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جامعة بيرزيت

Faculty of Engineering and Technology

Department of Mechanical and Mechatronics Engineering

REFRIGERATION AND AIR CONDITIONING

ENME432

AC Project (Heating Load)

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Calculations:

1. Transmission load (glass, walls, roof and floor):

$$q_{transmission} = U * A * \Delta T$$

$$q_{glass} = U_{glass} * A_{glass} * \Delta T_{glass}$$

$$A_{glass} = hieght * \sum glass\ lengths$$

U_{glass} = 3.3 W/m^2C

ΔT_{glass} = $T_i - T_\circ$ = 22-5 = 17C.

$$q_{wall} = U_{wall} * A_{wall} * \Delta T_{wall}$$

$$A_{wall} = hieght * \sum wall\ lengths$$

$U_{wall} = \frac{1}{\sum R_{wall}}$

$R_{wall} = R_\circ + R_{st} + R_c + R_{in} + R_B + R_{plas} + R_i$

ΔT_{wall} = $T_i - T_\circ$ = 22-5 = 17C.

$q_{roof} = U_{roof} * A_{roof} * \Delta T_{roof}$

A_{roof} =

$U_{roof} = \frac{1}{\sum R_{roof}}$

$R_{roof} = R_{\circ} + R_{st} + R_c + R_{in} + R_B + R_{plas} + R_i$

$\Delta T_{roof} = T_i - T_{\circ}$ = 22-5 = 17C.

$q_{floor} = U_{floor} * A_{floor} * \Delta T_{floor}$

A_{floor} =

$U_{floor} = \frac{1}{\sum R_{floor}}$

$R_{floor} = R_{\circ} + R_{st} + R_c + R_{in} + R_B + R_{plas} + R_i$

$\Delta T_{floor} = T_i - T_{\circ}$ = 22-5 = 17C.

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2. Ventilation load:

$q_{ventilation} = 1.23 * \dot{V}_{vent} * \Delta T + 3000 * \dot{V}_{vent} * \Delta\omega$

$\dot{V}_{vent} = (air\ requierments\ per\ person) * (number\ of\ people)$

$(number\ of\ people) = A_s * (occupation)$

$\Delta T = T_i - T_{\circ}$ = 22-5 = 17C.

$\Delta\omega = \omega_i - \omega_{\circ}$ = 0.008-.004 = 0.004.

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3. Infiltration load:

$q_{infiltration} = 1.23 * \dot{V}_{infil} * \ \Delta T + 3000 * \dot{V}_{infil} * \ \Delta\omega$

$\dot{V}_{infil}$ = $V * (air\ changes\ per\ second)$

ΔT = $T_i - \ T_\circ$ = 22-5 = 17C.

$\Delta\omega$ = $\omega_i - \ \omega_\circ$ = 0.008-.004 = 0.004.

For the gym:

1) Transmission load:

For the arena and reception area:

For the glass:

$$A_{glass} = hieght * \sum glass\ lengths$$

$$= 4\ \times (2.47 + 3.42 + 3.19 + 3.57 + 4.14 + 1.88 + 1.88 + 1.88 + (2 \times 0.81))$$

$$= 96.2\ m^2.$$

$$q_{glass} = U_{glass} * A_{glass} * \ \Delta T_{glass} = 3.3\ \times 96.2 \times 17 = 5396\ W.$$

For the walls:

$$A_{wall} = hieght * \sum wall\ lengths$$

$$= 4 \times (0.77 + 0.84 + 0.91 + 1.26 + 1.26 + 0.53 + 1.78 + 3.13 + 3.13 + 2.48 + 0.67 + 3.69)$$

$$A_{wall} = 81.8\ m^2.$$

U_{wall} was found based on the Table in Example 5-1 (Outside wall):

U_{wall} = 0.49 W/m^2C.

$$q_{walls} = 0.49 \times 81.9 \times 17 = 681\ W.$$

For the lockers room:

$A_{wall} = 3 \times 4 = 12\ m^2.$

$q_{wall} = 0.49 \times 12 \times 17 = 100\ W.$

For the roof:

$A_{reception} = 5.65\ \times 7.93 = 44.8\ \ m^2.$

$A_{arena} = (5.65 \times 4.05) + (15.49 \times 10.24) + (5.55 \times 6.7) = 219.17\ m^2.$

$A_{lockers} = 3 \times 5.55 = 16.6\ \ m^2.$

$A_{total} = 280.6\ \ m^2. = A_{roof} = A_{floor.}$

U_{roof} was taken as a ceiling the Table in Example 5-2 section (b):

