Tutorial

Importing full model and boundary conditions via STL files - Rainscreen cladding

SLD Tutorial b

SOLIDO

1. Introduction

rainscreen_cladding_STL_BRACKET.sld

This tutorial illustrates how to model the thermal transmittance of a rainscreen cladding wall by importing the full model and boundary conditions via STL files.

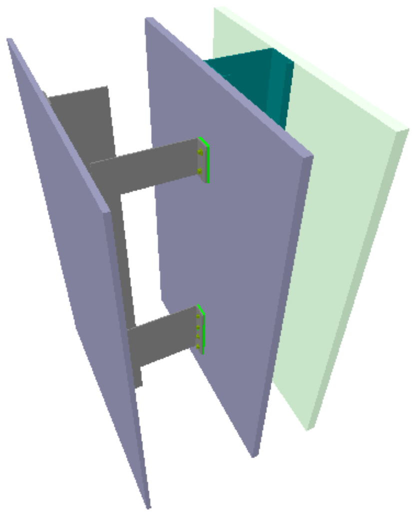
Key elements:

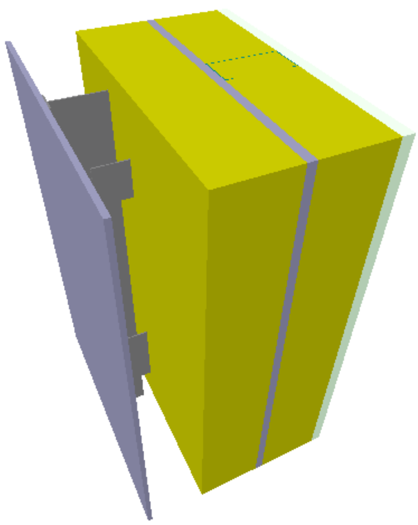
- Importing a rainscreen cladding wall via STL files
- Derived thermal properties: linear, point and equivalent thermal transmittance (ψ, χ, U_{equi})

2. Case study data

The example concerns a rainscreen cladding wall with a repetitive area of 600 mm by 900 mm (from inside to outside):

- Double gypsum board (λ = 0.25 W/(m.K), d = 2.5 cm)
- Insulation layer (λ = 0.035 W/(m.K), d = 15 cm) with metal U-profile (λ = 50 W/(m.K))
- Fibre cement board (λ = 0.23 W/(m.K), d = 1.8 cm)
- Insulation layer (λ = 0.035 W/(m.K), d = 15 cm) with 2 aluminium brackets (λ = 160 W/(m.K))
- Stainless steel screws: λ = 17 W/(m.K)
- 0.5 cm thick plastic pads between brackets and fibre cement board
- Highly ventilated cavity
- Fibre cement cladding board (λ = 0.23 W/(m.K), d = 1 cm), fixed with an aluminium T-profile to the brackets





The boundary conditions imposed are in line with EN ISO 6946:

- Indoors: θ_i = 20 °C, surface heat transfer coefficient = 7.7 W/m^{2}K

- Outdoors: θ_e = 0 °C, surface heat transfer coefficient = 25 W/m²K
- Highly ventilated outdoor cavity: θ_e = 0 °C, surface heat transfer coefficient = 7.7 W/m²K

