REDUCTION OF CALCULATION NODES THROUGH GEOMETRY SIMPLIFICATION OF STL INPUT

1. Introduction

A key advantage of SOLIDO is its ability to readily import highly complex geometries in STL format. However, increasing geometric complexity can significantly increase the number of computational nodes and, consequently, the required simulation time. This study evaluates the extent to which geometric simplification can improve computational efficiency while maintaining the accuracy of 3D thermal simulation results.

The analysis is based on two case studies of ventilated façade systems with different levels of geometric complexity. The first case study considers a façade incorporating a highly complex anchoring system, while the second examines a façade with a comparatively simple bracket system. By comparing the original and simplified geometries, the study assesses the resulting reductions in calculation nodes and simulation time, as well as their impact on the calculated thermal performance.

2. Case 1

2.1. Model

The figure below shows the model of the ventilated façade. The steel anchor is imported into SOLIDO as an STL file, while the remainder of the façade is built up from SOLID blocks. Capturing every detail of the anchor requires a very fine grid, so the anchor is simplified to reduce the computational cost while maintaining accuracy.

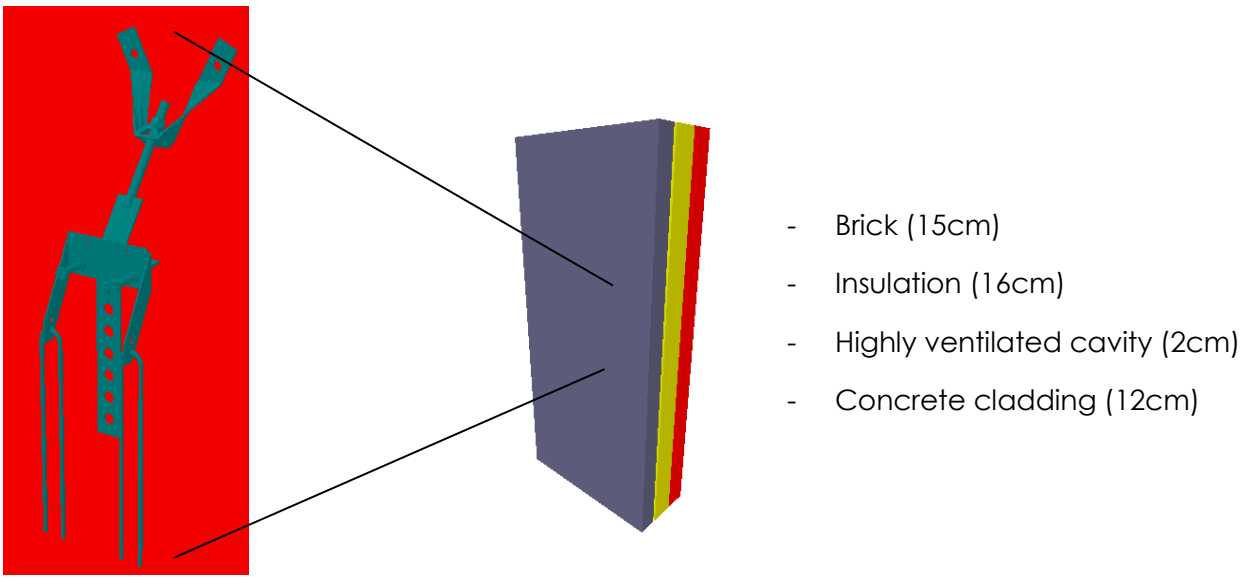


Figure 1 Model of the ventilated façade

2.2. Simplifications

full_detail.sld, simplified_1.sld, simplified_2.sld
full_detail.stl, simplified_1.stl, simplified_2.stl

Three variants of the anchor are considered, as shown in Figure 2:

- Full detail: the complete geometry as received from the anchor manufacturer
- Simplified 1: the legs and arms are simplified
- Simplified 2: the legs and arms are simplified and aligned

