Estimation of Cooling Load for India

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ABSTRACT

A software has been developed for the estimation of monthly-mean hourly cooling load for Indian cities by Cooling Load Temperature Difference (CLTD) method prescribed by ASHRAE. For this purpose empirical equations for the design temperatures, monthly-mean hourly wind velocities and humidity ratios at the locations are used. The software takes the city, month, wall orientation, building materials and their dimensions, wattage of lighting, number of occupants and occupancy hours and type of window glass with different types of shadings as input. The cooling loads for the month of May thus calculated are compared with those calculated using Solar Heat Gain Factor method. The computed values of cooling loads for eight cities, distributed all over India, are compared with these values and the results plotted to show the difference. The error analysis done for these calculations shows that the relative standard deviation for heat gain, through walls and roof, varies from 6.5% to 15.7% for different wall orientations.

1. INTRODUCTION

Heating or cooling load is the thermal energy that must be supplied to or removed from the interior of a building in order to maintain the desired comfort conditions. Air-conditioning field is having unlimited industrial and commercial applications. Hence it consumes a considerable amount of energy. The economy of installation and operating costs of an air-conditioning plant requires precise evaluation of thermal loads [1].

Particularly the last two decades have seen an intensive worldwide research effort on energy and buildings. Sparked by the oil crisis of 1970s, the emphasis was first on energy efficiency, but improved comfort and indoor air quality are emerging as important benefits of proper design [1]. Ding, et al. [2] presented the results of computer simulation studies on energy performance of a typical high rise office building floor module of local design practice in Singapore. Sullivan, et al. [3] developed algebraic expressions of various configurational parameters on building energy performance. They generated large data for five American locations using DOE 2.1B energy simulation package. In India, Sharma, et al. [4] presented the design climatic data for summer air conditioning load calculations for five Indian cities. They [5] also gave the calculated monthly-mean hourly values of solar radiation and solar heat gain factors through walls at different orientations and roof for eight Indian cities.

India being a tropical country with predominantly hot, dry and hot-humid regions, air-conditioners are mainly used to remove the heat from buildings during summer. The procedures available from ASHRAE, CIBSE, Carrier, etc., have used climatic and material data from their respective countries. The estimation of cooling load today is invariably based on these Guides and Tables available to the engineer and more often than not, reliance is placed on guess work and experience. There is, therefore, a need to rationalize the basis of computation of cooling load. This paper presents a procedure to estimate cooling load at different Indian locations.

2. ESTIMATION OF COOLING LOAD

Heat gains in building occurs in the form of solar radiation through transparent surfaces, heat conduction through exterior walls and roofs, heat conduction through interior partitions, ceilings and floors, heat generated within the space by occupants, lights and appliances, energy transfer as a result of a ventilation and infiltration of outdoor air [1]. The capacity of the plant is determined on the basis of either peak load, in places like auditorium, cinema houses, etc., where large number of people stay for a definite duration and the use of air-conditioning system is intermittent or 24 hour average cooling load, in places like, residential houses, hospitals, commercial offices, etc., where the use of air-conditioning system is more or less continuous [4].

2.1 CLTD/CLF Method for Cooling Loads

Prior to mid-1960s, the only method of designing load calculations was to use the product of its area (A), its conductance (U) and the temperature difference (ΔT) between the interior and outdoor temperatures. *ASHRAE Handbook of Fundamentals 1967* introduced the Total Equivalent Temperature Differential (TETD) method. In this method various components of space heat gain are added together to get an instantaneous total rate of space heat gain. This is converted to an instantaneous space cooling load by the Time Averaging (TA) technique of averaging the radiant load components with related values from a period of immediately preceding hours. In 1972 Mitalas [6] developed Transfer Function Method (TFM). Although similar in principle to the TETD method, it employs a series of *weighting factor* (called *coefficients of room transfer functions*) to apply to heat gain and cooling load values from several previous hours as well as the current hour, in order to account for the thermal effect in converting heat gain to cooling load. In 1975 ASHRAE sponsored a project to develop an improved cooling load calculation method [7]. Investigators used the methodology and basic equations of the Transfer Function Method to generate Cooling Load Temperature Difference (CLTD) data for direct one-step calculation of cooling load from conduction heat gain through sunlit walls and roofs and conduction through glass exposures. Also developed were Cooling Load Factors (CLF) for similar one-step calculation of solar load through glass and loads from internal sources. Both CLTDs and CLFs include the effect of time delay caused by thermal storage. Today CLTD/CLF method is widely used for the estimation of cooling loads.

