

### 1. Introduction

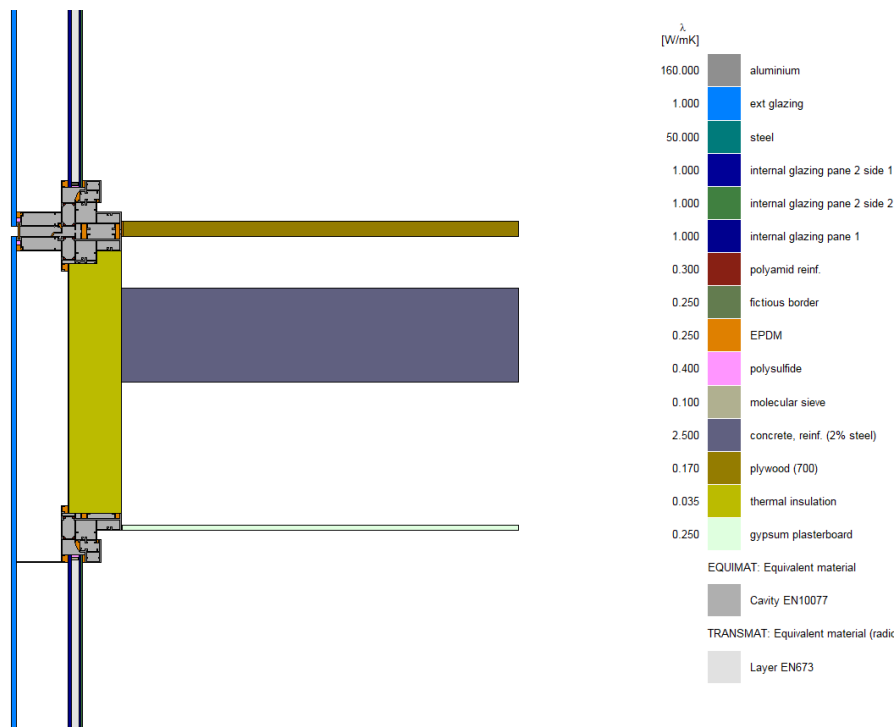
Determining the maximum temperature within the building envelope is key to assessing potential damage and degradation risks. A case study shows how the program BISTRA (2D) and VOLTRA (2D/3D) is used to simulate the temperature course in a glazed façade during a sunny day.

Determining the maximum temperature within the building envelope is key to assessing potential damage and degradation risks.

### 2. Case study. Glazed façade – floor connection in detail

BISTRA data [facade\\_floor.bst](#)

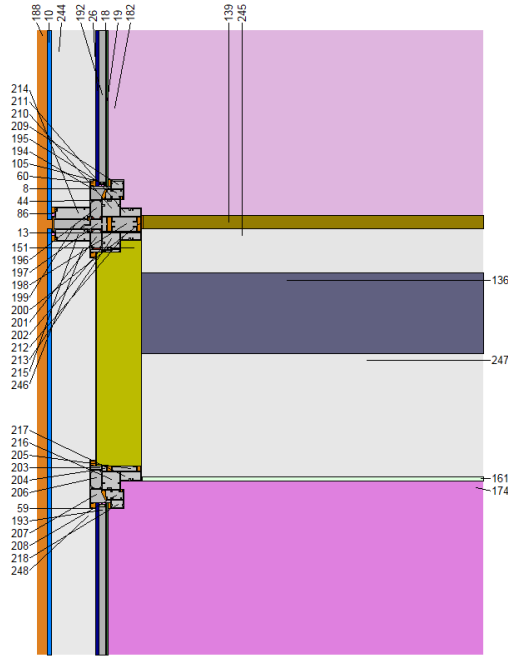
VOLTRA data [facede\\_floor.vtr](#)



**Figure 1 Glazed façade - floor connection vertical section**

A connection (Figure 1) of a façade of the so-called interactive wall type connected to a concrete floor with a suspended floor and ceiling is considered. It is located in New York City and has a south orientation. The transient thermal behaviour is simulated for the 8th September using the program BISTRA.

The file [facade\\_floor.bst](#) contains the complete data in BISTRA format. The major data part is given in Figure 2. We will discuss here some data highlights only.