$U_{roof} = 0.48\ \ W/m^2C.$

$q_{roof} = 0.48 \times 280.6 \times 17 = 2289\ W.$

For the floor:

$A_{floor} = 280.6\ \ m^2$

U_{floor} was taken according to the following values:

5) Floor:

Material (Floor)	Thermal conductivity (K) W/m.c	Material thickness cm
Gravel	K = 0.7	15
Light Concrete	K = 0.3	15
Moisture Insulator (Bitumen)	K = 0.17	5
Dense Concrete .	K = 1.75	25

In addition to ceramic (3 mm thickness and k=0.48) and inside and outside film resistance:

$$R_{floor} = \frac{0.15}{0.7} + \frac{0.15}{0.3} + \frac{0.05}{0.17} + \frac{0.25}{1.75} + \frac{0.003}{0.48} + 0.15 + .02 = 1.32\ \ m^2C/W.$$

$$U_{floor} = \frac{1}{1.32} = 0.757\ \ W/\ m^2C.$$

$q_{floor} = 0.757 \times 280.6 \times 17 = 3600\ W.$

2) Ventilation Load:

a) Arena:

$A_{arena} = 219.17\ \ m^2.$

$Occupation = 219.17 \times \frac{30}{100} = 66\ people.$

$\dot{V}_{vent}$ = $(air\ requierments\ per\ person) * (number\ of\ people)$

$\dot{V}_{vent} = 10\ \frac{L}{s.person} \times 66 = 660\ \ L/s.$

$q_{ventilation} = 1.23 * \dot{V}_{vent} *\ \Delta T + 3000 * \dot{V}_{vent} *\ \Delta\omega$

$q_{ventilation} = 1.23 \times 660 \times 17 + 3000 \times 660 \times 0.004 = 21720\ W.$

b) Reception:

$A_{reception} = 44.8\ \ m^2.$

$Occupation = 44.8 \times \frac{60}{100} = 27\ people.$

$\dot{V}_{vent} = 8\ \frac{L}{s.person} \times 27 = 216\ \ L/s.$

$q_{ventilation} = 1.23 \times 216 \times 17 + 3000 \times 216 \times 0.004 = 7108\ W.$

c) Lockers:

$A_{Lockers} = 16.6\ \ m^2.$

$Occupation = 16.6 \times \frac{50}{100} = 9\ people.$

$\dot{V}_{vent} = \frac{7.5+17.5}{2}\ \frac{L}{s.person} \times 9 = 112.5\ \ L/s.$

$q_{ventilation} = 1.23 \times 112.5 \times 17 + 3000 \times 112.5 \times 0.004 = 3702\ W.$

3) Infiltration Load:

a) Arena:

$ACPH = 1.5$

$\dot{V}_{infil}$ = $V * (air\ changes\ per\ second)$

$$= \frac{1.5}{3600} \times 219.17 \times 4 = 0.365\, m^3/s$$

$$= 365\ \ L/s.$$

$$q_{infiltration} = 1.23 * \dot{V}_{infil} * \ \Delta T + 3000 * \dot{V}_{infil} * \ \Delta\omega$$

$$= 1.23 \times 365 \times 17 + 3000 \times 365 \times 0.004 = 12012\, W.$$

b) Reception:

$$ACPH = 2$$

$$\dot{V}_{infil} = \frac{2}{3600} \times 44.8 \times 4 = 99\, L/s$$

$$q_{infiltration} = 1.23 \times 99 \times \ 17 + 3000 \times 99 \times \ 0.004 = 3258\, W.$$

c) Lockers:

$$ACPH = 1$$

$$\dot{V}_{infil} = \frac{1}{3600} \times 16.6 \times 4 = 18\, L/s$$

$$q_{infiltration} = 1.23 \times 18 \times \ 17 + 3000 \times 18 \times \ 0.004 = 592\, W.$$

For the supermarket:

1. Transmission load (glass, walls, roof and floor):

$$q_{transmission} = U * A * \ \Delta T$$

$$q_{wall} = U_{glass} * A_{glass} * \ \Delta T_{glass}$$

$$A_{glass} = hieght * \sum glass\ lengths$$

U_{glass} = 3.3

ΔT_{glass} = $T_i - T_\circ$ = 22-5 = 17C.

