ME-415

REFRIGERATION AND BUILDING MECHANICAL SYSTEMS

TOPIC : COOLING LOAD ESTIMATION

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Contents

1 CAD model of Room

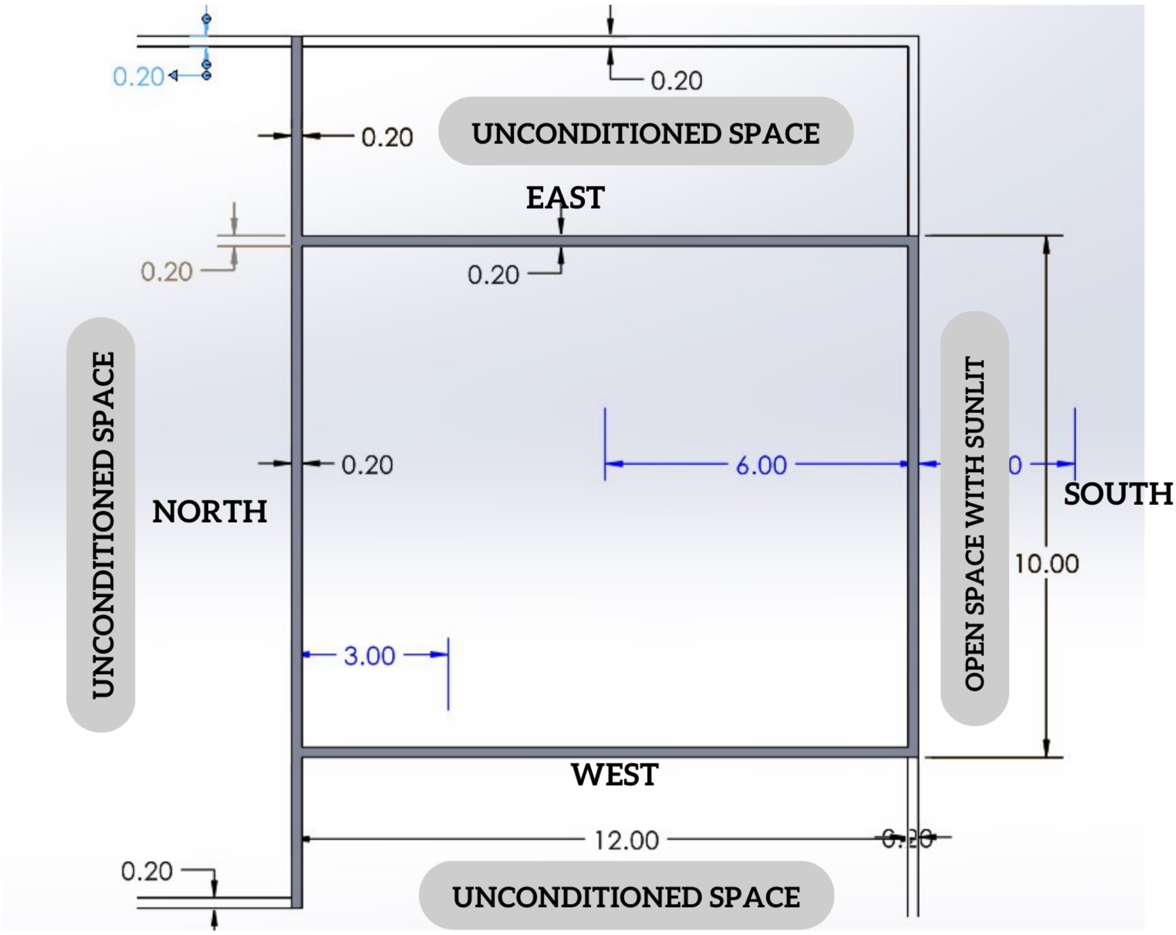

Figure 1: Top View of Room

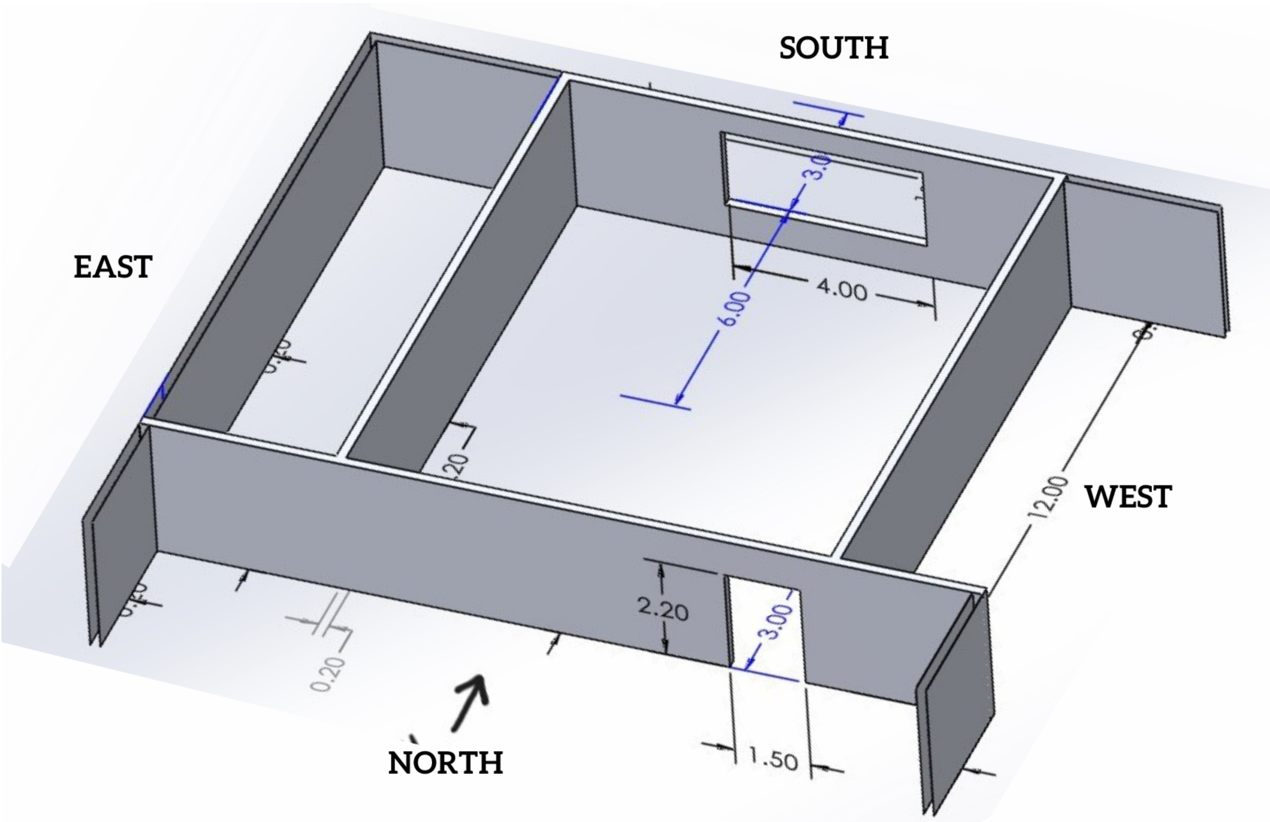

Figure 2: North to south view of Room

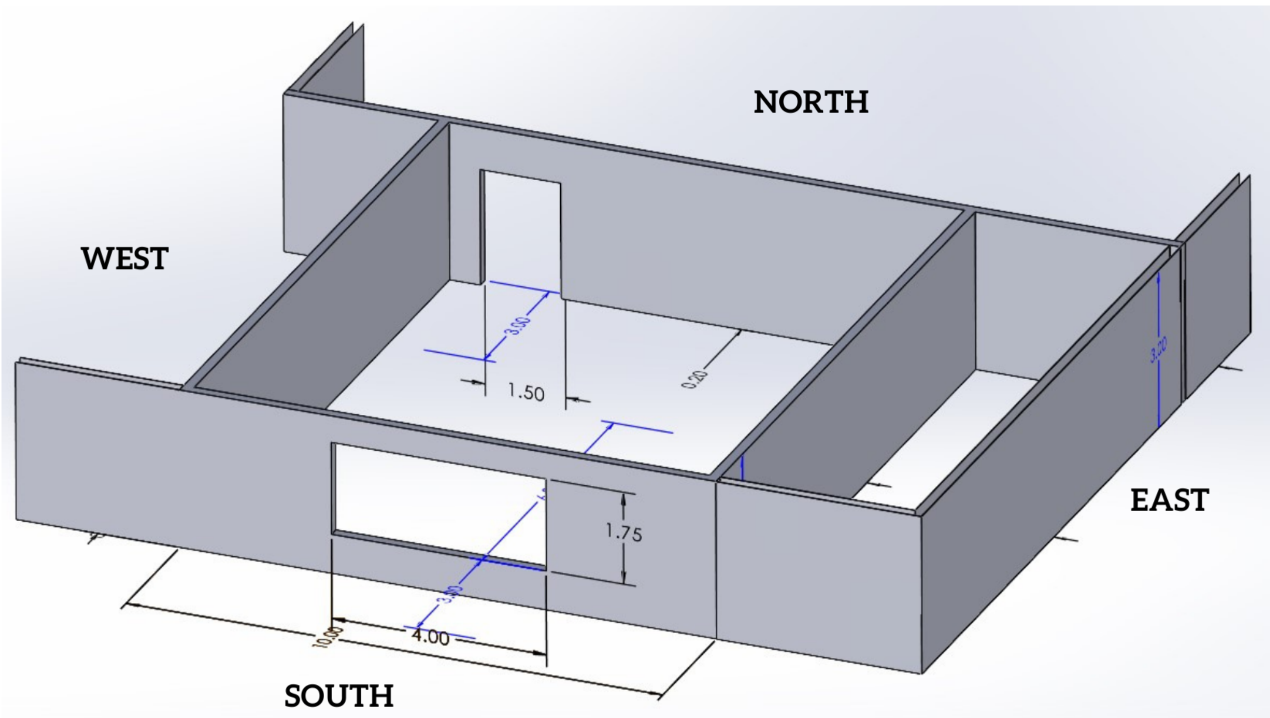

Figure 3: South to North view of Room

2 Model Specification

1. **Date & Time:** April Month, at 5 pm
2. **Location:** Lakshmipur, Bangladesh
3. **Temperature:** 25.5 °C
4. **Relative Humidity:** 50%
5. **Dimensions:**
   - Length : 12 m
   - Width : 10 m
   - Height : 3 m
