Cooling Load Estimation of Air Conditioning in Lecture Halls of Engineering Institute

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Abstract— In this paper the main concern on cooling load calculation and human comfort in Parthivi Engineering College and management, the central air-conditioning system is a process of controlling the air temperature, relative humidity, ventilation, air movement and air cleanliness of a given space in order to provide the occupants with a comfortable indoor temperature in class room of the engineering college. The objective of this project is to cooling load estimation of the engineering college class rooms and air conditionings used in class rooms for efficiently remove from the air micro-organisms, dust, and soot. So properly maintained air-conditioning system does not cause or promote illness, despite superstitions that air-conditioning is unconditionally dangerous to one's health.

Key words: Cooling load, Heat gain, Air conditioning, Human comfort

I. INTRODUCTION

The air-conditioning is a process that simultaneously conditions air; distributes it combined with the outdoor air to the conditioned space; and at the same time controls and maintains the required space's temperature, humidity, air movement, air cleanliness, sound level, and pressure differential within predetermined limits for the health and comfort of the occupants, for product processing, or both [6].

Air-conditioning System consists of a group of components or equipment connected in series to control the environmental parameters. An air-conditioning system, by ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) definition is a system that must accomplish four objectives simultaneously. These objectives are to: control air temperature; control air humidity; control air circulation; and control air quality [2].

Comfort Air-conditioning is a process of controlling the air temperature, relative humidity, ventilation, air movement and air cleanliness of a given space in order to provide the occupants with a comfortable indoor temperature whereas Air conditioning system consists of a group of components or equipment connected in series to control the environmental parameters [1].

II. RESEARCH AREA DETAILS

At Bhilai (Latitude-21˚13'0N, Longitudinal-81˚25'60E, Altitude-292 meter) I have considered the temperature and relative humidity of four month March, April, May, and June. We have calculated the mean, monthly maximum dry bulb temperature and its corresponding wet bulb temp.

Outside maximum temperature (Avg.)	38^{0}C & 40% RH
Outside minimum temperature (Avg.)	24.5^{0}C & 40% RH
Average temperature of high and low	31.25^{0}C
Inside design condition	25^{0}C & 50% RH
Equivalent temperature difference	6.25^{0}C

In this fig.1 show the average temperature graph data for Bhilai place of Chhatttisgarh.

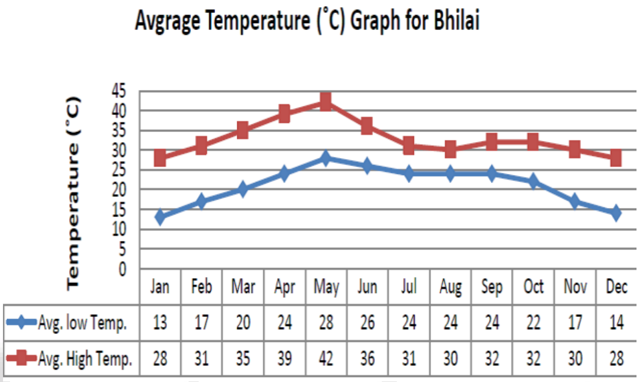

Fig. 1: Block Diagram of the Electricity generation by Rice Husk

The specification detail of the lecture halls (ground floor level) of the engineering institute shown in table 1

Lecture Hall	Area of Hall (m^2)	Capacity of Person	No. of Window and Door	No. of Fluorescents	No. of Fans
G-6	97.94	65-70	10	4	4
G-7	97.94	65-70	6	4	4
G-13	106.17	65-70	6	4	4
G-14	106.17	65-70	8	4	4

Table 1: Specification detail of ground floor of the lecture halls

III. COOLING LOAD CALCULATION

The methodology of cooling load calculation following steps:

A. Solar Heat Gain through Window Glass:

In this section the calculating of solar heat gain through glass of window and the window area is 2.178m^2 of the lecture hall rooms. The table 2 is shown the solar heat gain calculating with the help of SHGF value different for different window face directions and SC is the shading coefficient.

