Week 8 Maria Chiara Cigarini

Task 1 Using the diagrams given in the presentation calculate how much (%) is the effect of applying different modifications (changing the gas, adding an extra pane, using a low emissivity coating) on the U value with respect to a benchmark case of double layer with air and no coating ? (keep the gap thickenss to be 13 mm)

Answer

To calcolate the U value of the window

$$U_{window} = \frac{U_{center}A_{center} + U_{edge}A_{edge} + U_{fram}A_{fram}}{A_{window}}$$

If it's a double pane window, we can ignore the thermal resistance of glass layers

$$\frac{1}{U_{double} - pane} \cong \frac{1}{h_i} + \frac{1}{h_{space}} + \frac{1}{h_0} \; h_{space} = h_{rad,space} + h_{conv,space}$$

- The U_{center} of the h_{space} changes if we change the gas that fills the gap.
  From the diagram we can see that when the gap thickenss is 13 mm by changing the gas from air to argon, the U value of the centre of the gas decreases from 2.8 to 2.65 (5%); instead by changing the gas from air to krypton the U value decrease from 2.8 to 2.6 (7%)

- At the same time the U_{center} changes also by adding an extra pane.
  From the diagram we can see that when the gap thickenss is 13 mm and the gas is air, by adding an extra pain the U value decreases from 2.8 to 1.8 (35%).

- Otherwise we can change the U_{center} coating the glass surfaces whit a low emissivity film.
  From the diagram we can see that when the gap thikenss is 13 mm and the gas is air, by coating the glass surfaces with a film that has 0.1 emissivity, the U value of the centre decreases from 2.8 to 1.8, which means the U value decreases 35%.

Task 2 Consider the house that we analysed in the last two examples, calculate the heating and cooling load of the other windows which are fixed 14.4 m2 on the west, fixed 3.6 m2 on the south and an operable 3.6 m2 on the south (the same window and frame type). How much does the total value change if I change the frame of the window from wooden one to aluminium ?
The net area of walls (excluding doors and windows) of a building located in Piacenza is 105.8 m2, the calculated U value is 0.438 W/mq K for the winter and 0.435 w/mq K for the summer. Find the corresponding heating and cooling load.

PIACENZA, Italy WMO#: **160840**

Lat: **44.92N** Long: **9.73E** Elev: **138** StdP: **99.68** Time Zone: **1.00 (EUW)** Period: **89-10** WBAN: **99999**

Annual Heating and Humidification Design Conditions

Coldest Month	Heating DB		Humidification DP/MCDB and HR						Coldest month WS/MCDB				MCWS/PCWD to 99.6% DB		
			99.6%			99%			0.4%		1%				
	99.6%	99%	DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD	
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	
1	-6.2	-4.8	-11.6	1.4	3.1	-8.8	1.8	1.8	8.8	5.6	7.7	6.2	2.1	250	(1)

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

Hottest Month	Hottest Month DB Range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB		
		0.4%		1%		2%		0.4%		1%		2%				
		DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD	
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	
8	11.9	33.1	22.7	31.9	22.4	30.3	21.8	24.6	30.2	23.7	29.2	22.9	28.3	2.4	90	(2)

$\Delta T_{cooling} = 31.9 - 24 = 7.9\ °C$
$\Delta T_{heating} = 20 - (-4.8) = 24.8\ °C$
DR = 11.9 °C

- Calculating the cooling load of the fixed window of the west:

Cooling Load: Wooden Frame

$\dot{q}_{windowwest} = A \text{ x } CF_{windowwest}$
A = 14.4 m^2

$CF_{windowwest} = CF_{windowwest\_heattransfer} + CF_{windowwest\_irridiation}$
$CF_{windowwest}$ = U(ΔT - 0.46DR) + PXI x SHGC x IAC x FF_s
$CF_{windowwest\_heattransfer}$ = U(ΔT - 0.46DR)

The window has a fixed heat that absorb double layer grass with a wooden frame

U = 2.84
$CF_{windowwest\_heattransfer}$ = 2.84 (7.9 - (0.46)(11.9)) = 6.89 $\frac{W}{m^2}$
$CF_{windowwest\_irridiation}$ = PXI x SHGC x IAC x FF_s
PXI = $E_D - E_d = 559 + 188 = 747$
SHGC = 0.54

No internal shading so → IAC = 1

$FF_s = 0.56$
$CF_{windowwest\_irridiation}$ = 747 x 0.54 x 1 x 0.56 = 232.78 $\frac{W}{m^2}$
$CF_{windowwest} = CF_{windowwest\_heattransfer} + CF_{windowwest\_irridiation}$
$CF_{windowwest}$ = 6.89 + 225.89 = 232.78 $\frac{W}{m^2}$
$\dot{q}_{windowwest} = A \text{ x } CF_{windowwest} = 14.4 \text{ x } 232.78 = 3352.07\ \text{W}$