The cooling load due to conduction across an envelope element of area A and conductance U is given by:

$$q_{cond} = U(A).(T_o-T_i) \tag{1}$$

under static conditions, i.e., if indoor temperature T_i and outdoor temperature T_o were both constant.

But if the temperature follows a periodic pattern, day after day, q_{cond} will also follow a periodic pattern. Once q_{cond} has been calculated, one can define a CLTD as the temperature difference that gives the same cooling load when multiplied by *UA*. If such temperature differences are tabulated for typical construction and typical temperature patterns, they can be looked up for quick determination of the load. Thus the conductive cooling load [1] is:

$$q_{cond} = U(A)(\text{CLTD}) \quad (2)$$

The Cooling Load Factor (CLF) is defined such that it yields the cooling load at hour *t* when multiplied by daily maximum (q_{max}) of the heat gain.

$$q_{rad} = q_{max}(\text{CLF}) \quad (3)$$

The values of CLTDs and CLFs of ASHRAE [8] have been calculated by means of the transfer functions and are given in the form of tables. By using the above-described CLTD method the following procedure to calculate the heat gains from all the building components is outlined.

Heat Transfer Through Walls and Roofs

While developing CLTD in Eq. (2), ASHRAE [8] considered solar radiation for 40° N on July 21, T_i = 25.5°C and T_0 = 29.4°C. Therefore, for conditions other than these, the CLTD_c is to be used instead of CLTD. For calculating heat transfer rate through the wall or roof, Eq. (2) can be rewritten as:

$$q = U(A)(\text{CLTD}_c) \quad (4)$$

where

$$\text{CLTD}_c = [(\text{CLTD} + \text{LM})f + (25.5 - T_i) + (T_o - 29.4)] \quad (5)$$

$$U = 1/(1/h_o + x_1/k_1 + x_2/k_2 + x_3/k_3 + 1/h_i) \quad (6)$$

cooling load temperature difference (CLTD) values and latitude-month correction (LM) for walls and roof of the corresponding materials are taken from ASHRAE [8]. *f* is the color adjustment factor, $f = 1$, for dark colors; $f = 0.85$, for bright colors; T_i, T_o are the indoor and outdoor design temperatures. In the present study T_i for conditioned space is taken as 26.7°C [4]. Thermal conductivity and thickness of the material are denoted by *k* and *x*, respectively. Indoor heat transfer coefficient (h_i) is taken as 8.3 W/m² K as recommended by ASHRAE [8]. The values of heat transfer coefficient (*h*) varies with wind velocity. For outside heat transfer coefficient (h_o) of the building surfaces ASHRAE [8] recommended the wind speed of 6.7 m/s and corresponding h_o = 34 W/m² K for winter conditions; and wind speed of 3.4 m/s and h_o = 22.7 W/m²·K for summer conditions. However, in India the wind conditions are opposite to that in European countries, where the wind velocities at most of the places are 1 to 2.5 m/s in winter and 3 m/s to 5 m/s in summer [9]. Hence, the authors have used the following correlation given by the International Standards Organization [10]:

$$h_o = 4.1\,W + 10 \quad \text{(for vertical surfaces)} \quad (7)$$

$$h_o = 6.2(W^4/L)^{1/5} \text{ (for horizontal surfaces [1])} \tag{8}$$

where wind velocity (W) is to in m/s.