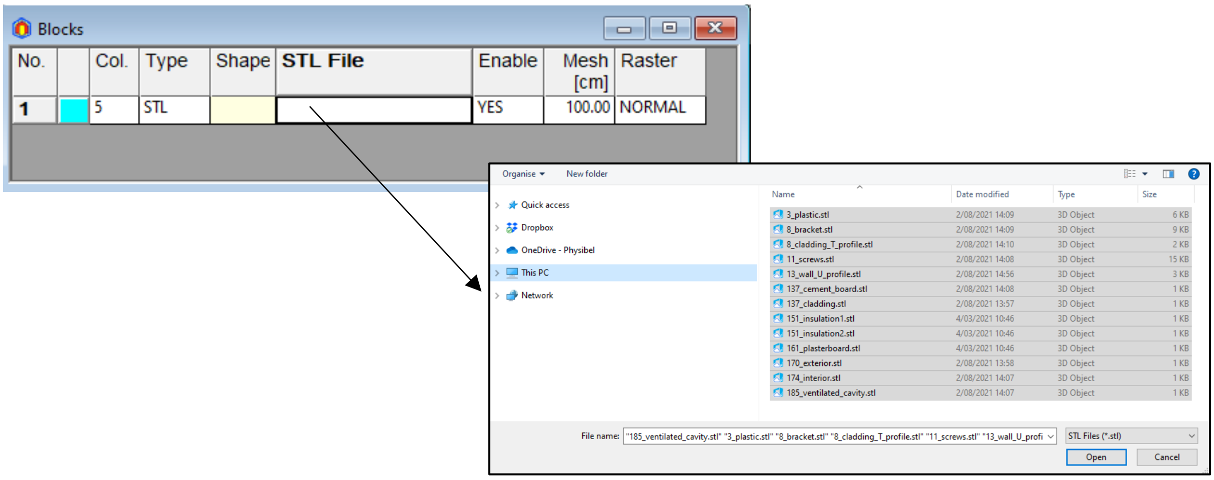
3. Entering the data

<u>Step 1: Open a new data file</u>

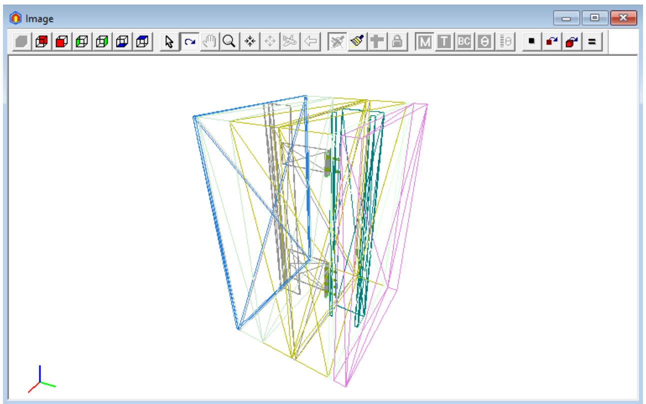
- Open a new file using the command *File → New* to start the data input. A default block (cube with side 100 cm) with colour number 5 is shown as starting data.

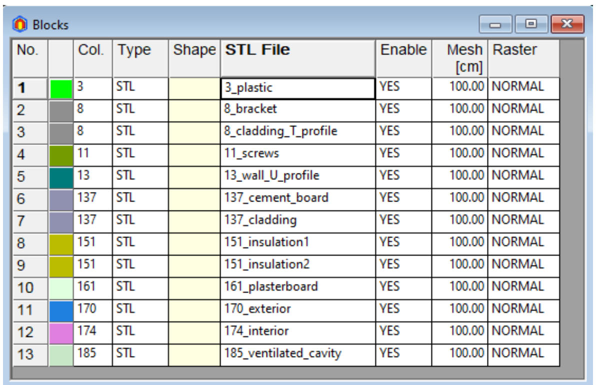
<u>Step 2: Import the STL files</u>

- In the **Blocks window**: switch the Type which is by default ‘SOLID’ to ‘STL’ by double clicking with the left mouse in this field or by pressing <enter> after the field is selected.
- Now, the column ‘STL-file’ becomes available. Double click with the left mouse in the field and select all STL files in 1 step by pressing <shift> while selecting the STL files.



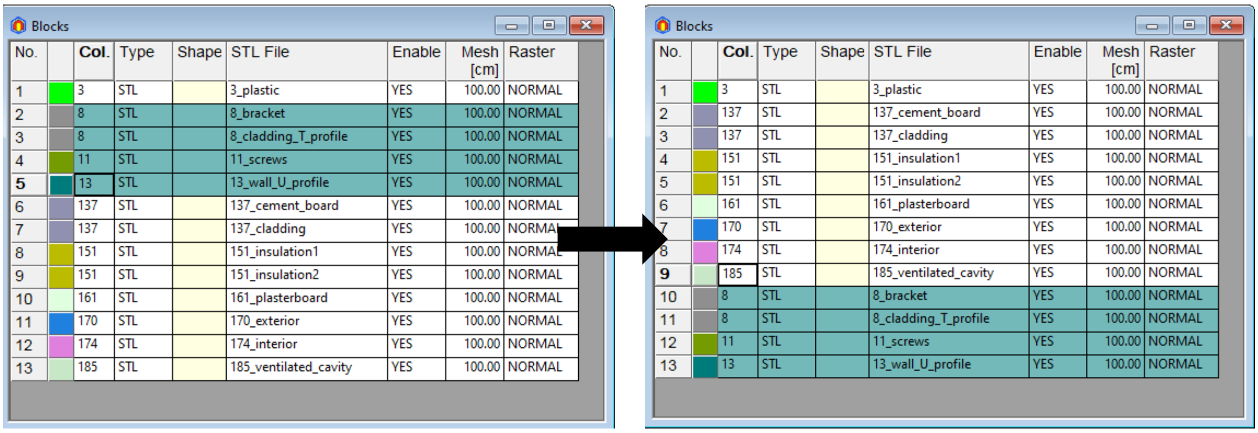
- In this example, the names of the STL files start with the Colour index corresponding to the material or boundary conditions in the Colour database. This allows directly linking the intended properties to the STL files. Alternatively, the properties can be manually defined or adjusted within the **Colours window**.
- The result is:





