing sloped metal bars, it is often of interest to make a rectangular simplification. A few simplification methods are validated.

2. Case study reference data

SOLIDO data test_a.sld

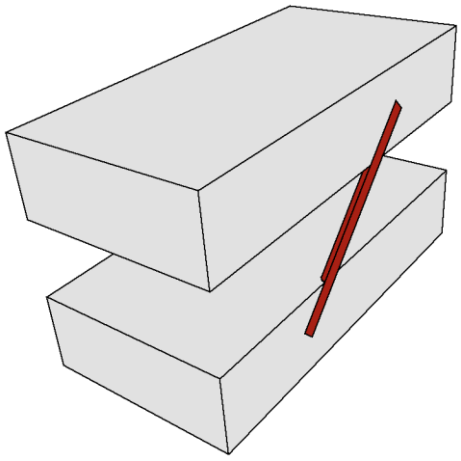


Figure 1 – Reference geometry

Figure 1 shows 2 half concrete slabs interconnected by a half sloped (θ = 45 °) steel bar. In between the slabs there is an insulation layer (not visualised in the figure). The upper side is a cold environment, the lower side is a warm environment. The vertical cut-off planes are adiabatic.

Dimensions:	concrete slab thickness = 100 mm insulation thickness = 100 mm half width x length = 250 mm x 500 mm steel bar length = 282.8 mm (= 200 $\sqrt{2}$ mm) steel bar diameter = 20 mm
Thermal conductivities	$\lambda_{concrete}$ = 2.0 W/mK $\lambda_{insulation}$ = 0.030 W/mK λ_{steel} = 50 W/mK
Boundary conditions	temperature θ_e = 0 °C, heat transfer coefficient h_e = 25 W/m^{2}K temperature θ_i = 20 °C, heat transfer coefficient h_i = 10 W/m^{2}K.

3. Simplified case data

SOLIDO data test_b.sld, TRISCO data test_c.trc, test_d.trc

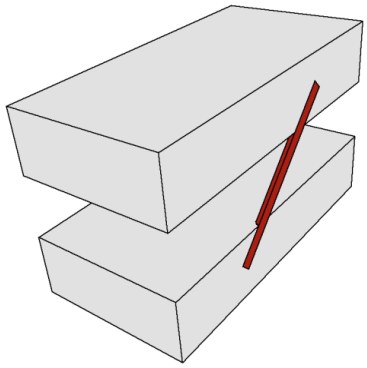
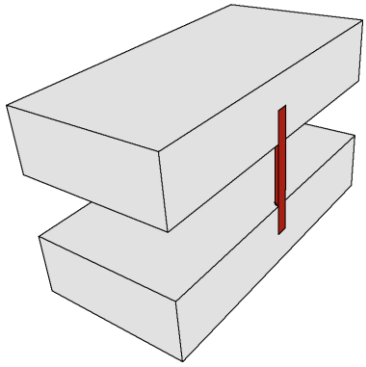
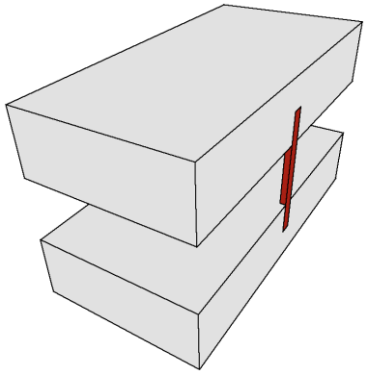
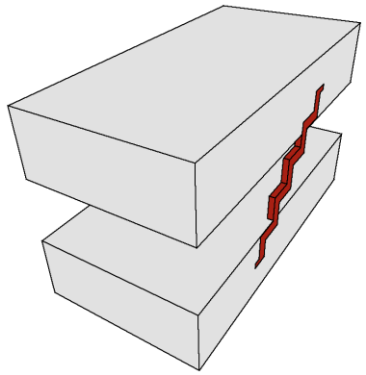
	Reference case A. SOLIDO data test_a.sld
	Simplified case B. SOLIDO data test_b.sld The steel bar is put perpendicular on the concrete slab. Because of its shorter length (200 mm instead of 200 x √2 mm) the thermal conductivity of the steel is reduced to 50 / √2 W/mK = 35.36 W/mK.
	Simplified case C. TRISCO data test_c.trc The steel bar is put perpendicular on the concrete slab with a reduced thermal conductivity as in case B. Furthermore a steel bar with a square section of 17.72 mm x 17.72 mm, equivalent to a section with diameter 20 mm is used.
	Simplified case D. TRISCO data test_d.trc The steel bar is modelled stepwise and with a square section of 17.72 mm x 17.72 mm, equivalent to a section with diameter 20 mm. Because the longer the steel bar now (400 mm instead of 200 x √2 mm) the thermal conductivity of the steel is increased to 50 x √2 W/mK = 70.71 W/mK.

Table 1- Reference and simplified cases

Table 1 lists the reference case A and 3 simplified cases B, C and D, for which the simplification method is explained.