Room No.	No. of Windows facing	Area of window (m^2)	SHGF Value (W/m^2)	Shading Coefficient, SC	Solar Heat Gain (Watt) = A*SHGF*SC

G-6	6 SE	2.178	470.25	0.95	5838
	4 SW	2.178	470.25	0.95	3892
G-7	2 SE	2.178	470.25	0.95	1946
	4 SW	2.178	470.25	0.95	3892
G-13	2 NE	2.178	520.5	0.95	2154
	4 NW	2.178	520.5	0.95	4308
G-14	2 NE	2.178	520.5	0.95	2154
	2 SW	2.178	470.25	0.95	1946
	4 NW	2.178	520.5	0.95	4308
Total					**30438**

Table 2: Solar heat gain through glass (windows and doors)

B. Solar Heat Gain through Wall:

In this section the calculating of solar heat gain through wall of the rooms in table 3 shown.

Room No.	Wall Face	Area of Wall A_w (m^2)	Equivalent Temp. Diff. T_w ^0C	Transmission coefficient U_w (Watt/m^2k)	Heat gain $U_w A_w T_w$ (Watt)	Total Heat Gain Room wise
G-6,	NE	60.7	6.25	1.372	521	1782.74
	SE	86.3	6.25	1.372	740.7	
	SW	60.7	6.25	1.372	521	
	NW	86.3	0	1.372	0	
G-7	NE	60.7	6.25	1.372	521.0	1782.74
	SE	86.3	0	1.372	0	
	SW	60.7	6.25	1.372	521.0	
	NW	86.3	6.25	1.372	740.7	
G-13	NE	91.8	6.25	1.372	787.7	2617.62
	SE	60.7	6.25	1.372	521.0	
	SW	91.8	6.25	1.372	787.7	
	NW	60.7	6.25	1.372	521.0	
G-14	NE	91.8	6.25	1.372	787.7	2617.62
	SE	60.7	6.25	1.372	521.0	
	SW	91.8	6.25	1.372	787.7	
	NW	60.7	6.25	1.372	521.0	
Total						**8800.7**

Table 3: Solar heat gain through wall in facing different direction

The above table calculating the heat gain of each room. So the total heat gain of all lecture hall room is 8800.72 Watt.

Table 1: Sustainable power of individual animals in good condition [4]

C. Heat Gain through Roof:

Roof of the class room material is used concrete. On ground floor the heat gain from the roof is zero, because equivalent temperature difference is zero. Roof thickness is 0.2032 m with plaster 0.012 m thickness.

Transmission co-efficient of roof, $U_r = 1.66$ W/ m^2K

$$U_r = \frac{1}{\frac{l_{rb}}{k_{rb}} + \frac{l_{rp}}{k_{rp}}}$$

$$U_r = \frac{1}{\frac{0.2032}{0.2910} + \frac{0.012}{0.7792}}$$

$$U_r = 1.4012 \text{ W/m}^2\text{.K}$$

The equivalent temperature difference of roof (from table) $T_r = 18.25$ ^{0}C. Total roof area of all ground floor room (G-6, G-7, G-13 and G-14), $A_r = 404.21$ m^2

Total heat gain through roof

$= U_r A_r T_r$

= 1.4012x404.21x18.25

= 10336.42 W.

D. Heat Gain through Appliances:

Heat gain from fluorescents

= Watts of fluorescents x 1.25 x No. of fluorescents

= 40x1.25x16

= 800 W

Where, 1.25 is factor considering the heat gain from choke.