Col.	Type	Subtype	Physical flow dir.	Geometrical flow dir.	Name	$\epsilon / \epsilon_2$ [- / -]	$\lambda$ [W/mK]	$c$ [-]	$\rho$ [kg/m <sup>3</sup> ]	$c$ [J/kgK]	$\theta$ [°C]	$h$ [W/m <sup>2</sup> K]	$q$ [W/m <sup>2</sup> ]	$\theta_a$ [°C]	$h_c$ [W/m <sup>2</sup> K]	$P_c$ [W/m]	$\theta_r$ [°C]	Sun	$\rho_s$ [-]	Specular [%]	$\tau_s$ [-]	Standard
8	MATERIAL				aluminium		160.000	0.90	2800	880									0.10	0	0.00	
10	MATERIAL				ext glazing		1.000	0.84	2500	750									R01	0	0.85	
13	MATERIAL				steel		50.000	0.90	7800	450									0.10	0	0.00	
18	MATERIAL				internal glazing pane 2 side 1		1.000	0.04	2500	750									0.29	0	0.79	
19	MATERIAL				internal glazing pane 2 side 2		1.000	0.84	2500	750									0.21	0	0.71	
26	MATERIAL				internal glazing pane 1		1.000	0.84	2500	750									0.07	0	0.84	
44	MATERIAL				polyamid reinf.		0.300	0.90	1450	1600									0.10	0	0.00	
59	MATERIAL				fictitious border		0.250	0.90	1	1000									0.00	0	1.00	
60	MATERIAL				EPDM		0.250	0.90	1150	1000									0.10	0	0.00	
86	MATERIAL				polysulfide		0.400	0.90	1000	1000									0.10	0	0.00	
105	MATERIAL				molecular sieve		0.100	0.90	1000	1000									0.10	0	0.00	
136	MATERIAL				concrete, reinf. (2% steel)		2.500	0.90	2400	1000									0.10	0	0.00	
139	MATERIAL				plywood (700)		0.170	0.90	700	1600									0.40	0	0.00	
151	MATERIAL				thermal insulation		0.035	0.90	30	1000									0.10	0	0.00	
161	MATERIAL				gypsum plasterboard		0.250	0.90	900	1000									0.10	0	0.00	
174	BC_SKY	NIHIL			interior (normal)									0	25.0	2.50		25.0	NO			
182	BC_SKY	NIHIL			interior (reduced)									0	25.0	2.50		25.0	NO			
188	BC_SIMPL	NIHIL			exterior (summer)						T01	13.50	0					YES				NIHIL
192	TRANSMAT	LAYER	HOR	X	100%Argon	0.017			1.699	519												EN673
193	TRANSMAT	LAYER	HOR	X	100%Argon	0.017			1.699	519												EN673
194	EQUIMAT	CAVITY	HOR	X	non ventilated cavity	0.90 / 0.90	0.154	0.90	1.2	1008												EN10077
195	EQUIMAT	CAVITY	HOR	X	non ventilated cavity	0.90 / 0.90	0.153	0.90	1.2	1008												EN10077
196	EQUIMAT	CAVITY	HOR	X	non ventilated cavity	0.90 / 0.90	0.112	0.90	1.2	1008												EN10077
197	EQUIMAT	CAVITY	HOR	X	non ventilated cavity	0.90 / 0.90	0.178	0.90	1.2	1008												EN10077
198	EQUIMAT	CAVITY	HOR	Y	non ventilated cavity	0.90 / 0.90	0.143	0.90	1.2	1008												EN10077
199	EQUIMAT	CAVITY	HOR	Y	non ventilated cavity	0.90 / 0.90	0.100	0.90	1.2	1008												EN10077
200	EQUIMAT	CAVITY	HOR	Y	non ventilated cavity	0.90 / 0.90	0.044	0.90	1.2	1008												EN10077
201	EQUIMAT	CAVITY	HOR	X	non ventilated cavity	0.90 / 0.90	0.112	0.90	1.2	1008												EN10077
202	EQUIMAT	CAVITY	HOR	X	non ventilated cavity	0.90 / 0.90	0.188	0.90	1.2	1008												EN10077
203	EQUIMAT	CAVITY	HOR	X	non ventilated cavity	0.90 / 0.90	0.085	0.90	1.2	1008												EN10077
204	EQUIMAT	CAVITY	HOR	Y	non ventilated cavity	0.90 / 0.90	0.056	0.90	1.2	1008												EN10077
205	EQUIMAT	CAVITY	HOR	X	non ventilated cavity	0.90 / 0.90	0.202	0.90	1.2	1008												EN10077
206	EQUIMAT	CAVITY	HOR	X	non ventilated cavity	0.90 / 0.90	0.112	0.90	1.2	1008												EN10077
207	EQUIMAT	CAVITY	HOR	X	non ventilated cavity	0.90 / 0.90	0.154	0.90	1.2	1008												EN10077
208	EQUIMAT	CAVITY	HOR	Y	non ventilated cavity	0.90 / 0.90	0.097	0.90	1.2	1008												EN10077
209	EQUIMAT	CAVITY	HOR	X	non ventilated cavity	0.90 / 0.90	0.111	0.90	1.2	1008												EN10077
210	EQUIMAT	CAVITY	HOR	X	non ventilated cavity	0.90 / 0.90	0.171	0.90	1.2	1008												EN10077
211	EQUIMAT	CAVITY	HOR	X	non ventilated cavity	0.90 / 0.90	0.182	0.90	1.2	1008												EN10077
212	EQUIMAT	CAVITY	HOR	X	non ventilated cavity	0.90 / 0.90	0.182	0.90	1.2	1008												EN10077
213	EQUIMAT	CAVITY	HOR	X	non ventilated cavity	0.90 / 0.90	0.170	0.90	1.2	1008												EN10077
214	EQUIMAT	CAVITY	HOR	X	non ventilated cavity	0.90 / 0.90	0.302	0.90	1.2	1008												EN10077
215	EQUIMAT	CAVITY	HOR	X	non ventilated cavity	0.90 / 0.90	0.302	0.90	1.2	1008												EN10077
216	EQUIMAT	CAVITY	HOR	X	non ventilated cavity	0.90 / 0.90	0.171	0.90	1.2	1008												EN10077
217	EQUIMAT	CAVITY	HOR	X	non ventilated cavity	0.90 / 0.90	0.182	0.90	1.2	1008												EN10077
218	EQUIMAT	CAVITY	HOR	X	non ventilated cavity	0.90 / 0.90	0.111	0.90	1.2	1008												EN10077
244	BC_FREE	NIHIL			cavity (CEN)				1.2	1005			0		2.50	0						NIHIL
245	BC_FREE	NIHIL			cavity (CEN)				1.2	1005			0		2.50	0						NIHIL
246	BC_FREE	NIHIL			cavity (CEN)				1.2	1005			0		2.50	0						NIHIL
247	BC_FREE	NIHIL			cavity (CEN)				1.2	1005			0		2.50	0						NIHIL
248	BC_FREE	NIHIL			cavity (CEN)				1.2	1005			0		2.50	0						NIHIL