Step 3: Re-arrange the blocks priority

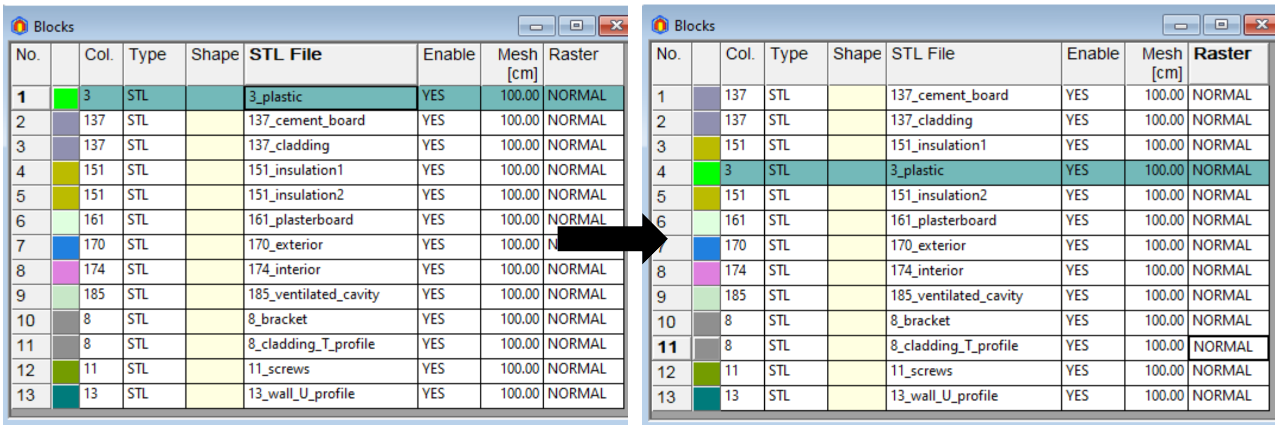
- By importing all the STL files in 1 step, the blocks are arranged in the **Blocks window** by their Colour index (see left-hand side figure above). In this example some STL files overlap. As consequence, it is important to re-arrange the order of the blocks in the **Blocks window**. SOLIDO applies the superposition principle: the highest row number, has the highest priority.
- Select the metal elements (row numbers 2-5) in the **Blocks window:**
  - select row 2 with left mouse and *Edit → Switch Select* (or press <Ctrl + L>)
  - select row 5 with left mouse and *Edit → Switch Select Upwards*
- The selected blocks are now highlighted in turquoise
- Select now the last row with the left mouse and *Blocks → Move Selection After*



No.	Col.	Type	Shape	STL File	Enable	Mesh [cm]	Raster
1	3	STL		3_plastic	YES	100.00	NORMAL
2	8	STL		8_bracket	YES	100.00	NORMAL
3	8	STL		8_cladding_T_profile	YES	100.00	NORMAL
4	11	STL		11_screws	YES	100.00	NORMAL
5	13	STL		13_wall_U_profile	YES	100.00	NORMAL
6	137	STL		137_cement_board	YES	100.00	NORMAL
7	137	STL		137_cladding	YES	100.00	NORMAL
8	151	STL		151_insulation1	YES	100.00	NORMAL
9	151	STL		151_insulation2	YES	100.00	NORMAL
10	161	STL		161_plasterboard	YES	100.00	NORMAL
11	170	STL		170_exterior	YES	100.00	NORMAL
12	174	STL		174_interior	YES	100.00	NORMAL
13	185	STL		185_ventilated_cavity	YES	100.00	NORMAL