   - Window : 4 m × 1.75 m (on south wall)
   - Door : 2.2 m × 1.50 m (on north wall)
6. **Surroundings**:
   - South side : Open Space & sunlit presence
   - East side : Unconditioned Space
   - North side : Unconditioned Space
   - West side : Unconditioned Space
7. **Construction:**
   - **Roof** : Type-4 with 50 mm insulation without suspended ceiling.
   - **All walls (N, E, S, W)** : 150 mm brick with 25 mm plaster on both sides.
   - **Door** : 25 mm thick hard wooden door.
   - **Window** : U = 2.5 $W/m^2 - K$ with 15 mm thick glass of light construction.
   - **Floor** : No heat transfer through floor.
8. **Other factors:**
   - 2 occupants seated with 1 using Laptop
   - 1 light of 25 W with flouroscence light
   - No other electronic devices
   - Lights and occupants from 11 am to 10 pm
   - Air change rate = 1.0 $/hr$

3 Heat Conduction through Partition walls / glasses

3.1 Roof

Type-4 with 50 mm insulation without suspended ceiling
From Table-12(a), Layers : **A0 E2 E3 B6 C12 E0**

Now, reading the values from table-16,

Layers	Layers Details	Resistance
A0	Outside Surface Resistance	0.059
E2	12 mm slag or stone	0.099
E3	10 mm felt and membrane	0.050
B6	50 mm insulation	1.173
C12	50 mm heavy weight concrete	0.029
E0	Inside surface resistance	0.121

