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Cooling load For a Institutional building

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ABSTRACT

Human comfortness is essential now a days because of the improvement in life style and increasing atmospheric temperature. Electrical air conditioning machines are not most suitable for large buildings because of the higher power consumption and shorter life. Central air conditioning is more reliable for easy operation with a lower maintenance cost. With large buildings such as commercial complex, auditorium, office buildings are provided with central air conditioning system. Educational and research institutions also need human comfortness, as the population of student community increase year by year. The effective design of central air conditioning can provide lower power consumption, capital cost and improve aesthetics of a building.

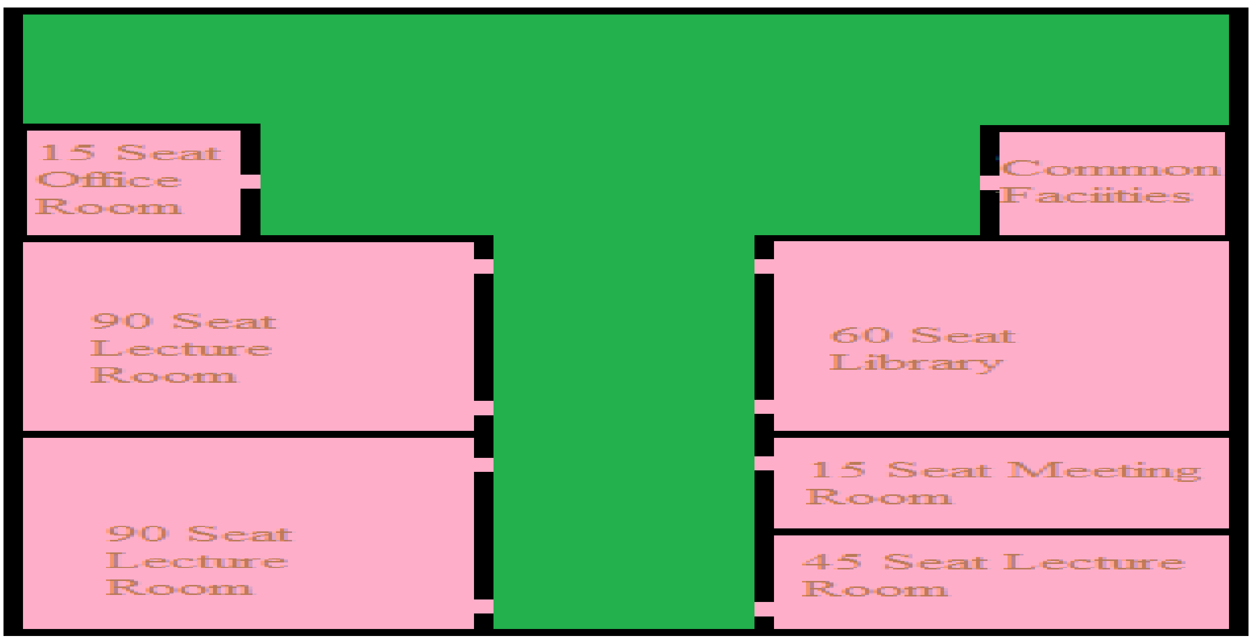
This thesis work establishes the results of cooling load calculation of different climate conditions by using CLTD method for a coaching institute. Cooling load items such as, people heat gain, lighting heat gain, infiltration and ventilation heat gain are all well accounted. The calculation is also done for cooling load due to walls and roofs. And results were compared with the standard data given by ASHRAE and CARRIER Fundamental Hand Books, and results are satisfactory. It is also seen that in this thesis work cooling requirement of summer is about 10 % more as compare to monsoon for climate condition of gangapur city.

INTRODUCTION

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. Building cooling load components are; direct solar radiation, transmission load, ventilation/infiltration load and internal load. Calculating all these loads individually and adding them up gives the estimate of total cooling load. The load, thus calculated, constitutes total sensible load. Normal practice is that, depending on the building type, certain percent of it is added to take care of latent load. Applying the laws of heat transfer and solar radiation makes load estimations. For the design conditions and the building materials used, cooling load temperature difference, solar heat gain factors and cooling load factors are calculated. Principles of solar energy calculation are applied to determine the direct and indirect solar heating component of the building. All these components, when added up, give the total cooling (or heating) load of a building.