$q_{wall} = U_{wall} * A_{wall} * \Delta T_{wall}$

$A_{wall} = hieght * \sum wall\ lengths$ = 4*81 = 324 m2

$R_{wall} = R_{\circ} + R_{st} + R_c + R_{in} + R_B + R_{plas} + R_i$ = 2.0166

$U_{wall} = \frac{1}{\sum R_{wall}}$ = 0.49 KW/m2.K

$\Delta T_{wall} = T_i - T_{\circ}$ = 22-5 = 17C.

$q_{wall} = U_{wall} * A_{wall} * \Delta T_{wall}$ = 0.49*324*17 = 2699 W

$q_{roof} = U_{roof} * A_{roof} * \Delta T_{roof}$

A_{roof} = 811.3 m2

$R_{roof} = R_{\circ} + R_{st} + R_c + R_{in} + R_B + R_{plas} + R_i$ = 2.0166

$U_{roof} = \frac{1}{\sum R_{roof}}$ = 0.49 KW/m2.K

$\Delta T_{roof} = T_i - T_{\circ}$ = 22-5 = 17C.

$q_{roof} = U_{roof} * A_{roof} * \Delta T_{roof}$ = 0.49*811.3*17 = 6618 W

$q_{floor} = U_{floor} * A_{floor} * \Delta T_{floor}$

A_{floor} = 811.3 m2

$R_{floor} = R_{\circ} + R_{st} + R_c + R_{in} + R_B + R_{plas} + R_i$ = 1.33

$U_{floor} = \frac{1}{\sum R_{floor}}$ = 0.75 KW/m2.K

$\Delta T_{floor} = T_i - T_\circ$ = 22-5 = 17C.

$q_{floor} = U_{floor} * A_{floor} * \Delta T_{floor}$ = 0.75*811.3*17 = 10340 W

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2. Ventilation load:

$q_{ventilation} = 1.23 * \dot{V}_{vent} * \Delta T + 3000 * \dot{V}_{vent} * \Delta\omega$

$(\#people) = A_s * (occupation)$ = 811.3 (m2) * 0.08 (people/ m2) = 65 people.

$\dot{V}_{vent}$ = $(air\ requierments/\ person) * (\#people)$ = 8(liters/person)* 65 = 520 liters.

$\Delta T = T_i - T_\circ$ = 22-5 = 17C.

$\Delta\omega = \omega_i - \omega_\circ$ = 0.008-.004 = 0.004.

$q_{ventilation} = 1.23 * \dot{V}_{vent} * \Delta T + 3000 * \dot{V}_{vent} * \Delta\omega$ = 1.23 *520*17 + 3000*520*.004 = 17113 W.

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3. Infiltration load:

$q_{infiltration} = 1.23 * \dot{V}_{infil} * \Delta T + 3000 * \dot{V}_{infil} * \Delta\omega$

$\dot{V}_{infil} = V * (air\ changes\ per\ second)$ = 811.3*4*(0.5/3600) = 450.6 liters.

$\Delta T = T_i - T_\circ$ = 22-5 = 17C.

$\Delta\omega = \omega_i - \omega_\circ$ = 0.008-.004 = 0.004.

$q_{infiltration} = 1.23 * \dot{V}_{infil} * \Delta T + 3000 * \dot{V}_{infil} * \Delta\omega$ = 1.23 *450*17 + 3000*450*.004 = 14829 W.

For the clothing and barber shops:

1. Transmission load (glass, walls, roof and floor):

$q_{glass} = U_{glass} * A_{glass} * \Delta T_{glass}$

$A_{glass} = hieght * \sum glass\ lengths$ = 4* 4.36 = 17.44 m2

U_{glass} = 3.3

ΔT_{glass} = $T_i - T_\circ$ = 22-5 = 17C.

$q_{glass} = U_{glass} * A_{glass} * \Delta T_{glass}$ = 3.3*17.44*17 = 978 W

$q_{wall} = U_{wall} * A_{wall} * \Delta T_{wall}$

$A_{wall} = hieght * \sum wall\ lengths$ = 4* 12.72 = 50.88 m2

$R_{wall} = R_\circ + R_{st} + R_c + R_{in} + R_B + R_{plas} + R_i$ = 2.1

$U_{wall} = \frac{1}{\sum R_{wall}}$ = 0.49 KW/m2.K

ΔT_{wall} = $T_i - T_\circ$ = 22-5 = 17C.