No.	Col.	Type	Shape	STL File	Enable	Mesh [cm]	Raster
1	3	STL		3_plastic	YES	100.00	NORMAL
2	137	STL		137_cement_board	YES	100.00	NORMAL
3	137	STL		137_cladding	YES	100.00	NORMAL
4	151	STL		151_insulation1	YES	100.00	NORMAL
5	151	STL		151_insulation2	YES	100.00	NORMAL
6	161	STL		161_plasterboard	YES	100.00	NORMAL
7	170	STL		170_exterior	YES	100.00	NORMAL
8	174	STL		174_interior	YES	100.00	NORMAL
9	185	STL		185_ventilated_cavity	YES	100.00	NORMAL
10	8	STL		8_bracket	YES	100.00	NORMAL
11	8	STL		8_cladding_T_profile	YES	100.00	NORMAL
12	11	STL		11_screws	YES	100.00	NORMAL
13	13	STL		13_wall_U_profile	YES	100.00	NORMAL

- Repeat this step to make the priority of plastic pads (3_plastic.stl) higher than the priority of the exterior insulation layer (151_insulation1.stl). The final order is then:



No.	Col.	Type	Shape	STL File	Enable	Mesh [cm]	Raster
1	3	STL		3_plastic	YES	100.00	NORMAL
2	137	STL		137_cement_board	YES	100.00	NORMAL
3	137	STL		137_cladding	YES	100.00	NORMAL
4	151	STL		151_insulation1	YES	100.00	NORMAL
5	151	STL		151_insulation2	YES	100.00	NORMAL
6	161	STL		161_plasterboard	YES	100.00	NORMAL
7	170	STL		170_exterior	YES	100.00	NORMAL
8	174	STL		174_interior	YES	100.00	NORMAL
9	185	STL		185_ventilated_cavity	YES	100.00	NORMAL
10	8	STL		8_bracket	YES	100.00	NORMAL
11	8	STL		8_cladding_T_profile	YES	100.00	NORMAL
12	11	STL		11_screws	YES	100.00	NORMAL
13	13	STL		13_wall_U_profile	YES	100.00	NORMAL

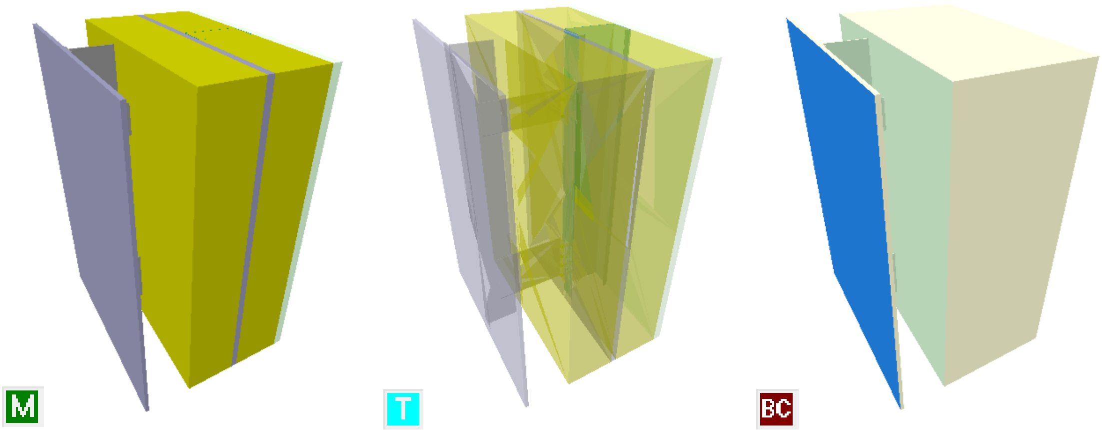
No.	Col.	Type	Shape	STL File	Enable	Mesh [cm]	Raster
1	137	STL		137_cement_board	YES	100.00	NORMAL
2	137	STL		137_cladding	YES	100.00	NORMAL
3	151	STL		151_insulation1	YES	100.00	NORMAL
4	3	STL		3_plastic	YES	100.00	NORMAL
5	151	STL		151_insulation2	YES	100.00	NORMAL
6	161	STL		161_plasterboard	YES	100.00	NORMAL
7	170	STL		170_exterior	YES	100.00	NORMAL
8	174	STL		174_interior	YES	100.00	NORMAL
9	185	STL		185_ventilated_cavity	YES	100.00	NORMAL
10	8	STL		8_bracket	YES	100.00	NORMAL
11	8	STL		8_cladding_T_profile	YES	100.00	NORMAL
12	11	STL		11_screws	YES	100.00	NORMAL
13	13	STL		13_wall_U_profile	YES	100.00	NORMAL