- Calcoulating the heating load of the fixed window on the west

Cooling Load: Aluminum Frame

$\dot{q}_{windowwest} = A \times CF_{windowwest}$
A = 14.4 m^2
$CF_{windowwest} = CF_{windowwest\_heattransfer} + CF_{windowwest\_irridiation}$
$CF_{windowwest} = U(\Delta T - 0.46DR) + PXI \times SHGC \times IAC \times FF_s$
$CF_{windowwest\_heattransfer} = U(\Delta T - 0.46DR)$
U = 3.61
$CF_{windowwest\_heattransfer} = 3.61\ (7.9 - (0.46)(11.9)) = 8.76\ \frac{W}{m^2}$
$CF_{windowwest\_irridiation} = PXI \times SHGC \times IAC \times FF_s$
PXI = $E_D - E_d = 559 + 188 = 747$
SHGC = 0.56
IAC = 1
$FF_s = 0.56$
$CF_{windowwest\_irridiation} = 747 \times 0.56 \times 1 \times 0.56 = 234.26\ \frac{W}{m^2}$
$CF_{windowwest} = 8.76 + 234.26 = 243.02\ \frac{W}{m^2}$
$\dot{q}_{windowwest} = A \times CF_{windowwest} = 14.4 \times 243.02 = 3499.47\ W$

Heating Load: Wooden Frame
$\dot{q}_{windowwest} = A \times HF_{windowwest}$
A = 14.4 m^2
$HF_{windowwest} = U_{windowwest} \times \Delta T_{heating}$
U = 2.84
$HF_{windowwest} = 2.84 \times 24.8 = 70.43\ \frac{W}{m^2}$
$\dot{q}_{windowwest} = A \times HF_{windowwest} = 14.4 \times 70.43 = 1014.22\ W$

Heating Load: Aluminum Frame
$\dot{q}_{windowwest} = A \times HF_{windowwest}$
A = 14.4 m^2
$HF_{windowwest} = U_{windowwest} \times \Delta T_{heating}$
U = 3.61
$HF_{windowwest} = 3.61 \times 24.8 = 89.53\ \frac{W}{m^2}$
$\dot{q}_{windowwest} = A \times HF_{windowwest} = 14.4 \times 89.53 = 1289.20\ W$

Difference:
Cooling Load = 147.4 W
Heating Load = 274.98 W

- Calcoulating the cooling load of the fixed window on the south

Cooling Load: Wooden Frame

$\dot{q}_{windowsouth} = A \times CF_{windowsouth}$
A = 3.6 m^2
$CF_{windowsouth} = CF_{windowsouth\_heattransfer} + CF_{windowsouth\_irridiation}$
$CF_{windowsouth} = U(\Delta T - 0.46DR) + PXI \times SHGC \times IAC \times FF_s$
$CF_{windowsouth\_heattransfer} = U(\Delta T - 0.46DR)$
U = 2.84

$CF_{windowsouth\_heattransfer}$ = 2.84 (7.9 - (0.46)(11.9)) = 6.89 $\frac{W}{m^2}$
$CF_{windowsouth\_irridiation}$ = PXI x SHGC x IAC x FF_s
PXI = $E_D - E_d = 348 + 209 = 557$
SHGC = 0.54
IAC = 1

$FF_s = 0.47$

$CF_{windowsouth\_irridiation}$ = 557 x 0.54 x 1 x 0.47 = 141.37 $\frac{W}{m^2}$
$CF_{windowsouth} = CF_{windowsouth\_heattransfer} + CF_{windowsouth\_irridiation}$
$CF_{windowsouth}$ = 6.89 + 141.37 = 148.26 $\frac{W}{m^2}$
$\dot{q}_{windowsouth} = A \text{ x } CF_{windowsouth} = 3.6 \text{ x } 148.26 = 533.74 \text{ W}$

Cooling Load: Aluminum Frame

$\dot{q}_{windowsouth} = A \text{ x } CF_{windowsouth}$
A = 3.6 m^2
$CF_{windowsouth} = CF_{windowsouth\_heattransfer} + CF_{windowsouth\_irridiation}$
$CF_{windowsouth}$ = U(ΔT - 0.46DR) + PXI x SHGC x IAC x FF_s
$CF_{windowsouth\_heattransfer}$ = U(ΔT - 0.46DR)
U = 3.61
$CF_{windowsouth\_heattransfer}$ = 3.61 (7.9 - (0.46)(11.9)) = 8.76 $\frac{W}{m^2}$
$CF_{windowsouth\_irridiation}$ = PXI x SHGC x IAC x FF_s
PXI = $E_D - E_d = 348 + 209 = 557$
SHGC = 0.56
IAC = 1
$FF_s = 0.47$
$CF_{windowsouth\_irridiation}$ = 557 x 0.56 x 1 x 0.47 = 146.60 $\frac{W}{m^2}$
$CF_{windowsouth}$ = 8.76 + 146.60 = 155.36 $\frac{W}{m^2}$
$\dot{q}_{windowsouth} = A \text{ x } CF_{windowsouth} = 3.6 \text{ x } 155.36 = 559.30 \text{ W}$