However, to use Eqs. (4 and 8) one should know the wind velocity (W) and the design temperature (T_o). Since meteorological stations are available at a limited number of places in India, the authors have developed [11] a procedure to predict monthly-mean hourly values of relative humidity (H_w), ambient temperature (T) and wind velocity (W) for Indian locations where measured data is not available. Sets of equations are developed to predict the said weather parameters, by the least square regression analysis of the meteorological data of 14 Indian cities distributed well over India, from their corresponding annual-mean values.

Values of monthly-mean hourly wind velocity and ambient temperature for any Indian location are obtained according to this developed procedure. These values of wind velocities are used in the outside surface heat transfer coefficient calculations [Eq. (5)] and outside design air temperature (T_o) [Eq. (4)] is taken as maximum for peak load design and average for average load design of the monthly-mean hourly ambient temperatures.

Partitions with an Unconditioned Space

The temperature of the adjoining unconditioned space should be determined by actual measurements but in the absence of any such data, and knowing that there are no heat sources in the adjoining space, the temperature can be taken as the outside design air-temperature -3° C [4]. Heat gain through such partitions, floors, ceilings are estimated by using the following equation:

$$q_{cond} = U(A)(\Delta T) \tag{9}$$

Solar Heat Gain Through Window

Solar heat gain through window (q_{win}) depends on the solar radiation falling on the window surface and is expressed by [8]:

$$q_{win} = \text{SHGF}(A)(\text{CLF})(\text{SC}) \tag{10}$$

where solar heat gain factor (SHGF) is the total amount of solar radiations falling on the window surface, CLF is cooling load factor as defined in Eq. (3) and their values are taken from ASHRAE [8], A is the area of window and shading coefficient (SC) is the ratio of thermal transmittance of given glass-shading combination to that of 3 mm clear glass. Values of SC for different glass-shading combinations are given [12] in Table 1. To estimate SHGF one should know solar radiation details at a given location. Since Meteorological stations are available at limited number of locations in India, there was a need to develop a procedure to estimate hourly solar radiation at any Indian location. Hourly solar radiation calculated for Indian locations using constants given by ASHRAE [8] predict higher beam radiation and lower diffuse radiation. Hence the authors have obtained sets of constants by least square regression analysis of the solar radiation data of ten Indian cities to estimate hourly solar radiation at any Indian location using ASHRAE equations. Procedures to estimate hourly solar radiation and SHGF on different orientations of building-surface at any Indian location is reported in the studies by Parishwad, et al. [13, 14] respectively. Values of SHGF in Eq. (10) are estimated according to these procedures.

The heat gain due to conduction through window is calculated by using Eq. (4) and the CLTD values are taken from ASHRAE [8].

Table 1 Shading Coefficient [12] for Different Types of Glass and Various Shading Devices [Eq. (7)]

Sr. No.	Type of shading	Description	Shading coefficient
1	External shading	Ordinary glass shaded completely with louvers, awnings, etc.	0.20
2	Internal shading	Ordinary glass with:	
		• Light color curtains	0.44
		• Dark color curtains	0.62
		• Light color venetian blinds	0.55
		• Dark color venetian blinds	0.64
		• White color opaque roller shade	0.25
		• Dark color opaque roller shade	0.59
3	Double glazing	• Ordinary clear glass both sides	0.70
		• Heat absorbing glass outside and plate glass inside	0.56
		• Heat reflecting glass outside and ordinary clear glass inside	0.17

Heat Gain Through Air

Fresh air in building is essential for comfort and health, and the energy for conditioning this air is an important factor. The supply of fresh air or air exchange is stated as the flow rate 'V' of the outdoor air that crosses the building boundary and needs to be conditioned. It is helpful to distinguish two mechanisms that contribute to the total air exchange [1]:

- *Infiltration*: Uncontrolled air flow through all the little cracks and openings in a building.
- *Ventilation*: Free flow or forced flow of air into the building.

