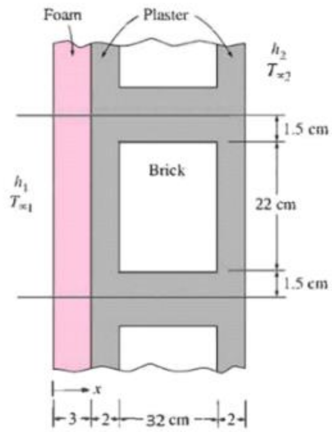
Week 3_Qureshi, Nahid

Question 1.
A 3 m high and 5 m wide wall consists of long 32 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 =40 W/m2 · °C, respectively. Assuming one-dimensional heat transfer and disregarding radiation, determine the rate of heat transfer through the wall.



Answer
Area A : 1m * 0.25m = 0.25 m^2

$$R_{conv1} = \frac{1}{h_1 \times A} = \frac{1}{10\frac{W}{m^{\circ}C} * 0.25\ m^2} = 0.4^{\circ}\frac{C}{W}$$

$$R_{foam} = \frac{L_f}{k_f \times A} = \frac{0.03m}{0.026\frac{W}{m^{\circ}C} * 0.25\ m^2} = 4.615^{\circ}\frac{C}{W}$$

$$\frac{1}{R_{parallel}} = \frac{1}{R_{plaster\_up}} + \frac{1}{R_{brick}} + \frac{1}{R_{plaster\_down}}$$

$$\therefore\ R_{plaster\_up} = R_{plaster\_down} = \frac{L_p}{k_p \times A_p} = \frac{0.32m}{0.22\frac{W}{m^{\circ}C} * 0.015m * 1m} = 96.97^{\circ}\frac{C}{W}$$

$$\therefore R_{brick} = \frac{L_{brick}}{k_{brick} \times A_b} = \frac{0.32}{0.72\frac{W}{m^{\circ}C} * 0.22m * 1m} = 2.0202^{\circ}\frac{C}{W}$$

$$\frac{1}{R_{parallel}} = \frac{1}{96.97^{\circ}\frac{C}{W}} + \frac{1}{2.0202^{\circ}\frac{C}{W}} + \frac{1}{96.97^{\circ}\frac{C}{W}}$$

$$\frac{1}{R_{parallel}} = 0.0103^{\circ}\frac{C}{W} + .4950^{\circ}\frac{C}{W} + 0.0103^{\circ}\frac{C}{W} = 0.5156^{\circ}\frac{C}{W}$$

$$R_{parallel} = 1.9394^{\circ}\frac{C}{W}$$

$$R_{plaster\_left} = R_{plaster\_right} = \frac{L_{p\_left\_right}}{k_p \times A} = \frac{0.02m}{0.22\frac{W}{m^{\circ}C} * 1m * 0.25\ m} = 0.3636^{\circ}\frac{C}{W}$$

$$R_{conv2} = \frac{1}{h_2 \times A} = \frac{1}{40\frac{W}{m^{\circ}C} * 0.25\ m^2} = 0.1^{\circ}\frac{C}{W}$$

$$R_{wall\_total} = R_{conv1} + R_{foam} + R_{parallel} + R_{plaster\_left} + R_{plaster\_right} + R_{conv2}$$

$$R_{wall\_total} = 0.4^{\circ}\frac{C}{W} + 4.615^{\circ}\frac{C}{W} + 1.9394^{\circ}\frac{C}{W} + 0.3636^{\circ}\frac{C}{W} + 0.3636^{\circ}\frac{C}{W} + 0.1^{\circ}\frac{C}{W}$$

$$R_{wall\_total} = 7.7816^{\circ}\frac{C}{W}$$

The heat transfer rate :

$$\dot{Q} = \frac{T_1 - T_{infinity}}{R_{wall\_total}} = \frac{20^{\circ}C - (-10^{\circ}C)}{7.7816^{\circ}\frac{C}{W}} = 3.8552\ W$$

We have calculated the $R_{wall_{total}}$ with thickness of brick inside a composite wall is 16mm

$$R_{wall\_total\_16mm} = 6.18^{\circ}\frac{C}{W}$$

The heat transfer rate :

$$\dot{Q} = \frac{T_1 - T_{infinity}}{R_{wall\_total\_16mm}} = \frac{20^{\circ}C - (-10^{\circ}C)}{6.18^{\circ}\frac{C}{W}} = 4.405\ W$$

By comparing the two results, we concluded that:
Doubling the thickness of brick wall inside a composite wall doesn't significantly increase the thermal resistance of the whole wall, thus the rate of heat transfer doesn't decrease.

So rather than increases the thickness of wall, increases the thickness of foam.
As more the thickness of foam, less the heat transfer.

Question 2
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 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. Find the R-values ?

Answer :

	Wood	Insulation
Outside air	0.03	0.03
Wood bevel (13-mm 200-mm)	.14	0.14
Plywood (13mm)	.11	0.11
Urethane rigid foam insulation (90mm)	no	0.98*90/25= 3.528
Wood studs (90mm)	.63	no
Gypsum board (13mm)	.079	0.079
Inside surface	.12	0.12

$$R'_{withwood} = (0.03 + .14 + .11 + .63 + .079 + .12)\ m^2 {}^\circ\!\!\cdot \frac{C}{W} = \ 1.109 m^{2\circ} \frac{C}{W}$$

$$R'_{withwood} = (.03 + .14 + .11 + 3.\mathring{5}28 + .079 + .12) m^2 {}^\circ\!\!\cdot \frac{C}{W} = 4.007 m^{2\circ} \frac{C}{W}$$