Question1:

Heat loss through a composite wall

A 3-m high and 5-m wide wall consists of long 32-m 22-m cross section horizontal bricks(k=0.72W/m · ℃) separated by 3cm thick plaster layers(k=0.22W/m·℃).

There are also 2cm thick plaster layers on each side of the brick and a 3-cm thick rigid foam (k=0.026W/m·℃) on the inner side of the wall The indoor and the outdoor temperatures are 20℃ and -10℃, and the convection heat transfer coefficients on the inner and outer sides are h_1=10W/m2·℃ and h_2=40W/m2·℃, respectively. Assuming one dimensional heat transfer and disregarding radiation, determine the rate of heat transfer through the wall.

Answer:

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

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

$$\because R_{\text{plaster.up}}=R_{\text{plaster.down}}=\frac{L_{p.up\ or\ dn}}{k_p*A_{p.up\ or\ dn(1-dimen)}}=\frac{0.32m}{0.22\frac{W}{m℃}*0.015m*1m}\approx 96.97\frac{℃}{W}$$

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

$\therefore \frac{1}{R_{total-parellet}} = \frac{1}{R_{plaster.up}} + \frac{1}{R_{Brick}} + \frac{1}{R_{plaster.down}} \approx \frac{1}{96.97\frac{℃}{W}} + \frac{1}{2.02\frac{℃}{W}} + \frac{1}{96.97\frac{℃}{W}} \approx 0.516\frac{W}{℃}$

i.e., $R_{\text{total-parellel}} = \frac{1}{0.516\frac{W}{℃}} \approx 1.94\frac{℃}{W}$

$R_{\text{plaster.left}} = R_{\text{plaster.right}} = \frac{L_{p.lt\ or\ rt}}{k_p * A_{p.lt\ or\ rt(1-dimen)}} = \frac{0.22m}{0.022\frac{W}{m℃} * (0.015+0.22+0.015)m * 1m} = 0.363\frac{℃}{W}$

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

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

$R_{2,\text{conv.}} \approx 0.4\frac{℃}{W} + 4.615\frac{℃}{W} + 0.363\frac{℃}{W} + 1.94\frac{℃}{W} + 0.363\frac{℃}{W} + 0.1\frac{℃}{W} = 7.781\frac{℃}{W}$

The heat transfer rate is:

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

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

$R_{wall,total(thickness\ of\ the\ brick=16mm)} \approx 6.81\frac{℃}{W}$

In this condition, the heat transfer rate is:

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

By comparing the two result, 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.

Question2:

A wood frame wall that is built around 38-mm 90-mm wood studs with a center-to-center distance of 400mm.The 90-mm-wide cavity between the studs is filled with urethane rigif foam insulation. The inside is finish 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)$m^2\frac{℃}{W}$=1.109$\frac{m^2℃}{W}$

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