- In this example we make use of the predefined colours in the Colour database corresponding to following colour types:

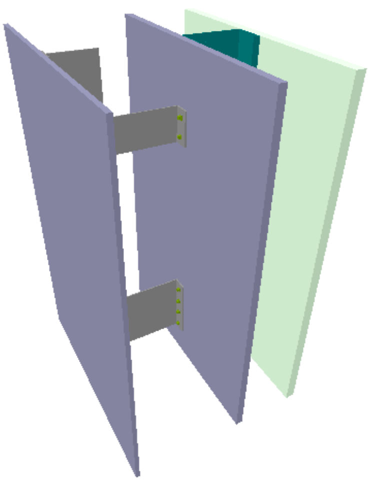
Colours

Col.		Type	Subtype	Physical flow dir.	Geometrical flow dir.	Name	ε1 / ε2 [- / -]	λ [W/mK]	ε [-]	θ [°C]	h [W/m²K]	q [W/m²]	θa [°C]	hc [W/m²K]	Pc [W]	θr [°C]	Standard
3		MATERIAL				PVC rigid		0.170									
8		MATERIAL				aluminium		160.000									
11		MATERIAL				stainless steel (austenitic/aust.fer		17.000									
13		MATERIAL				steel		50.000									
137		MATERIAL				cement-bonded particleboard		0.230									
151		MATERIAL				insulation 0.035 W/mK		0.035									
161		MATERIAL				gypsum plasterboard		0.250									
170		BC_SIMPL	HE			exterior				0.0	25.00	0					EN6946
174		BC_SIMPL	HI	HOR		interior (normal) horizontal heat				20.0	7.70	0					EN6946
185		BC_SIMPL	HI	HOR		highly ventilated cavity; horizont				0.0	7.70	0					EN6946

- So far, the objects geometry was depicted in the **Image window** as a wireframe model. To fill the object go to *Image → fill blocks (Triangulate)*. Now, the materials are shown for the filled triangulated object.
- With the triangulated object filled, it is possible to display the object transparently by selecting *Image → Show Transparent*.
- The contact surfaces of the boundary conditions on the object can be made visible by selecting the command *Image → Show BCs*.



- To inspect the model, SOLIDO allows to clip colours from the image: *Edit → Clip Colours*. In the example below the insulation layer (Colour 151) is clipped):

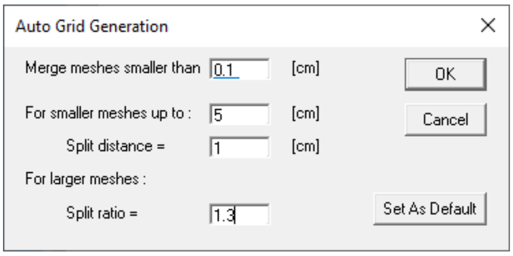


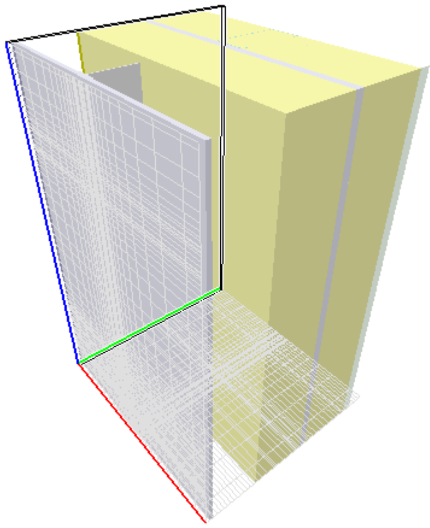
Clip Colours

Col.		Type	Subtype	Name	Show
8		MATERIAL		aluminium	YES
11		MATERIAL		stainless steel (austenitic/aust.ferritic)	YES
13		MATERIAL		steel	YES
137		MATERIAL		cement-bonded particleboard	YES
151		MATERIAL		insulation 0.035 W/mK	NO
161		MATERIAL		gypsum plasterboard	YES
170		BC_SIMPL	HE	exterior	YES
174		BC_SIMPL	HI	interior (normal) horizontal heat flow	YES
185		BC_SIMPL	HI	highly ventilated cavity; horizontal heat flow	YES

