

PRACTICE EXERCISES

CIVIL-407
Building Energetics

**Building
Envelope**

Assist. Professor
Dolaana KHOVALYG

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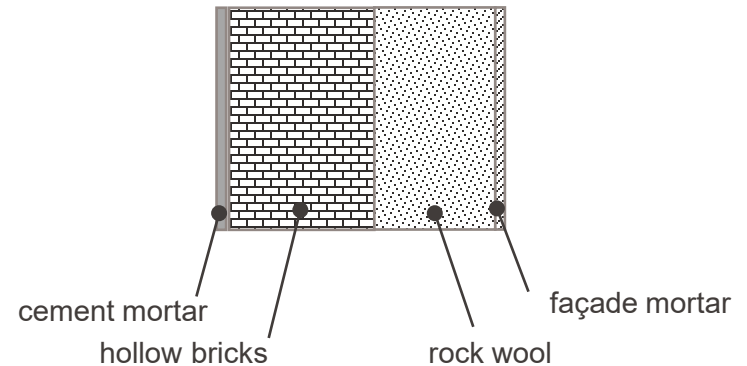


Exercise 1: Opaque Building Element

Determine the thermal transmittance of the vertical wall structure *adjacent* to exterior. The composition of the wall structure is given in the table.

1. Check whether it complies with the permissible limiting value U_{limit} for **renovation projects** per standard SIA 380
2. Determine the required thickness of the thermal insulation (rockwool) layer so that the U-value of the wall will comply with the SIA 380 requirements for **new buildings**.

	d (cm)	λ (W/mK)
cement mortar	2	1.40
hollow brick	19	0.52
rock wool	15	0.041
façade mortar	2	0.70



Hint: Use standardized values provided on slides 22-23 to guide your solution.

Exercise 1: Solution

1. Check whether it complies with the permissible limiting value U_{limit} for **renovation projects** per SIA 380

- Per table provided on slide 22, the limiting U-value for renovation projects is $0.25 \frac{W}{m^2K}$
- To comply with the requirements, actual thermal transmittance *should be less* than the limiting value ($U < U_{\text{limit}}$)
- We need to determine $U = 1/R_{\text{tot}}$, thus, overall thermal resistance is the main un-known value to be determined.
- Using the network of thermal resistances analysis presented on slides 18, R_{tot} can be expressed as a sum of surface thermal resistances (R_{si} , R_{se}) and conductive thermal resistances ($\sum R_{\text{cond},i}$)
- Since no detailed environmental (indoor and outdoor) parameters are given, **standard design surface resistances** from slide 23 should be considered. As vertical wall is analyzed, direction of the heat flow should be taken as **horizontal**. Thus, $R_{\text{si}} = 0.13 \frac{m^2K}{W}$ and $R_{\text{se}} = 0.04 \frac{m^2K}{W}$.

	d (cm)	λ (W/mK)
1	2	1.40
2	19	0.52
3	15	0.041
4	2	0.70

$$U = 1/R_{\text{tot}}$$

$$R_{\text{tot}} = R_{\text{si}} + \sum R_{\text{cond},i} + R_{\text{se}}$$

$$\sum R_{\text{cond},i} = \sum \frac{d_i}{k_i}$$

$$\sum R_{\text{cond},i} = \frac{0.02}{1.4} + \frac{0.19}{0.52} + \frac{0.15}{0.041} + \frac{0.02}{0.7} = 4.1 \frac{m^2K}{W}$$

$$R_{\text{tot}} = 0.13 + 4.10 + 0.04 = 4.27 \frac{m^2K}{W}$$

$$U = 1/4.27 = 0.234 \frac{W}{m^2K}$$

Answer: U-value complies with the permissible value for renovation projects

Exercise 1: Solution

2. Determine the required thickness of the thermal insulation (rock wool) layer so that the U-value of the wall will comply with the requirements for **new buildings**.