Table 1: Roof Layers

Total resistance, R = 1.581
$\therefore$ U = 1/R = 0.653

3.2 Walls

North, East, South & West Walls:
150 mm brick with 25 mm plaster on both sides

From table 16,

- For C4 : 100 mm common brick, k = 0.727 $W/m-K$
  Now, resistance for 150 mm brick,
  $R_2 = 0.150/0.727 = 0.206$
- For E1 : 20 mm plaster, k = 0.7277 $W/m-K$
  Now, resistance for 25 mm plaster,
  $R_1 = R_3 = 0.025/0.7277 = 0.0344$
- Total resistance, R = $R_o + R_1 + R_2 + R_3 + R_i$
  = 0.059 + 0.0344 + 0.206 + 0.0344 + 0.121
  = 0.4548
- U = 1/R = 2.199 W/m^2-K

3.3 Window

15 mm thick glass of light construction

- U = 2.5 W/m^2-K

3.4 Door

25 mm thick hard wooden door

- Door size : 2.2 m $\times$ 1.5 m
- From table-17.6, Hard wood : Oak, k = 0.16 $W/m-K$
  Now, resistance for 25 mm thick door,
  $R_{door} = 0.025/0.16 = 0.156$

- Total resistance, R = $R_o + R_{door} + R_i$
  = 0.059 + 0.156 + 0.121
  = 0.336
- U = 1/R = 2.976 $W/m^2 - K$

3.5 Calculation Table

- Assuming, $T_o = 30.5\ °C$ and $T_i = 25.5\ °C$.
- $T_{o,max} = 33°$ for Bangladesh [From table : 9]

SI. no.	Item	Description	A	U	TD	Q (watt)
1	Partition wall	North	26.7	2.199	5.0	293.57
2	Partition wall	East	36	2.199	5.0	395.82
3	Partition wall	West	36	2.199	5.0	395.82
4	Partition wall	South	23	2.199	7.5	379.33
5	Partition glass	South	7	2.50	7.5	131.25
6	Door	North	3.3	2.976	5.0	49.104
						1644.894

Table 2: Heat conduction through partition walls / glasses

4 Heat Conduction through roof & sunlit walls / glasses

4.1 Roof

Parameters:

$T_i = 25.5\ °C$
$T_{o,max} = 33\ °C$
$T_{o,av}$ = 33 - 11/2 = 27.5 $°C$ [Table : 9]
CLTD = 37 [Table: 12(b)]

Correction for Latitude & month,LM=0 [Table : 13]
Attic Fan Factor, f = 1
Color adjustment factor, K = 1 [dark color]

$$\begin{aligned} CLTD_c &= [(CLTD + LM)K + (25.5 - T_i) + (T_{o,av} - 29.4)]\, f \\ &= [(37 + 0)1 + (25.5 - 25.5) + (27.5 - 29.4)]\, 1 \\ &= 35.1 \end{aligned}$$

4.2 South Wall

Parameters:

$T_i = 25.5\ °C$
$T_{o,max} = 33\ °C$
$T_{o,av}$ = 33 - 11/2 = 27.5 $°C$ [Table : 9]
CLTD = 17 [Table: 15]

Correction for Latitude & month,LM= -1.6 [Table:13]
Attic Fan Factor, f = 1
Color adjustment factor, K = 1 [dark color]

$$\begin{aligned} CLTD_c &= [(CLTD + LM)K + (25.5 - T_i) + (T_{o,av} - 29.4)]\, f \\ &= [(17 - 1.6)1 + (25.5 - 25.5) + (27.5 - 29.4)]\, 1 \\ &= 13.5 \end{aligned}$$

4.3 Glass

From Table-20:
At 5 pm, CLTD = 7 [No correction needed]

4.4 Calculation Table

SI. no.	Item	Description	A	U	TD	Q (watt)
1	Roof	Type 4	120	0.653	35.1	2750.44
2	South wall	Type C4	23	2.199	13.5	682.79
3	Sunlit glass	South	7	2.50	7.0	122.5
						3555.73