The probable loads are included in the forms of load sheet. These consist of direct solar radiation, transmission load through exposed walls (un-insulated and those with different degree of insulation), partition walls, all the possible types of walls, roof, ceilings, floors and outdoor air load. In this load estimation form, all the transmission loads as well as ventilation/infiltration load are given as function of temperature difference between outdoor and indoor air.

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 paper Cooling load estimation for a coaching institute is presented using CLTD method.



The rate of heat transfer from outside air to inside air is calculated by the formula.

$$Q = UA\,(CLTD)\,corr$$

Where U = over all heat transfer coefficient (W/m^2- ^oC)

CLTD = cooling load temperature difference (^oC)

A = surface area (m^2)

CLTD corr = (CLTD + LM) K + (25.5 – Ti) + (To – 29.4)

Where To = outside design temperature (^oC)

Ti = inside design temperature (^oC)

LM = latitude month correction given table 3.7

K = correction factor depends on building color.

K = 1 for dark color, 0.85 for medium color and 0.65 for light color.

Transmission Heat Gain Through Glass:

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

By Solar Radiation:

$$Q = A \times SHGF_{max} \times SC \times CLF$$

$SHGF_{max}$ = maximum solar heat gain factor (W/m)

SC = Shading Coefficient depends on type of shading

CLF = cooling load factor

Sensible heat gain from occupants

$$Q_{s,person} = q_{s,person} . N . CLF$$

Latent heat gain from occupants

$$Q_{l,person} = q_{l,person} . N$$

Where

$q_{s,person}$ = sensible heat gain/person (W)

$q_{l,person}$ = latent heat gain/person (W)

N = total number of people present in conditioned space

CLF = cooling load factor

Q_{light} = Total wattage of light *Use factor * Allowance factor

Q equipement = Total wattage of equipment . Use factor . CLF

CLF = 1.0, if operation is 24 hours or of cooling is off at night or during weekends.

Heat Gain Due To Infiltration

Infiltration may be defined as the uncontrolled entry of untreated, outdoor air directly into the conditioned space in other words infiltration air is the air that enters a conditioned space through windows crack and opening and closing of doors. This is caused by pressure difference between the two sides of the windows and doors and it depends upon the wind velocity and its direction and difference in densities due to the temperature difference between the inside and outside air.

The sensible heat gain due to the infiltration is given by

$$Q_{S,inf} = 20.44 \times V_{inf} \times (T_o - T_i) \quad \text{Watts}$$

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And the latent heat gain due to the infiltration is given by

$$Q_{l,\,inf} = 50000 \times V_{inf} \times (W_o - W_i) \quad \text{Watts}$$

Where

T_o and T_i = Outside and inside design temperature respectively (^oC)

W_o and W_i = specific humidity of outside and inside at conditioned space (kg/kg of dry air)

Heat Gain Due To Ventilation

Human beings inside a space require freshness to air. It has been seen in studies by the ASHRAE, that, inadequate fresh air supply to a space leads to health problems for people inside it. This is called 'Sick Building Syndrome'.. The ventilation is provide to the conditioned space in order to minimize odor, concentration of smoke, carbon dioxide and other undesirable gases, so that freshness of air could be maintained. The quantity of outside air used for ventilation should provide at least one-half air change per hours in building with normal ceiling height. Also, if the infiltration air quantity is larger than the ventilation quantity, then the latter should be decreased to at least equal to the infiltration air. The outside air adds sensible as well as latent heat.

Total Loads

The sum of total room sensible heat gain and total room latent heat gain is known as room total heat load.

$$RTH = RSH + RLH$$

Total Room Sensible Heat Gain

Room sensible heat gain is a combination of all type of sensible heat gain at a conditioned space i.e.

RSHG = 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.

Total Room Latent Heat Gain

Room latent heat gain is a combination of all type of latent heat gain at a conditioned space i.e.