$q_{wall} = U_{wall} * A_{wall} * \Delta T_{wall}$ = 0.49 * 50.88*17 = 423.8 W

$q_{roof} = U_{roof} * A_{roof} * \Delta T_{roof}$

A_{roof} = 75.7 m2

$R_{roof} = R_\circ + R_{st} + R_c + R_{in} + R_B + R_{plas} + R_i$ = 2.1

$U_{roof} = \frac{1}{\sum R_{roof}}$ =0.48 KW/m2.K

ΔT_{roof} = $T_i - T_\circ$ = 22-5 = 17C.

$q_{roof} = U_{roof} * A_{roof} * \Delta T_{roof}$ = 0.48*75.7*17 = 617.6 W

$q_{floor} = U_{floor} * A_{floor} * \Delta T_{floor}$

A_{floor} = 75.7 m2
$R_{floor} = R_\circ + R_{st} + R_c + R_{in} + R_B + R_{plas} + R_i$ = 1.33
$U_{floor} = \frac{1}{\sum R_{floor}}$ = 0.75 KW/m2.K
$\Delta T_{floor} = T_i - T_\circ$ = 22-5 = 17C.

$q_{floor} = U_{floor} * A_{floor} * \Delta T_{floor}$ = 0.75*75.7*17 = <u>965 W.</u>

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2. Ventilation load:

$q_{ventilation} = 1.23 * \dot{V}_{vent} * \Delta T + 3000 * \dot{V}_{vent} * \Delta\omega$

$\# \, people$ = 15 people

$\dot{V}_{vent}$ = $(air\ requierments/person) * (\# \, people)$ = 5 (L/s) * 15 = 75 L/s

$\Delta T = T_i - T_\circ$ = 22-5 = 17C.

$\Delta\omega = \omega_i - \omega_\circ$ = 0.008-.004 = 0.004.

$q_{ventilation} = 1.23 * \dot{V}_{vent} * \Delta T + 3000 * \dot{V}_{vent} * \Delta\omega$ = 1.23 *75*17 + 3000*75*.004 = <u>2468 W.</u>

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3. Infiltration load:

$q_{infiltration} = 1.23 * \dot{V}_{infil} * \ \Delta T + 3000 * \dot{V}_{infil} * \ \Delta\omega$

$\dot{V}_{infil}$ = $V * (air\ changes\ per\ second)$ = 75.7*4*(1/3600) = 84 L/s

ΔT = $T_i - T_\circ$ = 22-5 = 17C.

$\Delta\omega$ = $\omega_i - \omega_\circ$ = 0.008-.004 = 0.004.

$q_{infiltration} = 1.23 * \dot{V}_{vent} * \ \Delta T + 3000 * \dot{V}_{vent} * \ \Delta\omega$ = 1.23 *84*17 + 3000*84*.004 = <u>2767 W.</u>

For Restaurants

(A) Juice Shop

- **Transmission load**

$- \boldsymbol{A_{wall} = 7.9 \times 4 + \left(2.4 \times 4 - (1.85 \times 1.5)\right) = 24.775\ m^2}$

$- \boldsymbol{A_{glass} = 1.85 \times 1.5 = 2.775\ m^2}$

The glass is **double** glassed, so U=3.3 $watt/\boldsymbol{m^2.K}$

$\boldsymbol{q_{wall} = U_{wall} \times A_{wall} \times (T_{in} - T_o)}$

$\boldsymbol{R_{total}}$=$\boldsymbol{R_{ai} + R_p + R_B + R_I + R_c + R_s + R_{ao}}$

R=L/k , where :

L:thikness

K: thermal conductivity

$\boldsymbol{U_{wall} = 1/(R_{ai} + R_p + R_B + R_I + R_c + R_s + R_{ao})}$ **, where:**

$\boldsymbol{R_{ai}: inside\ air\ resistance}$

$\boldsymbol{R_p}$**:Cement plaster resistance**

$\boldsymbol{R_B: Hollow\ Block\ resitanse}$

$\boldsymbol{R_I: Polystryne\ Insulator\ resistance}$

R_C: Concrete resistance

R_S: *Stone resistance*

R_{ao}: *Outside air resistance*

$$R_{total}==\frac{0.02}{1.2}+\frac{0.07}{1}+\frac{0.05}{0.03}+\frac{0.2}{1.75}+0.12+0.3=2.0166\ m^2k/w$$

$$U_{wall}=\frac{1}{2.0166}=0.49\ w/m^2k$$

$$q_{wall}=0.49\times 24.775\times(22-5)=208.9\ watt$$

$$q_{Glass}=3.3\times 2.775\times 17=155.6717\ watt$$

For Roof : $A_{Roof}=7.9\times 5.77=45.583m^2$

$$R_{total=}\ R_{asphalt}+\ R_{concrete}+\ R_{polysryne}+\ R_{concrete}+\ R_{brick}+\ R_{plaster}+\ R_{ai}+R_{ao}$$

$$=\frac{0.02}{0.7}+\frac{0.05}{1.75}+\frac{0.05}{0.03}+\frac{0.06}{1.75}+\frac{0.18}{0.95}+\frac{0.02}{1.2}= 2.0842\ m^2k/w$$