Table 3: Heat Conduction through Roof and Sunlit Walls/Glasses

5 Heat Gain

5.1 Solar Heat gain through glass

Shading factor, $SF = 0.85$ [Table : 21, for 15 mm thickness clear glass]
$SHGF_{max} = 237$ [Table : 18(a), for south wall in April month]
$CLF = 0.59$ [Table : 19, for south wall at 5 pm]
Window area = 4 m × 1.75 m = 7 m^2

$$\begin{aligned} Q &= A \times SF \times SHGF_{max} \times CLF \\ &= 7 \times 0.85 \times 237 \times 0.59 \\ &= 832 \text{ watt} \end{aligned}$$

5.2 Cooling Load for Air Exchange

Volume of the room = 12 × 10 × 3 = 360 m^3
Air change rate = 1.0 $/hr$
∴ Air change per hour, V = 360 m^3/hr = 0.1 m^3/s

W_o = 21.5 ×10⁻3 at 33° dbt and 27° wbt
W_i = 10 ×10⁻3 at 25.5° dbt and 50% RH

$$\begin{aligned} \text{Sensible Heat Gain, } Q_s &= \rho \times C_p \times V \times (T_o - T_i) \\ &= 1200 \times 0.1 \times (33 - 25.5) \\ &= 900 \text{ watt} \end{aligned}$$

$$\begin{aligned} \text{Latent Heat Gain, } Q_L &= \rho \times h_{gf} \times V \times (W_o - W_i) \\ &= 3010 \times 10^3 \times 0.1 \times (21.5 - 10) \times 10^-3 \\ &= 3461.5 \text{ watt} \end{aligned}$$

5.3 Heat Gain due to Occupants

From Table : 28, for apartments,
Sensible heat = 75 W
Latent heat = 55 W
For 2 occupants,

$Q_L = 55 \times 2 = 110$ watt
$Q_S = 75 \times 2 = 150$ watt

5.4 Heat gain due to Equipments

For 1 laptop, power = 100 watt
Cooling load factor, $CLF = 1$

$$
\begin{aligned}
Q &= P \times CLF \\
&= 100 \times 1 \\
&= 100 \text{ watt}
\end{aligned}
$$

5.5 Cooling load due to Lights

For 1 light,Lighting power, PL = 25 $W/m^2 \times 120m^2 = 3000\ W$
Cooling load factor, $CLF = 0.85$ [assuming]
Ballast factor, $BF = 1.2$ [flouroscent light]
Diversity factor, $D = 1$ [assuming]

$$
\begin{aligned}
Q &= PL \times BF \times D \times CLF \\
&= 3000 \times 1.2 \times 1 \times 0.85 \\
&= 3060 \text{ watt}
\end{aligned}
$$

6 Final Load Calculation

SI. no.	Items with Description	Q_s (watt)	Q_L (watt)	Q_T (watt)
1	Heat conduction through partition walls / glasses	1644.894	-	1644.894
2	Heat conduction through roof & sunlit walls / glasses	3555.73	-	3555.73
3	Solar heat gain through glass	832	-	832
4	Cooling load for air exchange	900	3461.5	4361.5
5	Heat gain due to occupants	150	110	260
6	Heat gain due to equipments	100	-	100
7	Cooling load due to lights	3060	-	3060
		10242.624	3571.5	13814.124

Table 4: Final Load Calculation

$$
\begin{aligned}
QT &= 13814.124 \text{ watt} \\
&= 13.814 \text{ kW} \\
&= \frac{13.814}{3.516} \text{ TR} \\
&= 3.93 \text{ TR} \\
\therefore QT &\approx 4 \text{ TR}
\end{aligned}
$$

REMARK: The required cooling load for the room is 4 TR.

7 Additional Links

Github Links for the project:
The solidworks model, model images, LaTeX and PDF files included here:-

https://github.com/HasibRockie/cooling-load-estimation