Analysis of Summer Cooling Load for Conference-Hall of NIT Raipur

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Abstract— This paper represents analytical approach of calculation of cooling load and air-conditioner required for the conference hall of National Institute of Technology (NIT) Raipur. The city Raipur (Latitude: 20.92° N, Longitude: 82.00° E) is the capital of state Chhattisgarh of India. The climatic condition of Raipur comes under composite zone of climate classification of India, where the summer is quite hot and temperature ranges 42℃-45℃ in the month of May. The total heat load of conference hall and the required number of air conditioner of 1.5 ton capacity has been calculated by considering conduction heat gain, ventilation heat gain, solar heat gain and internal gain. For the taken dimensions and structural properties of the conference hall the cooling load of the hall is 42.5 kw and the required number of air conditioner is 8.

Key words: Cooling load, conduction, ventilation, heat gain, air-conditioner

I. INTRODUCTION

The climate in Raipur is predominantly hot. It also has distinct cool and humid seasons. The weather condition of Raipur can be interpreted from the fig.1. The climate in Raipur is predominantly hot. April to June is very hot; May and June are particularly harsh, with maximum daytime temperatures of about 39℃. This leads the use of air conditioning system for achieving thermal comfort. The climate of Raipur can be classified into three categories as:

1) Winter season from November to February; in winter climate is slightly cold but within the comfortable range in day time, no extra heater is required.
2) Summer season from march to June; in march temperature is not so much high ventilation is enough to provide thermal comfort. But April to June is very hot and air conditioning is required.
3) Rainy season from july to October; July and August are hot and humid. September is warm and humid; air movement in the form of ventilation can help in achieving comfort. In October, days are hot and dry, nights are comfortable. Dehumidifier can be needed for some times in July and August and cooling may be required in day time of October. Relative humidity falls within the comfortable zone through-out the year in Raipur.

Now conference hall of NIT Raipur is considered to analyze the practical applicability of the system the dimension of the hall is 22.86x8.53x4.5, and the view of the hall can be seen in the fig. 2.

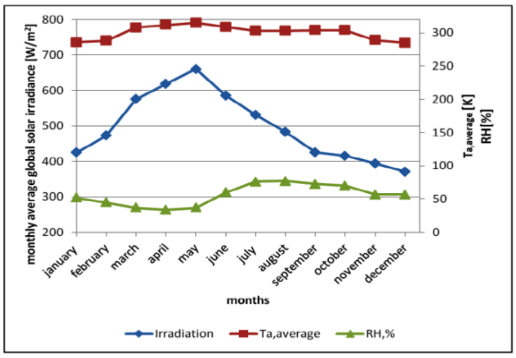

Fig. 1: weather data of Raipur

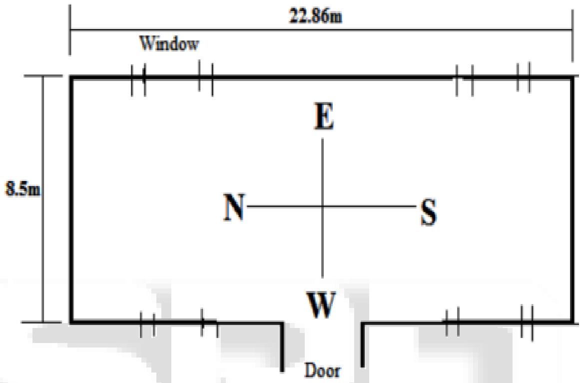

Fig. 2: view of conference hall of NIT Raipur

II. COOLING LOAD OF THE CONFERENCE HALL

Now for the hottest month i.e. in the summer cooling load and required number of air conditioner is calculated for the conference hall. There has been considered a conference room of 22.86 m length, 8.5 m width and 4.5 m height. The room is maintained at $25°C$ temperature by air-conditioners. Under the steady state approach (which does not account the effect of heat capacity of building materials), the heat balance for room air can be written as:

$$Q_{total} = Q_c + Q_s + Q_i + Q_v \qquad (1.1)$$

Where Q_c, Q_s, Q_i, Q_v is the heat gain by conduction, solar radiation, internal heat gain, heat gain by ventilation respectively *and* Q_{total} is the total heat gain of the room.

A. Heat gain by Conduction:

The rate of heat conduction (Qc) through any element such as roof, wall or floor under steady state can be written as:

$$Q_c = AU\Delta T \qquad (1.2)$$

Where, A = surface area(m^2) U = thermal transmittance(overall heat transfer coefficient)(W/m^2K), ΔT = temperature difference between inside and outside air.

B. Heat gain by ventilation:

The heat flow rate due to ventilation of air between the interior of a building and the outside depends on the rate of air exchange. It is given by:

$$Q_v = \rho V_r C\Delta T \qquad (1.3)$$

Where, ρ= density of air(m^3/kg), V_r = ventilation rate(m^3/sec), C = specific heat of air (J/kgK) , ΔT = temperature difference (To–Ti).

C. *Solar Heat Gain:*

The solar gain through transparent elements can be written as:

$$Q_s = \alpha_s \, \Sigma \qquad (1.4)$$

Where, α_s = mean absorptivity of the space ,A = area of the the transparent element (m^2) ,S = daily average value of solar radiation (including the effect of shading) on the the transparent element (W/m^2), τ = transmissivity of the the transparent element.