- The limiting value of the U-value for new buildings is $0.17 \frac{W}{m^2K}$ (slide 22). Thus, the required actual **U**-value should be less than U_{limit} . \rightarrow

$$R'_{tot} < \frac{1}{U_{limit}} = \frac{1}{0.17} = 5.88 \frac{m^2K}{W}$$

- To answer the question, let's abbreviate the required thickness of the rock wool as d'_3 , and solve the equation for R'_{tot}

	d (cm)	λ (W/mK)
1	2	1.40
2	19	0.52
3	15	0.041
4	2	0.70

$$R'_{tot} = R_{si} + \frac{d_1}{k_1} + \frac{d_2}{k_2} + \frac{d'_3}{k_3} + \frac{d_4}{k_4} + R_{se}$$

$$d'_3 = [R'_{tot} - (R_{si} + \frac{d_1}{k_1} + \frac{d_2}{k_2} + \frac{d_4}{k_4} + R_{se})] * k_3$$

$$d'_3 = [5.88 - (0.13 + \frac{0.02}{1.4} + \frac{0.19}{0.52} + \frac{0.02}{0.7} + 0.04)] * 0.041$$

$$d'_3 = 0.217 \text{ m} \rightarrow \mathbf{22 \text{ cm}}$$

Answer: The thermal insulation layer must be **22 cm thick** to comply with the SIA requirements for **new buildings**

Exercise 2: Window Performance

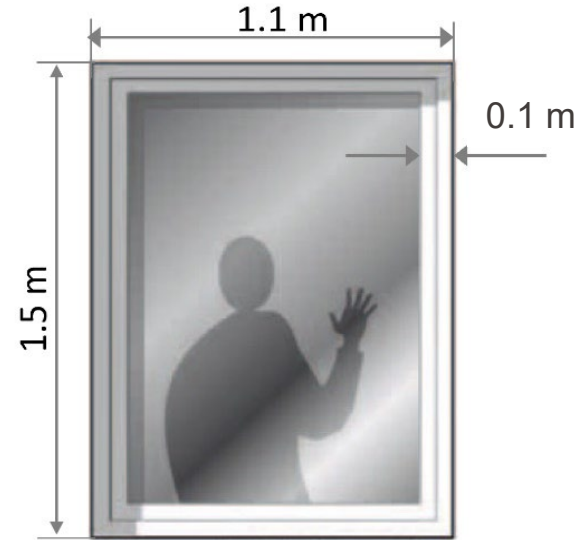
Consider a standard window facing outdoors shown on the picture. Two options of glazing for an air-tight double-pane window (filled with air) are available:

- (a) uncoated ($U_g=2.9 \frac{W}{m^2 \cdot K}$, $g=0.73$);
 (b) coated with low-e film ($U_g=2.0 \frac{W}{m^2 \cdot K}$, $g=0.65$)

Linear thermal transmittance of the glazing is $0.06 \frac{W}{m \cdot K}$ for uncoated glass and $0.08 \frac{W}{m \cdot K}$ for low-emissivity glass. The frame is a PVC-hollow profile ($U_f = 2.0 \frac{W}{m^2 \cdot K}$).

Determine which option of the glazing provides lower thermal transmittance of the window U_w and whether it complies with:

- (i) maximum permitted values for windows per SIA 180
- (ii) the limiting value for windows per SIA 380 standard



Hint: Use standardized values provided on a slide 22 to guide your answer.

Exercise 2: Window Performance

- This problem requires determining the overall U-value of the window per formulation on a slide 34.

$$U_w = \frac{(U_g A_g + U_f A_f + l_g \psi_g)}{(A_g + A_f)}$$

- As U_g , U_f , and ψ_g are given, only geometrical parameters need to be calculated based on the dimensions provided on the drawing

- Area of the glazing:

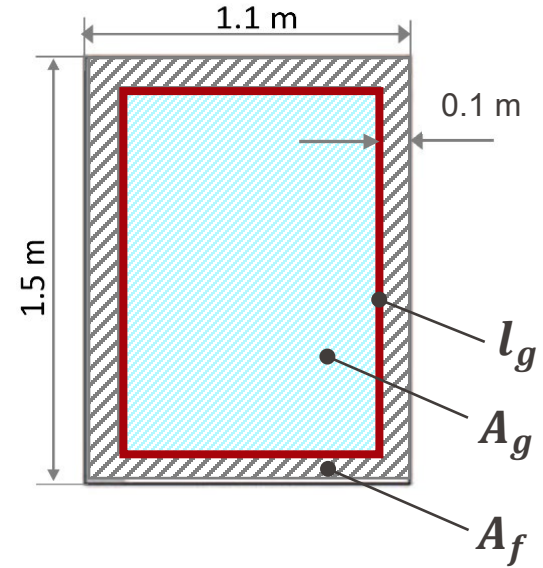
$$A_g = (1.1 - 2 \cdot 0.1) \times (1.5 - 2 \cdot 0.1) = 0.9 \times 1.3 = \mathbf{1.17 \text{ m}^2}$$