4. Reference case and simplified cases results

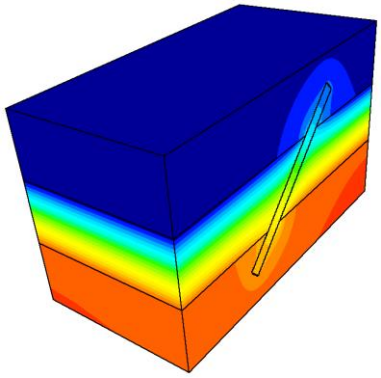
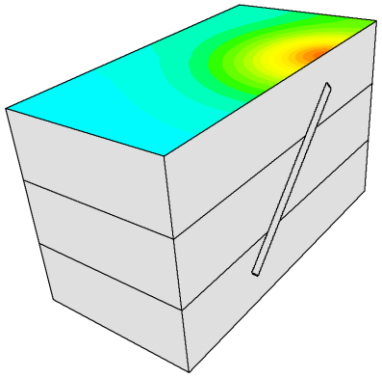
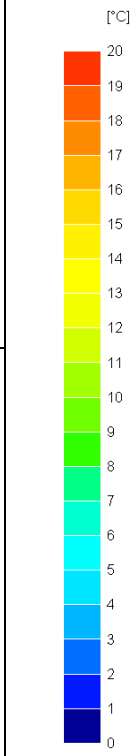
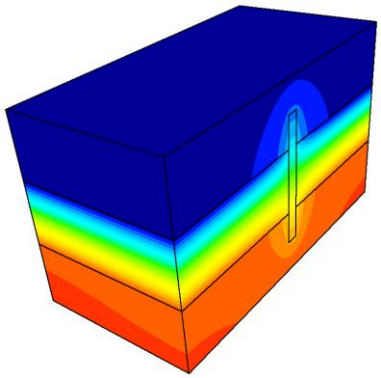
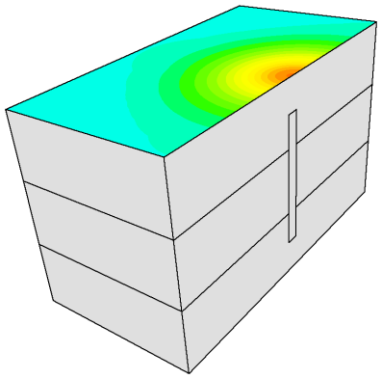
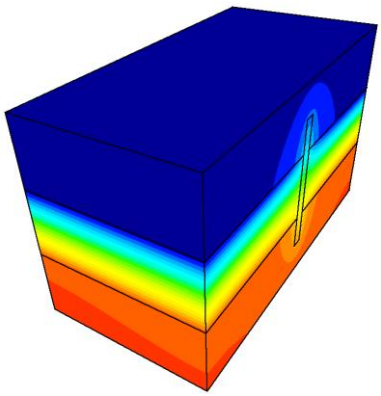
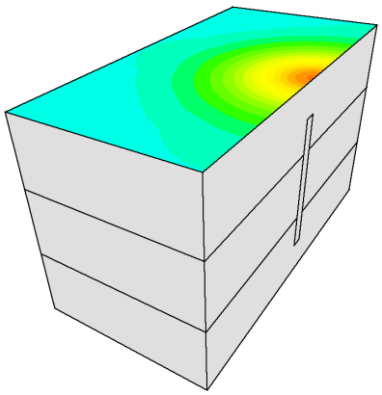
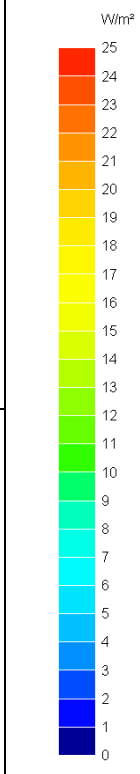
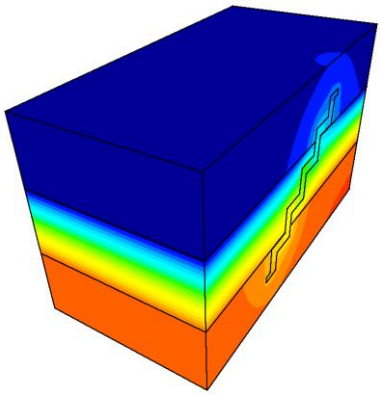
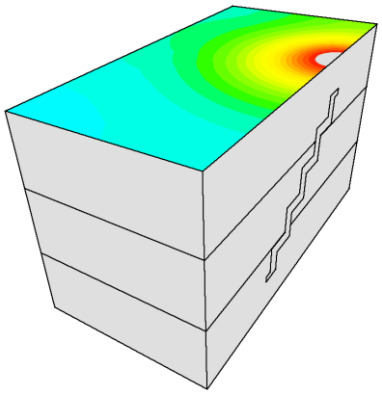
		Case A Q = 1.2251 W U = 0.4900 W/m^{2}K	
		Case B Q = 1.1860 W U = 0.474 W/m^{2}K Δ_{BA} = -3.2 %	
		Case C Q = 1.1903 W U = 0.476 W/m^{2}K Δ_{CA} = -2.8 % Δ_{CB} = 0.4 %	
		Case D Q = 1.3628 W U = 0.545 W/m^{2}K Δ_{DA} = +11.2 %	

Table 2 – Isotherms (left) and heat flow densities (right) for the reference and simplified cases

Table 2 shows the isotherms (left figures) and external surface heat flow densities (right figures) for the 4 cases. From the results the following conclusions can be drawn:

- Comparing case A with case B.

Replacing a sloped metal bar by a perpendicular bar with a reduced thermal conductivity ($\lambda' = \lambda \cos\theta$) has no significant effect on the simulated heat loss.

- Comparing case B with case C.

Replacing a circular bar by a square bar with the same cross section has no significant effect on the simulated heat loss.

- Comparing case A with case D.

Replacing a sloped metal bar by a stepwise rectangular bar with an increased thermal conductivity ($\lambda'' = \lambda \cos\theta + \lambda \sin\theta$) causes a slightly increased simulated heat loss. This is because the length of the heat loss path is shorter than ($\cos\theta + \sin\theta$) l_{bar} due to the relative thick rod. A lower deviation can be expected for thinner rods.