COOLING LOAD ESTIMATION BY CLTD METHOD AND HAP 4.5 FOR AN EVAPORATIVE COOLING SYSTEM

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Abstract - *This paper present the CLTD method for calculating the sensible cooling load estimation for evaporative cooling systems as a replacement of high power consuming air conditioners, partially or completely for maintaining thermal comfort in various climatic locations without compromising the indoor air quantity. In this manual calculations are made to estimate the cooling load and the results were compared by the outcomes from HAP 4.5 program for a three story shop building.*

Key words: - HVAC, CLTD, CLF, HAP, Cooling Load.

1 INTRODUCTION

Cooling & heating load calculations are normally made to size HVAC (heating, ventilating, and air-conditioning) systems and their components. In principle, the loads are calculated to maintain the indoor design conditions. The first step in any load calculation is to establish the design criteria for the project that involves consideration of the building concept, construction materials, occupancy patterns, density, office equipment, lighting levels, comfort ranges, ventilations and space specific needs. Architects and other design engineers converse at early stages of the project to produce design basis & preliminary architectural drawings.

Every air conditioning application has its own special „needs‟ and provided its own challenges. Shopping malls, office complexes, hotels, ATM's, Airports and banks need uniform comfort cooling in every corners of their sprawling spaces and activities involving computers, electronics, aircraft products, precision manufacturing, communication networks and operation in hospitals, infect many areas of programming will come to a halt, so air conditioning is no longer a luxury but an essential part of modern part of modern living.

The design basis typically includes information on:

1) Geographical site conditions (latitude, longitude, wind velocity, precipitation etc.)
2) Outdoor design conditions (temperature, humidity etc.)
3) Indoor design conditions
4) Building characteristics (materials, size, and shape)
5) Configuration (location, orientation and shading)
6) Operating schedules (lighting, occupancy, and equipment)
7) Additional considerations (type of air-conditioning system, fan energy, fan location, duct heat loss and gain, duct leakage, type and position of air return system…)

2 BUILDING LOCATION

The multi-story building considered in this study is situated in Pusad, District Yavatmal (M.S.), India, located at 77.55⁰E longitude, 19.89⁰N latitude and at an elevation of about 315 meters above mean sea level.

3 CLIMATE CONDITION

Pusad has a tropical climate; it is situated between hills from all four sides. Average annual rainfall ranges between 250 and 360 mm. The minimum and maximum temperatures ranges are 7 to 49 with a mean minimum and maximum temperature range of 9.8 to 42 during coldest and hottest months.

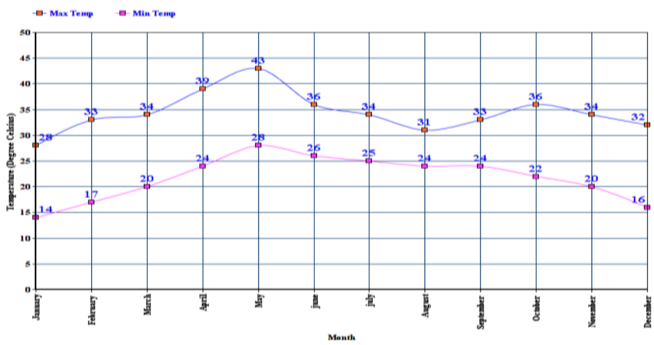

Fig - 1: Average Temperature Graph for Pusad.

4 BUILDING STRUCTURE

The dimension of the building which is to be air conditioned is, 10.59×6.12 m in size. It has three floors including the ground floor. The exterior walls of building consist of 102 mm face bricks and 203 mm face brick with 15 mm cement mortar sand 6 mm plaster on each side. The roof consists of 102 mm HW concrete with 6 mm plaster& air gap with pop 457 mm below the slab. The front display glass consists of single glass materials of 12 mm thick with frame panel.

