Cooling Load Estimation of College Reading Hall

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A B S T R A C T

Exact prediction of the cooling and heating load, proper sizing of the heat ventilation air-conditioning (HVAC) system and optimal control of the HVAC systems are important to minimize energy consumption. Calculation of thermal load of building is very essential to find exact air-conditioning equipment and air handling unit, to achieve comfort operation and good air distribution in the air-conditioned zone. This project Cooling load estimation for a Reading Hall of CAET, JAU presents by using TETD method. The Reading Hall considered in this study is situated in Junagadh (70.45°E, 21.52°N) district of Gujarat, India and elevation of about 107 meters above mean sea level. Junagadh has a tropical wet and dry climate. During monsoon, it receives high rainfall and retreats Northeast monsoon. The total heat required to be removed from the space in order to bring it at the desired temperature (21 – 26 °C) and relative humidity (60%) by the air conditioning equipment is known as cooling load or conditioned load. This load consists of external and internal loads. The cooling load of the Reading Hall is dependent on local climate, thermal characteristics of material and type of building. For calculating a cooling load using the transfer function method is to use the one step procedure, which was first presented in the ASHRAE Handbook of Fundamentals in the year 2005. This method is called the Total Equivalent temperature differences (TETD) method. In this method, hand calculation is used to calculate cooling load. The results show that the total cooling load for the AC required Reading Hall is 19.74 tons for summer (month of May). The m^2/ton for the Reading Hall is about 18.83 m^2/ton for summer, which is approximately same, comparing with the standard value about 20 m^2/ton. The average sensible heat ratio of the Reading Hall is 0.74 for summer.

Introduction

The basic objective is to calculate cooling load to find exact air-conditioning equipment and air handling unit, to achieve comfort operation and good air distribution in the air-conditioned zone. In present days the Energy consumption problem is one of the most serious problems. About 72% of world energy is consumed by infrastructure, industry, commercial buildings, residential houses, and markets. In a large building or complex, which is air-conditioned, about 60% of the total energy requirement in the building is allocated for the air-conditioning plant installed to use the cooling purpose.

Exact prediction of the cooling and heating load, proper sizing of the heat ventilation air-conditioning (HVAC) system and optimal control of the HVAC systems are important to minimize energy consumption. Root factors that affect cooling loads are the external climates such as outdoor temperature, solar radiation and humidity. Local climatic conditions are important parameters for the energy efficiency of buildings. Because the energy consumption in buildings depends on the climatic conditions and the performance of HVAC systems. The use of false ceiling, ceramic tiles on roof and floor, electro chromic reflective colored, 13mm air gap, clear glass gave the best possible retrofitting option (Kulkarni *et al.,* 2011).

Calculation of thermal load of building is very essential to find exact air-conditioning equipment and air handling unit, to achieve comfort operation and good air distribution in the air-conditioned zone. This load consists of external and internal loads. External heat gains arrive from the transferred thermal energy from outside hot medium to the inside of the room. The heat transfer takes place from conduction through external walls, top roof and bottom ground, solar radiation through windows and doors, ventilation and infiltration. Other sources are internal heat gain like people, electric equipment and light. Fig. 1 illustrates the load components. In one experiment, Duanmu *et al.,* (2013) found the hourly building cooling load for urban energy planning by using Hourly Cooling Load Factor Method (HCLFM) that can provide fast and fair estimate of building cooling load for a large-scale urban energy planning. Suziyana *et al.,* 2013 found the effects of different outdoor design conditions on cooling loads and air conditioning systems.

Materials and Methods

The cooling load of the Reading Hall is dependent on local climate, thermal characteristics of material and type of building. For calculating a cooling load using the transfer function method is to use the one step procedure, which was first presented in the ASHRAE Handbook of Fundamentals in the year 2005.The methodology showed good results for cases with low mass envelope, but revealed limitation to represent thermal inertia influence on the annual cooling and heating loads (Fernando *et al.,* 2010).

Climate condition

The minimum and maximum temperatures ranges are 10°C to 25°C with a mean minimum and maximum temperature range of 28 °C to 42 °C during winter and summer season.

Building structures

The dimension of the reading hall which is to be air conditioned is, 22.43× 16.67 × 3.7 m in size. The exterior walls of reading hall consist of 225 mm common bricks with 25 mm (12.5 mm both side) sand cement plaster. The roofs consist of 11.25 RCC slab + 7.5 lime concrete on top + 12.5 mm cement plaster. The windows consist of single glass materials of 50 mm thick with frame panel.

Load components

The total heat required to be removed from the space in order to bring it at the desired temperature (21 – 26 °C) and relative humidity (60%) by the air conditioning equipment is known as cooling load or conditioned load.

