Week3_Li, Junkai

2019年10月16日 15:07

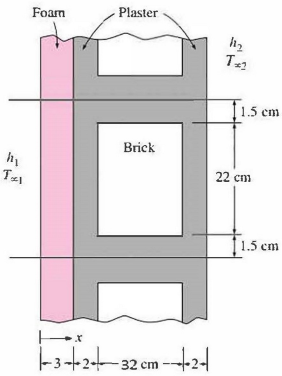
Question 1:

Heat loss through a composite wall

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 h_1 = 10 W/m2 · °C and h_2 = 40 W/m2 · °C, respectively. Assuming one-dimensional heat transfer and disregarding radiation, determine the rate of heat transfer through the wall.

Answer:



$$R_{1,conv.} = \frac{1}{h_1 * A_{1-dimen.}} = \frac{1}{10\frac{W}{m^2{}^\circ C} * (0.015 + 0.22 + 0.015)m * 1m} = 0.4\frac{^\circ C}{W}$$

$$R_{Foam} = \frac{L_{Foam}}{k_{Foam} * A_{1-dimen.}} = \frac{0.03m}{0.026\frac{W}{m^\circ C} * (0.015 + 0.22 + 0.015)m * 1m} \approx 4.615\frac{^\circ C}{W}$$

$$\because\ R_{Plaster.up} = R_{Plaster.down} = \frac{L_{P.up\ or\ dn}}{k_P * A_{P.up\ or\ dn(1-dimen)}} = \frac{0.32m}{0.22\frac{W}{m^\circ C} * 0.015m * 1m} \approx 96.97\frac{^\circ C}{W}$$

$$R_{Brick} = \frac{L_{Brick}}{k_{Brick} * A_{Brick(1-dimen)}} = \frac{0.32m}{0.72\frac{W}{m^\circ C} * 0.22m * 1m} \approx 2.02\frac{^\circ C}{W}$$

$$\therefore\ \frac{1}{R_{total-parellel}} = \frac{1}{R_{Plaster.up}} + \frac{1}{R_{Brick}} + \frac{1}{R_{Plaster.down}} \approx \frac{1}{96.97\frac{^\circ C}{W}} + \frac{1}{2.02\frac{^\circ C}{W}} + \frac{1}{96.97\frac{^\circ C}{W}} \approx 0.516\frac{W}{^\circ C}$$

$$i.e.,\ R_{total-parellel} = \frac{1}{0.516\frac{W}{^\circ C}} \approx 1.94\frac{^\circ C}{W}$$

$$R_{Plaster.left} = R_{Plaster.right} = \frac{L_{P.lt\ or\ rt}}{k_P * A_{P.lt\ or\ rt(1-dimen)}} = \frac{0.02m}{0.022\frac{W}{m^\circ C} * (0.015 + 0.22 + 0.015)m * 1m} = 0.363\frac{^\circ C}{W}$$

$$R_{2,conv.} = \frac{1}{h_2 * A_{1-dimen.}} = \frac{1}{40\frac{W}{m^2{}^\circ C} * (0.015 + 0.22 + 0.015)m * 1m} = 0.1\frac{^\circ C}{W}$$

$$R_{wall,total(1-dimen)} = R_{1,conv.} + R_{Foam} + R_{Plaster.left} + R_{total-parellel} + R_{Plaster.right} + R_{2,conv.}$$

$$\approx 0.4\frac{^\circ C}{W} + 4.615\frac{^\circ C}{W} + 0.363\frac{^\circ C}{W} + 1.94\frac{^\circ C}{W} + 0.363\frac{^\circ C}{W} + 0.1\frac{^\circ C}{W} = 7.781\frac{^\circ C}{W}$$

The heat transfer rate is:

$$\dot{Q} = \frac{T_1 - T_\infty}{R_{wall,total}} \approx \frac{20^\circ C - (-10)^\circ C}{7.781^\circ\frac{C}{W}} \approx 3.86W$$

Plus, we have already calculated the $R_{wall,total}$ while the thickness of brick in this composite wall is 16 mm,

$$R_{wall,total(Thickness\ of\ the\ brick=16mm)} \approx 6.81\frac{^\circ C}{W}$$

In this condition, the heat transfer rate is:

$$\dot{Q}' = \frac{T_1 - T_\infty}{R_{wall,total(Thickness\ of\ the\ brick=16mm)}} \approx \frac{20°C - (-10)°C}{6.81\frac{°C}{W}} \approx 4.41W$$

By comparing the two results, we can have this conclusion:

Simply double the thickness of a brick inside a composite wall dosen't significantly increase the thermal resistance of the whole wall, thus the rate of heat transfer dosen't significantly decrease.

Qusetion 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 rigif foam insulation. The inside is finished with 13-mm gypsum wallboard and the outside with 13 mm polywood 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 two R_{Unit} values.

Answer:

	Wood	Insulation
Outside Air	0.03	0.03
Wood Bevel(13mm*200mm)	0.14	0.14
Polywood(13mm)	0.11	0.11
Urethane Rigif Foam Ins.(90mm)	No	0.98*90/25=3.528
Wood Studs(90mm)	0.63	No
Gypsum Board(13mm)	0.079	0.079
Inside Surface	0.12	0.12

$$R'_{with\ wood} = (0.03 + 0.14 + 0.11 + 0.63 + 0.079 + 0.12)m^2\frac{°C}{W} = 1.109\frac{m^2°C}{W}$$

$$R'_{with\ insulation} = (0.03 + 0.14 + 0.11 + 3.528 + 0.079 + 0.12) = 4.007\frac{m^2°C}{W}$$