U=1/2.0842=0.48 w/m^2k

$$q_{Roof}=0.48\times 45.583\times 17=371.987\ watt$$

For Floor: $A_{Roof}=45.583m^2$

Ufloor=0.7575 w/m^2k

$$q_{Floor}=0.7575\times 45.583\times 17=587.05\ watt$$

$$q_{Transmmision\ total\ For\ Juice\ Shop}=q_{Floor}+q_{Roof}+q_{Wall}+q_{Glass}=997.213\ watt$$

(B) KFC Shop

- **Transmission load**

$- A_{wall} = 6.01 \times 4 + \left(3.97 \times 4 - (1.91 \times 1.51)\right) = 37.055 \ m^2$

$- A_{glass} = 1.91 \times 1.51 = 2.865 \ m^2$

$-A_{floor} = 4.59 \times 7 + 5.65 \times 3.97 + 4.952 \times 1.36 + 0.5 \times 4.9 \times 4.22$

$A_{floor} = 71.56 m^2$

$q_{wall} = U_{wall} \times A_{wall} \times (T_{in} - T_o) = 0.49 \times 37.055 \times 17 = 308.668 \ watt$

$q_{glass} = 3.3 \times 2.865 \times 17 = 160.7265 \ watt$

$q_{floor} = 0.7575 \times 71.56 \times 17 = 921.538 \ watt$

$q_{Roof} = 0.48 \times 71.56 \times 17$**=583.92**

$q_{Transmmision\ total\ For\ KFC\ Shop}$**=1974.89 watt**

(C) Shawarema Joint

- **Transmission load**

All walls is internal walls

$-A_{floor} = 6.96 \times 4.91 = 34.1736 m^2$

$q_{floor} = 0.7575 \times 34.1736 \times 17 = 440.07 \ watt$

$q_{Roof} = 0.48 \times 34.1736 \times 17$**=278.856 watt**

$q_{Transmmision\ total\ For\ Shawerma\ Joint}$**=718.926 watt**

(D) Cafeteria

- **Transmission load**

All walls is internal walls

$-A_{Sky\ lights} = 23.77 \times 19.56 + 14.87 \times 5.22 + 9.72 \times 4.69 +$

$$\mathbf{17.06 \times 1.5 = 613.739\boldsymbol{m}^2}$$

$$q_{floor} = \mathbf{0.7575 \times 613.739 \times 17 = 790.424}\ \boldsymbol{watt}$$

$q_{Sky\ lights} = \mathbf{3.3 \times 613.739 \times 17}$**=34430.7 watt**

$q_{Transmmision\ total\ For\ Cafeteria}$**=35221.124 watt**

- Ventilation

  -For cafeteria assume in max occupancy per 100 $\boldsymbol{m}^2 = \mathbf{50}, \boldsymbol{and}$ **Ventlation air req=10L/s/person**

  The area of the cafeteria = $\mathbf{613.739\boldsymbol{m}^2}$

  ,so the max occupancy= $\frac{613.739}{2} = \mathbf{306.8695}$

$$\dot{V}_{vent} = 306.8695 \times 10 = 3068.695\ L/s$$

$$q_{total\ ventliation} = \mathbf{1.23} \times \dot{V}_{vent}\Delta T + 3000\dot{V}_{vent}\Delta w$$

$$q_{total} = 1.23 \times 3068.695 \times 17 + 3000 \times 3068.695 \times 0.004 = 100990.7525\ watt$$

- Infiltration

  -ACPH=1

$\dot{V}_{inf} = \frac{1}{3600} \times 613.739 \times 4 = 0.6819\boldsymbol{m}^3/\boldsymbol{s}$**=681.9 L/s**

$$q_{total\ infiltration} = 1.23 \times 681.9 \times 17 + 3000 \times 681.9 \times 0.004 = 22445\ watt$$

$q_{room\ total\ cafteria} = q_{total\ infiltration} + q_{Transmmision\ total\ For\ Cafeteria}$=**64778.424watt**