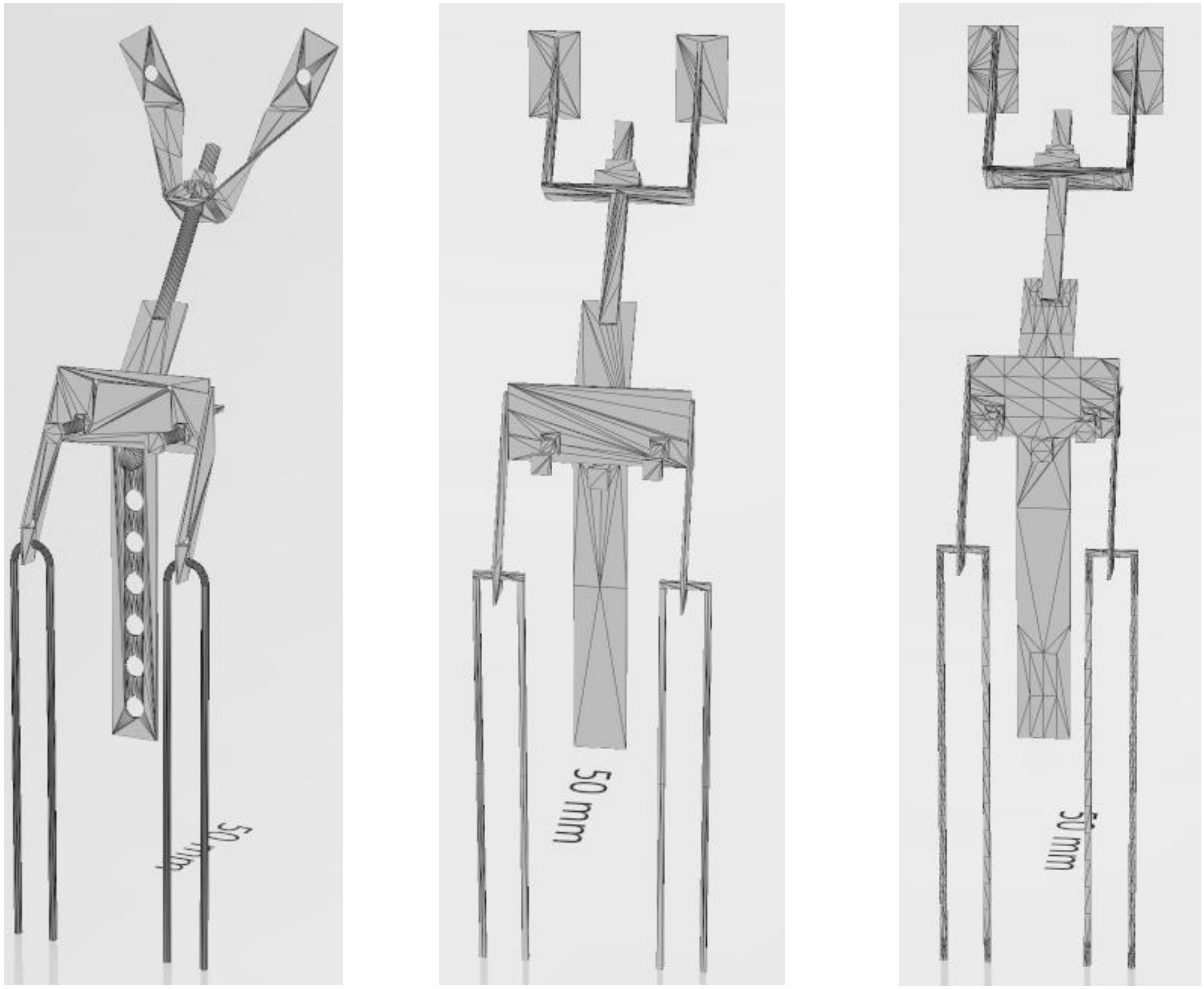


Figure 2 Anchor variations: Full detail (left), Simplified 1 (middle), Simplified 2 (right)

2.3. Symmetry

full_detail_half.sld, simplified_1_half.sld, simplified_2_half.sld

Because the anchor and the façade elements are symmetric about the y-axis, only half of the model needs to be calculated. To achieve this, an adiabatic block (colour 191) is added as the last block, covering one half of the model. By the superposition principle, only the remaining half is then included in the calculation, with an adiabatic boundary condition at the symmetry plane.

