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Study of Cooling Load for Student Activity Centre, Greater Noida using CLTD/CLF Method

Anurag Kumar Singh
M tech Scholar, Sharda University, Greater Noida, India.

Akanksha Mishra
Assistant Professor, Sharda University, Greater Noida, India.

K. K. Dubey
Assistant Professor, Sharda University, Greater Noida, India.

Abstract : Nowadays air conditioning is longer a luxury but it has become absolutely necessary part of our life. So, right selection of air conditioning equipment is extremely important. If the air conditioning equipment is oversized then it will lead to high operational cost and if the air conditioning equipment is undersized then it will lead to breakdown. For the right selection of air conditioning equipment there is need to understand all the factors which are contributing heat inside the room. In this paper load calculation is done for Student Activity Centre which is having four floors. Each floor is used for different purposes, having different floor area and different number of doors and windows. So, different floors need different cooling load. For the determination of heat gain Cooling Load Temperature Difference / Cooling Load Factor (CLTD/CLF) method is used which is based on ISHRAE (Indian Society of Heating, Refrigerating, and Air-Conditioning Engineers) handbook is used.

Index Terms – Cooling load, heating load, Air Conditioning

NOMENCLATURE

Q_{Wall} = Heat transfer through wall

U = Overall heat transfer coefficient (Btu / (hr – ft^2 – ^{0}F)

A= Area (ft^2)

Δ T = Temperature Difference (^{0}F)

BF = Bypass Factor of the cooling coil

EqTD = corrected equivalent Temperature Difference (^{0}F)

R_{Air} = Thermal Resistance of air (hr– ft^2 – ^{0}F)/ Btu

R_{Brick} = Thermal Resistance of brick (hr – ft^2 – ^{0}F)/ Btu

$R_{Plaster}$ = Thermal Resistance of plaster (hr – ft^2 – ^{0}F)/ Btu

R_{Total} =Total Thermal Resistance (hr – ft^2 – ^{0}F)/ Btu

Q_{v1} = Ventilation rate required by person

Q_{v2} = Ventilation rate required by floor area

w = Moisture content (grams of water vapour / kg of dry air)

Q_{People} = Heat transfer by people

Q_{Glass} = Heat transfer through glass

$Q_{Incandescent\ bulb}$ = Heat transfer by Incandescent bulb

$Q_{Fluorescent\ light}$ = Heat transfer by Fluorescent light

$Q_{Appliances}$ = Heat transfer by Appliances

$Q_{Sensible}$ = Sensible heat gain

Q_{Latent} = Latent heat gain

1. INTRODUCTION

Greater Noida has hot and humid climate in the summer. The city becomes very hot in the month of May and June due to continue flow of hot and humid air from Thar deserts. The temperature increases too high that it becomes very difficult to survive under fans or desert coolers. Fans and desert coolers cool the air but up to a certain limit and also they are not able to control humidity and purity of air. Under such situation HVAC (Heating Ventilation and Air Conditioning) systems are useful [1].

The main function of HVAC is maintaining or controlling the required temperature inside the room w.r.t. surrounding, provide comfort and healthy indoor environment of the buildings, provide air filtration to remove bacteria, high indoor quality, avoid cross contamination, to maintain the humidity level of the room, controls the velocity of air and purify the air [2].

Not only for human comfort but air conditioning is used for produce goods in better way, faster and more economically. In fact many of goods cannot be produced if the indoor environment is not controlled [3].

In earlier days air conditioning systems were designed without paying or least paying attention towards energy conservation since fuels were abundant and inexpensive. But now increasing cost of energy have forced toward increasing efficiency of thermal unit. The need for controlled indoor environment in laboratories, hospitals and industry have increased. Now the scientist have big challenge towards improving the efficiency of the Heating Ventilation and Air Conditioning, for this we need to analyze all the types of heat inside the room.

The factors which are responsible for heat gain in the room are orientation of building, number of person, number of doors and windows in different direction and their sizes, materials used in construction of wall, floor, roof and window, number of electrical equipment used, use of the room and size of the room [4].

Heat gain inside the room from outside environment is by three modes i.e. conduction (heat transfer takes place through microscopic collision of particles and through collision of electrons), convection (heat transfer takes place by the motion of liquid and gases) and radiation (heat transfer takes place by electromagnetic waves).

In this paper Student Activity Centre situated at Sharda University, Greater Noida has been selected for calculating Cooling Load of the building.