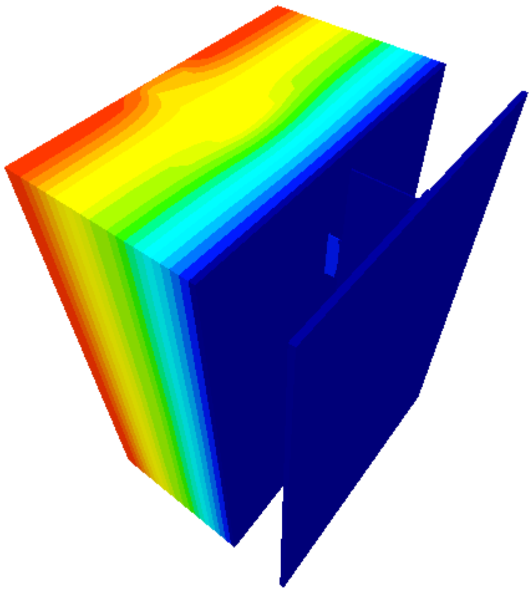
4. Preparing the calculation grid and run simulation

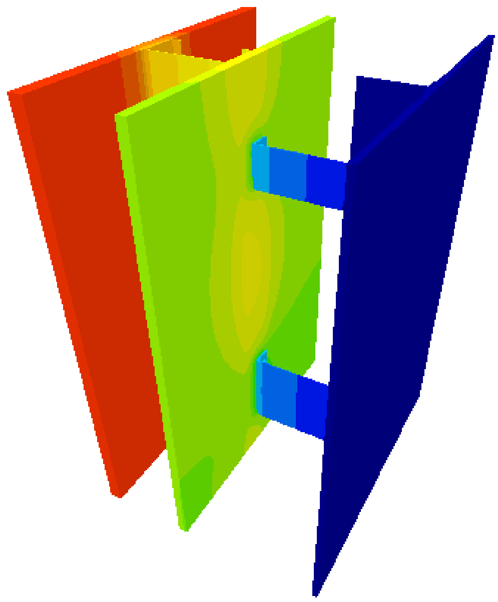
- In this example we will use the Automatic Grid Generation function in SOLIDO to generate the calculation mesh. Go to *Grid → Auto Grid Generation...* and use the following settings:





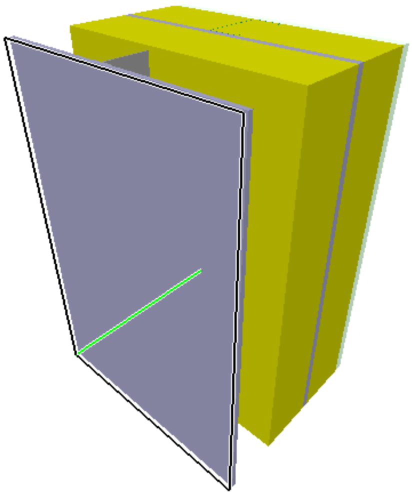
- Solve the system: *Calc → Calc System.*
- The system contains 99 876 nodes and is solved in a few seconds. The resulting temperature profile is show below (in the right figure the insulation is clipped)

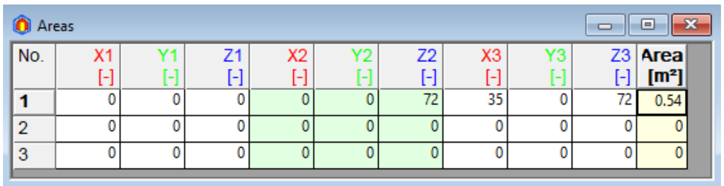




5. Equivalent thermal transmittance (U_{equi})

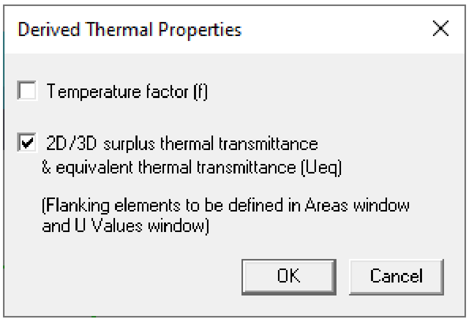
- The 3D equivalent thermal transmittance (U_{equi}) can be found after defining the wall surface area.
- Define the area of the wall: *Edit → Area* and fill in the coordinates of 3 points to define the area. In order to define these coordinates it might be easier to switch to Grid number coordinates (*Blocks → Grid Number Coordinates).*



