Example: Heat loss through a composite wall

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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 (k0.026 W/m ·° C) on the inner side of the wall. The indoor and the outdoor temperatures are20°C and 10°C, and the convection heat transfer coefficients on the inner and the outer sides areh1=10W/m2 ·°C andh2 =25 W/m2 ·°C, respectively. Assuming one-dimensional heat transfer and disregarding radiation, determine the rate of heat transfer through the wall.

Answer:

$$A = (0.015 + 0.22 + 0.015) * 1 = 0.25\text{m2}$$

$$\text{R1, conv.} = \frac{1}{\text{h1xA1}} = \frac{1}{10\text{x}0.25} = 0.4\ \frac{\text{C}}{\text{W}}$$

$$\text{Rf} = \frac{\text{Lf}}{\text{KfxA1} - \text{dimen}} = \frac{0.03}{0.026\text{x}0.25} = 4.615\frac{\text{C}}{\text{W}}$$

$$\text{Rp1} = \text{Rp2} = \frac{\text{Lp}}{\text{Kp} * \text{Ap}} = \frac{0.32}{0.22 * 0.15 * 1} = 96.97\ \frac{\text{C}}{\text{W}}$$ (p: 2cm thick plastic layers)

$$\text{Rb} = \frac{\text{Lb}}{\text{KbxAb}} = \frac{0.32}{0.72\text{x}0.22\text{x}1} = 2.02\ \frac{\text{C}}{\text{W}}$$

$$\frac{1}{\text{Rtotal. parallel}} = \frac{1}{96.97} + \frac{1}{2.02} + \frac{1}{96.97} = 0.516\ \frac{\text{C}}{\text{W}}$$ (Brick and two plastic layers)

$R_{\text{total parallel}} = \frac{1}{0.516} = 1.94\ \frac{\text{C}}{\text{W}}$

$$\text{Rp1} = \text{Rp2} = \frac{\text{Lp}}{\text{Kp} * \text{Ap}} = \frac{0.02}{0.22\text{x}0.25\text{x}1} = 0.363\ \frac{\text{C}}{\text{W}}$$ (p: 2cm thick plastic layers)

$$\text{R2, conv.} = \frac{1}{\text{h2} * \text{A1}} = \frac{1}{40\text{x}0.25} = 0.1\ \frac{\text{C}}{\text{W}}$$

$R_{\text{wall total}} = 0.4+4.615+0.363+1.94+0.363+0.1 = 7.781\ \frac{\text{C}}{\text{W}}$

The Rate of heat transfer loss: $\dot{Q} = \frac{T1 - T\infty}{\text{Rwall.total}} = \frac{20-(-10)}{7.781} = 3.86\ \text{W}$

But $R_{\text{wall.total}}$ when Thickness of brick=16 mm
$=6.81\ \frac{\text{C}}{\text{W}}$
SO, the heat transfer rate is:

$$\dot{Q} = \frac{T1 - T\infty}{\text{Rwall. total}} = \frac{20 - (-10)}{6.81} = 4.41\ \text{W}$$

So By comparing the two results 4.41w and 3.86w, we found that: double the thickness of a brick inside a composite wall increases slightly the thermal resistance of thewall, so the rate of heat transfer slightly decreases.