RLHG = 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

Room sensible heat factor is defined as the ratio of the room sensible heat to the room total heat. Mathematically, room sensible heat factor .

RSHF = RSH / (RSH + RLH) = RSH / RTH

Total Load In Tons

Total heat gain obtained by all above modes is in Watts and we can convert this value from Watts to tons with help of this Equation

Total Load In Tonnes = Total Load In Watts /3500

In any building, heat is transmitted through external walls, top roof, floor of the ground floor, windows and doors. Heat transfer takes place by conduction, convection and radiation. The cooling load of the building is highly dependent on local climate, thermal characteristics of material and type of building. For cooling load calculation , there are many types of software such as doe 2.1e, blast, elite or hap 4.3 available which use the transfer functions method and heat balance method. These methods require a complex and lengthy data input. Therefore, most of the designers do not use these methods. They prefer a more compact and easy method for calculating the cooling load of a building. A more basic version 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 cooling load temperature differences (CLTD) method. In this method, hand calculation is used to calculate cooling load.

Hand calculations were done for an institutional building using all the equations and ASHARE informations calculation procedures. In the Institute building there are total 7 rooms where air conditioning is required including lecture rooms, meeting rooms, library etc. Each one of them is treated as separate system. All equations required for heat transfer through the building and for the inside's load were used to get the thermal load or say cooling load required. Then, all the equations were used to get the results.

The general step by step procedures for calculating the total heat load are follows

i. Select inside design condition (Temperature, relative humidity).

ii. Select outside design condition (Temperature, relative humidity).

iii. Determine the overall heat transfer coefficient U_o for wall, ceiling, floor, door, windows, below grade.

iv.Calculate area of wall, ceiling, floor, door, window.

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v.Calculate heat gain from transmission.
vi.Calculate solar heat gain
vii.Calculate sensible and latent heat gain from ventilation, infiltration and occupants. viii. Calculate lighting heat gain
ix. Calculate total heat gain
x. Calculate TR

Design condition

The amount of cooling that has to be accomplished to keep buildings comfortable in summer and winter depends on the desired indoor conditions and on the outdoor conditions on a given day. These conditions are, respectively, called the "indoor design condition" and the "outdoor design condition".
For most of the comfort systems, the recommended indoor temperature and relative humidity are as follows

DBT – 22.78 ^{O}C to 26.11 ^{O}C, and RH – 50% for summer

DBT – 22.11 ^{O}C to 22.22 ^{O}C and RH – 20 to 30% for winter

The cooling load of the institutional is based on 23 ^{O}C dry bulb temperature and 50% relative humidity Indoor design conditions.
The outdoor design conditions are determined from published data for the specific location, based on weather bureau or airport records. Outdoor design conditions in gangapur city is 43 ^{O}C DBT and Relative Humidity 46% for summer (month of May) and 36 ^{O}C DBT and 84 % RH for monsoon (month of July).

Data Required
Thermal conductivity of brick (k_{brick}) = 0.77 W/m-K
Thermal conductivity of plaster ($k_{plaster}$) = 8.65 W/m-K
Thermal conductance of air gape = 5.8 W/m^2-K Outside film coefficient = 23 W/m^2-K
Inside film coefficient = 8.5 W/m^2-K

GROUND FLOOR						
S.N.	**Room/ Hall**	**Width (m)**	**Length (m)**	**Area (m^2)**	**Celling Ht (m)**	**AC Requirement**
1	90 seat Lecture room	8.53	12.19	103.98	3.70	103.98

2	90 seat Lecture room	8.53	12.19	103.98	3.70	103.98
3	Library	8.53	12.19	103.98	3.70	103.98
4	Staff room	8.53	6.1	52.03	3.70	52.03
5	45 seat lecture room	8.53	6.1	52.03	3.70	52.03

RESULTS AND DISCUSSION

The maximum cooling loads, sensible heat ratios of the sample building (institutional building) has been calculated using cooling load temperature difference (CLTD) method. In institutional building there are total 7 rooms where air conditioning is required including lecture rooms, meeting room, library etc. Each one of them is treated as separate system. The cooling load details for all rooms are given in Table 5.1 at summer (month of May) and in Table 5.2 at monsoon (month of July).