Table - 1: SUMMARY OF BUILDING SPECIFICATIONS

Item	Description	Ground Floor	1st Floor	2nd Floor
1	Total Interior Space (Volume)	187.52 m^2	187.52 m^2	187.52 m^2
2	Total Exterior Wall Area	82.53 m^2	82.53 m^2	82.53 m^2
3	Total Roof Area	56.13 m^2	56.13 m^2	64.8 m^2
4	Total Glass/ Window Area	7.36 m^2	18.48 m^2	18.48 m^2
5	Number of Employees/ Staff	05	05	05
6	Number of visitors per hour	10	10	10
7	U value for wall	1.39 W/m^{2}k	1.39 W/m^{2}k	1.39 W/m^{2}k
8	U value for Roof	1.68W/m^{2}k	1.68 W/m^{2}k	1.68 W/m^{2}k
9	U value for Glass	2.21 Watt	2.21 Watt	2.21 Watt

5 LOAD COMPONENTS

The total heat required to be removed from the space in order to bring it at the desired temperature30^{0}C and relative humidity (50%) by the air conditioning equipment is known as cooling load or conditioned load. This load consists of external and internal loads.

5.1 External and Internal heat gains

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.

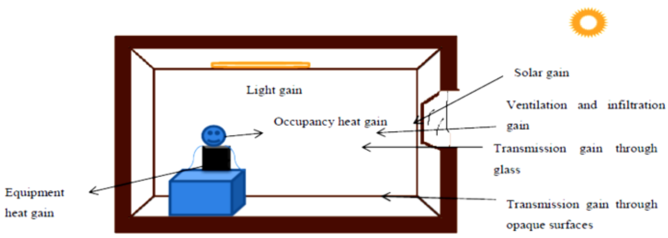

Fig - 2: Load Components

a. Sensible Heat Gain through Opaque Surface

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

Where,

U = over all heat transfer coefficient (W/m^2 ^{0}C)

CLTD = cooling load temperature difference (^{0}C)

A = surface area (m^2)

Overall heat transfer coefficient

$$U = \frac{1}{\frac{1}{ho} + \frac{x1}{k1} + \frac{1}{ka} + \frac{x2}{k2} \dots \dots \dots \dots \frac{1}{hi}}$$

$CLTD_{corr} = (CLTD + LM)\,K + (25.5 - T_i) + (T_o - 29.4)$

Where,

T_o = outside average temperature (^{0}C)

T_i = inside design temperature (^{0}C)

LM = latitude month correction

K = correction factor depends on building color.

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

b. Heat Gain through Glass

Transmission heat gain through glass

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

By solar radiation

$Q=A*SHGF_{max}*SC*CLF$

Where

$SHGF_{max}$= maximum solar heat gain factor (W/m^2)

SC= shading coefficient depends on type of shading

CLF = cooling load factor

c. Heat Gain from Occupants

Sensible heat gain from occupants

$Q_{s\ person} = q_{sperson} * N * CLF$

Where

$Q_{s\ person}$= sensible heat gain/person (W)

N = total number of people present in conditioned space

CLF = cooling load factor

d. Heat Gain from Lighting Equipment's

$Q_{el} = HG_{el} * CLF_{el}$

Q_{el}= Cooling load from lighting, W

HG_{el}= Heat gain from lighting

CLF_{el} = Lighting cooling load factor

$HG_{el} = W * F_{ul} * F_{sa}$

W = Total light wattage

F_{ul} = Lighting use factor = 1 (for commercial appliances)

F_{sa}= Lighting special allowance factor = 1.20 (for general application)

e. Heat gain from electric equipment's

$Q_{equipment}$ = 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.

f. Heat gain from office equipment's

Table - 2: Heat gain rate for office equipment's (2001 ASHRAE Fundamentals Hand Book)