Sensible heat gain through opaque surface

$$Q=UA(TETD)_{corr}$$

Where, U = over all heat transfer coefficient (W/m^2°C)

TETD = total equivalent temperature difference (°C)

A = Surface area (m^2)

Overall heat transfer coefficient

$$U = \cfrac{1}{\cfrac{1}{h_o} + \cfrac{x_1}{k_1} + \cfrac{1}{k_a} + \cfrac{x_2}{k_2} \cdots \cfrac{1}{h_i}}$$

Surface area

Area = Length × Width

Total equivalent temperature difference (TETD)

TETD = $(t_{ea} - t_i) + \lambda (t_{e\delta} - t_{e\alpha})$

Where

t_{ea}= Average sol-air temperature for the given day of the year, location of interest
and surface orientation.

t_i= Inside design temperature °C

λ = Decrement factor.

$t_{e\delta}$ = Sol-air temperature, δ hours before the time at which TETD is being
calculated.

δ = Depends upon the types of the wall.

$$t_e = t_o + \frac{\alpha . I_t}{h_o} - \frac{\varepsilon \Delta R}{h_o}$$

Where,

t_e= Sol-air temperature °C

t_o= Outside air temperature °C

α = Absorptivity of the surface

I_t= Total solar radiation inside on the surface W/m^2= 1.15 SHGF

h_o= Co-efficient of heat transfer by radiation and convection at outside W/m^2°K

ε = Hemispherical emittance of the surface

ΔR = The difference between the long wave radiation incident on the surface from
the sky and surroundings and the radiation emitted by a black body at outer
air temperature W/m^2.

$\frac{\varepsilon \Delta R}{h_o}$ = 0 °C for vertical wall = −3.9 °C for horizontal wall.

$$t_{e\alpha} = t_{o\alpha} + \frac{\alpha}{h_o} \left(\frac{I_{DT}}{24} \right) - \frac{\varepsilon \Delta R}{h_o}$$

Where,

$t_{o\alpha}$= Average outdoor temperature °C

I_{DT}= [The sum of two appropriate half day totals of SHGF] × 1.15.

[Source: REFRIGERATION AND AIR CONTIONING – PART 2 Page 128 – 130]

Cooling load calculation due to wall/ceiling

Q = UA [F$_C$ (TETD)$_{Peak}$ + F$_R$ (TETD)$_{AVE}$] W

[Source: REFRIGERATION AND AIR CONTIONING – PART 2 Page 130 – 131]

Heat gain through glass

Q$_{glass}$ = A [SC{F$_C$(SHGF)$_P$ + F$_R$ (SHGF)$_A$} + UΔT] W

Where,

SHGF = Solar heat gain factor (W/m^2)

SC = Shading coefficient depends on type of shading.

[Source: REFRIGERATION AND AIR CONTIONING – PART 2 Page 132 – 133]

Heat gain from occupants

Heat given by occupants = No. of occupants × Allowance Factor

Heat gain from electric light

Q$_{Light}$ = Total wattage of light × Use factor × Allowance factor

Heat gain from electric fan

Q$_{Fan}$= Power (kW) × Use factor × Hours using

Heat gain due to Infiltration

Crack Infiltration = $q_i = \dfrac{H \times L \times W \times G}{60}$ m^3/min

Where,
H = Height of the room (m)
L = Length of the room (m)
W = Width of the room (m)
G = No. of air change/hand

Door Infiltration = $\dfrac{\dfrac{Door\ opening}{Hour} \times Factor}{60}$

Total Infiltration = Q = Crack Infiltration + Door Infiltration
The sensible heat gain due to the infiltration is given by Eq^n
$Q_{s\ inf} = 20.43 \times Q\ (t_o - t_i)$ Watts
And the latent heat gain due to the infiltration is given by Eq^n
$Q_{linf} = 49.1 \times Q\ (w_o - w_i)$ Watts

Where, t_o and t_i = Outside and inside design temperature respectively (°C)
w_o and w_i= specific humidity of outside and inside at conditioned space (kg/kg of dry air)

Heat gain due to ventilation

Sensible Heat Load due to Ventilation = No. of person × Factor
Latent Heat Load due to Ventilation = No. of person × Factor

Total Loads

RTHG = RSHG + RLHG

Where,
RSHG(Total Room Sensible Heat Gain) = Sensible heat gain through walls, floors and ceilings + Sensible heat gain through glasses + Sensible heat gain due to occupants + Sensible heat gain due to infiltration air + Sensible heat gain due to ventilation + Sensible heat gain due to lights and fans.