Table 5.1 Total cooling loads, SHR for institutional building at summer.

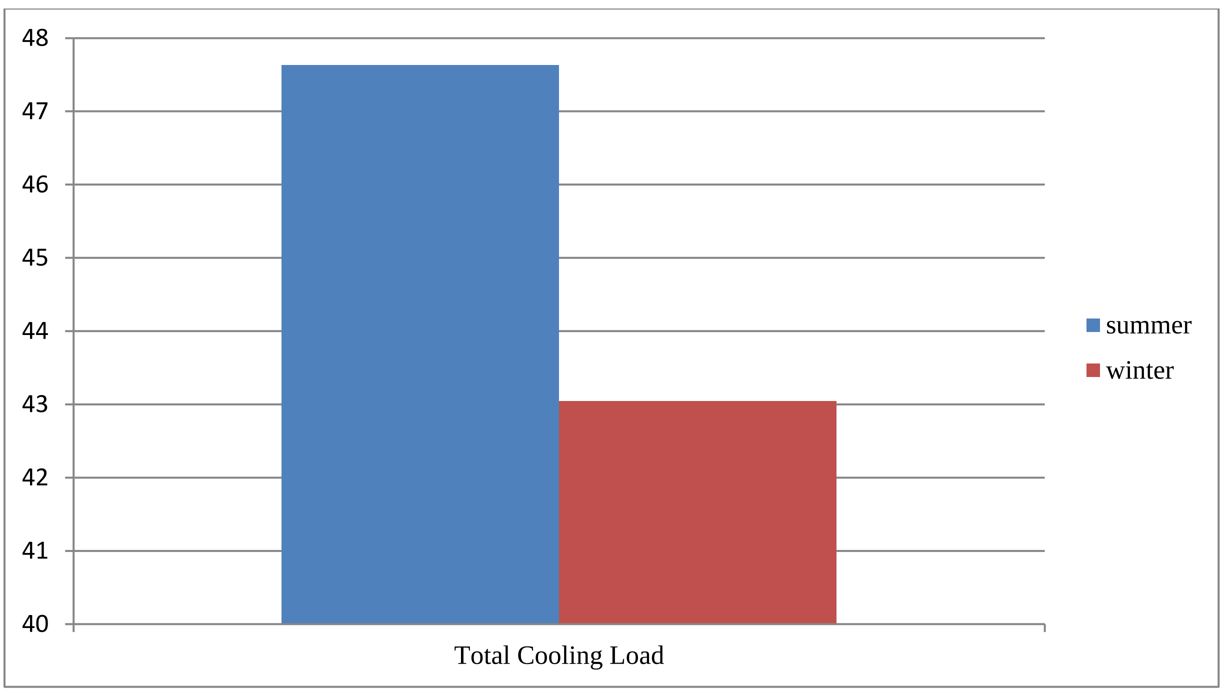
Room Name	Area of Room (m^2)	Total load (Tons)	SHR
90 Seat Lecture Room 1	103.98	10.28	0.70
90 Seat Lecture Room 2	103.98	10.28	0.70
Common Facilities	26.04	3.22	0.73
Library	103.98	10.24	0.72
Meeting Room	52.03	4.61	0.76
45 Seat Lecture Room 3	52.03	5.67	0.72
Office / Admin Room	26.04	3.33	0.80
Total	468.08	47.63	Avg.= 0.732