Figure 2 BISTRA data [facade floor.bst](#)

- The outdoors is defined as a BC\_SIMPL type using a global surface heat transfer coefficient  $h_e = 13.5 \text{ W/m}^2\text{K}$ <sup>1</sup>. An alternative would be to use a BC\_SKY type.

The outdoors temperature T01 (Figure 2, column  $\theta$ ) is a time function. The outdoors is defined as the 'sun' zone (Figure 2, column Sun). Also the solar radiation data are time functions. Hourly values of air temperature, global (and diffuse) solar radiation on a yearly basis can be retrieved from databases and imported to BISTRA as [.EPW](#) or [.TMY3](#) files.

The orientation of the façade is defined in the Solar Data window. A horizon with a height of 5° in all directions is defined in the Sun Obstacles window.

- The indoor is defined as a BC\_SKY type. A constant indoor air and radiation temperature = 25 °C is assumed. The convective surface heat transfer coefficient is  $h_c = 2.5 \text{ W/m}^2\text{K}$ .
- The material properties thermal conductivity  $\lambda$ , density  $\rho$  and specific heat  $c$  were taken from ISO 10456. The double glazing cavity gas is defined as argon-filled according to EN 673.
- The façade and floor air spaces are BC\_FREE types, i.e. with unknown air temperature. In reality there will be some temperature stratification. It can be expected that the upper part of the façade cavity will warm up more than the lower part. Therefore a fictitious border (1 mm thick material layer) is drawn between both cavity parts (Figure 2, row colour 59). The convective surface heat transfer coefficient is  $h_c = 2.5 \text{ W/m}^2\text{K}$ .

