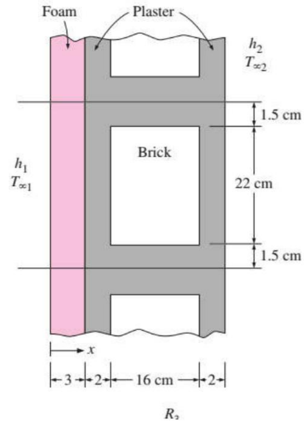
#Week 3_WANG YIJIN

Q1: Heat through a composite wall

- ✓ A 3 m high and 5 m wide wall consists of long 16 cm 22 cm cross section horizontal bricks (k =0.72 W/m · °C) separated by 3 cm thick plaster layers (k =0.22 W/m · °C).
- ✓ There are also 2 cm thick plaster layers on each side of the brick and a 3-cm-thick rigid foam (k 0.026 W/m · °C) on the inner side of the wall
- ✓ The indoor and the outdoor temperatures are 20°C and 10°C, and the convection heat transfer coefficients on the inner and the outer sides are $h1$=10 W/m2 · °C and $h2$ =25 W/m2 · °C, respectively. Assuming one-dimensional heat transfer and disregarding radiation, determine the rate of heat transfer through the wall.



1)

$$A = 0.015 + 0.22 + 0.015 = 0.25\mathrm{m}^2$$

$$R_{\mathrm{indoor}} = \frac{1}{\mathrm{h}_1 A} = \frac{1}{10\times 0.25} = 0.4℃/\mathrm{w}$$

$$\mathrm{R}_{\mathrm{foam}} = \frac{\mathrm{L}_{\mathrm{foam}}}{K_{foam} A} = \frac{0.03}{0.026\times 0.25} = 4.615℃/\mathrm{w}$$

$$\mathrm{R}_{\mathrm{plastic1}} = \frac{\mathrm{L}_{\mathrm{plastic1}}}{K_{plastic} A} = \frac{0.02}{0.22\times 0.25} = 0.3636℃/\mathrm{w}$$

$$\mathrm{R}_{\mathrm{plastic2}} = \frac{\mathrm{L}_{\mathrm{plastic2}}}{K_{plastic} A_{\mathrm{plastic2}}} = \frac{0.16}{0.22\times 0.015} = 48.48℃/\mathrm{w}$$

$$\mathrm{R}_{\mathrm{brick}} = \frac{\mathrm{L}_{\mathrm{brick}}}{K_{brick} A_{\mathrm{brick}}} = \frac{0.16}{0.72\times 0.22} = 1.01℃/\mathrm{w}$$

$$\frac{1}{\mathrm{R}_{\mathrm{para}}} = \frac{1}{\mathrm{R}_{\mathrm{plastic2}}}\times 2 + \frac{1}{\mathrm{R}_{\mathrm{brick}}} = \frac{1}{48.48}\times 2 + \frac{1}{1.01} = 1.03 \rightarrow \mathrm{R}_{\mathrm{para}} = \frac{1}{1.03} = 0.97℃/\mathrm{w}$$

$$R_{\mathrm{outdoor}} = \frac{1}{\mathrm{h}_2 A} = \frac{1}{40\times 0.25} = 0.1℃/\mathrm{w}$$

$$\mathrm{R}_{\mathrm{total}} = \mathrm{R}_{\mathrm{indoor}} + \mathrm{R}_{\mathrm{foam}} + 2\mathrm{R}_{\mathrm{plastic1}} + \mathrm{R}_{\mathrm{para}} + R_{\mathrm{outdoor}} = 0.4 + 4.615 + 0.3636\times 2 + 1.01 + 0.97 + 0.1 = 6.81℃/\mathrm{w}$$

$$\dot{Q} = \frac{T_{indoor} - T_{outdoor}}{\mathrm{R}_{\mathrm{total}}} = \frac{20-(-10)}{6.81} = 4.41W$$