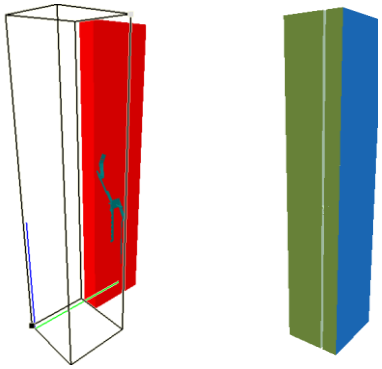


Figure 3 Symmetry of the case study model (left) and adiabatic boundary condition at the symmetry plane (right)

2.4. Results and conclusion

Table 1 shows the results. Simplifying the geometry reduces the number of nodes by 38% for Simplified 1 and by 47% for Simplified 2, with a corresponding reduction in calculation time of 41% and 42% respectively. The thermal results remain close to the full-detail reference: the heat flow deviates by no more than 1.4%, and the equivalent thermal transmittance and the point thermal transmittance are essentially unchanged.

Exploiting the symmetry reduces the number of nodes by up to 73%, with a comparable reduction in calculation time and a deviation in the results of no more than 1.5%. Note that the reported heat flow is only half of the total heat flow, as is the chi value; both must be multiplied by two to be compared with the full-model results.

Table 1 Results of the simplification (case 1)

	number of nodes	node reduction (%)	total time (s)	time reduction (%)	heat flow (W)		U_{3D} (W/m²K)
full detail	1.88E+07	ref.	423.75	ref.	6.918	ref.	0.132
simpl. 1	1.17E+07	-38%	251.53	-41%	7.013	1.4%	0.134
simpl. 2	9.95E+06	-47%	244.41	-42%	7.006	1.3%	0.134
full det. half	9.32E+06	-50%	184.53	-56%	3.459 (x2)	0.0%	0.132
simpl. 1 half	5.92E+06	-69%	116.72	-72%	3.512 (x2)	1.5%	0.134
simpl. 2 half	5.05E+06	-73%	111.47	-74%	3.508 (x2)	1.4%	0.134

In conclusion, replacing complex free-form geometries with simplified rectangular shapes can substantially reduce computational time, while having only a limited impact on the calculated results (<1.5% for the case considered). The findings therefore indicate that geometric simplification can be an effective approach for improving the computational efficiency of 3D thermal simulations. Further reductions in calculation nodes can be achieved by exploiting symmetry and modelling only half of the geometry. In SOLIDO, this can be readily implemented by overlaying one half of the geometry with an adiabatic block (colour 191).

3. Case 2

For the second case the rainscreen wall with bracket from the SOLIDO tutorial E is used.

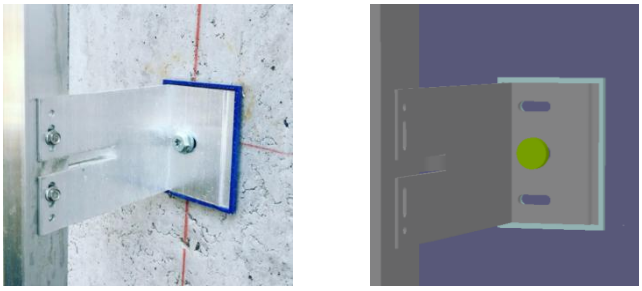


Figure 4 Detailed bracket in STL format

The model consists of a 20 cm thick concrete wall with a thermal conductivity of $\lambda = 2$ W/(m·K), combined with a 16 cm thick insulation layer with $\lambda = 0.035$ W/(m·K). The insulation layer is interrupted by a bracket incorporating a thermal insulator. The geometries of both the bracket and the insulator are imported in high detail using STL files. All other materials and boundary conditions are defined using rectangular blocks in SOLIDO.

3.1. Simplifications

T-SLDe_STL_rainscreen_cladding_detail.sld
T-SLDe_STL_rainscreen_cladding_simpl.sld
T-SLDe_STL_rainscreen_cladding_simpl_no_screw.sld
T-SLDe_STL_rainscreen_cladding_simpl.trc

Two variants are considered:

- Full-detail model, in which the bracket, insulator, and screws are represented using their detailed STL geometries.
- Simplified model, in which the bracket, insulator, and screws are replaced by rectangular elements. For the screws, an equivalent square cross-section with the same area as the original circular cross-section is used.