The air spaces are considered as non-ventilated, which is a conservative assumption. Ventilation could be considered through the Ventilation Flows window.

- The frame cavities are EQUIMAT types (calculated according to the standard EN 10077). The heat flow direction (X or Y) is automatically calculated at each time step (Calculation Parameter window).
- The long wave emissivity  $\varepsilon$  of all<sup>2</sup> material surfaces is 0.9, except for the glazing surfaces that have a long wave emissivity  $\varepsilon = 0.837$  according to EN 673. A low emissivity coating with  $\varepsilon = 0.037$  is applied on side 3 of the double glazing (Figure 2, row colour 18).
- The external single glazing is assumed to be a clear single glazing. The internal double glazing has a U-value  $U = 1.1 \text{ W/m}^2\text{K}$  and a solar factor  $g = 0.56$ .
- It should be emphasized that the definition of the solar transmittance as defined in BISTRA and VOLTRA is different to the more commonly used definition as used in glazing technology. In BISTRA and VOLTRA the solar transmittance is the one after deduction of reflection:

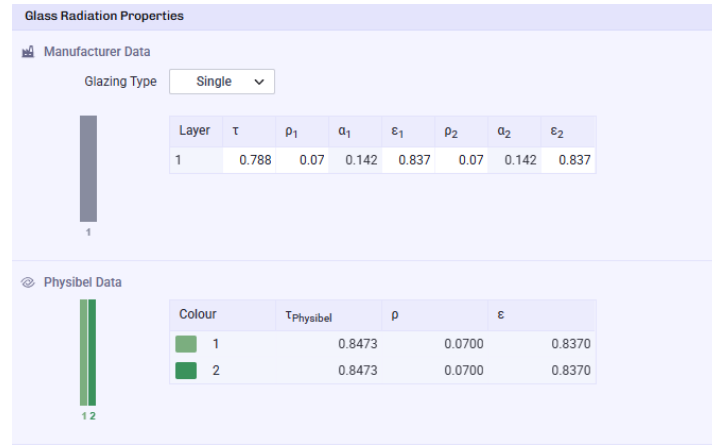
$$\tau_{s\text{-BISTRA-VOLTRA}} = \frac{\tau}{1-\rho} \quad (1)$$

The [Physibel Toolbox](#) can be used to derive the solar property values for input in BISTRA and VOLTRA.

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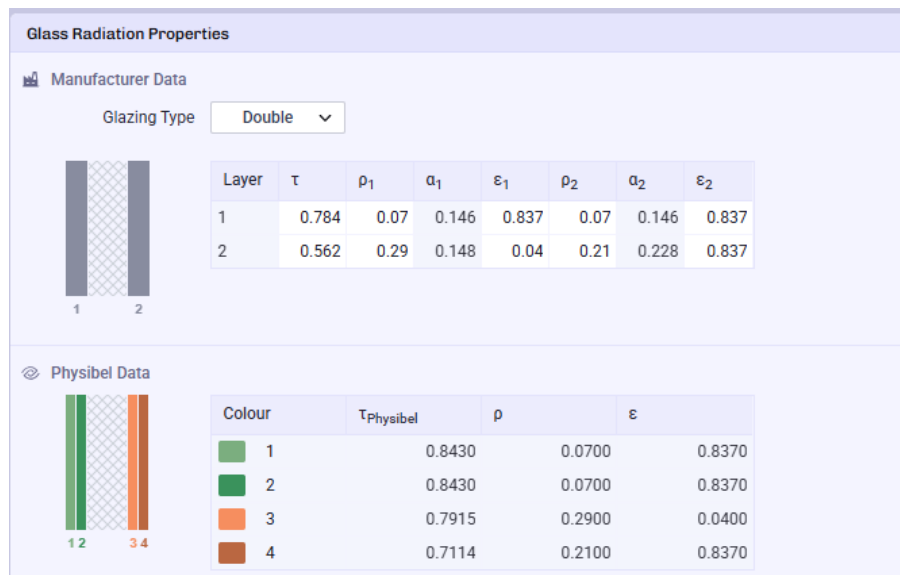
<sup>1</sup> See Physibel Knowledge Base → [C1 - Thermal analysis of the building envelope in summer conditions part 1: opaque constructions](#)

