Week4_Li, Junkai

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Qusetion:

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 (this means 75% of area is insulation and 25% can be considered wood).

Find the two R_{Unit} values, determine the overall unit thermal resistance (the R-value) and the overall heat transfer coefficient (the U-factor)

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. Take the indoor design temperature to be 22 C and assume 20 percent of the wall area is occupied by glazing.

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

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

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

$$U_{Wood} = \frac{1}{R'_{with\ wood}} = \frac{1}{1.109\ \frac{m^2 °C}{W}} \approx 0.9017\ \frac{W}{m^2 °C}$$

$$U_{Insulation} = \frac{1}{R'_{with\ wood}} = \frac{1}{4.007\ \frac{m^2 °C}{W}} \approx 0.2496\ \frac{W}{m^2 °C}$$

$$\because \frac{1}{R_{Total}} = \frac{1}{R_{Wood}} + \frac{1}{R_{Insulation}}, R = \frac{R'}{A}, i.e., \frac{1}{R} = \frac{A}{R'},$$

$$\therefore \frac{A_{Total}}{R'_{Total}} = \frac{A_{Wood}}{R'_{Wood}} + \frac{A_{Insulation}}{R'_{Insulation}}$$

$$autem,\ U = \frac{1}{R'},$$

$i.e., \ A_{Total} * U_{Total} = A_{Wood} * U_{Wood} + A_{Insulation} * U_{Insulation}$

Both sides of the equation divided by U_{Total}:

$$U_{Total} = U_{Wood} * \frac{A_{Wood}}{A_{Total}} + U_{Insulation} * \frac{A_{Insulation}}{A_{Total}}$$

$$= (21\% + 4\%) \times U_{Wood} + 75\% \times U_{Insulation}$$

$$\approx 25\% \times 0.9017 \ \frac{W}{m^2 °C} + 75\% \times 0.2496 \ \frac{W}{m^2 °C} \approx 0.4126 \ \frac{W}{m^2 °C}$$

The overall unit thermal resistance $R_{value} = \frac{1}{U_{Total}} \approx \frac{1}{0.4126 \frac{W}{m^2 °C}} \approx 2.4237 \ \frac{m^2 °C}{W}$

The rate of heat loss through the walls

$$\dot{Q}_{Total} = U_{Total} * A_{Total} * \Delta T$$

$$\approx \ 0.4126 \ \frac{W}{m^2 °C} \times 50 \ m \times 2.5 \ m \ \times (1 - 20\%) \times 22 \ °C \ - (-2 \ °C) = 990.24 \ W$$

Summary about radiation and radiative heat transfer

Definition:

Thermal radiation is the emission of electromagnetic waves from all matter that has a temperature greater than absolute zero, i.e., 0 K or −273.15 °C, it is due to the heat of the material, the characteristics of whch depend on its temperature. The type of electromagnetic radiation that is pertinent to heat transfer is the thermal radiation emitted as a result of energy transitions of molecules, atoms, and electrons of a substance. That explains the temperature in the physical field: temperature is a measure of the strength of these activities at the microscopic level, and the rate of thermal radiation emission increases with increasing temperature.

Since absolute zero is an idealized physical condition, thermal radiation happens almost in all objects, regardless of the material form of the object, whether it is solid, liquid or gas, basically everything around us keeps emitting thermal radiation to its surroundings.

A significant difference between thermal radiation and other mechanisms of heat transfer is, thermal radiation does not need the presence of a material medium to take place. So thermal radiation can occur in vacuum."

Electromagnetic wave

Thermal radiation is an electromagnetic wave, it is characterized by its frequency v and wavelength λ. Wavelength and frequency are inversely proportional: that is, the shorter the wavelength, the higher the frequency, and vice versa. This relationship is given by the following equation:

$c=\lambda v$ ($c=299\ 792\ 458$ m/s $\approx 3{,}00 \times 10^8$ m/s is the speed of light in vacuum)

Therefore, all electromagnetic waves, certainly including thermal radiation, regardless of wavelength or frequency, travels at the speed of light. It is easy to understand, for example, Sunshine, or solar radiation, is thermal radiation from the extremely hot gasses of the sun, and this radiation heats the earth.

Emission, absorption and reflection; definition of a black body

The thermal radiation is continually emitted from every part of the surface of the object that has a temperature greater than absolute zero into every direction.

Surfaces emit thermal radiation and reflect electromagnetic waves at the same time. If we assume an object that emits radiation but does not reflect any electromagnetic waves, it is a “black body”, which is an idealized body that doesn’t exist in real life. A blackbody emits the maximum amount of radiation by a surface at a given temperature, and absorbs all incident radiation, regardless of wavelength and direction.

Amount of emission, wavelength and temperature

The emitted radiation is a continuous function of wavelength. At any specified temperature, it increases with wavelength, reaches a peak, and then decreases with increasing wavelength. At any wavelength, the amount of emitted radiation increases with increasing temperature.