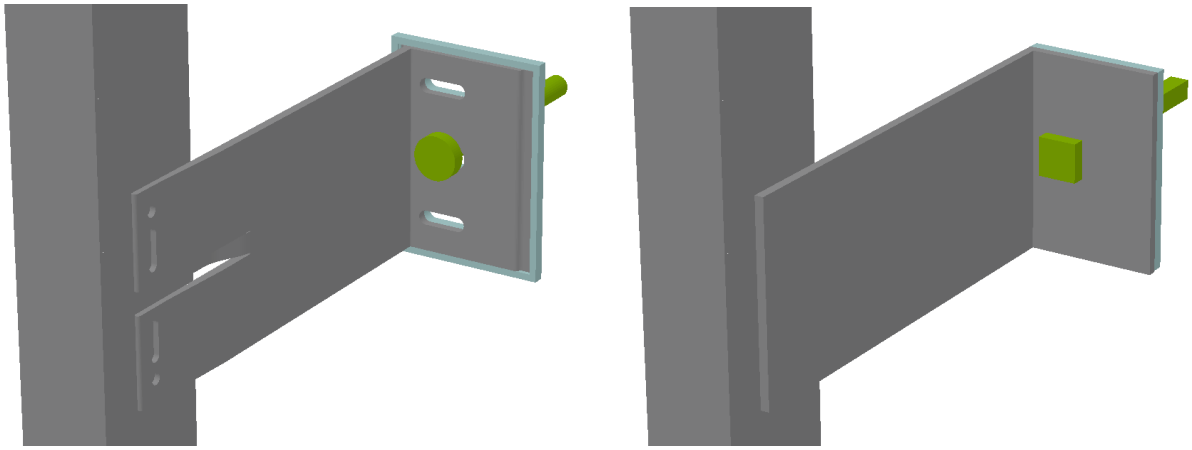


Figure 5 Full detail (left) and Simplified (right)

Both models are discretized using the following parameters.

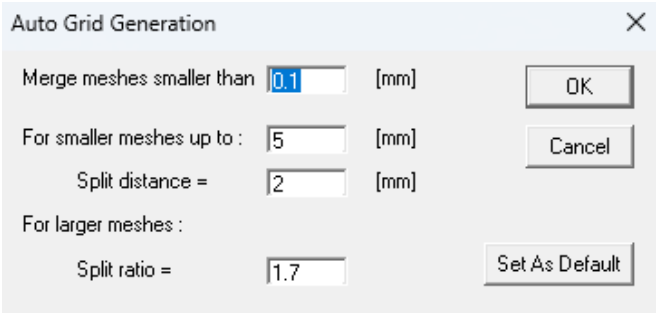


Figure 6 Discretisation settings

As additional variants, the simulations are repeated for (1) a model without screws and (2) a half model using symmetry. The results of all variants are summarized in the table below.

3.2. Results and conclusion

In this example, the overall number of calculation nodes is relatively low, resulting in simulation times of only a few seconds. Therefore, only the reduction in the number of calculation nodes is reported, rather than the reduction in simulation time. The results show that simplifying the geometry of the bracket, insulator, and screw substantially reduces the number of calculation nodes, while having no significant impact on the calculated thermal performance. Furthermore, the results indicate that the screw should not be omitted from the model, as its omission results in a reduction in the calculated heat flow of nearly 3%.

Table 2 Results of the simplification (case 2)

	number of nodes	node reduction (%)	heat flow (W)		U_{3D} (W/m²K)
full detail	895 290	ref.	5.050	ref.	0.253
simpl. 1	159 680	-82%	5.059	0.18%	0.255
simpl. + No screw	68 180	-92%	4.902	-2.93%	0.245
simpl. half	83 170	-91%	2.541 (x2)	0.63%	0.254

4. Overall conclusion

This study demonstrates that simplifying complex geometries can substantially reduce the number of calculation nodes and, consequently, the required simulation time, while maintaining comparable simulation results.

Ultimately, the benefit of geometric simplification depends on the complexity of the original model and the effort required to prepare the simplified geometry. The user should therefore balance the additional modelling effort against the expected reduction in simulation time.