EPFL

ENG-445 Building Energetics

Building Envelope

PRACTICE EXERCISES

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Exercise 1: Opaque Building Element

Determine the thermal transmittance (*U-value)* of the vertical wall structure *adjacent* to exterior. The composition of the wall structure is given in the table.

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

	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

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1. Check whether it is *lower* than 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 ($\boldsymbol{U < U_{limit}}$)
- We need to determine $\boldsymbol{U = 1/R_{tot}}$, thus, overall thermal resistance is the main un-known value to be determined.
- Using the network of thermal resistances analysis presented on slides 17, 23, $\boldsymbol{R_{tot}}$ can be expressed as a sum of surface thermal resistances ($\boldsymbol{R_{si}}$, $\boldsymbol{R_{se}}$) and conductive thermal resistances ($\sum \boldsymbol{R_{cond,i}}$)
- 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, $\boldsymbol{R_{si} = 0.13}\frac{m^2K}{W}$ and $\boldsymbol{R_{se} = 0.04}\frac{m^2K}{W}$.

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

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

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

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

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

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

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

Answer: Actual ***U*-value** is **less** than 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**.

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

- 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 $U_{limit.}$ →

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

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

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

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

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

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

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

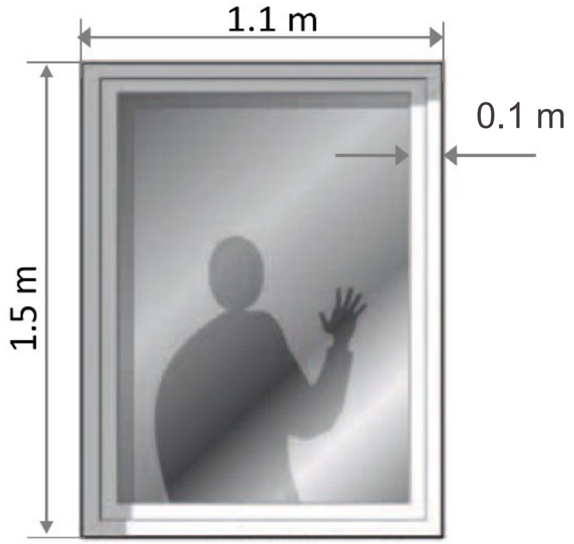
Exercise 2: Window Performance

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 $\boldsymbol{U_w}$ 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.

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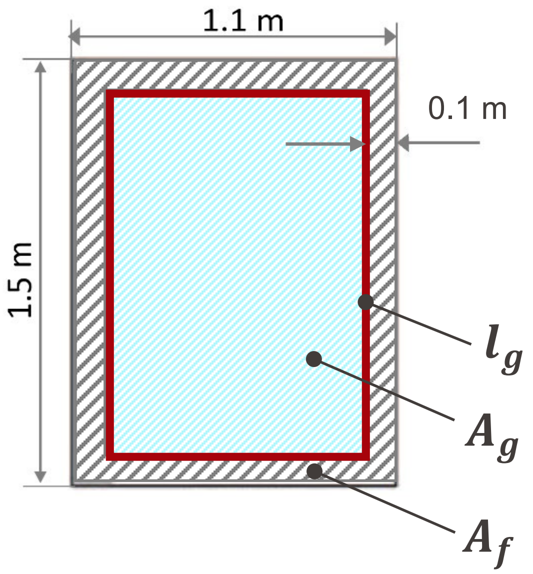
Exercise 2: Window Performance

- This problem requires determining the overall U-value of the window per formulation on a slide 36.

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



- As $\boldsymbol{U_g}$, $\boldsymbol{U_f}$, and $\boldsymbol{\psi_g}$ are given, only geometrical parameters need to be calculated based on the dimensions provided on the drawing
  - Area of the glazing:

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

  - Area of the frame:

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

  - Length of the linear thermal bridge:

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

Exercise 2: Window Performance

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

$$A_g = 1.17\, m^2 \qquad A_f = 0.48\, m^2 \qquad l_g = 4.4\, m$$

- **Thermal transmittance for the glazing option (a):**

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

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

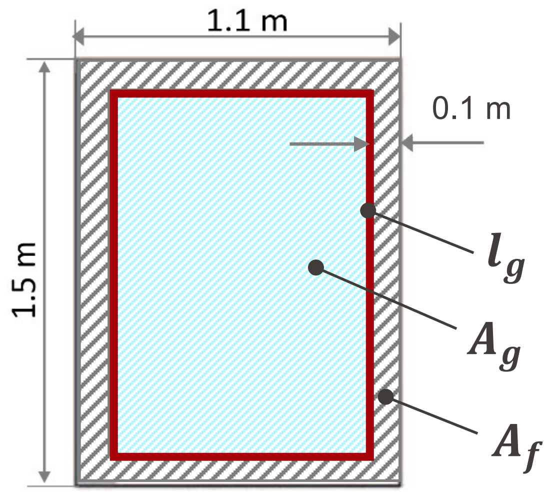
- **Thermal transmittance for the glazing option (b):**

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

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

- **Standard values pers SIA 180 and SIA 380:**

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



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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 imprved, perhaps, by using a triple-pane window.