- Area of the frame:

$$A_f = 2 \times (1.1 \cdot 0.1) + 2 \times [(1.5 - 2 \cdot 0.1) \cdot 0.1] = 0.22 + 0.26 = \mathbf{0.48 \text{ m}^2}$$

- Length of the linear thermal bridge:

$$l_g = 2 \times (1.1 - 2 \cdot 0.1) + 2 \times [(1.5 - 2 \cdot 0.1)] = 1.8 + 2.6 = \mathbf{4.4 \text{ m}}$$



Exercise 2: Window Performance

- Geometrical parameters for both options (a) and (b) are :

$$A_g = 1.17 \text{ m}^2 \quad A_f = 0.48 \text{ m}^2 \quad l_g = 4.4 \text{ m}$$

- Thermal transmittance for the glazing option (a):

$$U_g = 2.9 \frac{\text{W}}{\text{m}^2 \cdot \text{K}} \quad U_f = 2.0 \frac{\text{W}}{\text{m}^2 \cdot \text{K}} \quad \psi_g = 0.06 \frac{\text{W}}{\text{m} \cdot \text{K}}$$

$$U_{w,a} = \frac{(2.9 \cdot 1.17 + 2.0 \cdot 0.48 + 4.4 \cdot 0.06)}{(1.17 + 0.48)} = \frac{4.62}{1.65} = 2.8 \frac{\text{W}}{\text{m}^2 \cdot \text{K}}$$

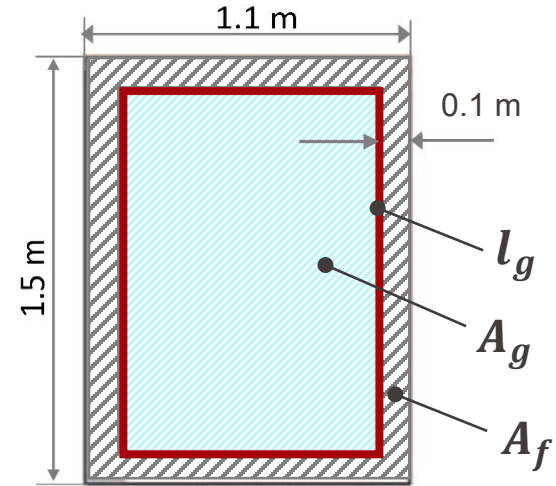
- Thermal transmittance for the glazing option (b):

$$U_g = 2.0 \frac{\text{W}}{\text{m}^2 \cdot \text{K}} \quad U_f = 2.0 \frac{\text{W}}{\text{m}^2 \cdot \text{K}} \quad \psi_g = 0.08 \frac{\text{W}}{\text{m} \cdot \text{K}}$$

$$U_{w,b} = \frac{(2.0 \cdot 1.17 + 2.0 \cdot 0.48 + 4.4 \cdot 0.08)}{(1.17 + 0.48)} = \frac{3.65}{1.65} = 2.2 \frac{\text{W}}{\text{m}^2 \cdot \text{K}}$$

- Standard values per SIA 180 and SIA 380:

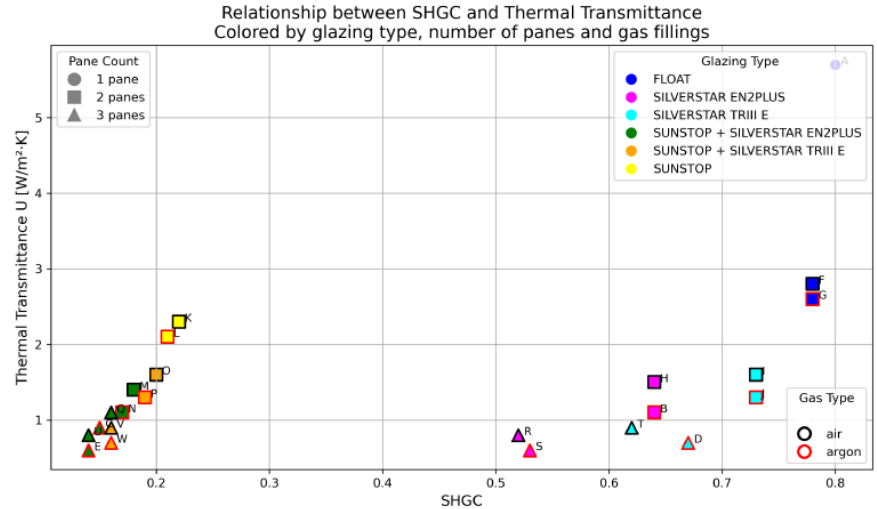
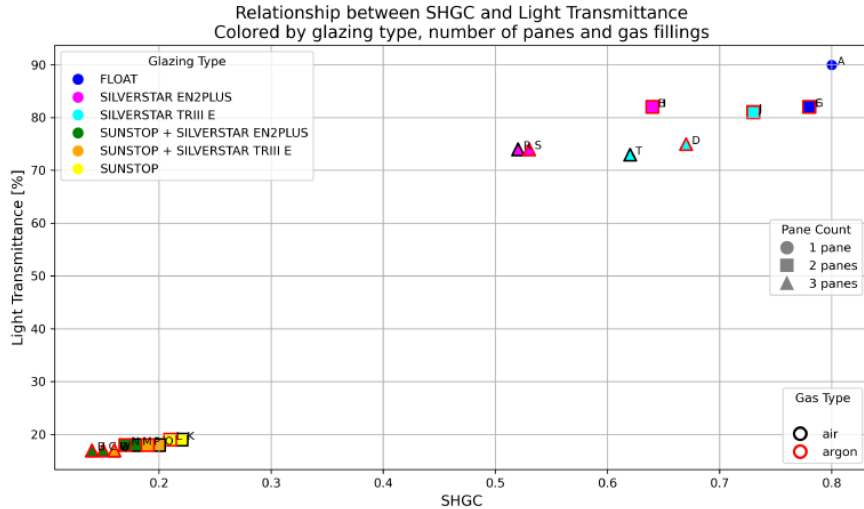
$$U_{w,max} = 2.4 \frac{\text{W}}{\text{m}^2 \cdot \text{K}} \quad U_{w,lim} = 1.0 \frac{\text{W}}{\text{m}^2 \cdot \text{K}}$$



Answer:

A window with the glazing option (b) with low-emissivity coating has lower U_w . However, this value complies only with the maximum permitted $U_{w,max}$ and way above the limiting value of $U_{w,lim}$.

Thus, construction of the window needs to be improved, perhaps, by using a triple-pane window.



Characteristics of various glazing types offered by the *GlasTrösch* manufacturer are shown on the plots. Based on the data shown, answer to the following questions:

1. What are the types of the glazing types that could be suitable for new buildings considering SIA 380 limiting requirements
2. What should be characteristic of the glazing (U-value and g-values) and for buildings located in different climate zone:
 - (a) cold climate, (b) hot climate, (c) temperate climate

1. What are the types of the glazing types that could be suitable for new buildings considering SIA 380 limiting requirements

Triple-pane windows (filled either with air or argon)

2. What should be characteristic of the glazing (U-value and g-values) and for buildings located in different climate zone:

(a) cold climate, (b) hot climate, (c) temperate climate

Table 1: Recommendations for Glazing Selection Based on Climate

Climate Condition	Recommended Glazing Type(s)*	Key Characteristics	Justification
Cold Climate	Glass D	Very low U-values (0.6–0.7), high SHGC (≥ 0.5)	Strong insulation with beneficial solar heat gain.
Hot Climate	Glass C and E	Low U-value (~ 0.9 -0.6), very low SHGC (~ 0.15)	Minimizes solar gains and cooling loads.
Temperate Climate	Glass B	Moderate U-value (~ 1.1), balanced SHGC (~ 0.64)	Balanced performance for mixed climates.

* References to glass types from lab illustration on slide 39