Appliance	Continuous	Average	Ideal
Computer -15" Monitor	110		20
-17" Monitor	125		25
-19" Monitor	135		30
Laser printer-Desktop	130	100	10
-Small office	320	160	70
-Large office	550	275	125
Fax machine		30	
Facsimile Machine	30		15
Image Scanner	25		15
Dot Matrix Printer	50		25
Desktop Copier	400	85	20
Office Copier	1100	400	300

g. Heat gain due to Infiltration

$$Q_{infiltration} = \frac{\text{volume X ACH X 1000}}{3600}$$

$Q_{sensible} = 1.23 * Q_{infiltration} * \Delta T$

h. Heat gain due to Ventilation Sensible load

$Q_{sensible} = 1.23 * Q * (t_o - t_i)$

Ventilation required = 1 L/sec/person

T_o and T_i = Outside and inside design temperature respectively (^{0}C)

Table - 3: Manual Calculations for Sensible Load

SR. No.	Sensible Heat Gain	Ground Floor	1st Floor	2nd Floor
1	Heat transfer through North side wall:	934.509	934.509	934.509
2	Heat transfer through West side wall:	999.270	999.270	999.270
3	Heat transfer through South side wall	783.207	783.207	783.207
4	Heat transferred through Glass by Radiation	2477.376	6220.37	6220.37
5	Heat transferred through Glass by Conduction	375.735	943.422	943.422
6	Heat transferred through Ceiling	992.984	942.984	1088.64
7	Heat transferred through Floor	1789.032	--	--
8	Heat transferred through Plywood	276.006	276.006	276.006
9	Heat gain from people	1125	1125	1125
10	Heat gain from lighting equipment's	432	432	432
11	Heat gain from Computer	200	--	--
12	Heat gain from Printer	292	--	--
13	Heat gain from Barcode Printer	370	--	--
14	Heat gain from Fan	180	180	180
15	Heat gain from Door	740.09	--	--
16	Ventilation	184.5	184.5	184.5
17	Infiltration rate	619.6	619.6	619.6
	Total Load (kW)	**12.76 kW**	**12.98 kW**	**13.12 kW**

6. HOURLY ANALYSIS PROGRAM SOFTWARE 4.5

HAP is a computer tool which assists engineers in designing HVAC systems for commercial buildings. HAP is two tools in one. First it is a tool for estimating loads and designing systems. Second, it is a tool for simulating energy use and calculating energy costs. HAP uses the ASHRAE-endorsed transfer function method for load calculations and detailed 8,760 hour-by-hour energy simulation techniques for the energy analysis.

6.1 HAP system design features

HAP estimates design cooling and heating loads for commercial buildings in order to determine required sizes for HVAC system components. Ultimately, the program provides information needed for selecting and specifying equipment. Specifically, the program performs the following tasks:

- Calculates design cooling and heating loads for spaces, zones, and coils in the HVAC system.
- Determines required airflow rates for spaces, zones and the system.
- Sizes cooling and heating coils.
- Sizes air circulation fans.

Before design calculations can be performed types of information needed include:

- Climate data
- Construction material data for walls, roofs, windows, doors, exterior shading devices and floors, and for interior partitions between conditioned and non-conditioned regions.
- Size and layout data including wall, roof, window, door and floor areas, exposure orientations and external shading features.
- Internal load characteristics determined by levels and schedules for occupancy, lighting systems, equipment.
- Data concerning HVAC equipment, controls and components to be used.

6.2 HAP 4.5 Results

Table - 4: HAP 4.5 Results Central Coil Sizing Data

	Ground Floor	1st Floor	2nd Floor
Sensible coil load	12.6 kW	13.0 kW	13.0 kW

7. CONCLUSION

In this paper the investigation on calculation of Sensible Cooling Load for Evaporative Cooling System has been conducted for two story shop building by CLTD method and HAP program produced by carrier for cooling load estimation was used to verify the results. The manual calculation results show that the total cooling load required for ground, first and second floor is 13.49 kW,14.36 kW and14.50 kW for summer (month of May). HAP result for the peak month (May) are 12.6 kW, 13.0 kW and 13.0 kW. The results were compared with manual calculations and it was noticed a dis-similarity between the two, because manual calculations considers peak value of the day whereas HAP gives weighted average value.

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