2. METHODOLOGY

Heating/ cooling load calculation is done for Student Activity Center which is in Sharda University, Greater Noida. Sharda University is at a distance of 42 KM from New Delhi at a Latitude of 28.35 ^{0}N. The Dry bulb temperature and Wet bulb temperature is 110 ^{0}F and 75 ^{0}F respectively and average relative humidity for summers is 20 $^0/_0$.

There are four floors in the building. Each floor is having different floor area. Ground floor is used as Restaurant, at first floor there is a library, second floor is used as Gym and finally sports center at the third floor.

2.1. Solar Radiation through Glass

Solar radiations enter inside the room through the glasses and get absorbed by the objects. These radiations depends on many factors such as orientations of the building, time, month, latitudes, type of window glass i.e. shaded or ordinary, ventilation blinds or type of curtains used [5]. These all value can be find from ISHRAE Handbook. For different direction heat gain calculation is done separately. Heat is also absorbed by window frames i.e. metal frames or wooden frames. The value of solar heat gain is taken from ISHRAE Handbook 2014,Table 1-T-12 [6].

Heat gain :-

Q = Area × solar heat gain (R) × Multiplying factors for ordinary of glasses (1)

2.2. Solar Radiation through the walls and roof

Solar radiations are absorbed by the walls and roof. It get transmitted inside the room due to the temperature difference [5]. The value of R is taken from ISHRAE Handbook 2014,Table 1-T-20 [6].

Heat gain :-

$$Q_{Wall} = U \times A \times EqTD \quad (2)$$

$$R_{Total} = R_{Air} + R_{Plaster} + R_{Brick} + R_{Plaster} + R_{Air} \quad (3)$$

$$U = 1/ R_{Total} \quad (4)$$

2.3. Conduction through the glass and partitions

The exchange of heat takes place between surrounding and conditioned space through glass due to the temperature difference between outside condition and inside condition [5]. Also there is heat gain through partition wall between conditioned and non-conditioned rooms.

Heat gain :-

$$Q_{Glass} = U \times A \times \Delta T \quad (5)$$

2.4. Infiltration

The air which enters inside the room through door or window opening or cracks carries both sensible and latent heat. But most of the time this value is ignored as this value is merged with the ventilation.

Heat gain :-

For sensible heat

Q = infiltration rate × temperature difference × 1.08 (6)

For latent heat

Q = infiltration rate × humidity × 0.68 (7)

2.5. By Passed Air

The air passes through the coil without coming in contact with coil. These air have both sensible and latent heat. value of volume of air required by per person is taken from ISHRAE Handbook 2014, Table 1-T-53[6].

Heat gain:-

Ventilation rate

Q_{v1} = number of person × volume of air required by per person (8)

Q_{v2} = floor area × volume of air required by per area (9)

$$Q_{Ventilation} = Q_{v1} + Q_{v2} \quad (10)$$

The sensible heat due to by pass fresh air = ventilation air × air density × specific heat of air ×by pass factor × temperature difference

The sensible heat due to by pass fresh air = 1.08 ×cfm × BF × Δ T (^{0}F) (11)

The latent heat gain due to by pass fresh air = fresh air quantity × 60 × density of air × latent heat of condensation of water vapour × bypass factor × difference between moisture content at outside and inside conditions(from psychrometric chart).

The latent heat gain due to by pass fresh air = cfm × BF × (w_0-w_1) × 0.68 (12)

Air density = 0.075 lb/cft

Specific heat of air = 0.24 Btu/lb

2.6. Heat gain through (1-BF) air

These air come in contact with the cooling coil during ventilation process. So, it is carrying both sensible heat and latent heat.

Heat gain :-

$Q_{Sensible}$ = ventilation air (cfm) × CLTD ×1.08 ×(1- by pass factor) (13)

Q_{Latent} = ventilation air (cfm) × moisture content (gr/lb) × 0.68 ×(1- by pass factor) (14)

2.7. People

Human bodies also generate heat by the process of metabolism. It depends on the activity of person. A running body produces more heat as compared to walking body. The value of latent heat factor and sensible heat factor is taken from ISHRAE Handbook 2014, Table 1-T-24 [6].

Heat gain :-

Q_{People} = Number of people × sensible heat factor (15)

Q_{People} = Number of people × latent heat factor (16)

2.8. Light

Depending on different types of tube light and light bulbs used adds heat inside the room. Heat released from bulbs gets absorbed by the furniture and other objects inside the room [7].

Heat gain :-

$Q_{Incandescent\ bulb}$ = Total light in watt × 3.4 (17)

$Q_{Fluorescent\ light}$ = Total light in watt × 1.25 × 3.4 (18)

2.9. Appliances

Appliances used inside room produces heat that depends on its type. Different appliances produces different amount of heat [7].