<sup>2</sup> Only for material surfaces that are in direct contact with a BC\_FREE, BC\_SKY or TRANSMAT type the value of the long wave emissivity is taken into account in the simulation.



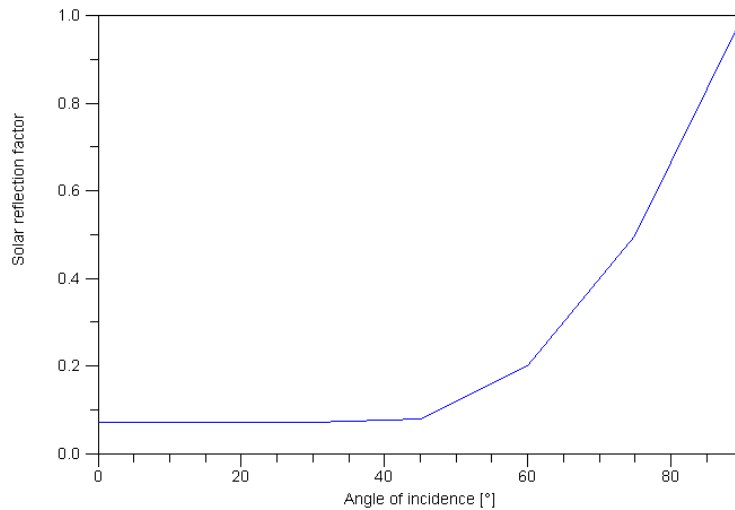
**Figure 3 Physibel values for single glazing**

- Different colours should be used to represent the properties on each side of a pane. If both sides have identical properties as in the single external glazing (Figure 3) only one colour is enough.



**Figure 4 Physibel values for double glazing**

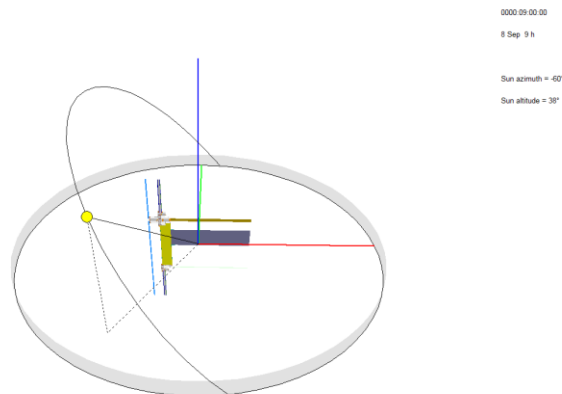
- Similar to single glazing, pane 1 has the same properties on both sides; therefore, a single colour (26) is sufficient. In contrast, pane 2 has different properties on each side, so two colours (18 and 19) are required to clearly distinguish between them.
- The external glazing reflection is assumed to be angle dependent. The function reference R01 (Figure 2, row colour 10) refers to the function [glass reflection angle func 0p070.FRF](#) (Figure 5).