D. *Internal Gain*

The heat generated by occupants is a heat gain for the building; its magnitude depends on the level of activity of a person. Table 1 shows the heat output rate of human bodies for various activities [1]. The total rate of energy emission by electric lamps is also taken as internal heat gain. The heat gain due to appliances (televisions, radios, etc.) should also be added to the Q_i.

Q_i = (No of people × heat output rate) + Rated wattage of lamps + Appliance load (1.5)

Activity	Rate of heat production	
	(W)	(W/m²)
Sleeping	60	35
Resting	80	45
Sitting, Normal office work	100	55
Typing	150	85
Slow walking (3 km/h)	200	110
Fast walking (6 km/h)	250	140
Hard work (filing, cutting, digging etc.)	More than 300	More than 170

Table I: Heat Production Rate Related To Human Body

For Raipur following data are available [1,2]:
Place: Raipur (Chhattisgarh)
Month: May
Ventilation rate: 2 h^{-1}
Artificial light: 20 lights of 30 W each are continuously used
Occupants: 50 persons (normal office work; 8hours occupancy, each 100W heat production)
Window: (1.5m X 1.2m)×4 on west wall, paneled window
Window: (1.5m X 1.2m)×4 on east wall, paneled window
Door: (2.7m X 1m)×1 on west wall, paneled and glazed
Glazed area: 1.35 m^2
U_{wall} = 1.65 W/m^2K
$U_{roof} = U_{floor}$ = 2.3 W/m^2K
U_{window} = 2.6 W/m^2K
U_{door} = 5.18 W/m^2K
$U_{glazing}$= 5.12 W/m^2K
Daily average high outside temperature in May: 40 ºC
Absorptance of external wall surfaces: 0.3
Outside and inside heat transfer coefficient: 22 W/m^2K and 6 W/m^2K respectively.
Inside design temperature: 25 ºC
Appliance load: 1000W-10000W (according to use of appliances)[3]
Mean absorptivity of the space: 0.6
Transmissivity of glazing: 0.8
Density of air: 1.2 m^3/kg [4]
Specific heat of air: 1005 J/kgK
Average solar radiation: 450W/m^2 [5]

Using equations (1.2), (1.3), (1.4) and (1.5) in equation (1.1), we get

$Q_{total} = Q_c + Q_s + Q_i + Q_v$

Q_c = 1.65 ×(2x8.5x4.5)x15 + 1.65 x (22.86x4.5 - 4x1.5x1.2)x15 + 1.65 x(22.86x4.5–4x1.5x1.2-2.7x1)x15 + 2.3 x (22.86x8.5x2)x15 + 2.6 x 8 x 1.5 x 1.2x15 + 5.18 x 2.7x1x15

= 1893.4 + 2367.8 + 2301 + 13407.4 + 345.6 + 209.8 = 20524.6 W

Q_v = 1.2 x 1005 x 0.5 x (42–27)
= 9045 W

Q_s = 0.6 x [1.35x450] x 0.8
= 291.6 W

Q_i = 50 x 100 + 20 x 30 + 7000
= 12600W

Thus, $\boldsymbol{Q_{total}}$ **= 20524.6 + 4522.5 + 291.6 + 12600 = 42460.6 W = 42.5 kW.**

It represents that total heat gain of the building is about 42.68kW.

III. Air-conditioner required for conference hall

Now for the conference hall total quantity of air conditioner of capacity 1.5TR(=1.5x3514W) required can be calculated as

$$\because \frac{Total\ heat\ gain\ of\ the\ room}{capacity\ of\ single\ A.C.system} = \frac{42.5}{1.5X3.514} = 8.0$$

Therefore in the conference hall 8 air conditioners of 1.5TR capacity are used for space conditioning at present.

The COP of a standard window air conditioner of 1.5TR cooling capacity is about 2.8. So the power required is 15 kW(42/2.8=15). Suppose the machine is to be used for 8 hours a day; then it would consume 15 kWh per day (15 kWh×8) or 120 units (One kWh is equivalent to one unit) of electricity supplied by the power company. Now at rate of Rs. 5 per unit, or expenses would amount to Rs. 120×5/- per day and finally Rs. 45000 for three months(april, may, june) if 25 days in a month (an average) is considered.

IV. Conclusion

In this way for the taken dimensions and structural properties of the conference hall the cooling load of the hall is 42.5 kw and the required number of air conditioner is 8 for achieving thermal comfort in hall in summer duration. The electricity consumption is 120 units per day with Rs. 45000 electric bill per month. Now the carbon component emitted by the use of this ac is 5344 g [6] per day. Total carbon produced by using 1.5 ton A.C. is (5344/24) g=222.7 g per hour, therefore if It is considered that out of 8 air conditioners 5 air conditioners are used as an average then per annum use of such air conditioner system will emit (222.7×5×8×25×3) 2672.4 kg if the air conditioner works for 25 days per month as an average. In this way it can be concluded that though air conditioners provide required thermal comfort in buildings but also release carbon particles in the atmosphere which is responsible for global warming and environment pollution. So to get rid of such problems we must search for other means of air conditioning system which does not pollute the environment or can reduce the application of conventional air conditioners by assisting them.

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