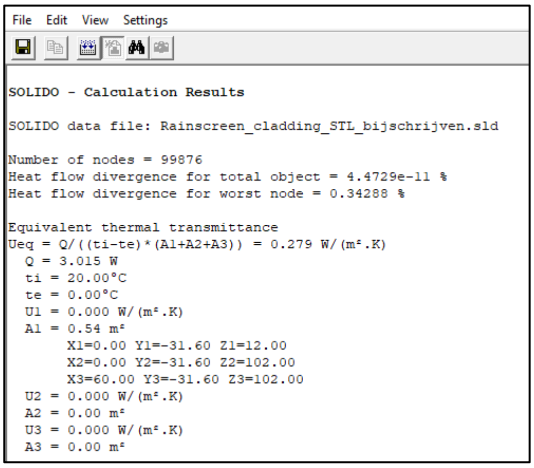


No.	X1 [-]	Y1 [-]	Z1 [-]	X2 [-]	Y2 [-]	Z2 [-]	X3 [-]	Y3 [-]	Z3 [-]	Area [m²]
1	0	0	0	0	0	72	35	0	72	0.54
2	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0

- Select the desired derived thermal properties: *Edit → Derived Thermal Properties:*



- The U_{equi}-value (0.279 W/m^{2}K) can now be retrieved in the **Text Output** :

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SOLIDO - Calculation Results

SOLIDO data file: Rainscreen_cladding_STL_bijschrijven.sld

Number of nodes = 99876
Heat flow divergence for total object = 4.4729e-11 %
Heat flow divergence for worst node = 0.34288 %