Heat gain :-

$Q_{Appliances}$ = Number of appliances × watts of each appliances ×3.4 (19)

2.10. Safety factor

5 % of safety factor is taken. It is applied to the outdoor/indoor design conditions, building components, duct condition or ventilation/infiltration conditions.

2.11. Supply Duct Heat Gain and Return Duct Heat Gain

There can be leakage in supply duct or return duct. It is ignored if heat gain is calculated for small area as this value is considered in safety factor mentioned above. But if we are calculating heat gain for larger areas then it cannot be ignored.

Heat gain :-

8% of Room Sensible Heat (20)

3. RESULT

Specification of the Student Activity Centre is given below :-

Window 1	(6.36 × 6.36) ft^2
Window 2	(2.46 × 10.006) ft^2
Window 3	(6.36 × 10.006) ft^2
Door 1	(6.36 × 10.006) ft^2
Door 2	(29.26 × 12) ft^2
Door 3	(14.76 × 9.67) ft^2
Door 1	(6.36 × 8.36) ft^2
Size of Wall bricks	9 inch
Roof is made of concrete	6 inch
Size of plaster	1/2 inch

Table 1

Ground floor (Restaurant)

Floor area = 14387.6 ft^2

Height = 12 ft

Number of people = 30

$Q_{Ventilation}$ = 2889.76 cfm

$Q_{Solar\ Radiation\ through\ Glass}$ = 108155.7118 Btu/hr

$Q_{Solar\ Radiation\ through\ the\ walls\ and\ roof}$ = 24944.7148 Btu/hr

$Q_{Conduction\ through\ the\ glass\ and\ partitions}$ = 155881.696 Btu/hr

Q_{Floor} = 119704.83 Btu/hr

Q_{People} = 8400 Btu/hr

Q_{Light} = 10200 Btu/hr

$Q_{\text{Appliances}}$ = 45288 Btu/hr

Room Sensible Heat = 496259.181 Btu/hr

$Q_{\text{Sensible Outdoor Air}}$ = 11024.43 Btu/hr

Effective Room Sensible Heat = 546984.341 Btu/hr

Room Latent Heat = 8505 Btu/hr

$Q_{\text{Latent Outdoor Air}}$ = 1179.022 Btu/hr

Effective Room Latent Heat = 9684.022 Btu/hr

Effective Room Total Heat (ERTH) = Effective Room Latent Heat + Effective Room Sensible Heat = 556668.363 Btu/hr

$Q_{\text{Sensible Heat gain through (1-BF) air}}$ = 99219.90 Btu/hr

$Q_{\text{Latent Heat gain through (1-BF) air}}$ = 10611.198 Btu/hr

Grand Total Heat (GTH) = ERTH + $Q_{\text{Sensible Heat gain through (1-BF) air}}$ + $Q_{\text{Latent Heat gain through (1-BF) air}}$ = 706200.191 Btu/hr

Since 12000 Btu/hr = 1 TR

So, 706200.191 Btu/hr = 58.85 TR

First floor (library)

Floor area = 15007.675 ft^2

Height = 12 ft

Number of people = 50

$Q_{\text{Ventilation}}$ = 2650.921 cfm

$Q_{\text{Solar Radiation through Glass}}$ = 113010.913 Btu/hr

$Q_{\text{Solar Radiation through the walls and roof}}$ = 37589.95 Btu/hr

$Q_{\text{Conduction through the glass and partitions}}$ = 124619.29 Btu/hr

Q_{People} = 11500 Btu/hr

Q_{Light} = 10200 Btu/hr

$Q_{\text{Appliances}}$ = 1224 Btu/hr

Room Sensible Heat = 313051.35 Btu/hr

$Q_{\text{Sensible Outdoor Air}}$ = 10113.2636 Btu/hr

Effective Room Sensible Heat = 348208.721 Btu/hr

Room Latent Heat = 6300 Btu/hr

$Q_{\text{Latent Outdoor Air}}$ = 1081.575 Btu/hr

Effective Room Latent Heat = 7381.575 Btu/hr

Effective Room Total Heat (ERTH) = Effective Room Latent Heat + Effective Room Sensible Heat = 355590.296 Btu/hr

$Q_{\text{Sensible Heat gain through (1-BF) air}}$ = 91019.37 Btu/hr

$Q_{\text{Latent Heat gain through (1-BF) air}}$ = 9734.17 Btu/hr

Grand Total Heat (GTH) = ERTH + $Q_{\text{Sensible Heat gain through (1-BF) air}}$ + $Q_{\text{Latent Heat gain through (1-BF) air}}$ = 481387.944 Btu/hr