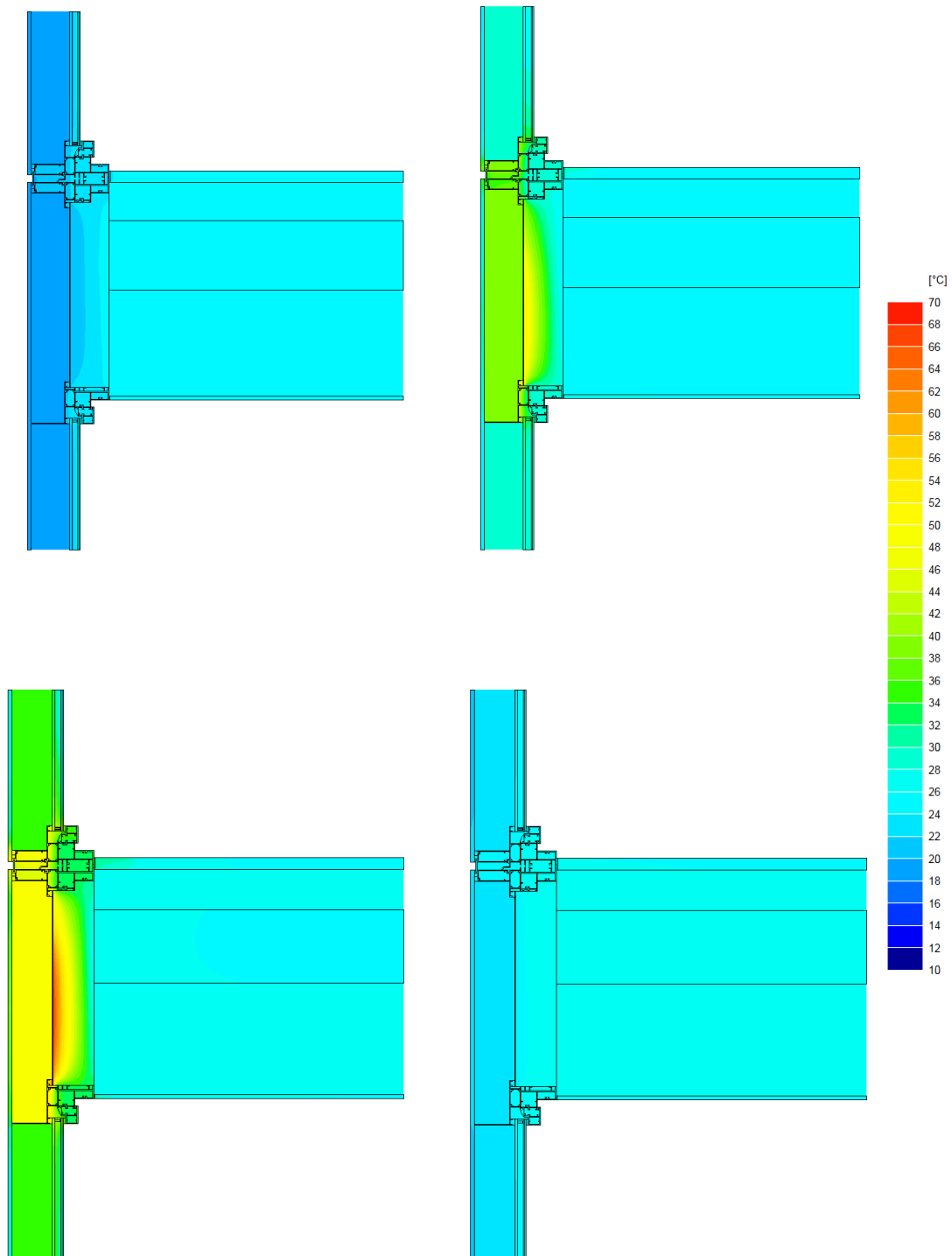
**Figure 5 Angular dependent solar reflectance of the external glazing**

- The solar transmittance of opaque materials of course is  $\tau_s = 0$ . Dark coloured surfaces are assumed for all opaque materials that can receive solar radiation. Therefore a solar reflectance  $\rho_s = 0.1$  (and thus  $\alpha_s = 0.9$ ) is used for all materials, except for the floor surface for which  $\rho_s = 0.4$  (and thus  $\alpha_s = 0.6$  corresponding to an intermediate colour) is used.
- The following calculation parameters are defined:
  - time step = 10'
  - start-up calculation duration = 2 days (due to the inertia of the floor)
  - calculation duration = 1 day
  - day number 251 (8 September)
  - non-linear radiation model.

Figure 6 displays the sun position at 09h00 and Figure 7 shows the simulated temperature course at 4 different times.



**Figure 6 Sun position at 09:00**



**Figure 7 Temperature course at 06:00, 09:00, 13:00, 18:00**

### 3. References

ISO 10456:2007 *Building materials and products -Hygrothermal properties.*

EN 673:2024 *Glass in building - Determination of thermal transmittance (U value) - Calculation method.*