Sensible (q_{is}) and latent (q_{il}) heat gain of infiltrated air are estimated using the following equations:

$$q_{is} = 1.232\,(V_{win}+V_d)\,(T_o - 26.7) \tag{11}$$

$$q_{il} = 3012\,(V_{win}+V_d)\,(w_o - w_i) \tag{12}$$

Ventilated (q_{vs}) and latent (q_{vl}) heat gain of infiltrated air are estimated using the following equations:

$$q_{vs} = 1.232\,V\,(T_o - 26.7) \tag{13}$$

$$q_{vl} = 3012\,V\,(w_o - w_i) \tag{14}$$

where ventilated air required per person [8], $V = 7$ l/s, T_o is the outdoor design temperature in °C; w_0 and w_i outdoor and indoor humidity ratios of the air, and infiltration through window (V_{win}) or door (V_d) is estimated using the following equation:

$$V_{win/d} = C(H)(\Delta p^{0.5}) \tag{15}$$

where C = coefficient incorporating friction
= 1.0 for tightly closed, very small gaps up to 0.4 mm, weather stripped
= 2.0 for averagely closed, non weather-stripped, gaps up to 0.4 mm
= 6.0 for loosely closed doors, non weather-stripped, large gaps up to 2.4 mm

H is the perimeter of the crack in m, W is the wind velocity in m/s, Δp is the pressure difference due to wind velocity given by [1]:

$$\Delta p = C_p(\rho)\,(0.5\,W^2) \tag{16}$$

where ρ is the density of air in kg/m³ and Cp is the coefficient of pressure which varies with direction of wind whose value is taken from Kreider and Rabl [1]. Average value of Cp may be taken as 0.2.

Heat Gain From People

The human body obtains energy by the intake of food (fuel), and expends energy in doing work. There is also a release of heat due to thermal inefficiency in burning the fuel, which is dissipated by heat and water transfer from the skin and by exhalation and excretion. The total heat production is known as the metabolic rate, which vary from activity to activity. Variations in the metabolic rate will occur between individuals having the same activity energy output depending on age, sex, stage of food digestion, etc., but because such changes are less important than those associated with activity, care should be taken to select the appropriate activity [15].

Heat gains from people will be both sensible and latent and the quantity of heat will vary with the rate of activity and the ambient temperature. The latent heat gain caused by human beings can be considered as an instantaneous cooling load, but the total sensible heat gain is not converted directly to cooling load. The radiant portion is first absorbed by the surroundings, then convected to the room at a later time, depending on the thermal characteristics of the room.

Sensible heat load (qs) and latent heat load (ql) are calculated by following equations.

$$q_s = N(q_s)\mathrm{CLF} \tag{17}$$

$$q_1 = N(q_1) \tag{18}$$

where N is the number of persons stayed, and q_s, q_1 are sensible and latent heat gains respectively and are taken from ASHRAE [8].

Heat Gain Through Lights and Equipment

An accurate estimate of the space cooling load imposed by lighting and equipment, often the major space load component, is essential in air-conditioning system design. The rate of heat gain to the air caused by lights can be quite different [8] from the power supplied to the lights. Some of the energy emanating from lights is in the form of radiation that only affects the air after it has been absorbed by walls, floors and furniture and has warmed them to a temperature higher than the air temperature. This absorbed energy, stored by the structure, contributes to the space-cooling load after a time lag, and is present after the lights or equipment are switched off.

The instantaneous rate of heat gain from electric lighting or equipments in watts can be calculated from:

$$\text{Load due to light} = (\text{Total wattage or Rated power})\ CLF \quad (19)$$

Several studies have indicated the effect on cooling load of light fixture type, type of air supply and return, space furnishings and thermal characteristics of the space. Mitalas [16] formulated these parameters into a set of numerical values permitting calculation of appropriate cooling load factors (CLF). The CLF values for lights and equipment are taken from ASHRAE [8].

2.2 Total Cooling Load

Total cooling load is the addition of heat gains through all the building components. Conduction heat gain through walls at different orientations and roof, solar and conduction heat gain through windows at different orientations, heat gain through lighis and equipments, sensible and latent heat gain through air exchange and occupants, etc., all of them add together to give cooling load.