RLHG(Total Room Latent Heat Gain) = Latent heat gain due to infiltration + Latent heat gain due to ventilations + Latent heat gain from persons + Latent heat gain due to appliances.

Room sensible heat factor

$RSHF = \dfrac{RSHG}{RSHG + RLHG} = \dfrac{RSHG}{RTHG}$

Total load in tons

Total load in tons = $\dfrac{Total\ load\ in\ watts}{3500}$

Results and Discussion

This is the analysis and representation of the experimental data collected during the course investigation.

Hand calculations were done for a Reading Hall using the all equations are mentioned. All the equations were inserted in a particular program MS Excel, to get the results.

The details of cooling load calculations of the Reading hall are given on the calculation sheet in Table 1.

Calculation of sensible heat factor

RSHF=

$\dfrac{RSHG}{RSHG + RLHG} = \dfrac{RSHG}{RTHG} = \dfrac{52332.434}{69093.916} = 0.757$
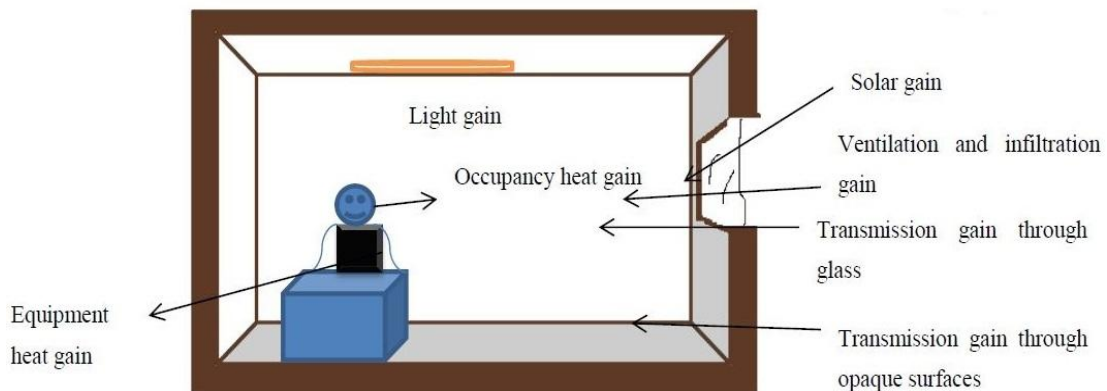
Calculation of plant capacity

Total load in tons=

$\dfrac{Total\ load\ in\ watts}{3500} = \dfrac{69093.916}{3500} = 19.741$

Table.1 Details about load calculation

Sr. No.	Particulars	Sensible W	Latent W	Total W
	Details about load calculation			
1	Wall			
	1. South	1176.563	0	1176.56289
	2. West	2072.757	0	2072.75701
	3. North	2146.332	0	2146.33248
	4. East	0	0	0
	5. Ceiling	2933.036	0	2933.03649
	6. Floor	2933.036	0	2933.03649
	Sub Total	**11261.73**	**0**	**11261.72536**
2	Glass			
	1. South	1167.324	0	1167.323777
	2. West	578.1439	0	578.1438514
	3. North	1317.254	0	1317.254137
	4. East	0	0	0
	Sub Total	**3062.722**	**0**	**3062.721766**
3	Infiltration	19438.81	53.71153224	19492.52081
4	Occupants	12272	15184	27456
5	Lights	216	0	216
6	Fans	1323.684	0	1323.68375
	Sub Total	**33250.49**	**15237.71153**	**48488.20456**
	Total	**47574.94**	**15237.71153**	**62812.65168**
7	Safety (10% of Total)			
		4757.494	1523.771153	6281.265168
	Grand TOTAL	**52332.43**	**16761.48269**	**69093.91685**

Fig.1 Load components

In conclusion, it is known fact that people living in colder climates feel comfortable at a lower effective temperature than those living in warmer regions. There is a relationship between the optimum indoor effective temperature and the optimum outdoor temperature, which change with seasons. Cooling load items such as, people, light, fan, infiltration and ventilation can easily be putted to the MS-Excel program. The program can also be used to calculate cooling load due to walls and roofs.

The major conclusions drawn from this experiment were;

The results show that the total cooling load for the AC required Reading Hall is 19.74 tons for summer (month of May). The m^2/ton for the Reading Hall is about 18.83 m^2/ton for summer, which is approximately same, comparing with the standard value about 20 m^2/ton.

The average sensible heat ratio of the Reading Hall is 0.74for summer. It shows that the cooling load calculation is properly done with well accounted of latent heat came from the people and infiltration, especially in humid weather.

These all factors show that the cooling load calculation of Reading Hall is satisfactory.

Acknowledgement

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