Table 5.2 Total cooling loads, SHR for institutional building at monsoon

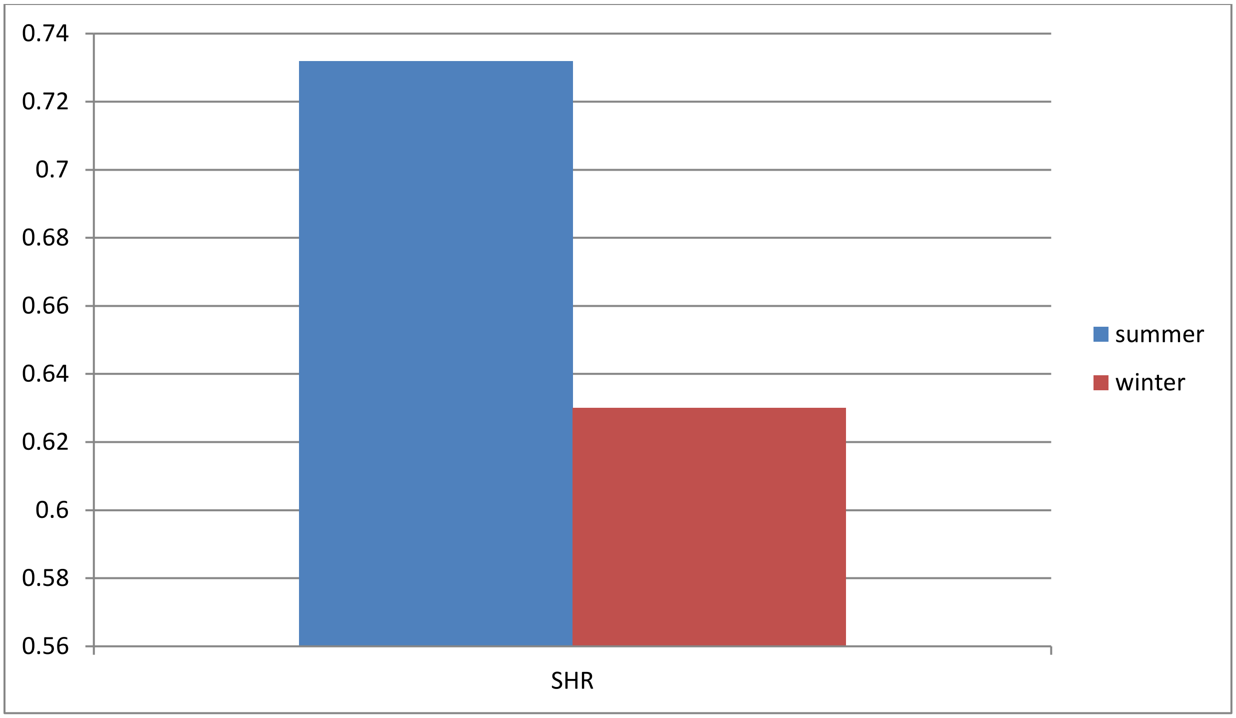
Room Name	Area of Room (m^2)	Total load (Tons)	SHR
90 Seat Lecture Room 1	103.98	9.48	0.60
90 Seat Lecture Room 2	103.98	9.48	0.60
Common Facilities	26.04	2.86	0.63
Library	103.98	9.56	0.61
Meeting Room	52.03	3.82	0.63

45 Seat Lecture Room 3	52.03	4.87	0.62
Office / Admin Room	26.04	2.98	0.72
Total	468.08	43.05	Avg.= 0.630

The result shows that when using CLTD method, the total cooling load of institute building is 47.63 tons for summer and 43.05 tons for monsoon. The average sensible heat ratio of the building is 0.732 for summer and 0.63 for monsoon. 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.



Graph 5.1 Variation Of Cooling Load Requirement For Summer And Monsoon



Graph 5.2 Variation Of SHRF For Summer And Monsoon

CONCLUSION

In this study, an institutional building located in gangapur city was considered for calculating cooling loads. Cooling load temperature difference (CLTD) method was used to find the cooling load for summer (month of May) and monsoon (month of July).

Cooling load items such as, people, light, infiltration and ventilation were well accounted for calculation.

- The results show that the total cooling load for the AC required rooms is 47.63 tons for summer (month of May) and for monsoon (month of July) total cooling load is 43.05 tons. The m^2/ton for the TIIR building is about 9.82 m^2/ton for summer and 10.87 m^2/ton for monsoon, which is approximately same, comparing with the standard value about 10 m^2/ton.
- The average sensible heat ratio of the building is 0.732 for summer and 0.63 for monsoon. 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.
- It is also seen that in this paper cooling requirement of summer is about 10 % more as compare to monsoon for climate condition of Gangapur city.

These all factors show that the cooling load calculation of institutional building is satisfactory.

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