Since 12000 Btu/hr = 1 TR

So, 481387.944 Btu/hr = 40.11 TR

Second floor (Gym)

Floor area = 15875.98 ft^2

Height = 12 ft

Number of people = 30

$Q_{\text{Ventilation}}$ = 4207.67 cfm

$Q_{\text{Solar Radiation through Glass}}$ = 104235.28 Btu/hr

$Q_{\text{Solar Radiation through the walls and roof}}$ = 47058.348 Btu/hr

$Q_{\text{Conduction through the glass and partitions}}$ = 134611.4337 Btu/hr

Q_{People} = 15750 Btu/hr

Q_{Light} = 10200 Btu/hr

$Q_{\text{Appliances}}$ = 27608 Btu/hr

Room Sensible Heat = 356436.214 Btu/hr

$Q_{\text{Sensible Outdoor Air}}$ = 16052.26 Btu/hr

Effective Room Sensible Heat = 401003.371 Btu/hr

Room Latent Heat = 29137.5 Btu/hr

$Q_{\text{Latent Outdoor Air}}$ = 1716.72 Btu/hr

Effective Room Latent Heat = 30854.22 Btu/hr

Effective Room Total Heat (ERTH) = Effective Room Latent Heat + Effective Room Sensible Heat = 431857.591 Btu/hr

$Q_{\text{Sensible Heat gain through (1-BF) air}}$ = 144470.349 Btu/hr

$Q_{\text{Latent Heat gain through (1-BF) air}}$ = 15450.564 Btu/hr

Grand Total Heat (GTH) = ERTH + $Q_{\text{Sensible Heat gain through (1-BF) air}}$ + $Q_{\text{Latent Heat gain through (1-BF) air}}$ = 620293.384 Btu/hr

Since 12000 Btu/hr = 1 TR

So 620293.384 Btu/hr = 51.69 TR

Third floor (sports center)

Floor area = 15875.98 ft^2

Height = 12 ft

Number of people = 40

$Q_{\text{Ventilation}}$ = 3746.60 cfm

$Q_{\text{Solar Radiation through Glass}}$ = 104235.28 Btu/hr

$Q_{\text{Solar Radiation through the walls and roof}}$ = 47058.348 Btu/hr

$Q_{\text{Conduction through the glass and partitions}}$ = 134611.4337 Btu/hr

Q_{People} = 10810 Btu/hr

Q_{Light} = 10200 Btu/hr

$Q_{\text{Appliances}}$ = 5916 Btu/hr

Room Sensible Heat = 328472.6117 Btu/hr

$Q_{\text{Sensible Outdoor Air}}$ = 14293.279 Btu/hr

Effective Room Sensible Heat = 369043.6936 Btu/hr

Room Latent Heat = 11119.5 Btu/hr

$Q_{\text{Latent Outdoor Air}}$ = 1528.612 Btu/hr

Effective Room Latent Heat = 12648.112 Btu/hr

Effective Room Total Heat (ERTH) = Effective Room Latent Heat + Effective Room Sensible Heat = 381691.8056 Btu/hr

$Q_{\text{Sensible Heat gain through (1-BF) air}}$ = 128639.511 Btu/hr

$Q_{\text{Latent Heat gain through (1-BF) air}}$ = 13757.5152 Btu/hr

Grand Total Heat (GTH) = ERTH + $Q_{\text{Sensible Heat gain through (1-BF) air}}$ + $Q_{\text{Latent Heat gain through (1-BF) air}}$ = 550366.6398 Btu/hr

Since 12000 Btu/hr = 1 TR

So 550366.6398 Btu/hr = 45.86 TR

Total Ton of Refrigeration = 58.85 + 40.11 +51.69 + 45.86 = 196.51

So, there is requirement of 196.51 TR of air conditioning for Student Activity Center.

4. CONCLUSION

Heat gain can be control by using colored glasses, ventilation blind, thick curtains on the windows, brick wall with panels.

The cooling load estimation is done for four floors in a Student Activity Center by using Cooling Load Temperature Difference / Cooling Load Factor (CLTD/CLF) method. Each floor is used for different purpose. Hence we get different values of Tonnage Refrigeration (TR) for different floors. There is requirement of 196.51 TR of air conditioning for the building. Accordingly suitable air conditioning equipment can be selected. For the proper distribution of air proper duct work is required.

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