Heat gain from fans

= Watts of Fan x No. of Fans

= 60x16 = 960 W

Total heat gain from Appliances (fluorescents and fans):

= 800 + 960= 1760 W

E. Heat Gain from Occupancy

- Number of people in each class room = 66
- Number of class room = 4
- Duration of occupancy = 7 hr.
- Nature of activity – Study
- Total number of people = 4x66 = 264
- Average metabolic rate of adult male at 25^{0}C gives

- Sensible heat =70 W
- Latent heat = 45 W
- Total sensible heat gain =70x264 = 18480 W
- Total latent heat gain = 45x264 = 11880 W
- Total heat gain from occupancy = 30360 W

F. Infiltration:

Infiltration may be defined as the uncontrolled entry of untreated, outdoor air directly into the conditioned space.

1) Infiltration through doors:

- Door size = 2.83 x 1.524 m^2
- Number of doors in each room = 01
- Air wind velocity = 12 km/hr
- Wood door – average used

To calculate the heat gain through door, we determine m^3/min/person. From table and then psychometric chart determines sensible and latent heat.

m^3/ min/ person = 0.09912
Area of the door = 4.313 m^2
From psychrometric chart,
At 25˚C and 50% RH,
h_i = 51.00 kJ/kg of air
v_i = 0.86 m^3 /kg
At 38˚C and 40% RH,
h_o = 80.1 kJ/kg of air
v_o = 0.90 m^3 /kg
At 31.25˚C and 40% RH,
h_k = 64 kJ/kg of air
Sensible enthalpy gain $=\left(h_k - h_i\right)$ = 13 KJ/kg
Latent enthalpy gain $=\left(h_o - h_k\right)$ = 16.1 KJ/kg
Mass of infiltration air/person (m_i) = (m^3/min person)/ (v_o) = V/v_o
m_i = 0.09912/0.90 = 0.11013 kg/min
m_i = 0.001836 kg/sec
Sensible heat gain (S.H.G) $= m_i\left(h_k - h_i\right)$
= 0.001836 x 13 = 23.86 W
Latent heat gain (L.H.G) $= m_i\left(h_o - h_k\right)$
= 0.001836 x 16.1 = 29.56 W
Total sensible heat gain (T.S.H.G) = 264 x 23.86
= 6299.04 W
Total latent heat gain (T.L.H.G) = 264 x 29.56
= 7803.84 W
Total heat gain (T.H.G) = (T.S.H.G) + (T.L.H.G)
= 14102.88 W

2) Infiltration through window:

Area of window =A_w =2.178 m^2
At 12 km/hr(200 m/min) average velocity of wind.
From table
m^3/min m^2 = 0.067
m^3/min (for 1 window) = 0.067x 2.178 = 0.146 m^3/min.
Mass flow rate due to infiltration through window (m_{iw})
= 0.146 / 0.90 = 0.162 kg/min
m_{iw} =0.0027023 kg/sec
Total number of window = 30
Total number of persons = 264
Sensible heat gain / window $= m_{iw}\left(h_k - h_i\right)$ = 0.0027023x 13 x 1000 = 35.13 W
Latent heat gain /window $= m_{iw}\left(h_o - h_k\right)$ = 0.0027023x 16.1 x 1000 = 43.51 W
Total sensible heat gain (T.S.H.G)
= 264 x 35.13 = 9274.32 W
Total latent heat gain (T.L.H.G)
= 264 x 43.51 = 11486.64 W
Total heat gain (T.H.G) = (T.S.H.G) + (T.L.H.G)
= 20760.96 W

G. Ventilation:

The introduction of outer air for ventilation of conditioned space is necessary to dilute the odours given off by people, smoking and other internal air contaminants. The amount of ventilation varies primarily with total number of people, the ceiling height and the number of people smoking. People give off body odours which require minimum of 0.28 m^3 /min/ person for satisfactory dilution.

Number of persons = 264
Outer air (V_o) = 264 x 0.28 = 73.92 m^3/min
From psychrometric chart
At 25˚C and 50% RH,
h_i = 51.00 kJ/kg of air
v_i = 0.86 m^3 /kg
At 38˚C and 40% RH,
h_o = 80.1 kJ/kg of air
v_o = 0.90 m^3 /kg
At 31.25˚C and 40% RH,
h_k = 64 kJ/kg of air

1) OASH = Outside air sensible heat,
2) OALH = Outside air latent heat,
3) BPF = Bypass factor,
4) ERSH = Effective room sensible heat,
5) ERLH = Effective room latent heat,
6) ESHF = Effective room sensible heat factor.