Heating Load: Wooden Frame

$\dot{q}_{windowsouth} = A \text{ x } HF_{windowsouth}$
A = 3.6 m^2
$HF_{windowsouth} = U_{windowsouth}$ x $\Delta T_{heating}$
U = 2.84
$HF_{windowsouth}$ = 2.84 x 24.8 = 70.43 $\frac{W}{m^2}$
$\dot{q}_{windowsouth} = A \text{ x } HF_{windowsouth} = 3.6 \text{ x } 70.43 = 253.08 \text{ W}$

Heating Load: Aluminum Frame

$\dot{q}_{windowsouth} = A \text{ x } HF_{windowsouth}$
A = 3.6 m^2
$HF_{windowsouth} = U_{windowsouth}$ x $\Delta T_{heating}$
U = 3.61
$HF_{windowsouth}$ = 3.61 x 24.8 = 89.53 $\frac{W}{m^2}$
$\dot{q}_{windowsouth} = A \text{ x } HF_{windowsouth} = 3.6 \text{ x } 89.53 = 322.31 \text{ W}$

Difference:
Cooling Load = 25.56 W

Heating Load = 69.23 W

SOUTH WINDOW (OPERABLE)

Cooling Load: Wooden Frame

$\dot{q}_{windowsouth} = A \times CF_{windowsouth}$

A = 3.6 m^2

$CF_{windowsouth} = CF_{windowsouth\_heattransfer} + CF_{windowsouth\_irridiation}$

$CF_{windowsouth} = U(\Delta T - 0.46DR) + PXI \times SHGC \times IAC \times FF_s$

$CF_{windowsouth\_heattransfer} = U(\Delta T - 0.46DR)$

U = 2.87

$CF_{windowsouth\_heattransfer} = 2.87\ (7.9 - (0.46)(11.9)) = 6.96\ \frac{W}{m^2}$

$CF_{windowsouth\_irridiation} = PXI \times SHGC \times IAC \times FF_s$

$PXI = E_D - E_d = 348 + 209 = 557$

SHGC = 0.46

IAC = 1

$FF_s = 0.47$

$CF_{windowsouth\_irridiation} = 557 \times 0.46 \times 1 \times 0.47 = 120.42\ \frac{W}{m^2}$

$CF_{windowsouth} = CF_{windowsouth\_heattransfer} + CF_{windowsouth\_irridiation}$

$CF_{windowsouth} = 6.96 + 120.42 = 127.38\ \frac{W}{m^2}$

$\dot{q}_{windowsouth} = A \times CF_{windowsouth} = 3.6 \times 127.38 = 458.57\ W$

Cooling Load: Aluminum Frame

$\dot{q}_{windowsouth} = A \times CF_{windowsouth}$

A = 3.6 m^2

$CF_{windowsouth} = CF_{windowsouth\_heattransfer} + CF_{windowsouth\_irridiation}$

$CF_{windowsouth} = U(\Delta T - 0.46DR) + PXI \times SHGC \times IAC \times FF_s$

$CF_{windowsouth\_heattransfer} = U(\Delta T - 0.46DR)$

U = 4.62

$CF_{windowsouth\_heattransfer} = 4.62\ (7.9 - (0.46)(11.9)) = 11.21\ \frac{W}{m^2}$

$CF_{windowsouth\_irridiation} = PXI \times SHGC \times IAC \times FF_s$

$PXI = E_D - E_d = 348 + 209 = 557$

SHGC = 0.55

IAC = 1

$FF_s = 0.47$

$CF_{windowsouth\_irridiation} = 557 \times 0.55 \times 1 \times 0.47 = 143.98\ \frac{W}{m^2}$

$CF_{windowsouth} = 11.21 + 143.98 = 155.19\ \frac{W}{m^2}$

$\dot{q}_{windowsouth} = A \times CF_{windowsouth} = 3.6 \times 155.19 = 558.68\ W$

Heating Load: Wooden Frame

$\dot{q}_{windowsouth} = A \times HF_{windowsouth}$

A = 3.6 m^2

$HF_{windowsouth} = U_{windowsouth} \times \Delta T_{heating}$

U = 2.87

$HF_{windowsouth} = 2.87 \times 24.8 = 71.18\ \frac{W}{m^2}$

$\dot{q}_{windowsouth} = A \times HF_{windowsouth} = 3.6 \times 71.18 = 256.23\ W$

Heating Load: Aluminum Frame

$\dot{q}_{windowsouth} = A \times HF_{windowsouth}$

A = 3.6 m^2

$HF_{windowsouth} = U_{windowsouth}$ x $\Delta T_{heating}$

U = 4.62

$HF_{windowsouth}$ = 4.62 x 24.8 = 114.58 $\frac{W}{m^2}$

$$\dot{q}_{windowsouth} = A \times HF_{windowsouth} = 3.6 \times 114.58 = 412.47\ W$$

Difference:

Cooling Load = 100.11 W

Heating Load = 156.24 W

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