2) When the thickness of the brick is increased to 32 cm,

$$A = 0.015 + 0.22 + 0.015 = 0.25\mathrm{m}^2$$

$$R_{\text{indoor}} = \frac{1}{\mathrm{h}_1 A} = \frac{1}{10 \times 0.25} = 0.4℃/\mathrm{w}$$

$$\mathrm{R}_{\text{foam}} = \frac{\mathrm{L}_{\text{foam}}}{K_{foam} A} = \frac{0.03}{0.026 \times 0.25} = 4.615℃/\mathrm{w}$$

$$\mathrm{R}_{\text{plastic1}} = \frac{\mathrm{L}_{\text{plastic1}}}{K_{plastic} A} = \frac{0.02}{0.22 \times 0.25} = 0.3636℃/\mathrm{w}$$

$$\mathrm{R}_{\text{plastic2}} = \frac{\mathrm{L}_{\text{plastic2}}}{K_{plastic} A_{\text{plastic2}}} = \frac{0.32}{0.22 \times 0.015} = 96.97℃/\mathrm{w}$$

$$\mathrm{R}_{\text{brick}} = \frac{\mathrm{L}_{\text{brick}}}{K_{brick} A_{\text{brick}}} = \frac{0.32}{0.72 \times 0.22} = 2.02℃/\mathrm{w}$$

$$\frac{1}{\mathrm{R}_{\text{para}}} = \frac{1}{\mathrm{R}_{\text{plastic2}}} \times 2 + \frac{1}{\mathrm{R}_{\text{brick}}} = \frac{1}{96.97} \times 2 + \frac{1}{2.02} = 0.52 \to \mathrm{R}_{\text{para}} = \frac{1}{0.52} = 1.92℃/\mathrm{w}$$

$$R_{\text{outdoor}} = \frac{1}{\mathrm{h}_2 A} = \frac{1}{40 \times 0.25} = 0.1℃/\mathrm{w}$$

$$\mathrm{R}_{\text{total}} = \mathrm{R}_{\text{indoor}} + \mathrm{R}_{\text{foam}} + 2\mathrm{R}_{\text{plastic1}} + \mathrm{R}_{\text{para}} + R_{\text{outdoor}} = 0.4 + 4.615 + 0.3636 \times 2 + 2.02 + 1.92 + 0.1 = 9.78℃/\mathrm{w}$$

$$\dot{Q} = \frac{T_{indoor} - T_{outdoor}}{\mathrm{R}_{\text{total}}} = \frac{20-(-10)}{9.78} = 3.07W$$

Conclusion：

When the length of the parallel plate is doubled, the total thermal resistance of the parallel plate is also doubled, but the influence on the total thermal resistance of the composite plate is not significant, so the influence on heat transfer is not significant.

Q2: Heat transfer through the simplified wall

Determine the overall unit thermal resistance (the R-value) and the overall heat transfer coefficient (the U-factor) of a wood frame wall that is built around 38-mm 90-mm wood studs with a center-to-center distance of 400 mm. The 90-mm-wide cavity between the studs is filled with urethane rigid foam insulation. The inside is finished with 13-mm gypsum wallboard and the outside with 13 mm wood plywood and 13-mm 200-mm wood bevel lapped siding. The insulated cavity constitutes 75 percent of the heat transmission area while the studs, plates, and sills constitute 21 percent. The headers constitute 4 percent of the area, and they can be treated as studs. Also, determine the rate of heat loss through the walls of a house whose perimeter is 50 m and wall height is 2.5 m in Las Vegas, Nevada, whose winter design temperature is -2 C.

$R_{UNIT}\,(\mathrm{m}^2\cdot℃/\mathrm{w})$	wood	Insulation
Outside air	0.03	0.03
Wood bevel	0.14	0.14
urethane rigid foam insulation	NO	0.98*90/25=3.528
Wood studs(90mm)	0.63	NO
gypsum wallboard	0.079	0.079
wood plywood	0.11	0.11
Inside air	0.12	0.12

$$R'_{\mathrm{with}WOOD} = 0.03 + 0.14 + 0.63 + 0.079 + 0.11 + 0.12 = 1.109\mathrm{m}^2 \cdot ℃/\mathrm{w}$$

$$R'_{\mathrm{withINS}} = 0.03 + 0.14 + 3.528 + 0.079 + 0.11 + 0.12 = 4.007\mathrm{m}^2 \cdot ℃/\mathrm{w}$$