1) OASH = 0.0204 x V_o (Outside temperature – Inside temperature) x BPF
= 0.0204 x 73.92 x (38-25) x 0.52
= 10.2 kW = 10200 W
From psychrometric chart
At 25˚C and 50% RH,
Inside humidity ω_i = 0.010 kg/kg dry air
At 38˚C and 40% RH,
Inside humidity ω_o = 0.017kg/kg dry air
2) OALH = 50 x V_o (Outside humidity –Inside humidity) x BPF
= 50x 73.92 x (0.017-0.010) x 0.52
= 13.45 kW = 13450 W

Type of Load (Watt)	Sensible Heat (S.H) (Watt)	Latent Heat (L.H.) (Watt)
Solar heat gain through glass by transmission	30438	
Solar heat gain through wall by conduction	8800.72	
Solar heat gain through roof	10336.42	
Heat gain from appliances	1760	
Heat gain from occupancy	18480	11880
Infiltration (door)	6299.04	7803.84
Infiltration (window)	9274.32	11486.64
Sub total	85388.5	31170.48

Safety factor (5%)	4269.43	1558.52
Room heat	89657.93	32729
Supply duct leakage losses (0.5%)	448.3	163.64
Fan HP (5%)	4483	1636.4
Effective load	94589.11	34529.1

H. Dehumidified Air Quantity:

The calculating Dehumidified air quantity,

The value ERSH taken from above table is 94.59 kW and also taken value of ERLH is 34.53 kW

So the Effective room sensible heat factor value calculating

ESHF = ERSH/ (ERSH+ERLH)

= 94.59 / (94.59 + 34.53) = 0.733

ADP of coil = 13.5^{0}C (from psychrometric chart)

Dehumidified air quantity

$$= \text{ERSH}/\left[(T_1 - T_{ADP})(1-\text{BPF})0.0204\right]$$

= 94.59 / [(25-13.5) x (1-0.52) x 0.0204]

= 843.28 $(m^3 / min)_d$

Re-circulated room air:

= $(m^3 /min)_d - (m^3 /min)_o$

= 843.28 – 203.28= 640.02 m^3 /min

From psychrometric chart

At 25˚C and 50% RH,

h_i = 51.00 kJ/kg of air

v_i = 0.86 m^3 /kg

At 38˚C and 40% RH,

h_o = 80.1 kJ/kg of air

v_o = 0.90 m^3 /k

At 31.25˚C and 40% RH,

h_x = 64 kJ/kg of air

At 18.25˚C,

h_y = 37 kJ/kg of air

Mass flow rate of outside air $= \dfrac{(m^3/min)}{V_O}$

m_o = 843.28/(0.9x60) = 15.62 kg/s

Tonnage of plant $= m_o\left(h_x - h_y\right)$

= 15.62 (64 - 37) = 421.74 kW = 120.5 TR

Moisture removed = 0.0115 - 0.0095 (from psychrometric chart)

= 0.002 kg/kg of air

Moisture removed = 15.62 x 3600x 0.002= 112.46 kg/hr

IV. RESULT AND DISCUSSION

In this paper the lecture hall of the engineering institute is centrally air-cooled than the students living there will feel comfortable by providing uniform comfortable ambient, their working capability will increase, consequently, this will be useful in studying for prolonged hours, which ultimately cater them good-marks and better academic output. This will prove as a boon for their career.

- The load calculation has been done for the peak load on the plant that may be encountered during the month of May as a peak summer duration.
- Only one centralized air conditioning plant for the both the floor has been suggested with the capacity of nearly 120.5 TR.

V. ACKNOWLEDGMENT

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