Equivalent thermal transmittance
Ueq = Q/((ti-te)*(A1+A2+A3)) = 0.279 W/(m².K)
  Q = 3.015 W
  ti = 20.00°C
  te = 0.00°C
  U1 = 0.000 W/(m².K)
  A1 = 0.54 m²
       X1=0.00 Y1=-31.60 Z1=12.00
       X2=0.00 Y2=-31.60 Z2=102.00
       X3=60.00 Y3=-31.60 Z3=102.00
  U2 = 0.000 W/(m².K)
  A2 = 0.00 m²
  U3 = 0.000 W/(m².K)
  A3 = 0.00 m²
```

6. The linear thermal transmittance ψ of the steel frame, the point thermal transmittance χ of the double aluminum bracket (optional)

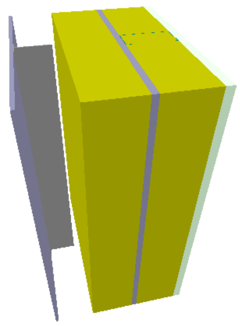
The U_{equi}-value is valid for the rainscreen cladding wall with metal frames each 600 mm and the double bracket each 900 mm. For other distances, of course a new 3D simulation can provide the thermal transmittance, but an alternative solution is to derive the linear thermal transmittance ψ of the steel frame and the point thermal transmittance χ of the steel brackets.

The derivation of the ψ-value and of the χ-value requires an additional simulation of the geometry without the 2 brackets (Rainscreen_cladding_STL_without_bracket.sld).

- The original model (Rainscreen_cladding_STL.sld) is re-opened and saved under a different name (Rainscreen_cladding_STL_without_bracket.sld). In the **Blocks window** now all the blocks related to the brackets are disabled:

Blocks

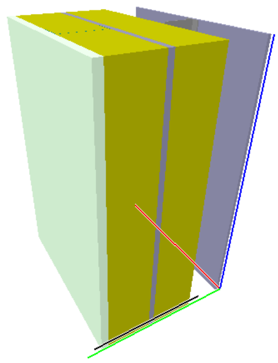
No.	Col.	Type	Shape	STL File	Enable	Mesh [cm]	Raster
1	137	STL		137_cement_board	YES	100.00	NORMAL
2	137	STL		137_cladding	YES	100.00	NORMAL
3	151	STL		151_insulation1	YES	100.00	NORMAL
4	3	STL		3_plastic	NO	100.00	NORMAL
5	151	STL		151_insulation2	YES	100.00	NORMAL
6	161	STL		161_plasterboard	YES	100.00	NORMAL
7	170	STL		170_exterior	YES	100.00	NORMAL
8	174	STL		174_interior	YES	100.00	NORMAL
9	185	STL		185_ventilated_cavity	YES	100.00	NORMAL
10	8	STL		8_bracket	NO	100.00	NORMAL
11	8	STL		8_cladding_T_profile	YES	100.00	NORMAL
12	11	STL		11_screws	NO	100.00	NORMAL
13	13	STL		13_wall_U_profile	YES	100.00	NORMAL



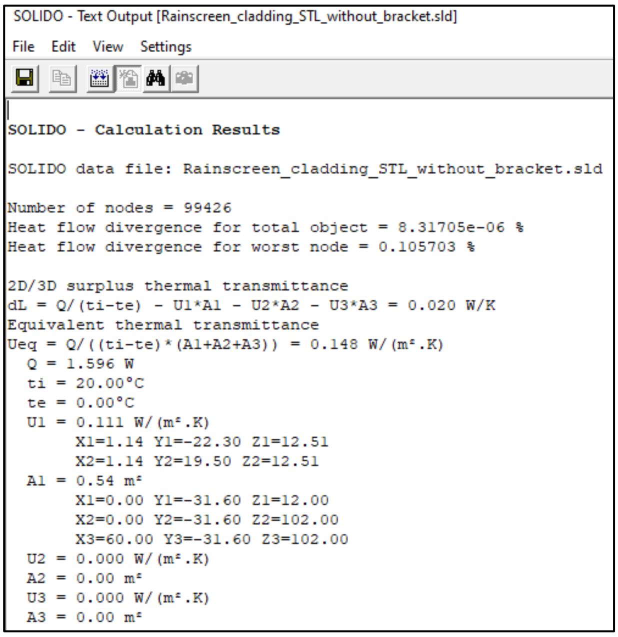
- This results in a 2D model for which the linear thermal transmittance of the frame can be found. Define the U_{1D}-value of the cladding wall: *Edit → U-values*:

U Values

No.	X1 [-]	Y1 [-]	Z1 [-]	X2 [-]	Y2 [-]	Z2 [-]	U [W/m²K]
1	1	10	1	1	52	1	0.111
2	0	0	0	0	0	0	0.000
3	0	0	0	0	0	0	0.000



- Re-calculate the system. *Calc → Calc System* .
  It is not necessary the create a new calculation grid.
- The ψ-value (0.02 W/m²K) can now be retrieved in the **Text Output :**



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SOLIDO - Text Output [Rainscreen_cladding_STL_without_bracket.sld]
File  Edit  View  Settings

SOLIDO - Calculation Results

SOLIDO data file: Rainscreen_cladding_STL_without_bracket.sld

Number of nodes = 99426
Heat flow divergence for total object = 8.31705e-06 %
Heat flow divergence for worst node = 0.105703 %

2D/3D surplus thermal transmittance
dL = Q/(ti-te) - U1*A1 - U2*A2 - U3*A3 = 0.020 W/K
Equivalent thermal transmittance
Ueq = Q/((ti-te)*(A1+A2+A3)) = 0.148 W/(m².K)
  Q = 1.596 W
  ti = 20.00°C
  te = 0.00°C
  U1 = 0.111 W/(m².K)
       X1=1.14 Y1=-22.30 Z1=12.51
       X2=1.14 Y2=19.50 Z2=12.51
  A1 = 0.54 m²
       X1=0.00 Y1=-31.60 Z1=12.00
       X2=0.00 Y2=-31.60 Z2=102.00
       X3=60.00 Y3=-31.60 Z3=102.00
  U2 = 0.000 W/(m².K)
  A2 = 0.00 m²
  U3 = 0.000 W/(m².K)
  A3 = 0.00 m²
```

- The point thermal transmittance χ of the brackets can now be found as the difference between the heat flow through the model with brackets (Rainscreen_cladding_STL.sld) and the model without brackets (Rainscreen_cladding_STL_without_bracket.sld):

$$\chi = \frac{Q_{with\ brackets} - Q_{without\ brackets}}{\Delta T} = \frac{3.015\,W \; - \; 1.596W}{20K} = \;0.071\;W/K$$

In summary, the results are:

- U_{1D} = 0.111 W/(m²K)
- ψ = 0.02 W/(m.K)
- χ = 0.071 W/K

For a façade with height H and width B, with a total steel frame length L and with n steel brackets (double), the U-value can now be calculated using

$$U = \frac{BHU_{1D} + L\psi + n\chi}{BH}$$