3. COMPARISON OF ESTIMATED AND AVAILABLE COOLING LOADS

Software has been developed, in language 'C', to calculate the cooling loads of the buildings for any city in India. The software takes the following parameter as input parameters and estimates heat gain through each building component and total cooling load.

- Name of the city, month,
- Orientations, dimensions, materials, number of layers and thickness of building walls and roof.
- Number of windows and doors, and their dimensions, window glass thickness, internal and external shading details.
- Number of occupants and details of their activity.
- Number of lights, equipment and their wattage.

Monthly-mean hourly values heat gain, for the month of May, for walls at different orientations and roof for eight cities, namely, New Delhi, Mumbai, Calcutta, Lucknow, Jodhpur, Ahmedabad, Bhopal and Roorkee were given by Sharma et al. [5]. Monthly-mean hourly heat gain for the same cities, months, and orientation walls were calculated by the developed software and compared with the available data to decide the validity of the software. The statistical comparison was made by using two statistical indicators namely, Standard Deviation (SD) and Relative Standard Deviation (RSD) which were calculated by using the equations given below [17]:

$$SD = [(1/n)\sigma\Sigma\,(M_i - C_i)^2\,]^{1/2} \quad (20)$$

$$RSD = \{(1/n)\,\Sigma\,[(M_i - C_i)/C_i]^2\}^{1/2} \times 100 \quad (21)$$

where M_i and C_i are the available and computed parameters, respectively and n is the number of data used.

4. RESULTS AND DISCUSSION

With the help of the developed software heat gain through different building components and effect of various shading devices were studied. Figure 1 shows the monthly-mean hourly heat gain per unit area through traditionally used walls (225 mm Brick + 12.5 mm Plastering on both sides) and roof (112.5 mm RCC + 112.5 mm Lime concrete) at New Delhi (Latitude: 28.58° N, Longitude: 77.20°E, HAMSL: 216 m) for the month of May. It is observed that the average heat gain through roof of an isolated room is 78% more than the average wall heat gain. Hence more attention may be given towards the insulation of roofs as compared to walls to reduce the cooling load.

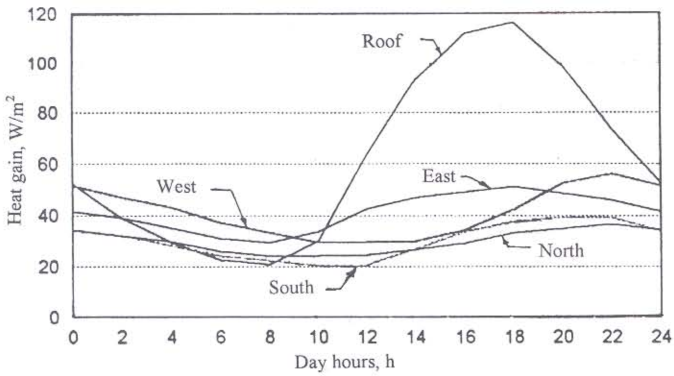

Fig. 1. Monthly-mean hourly heat gain per unit area through traditionally used walls (225 mm Brick + 12.5 mm Plastering on both sides) and roof (112.5 mm RCC + 112.5 mm Lime concrete) in New Delhi for the month of May.

Solar heat gain through single-glazing windows at four different orientations, at New Delhi for the month of May is shown in Fig. 2. Heat gain through East and West windows are maximum during 0800-0900 hours and 1500-1600 hours respectively. Comparison of single and double glazing, light and dark color of curtains and curtain and venetian blind is shown in Fig. 3 to Fig. 5. On an average light colored curtain gives 29% less heat gain than dark colored curtains in the month of May, the curtain gives less heat gain than venetian blind and double glazing reduces solar heat through window by about 30% as against that through single-glazing.

A sample variation of heat gain due to 300 W lights at an office if lights are switched on during 0900 hours to 1700 hours is shown in the Fig. 6. Gradual increase and decrease of heat gain due to lights are observed when lights are switched on and off respectively.

Statistical comparison of estimated and available [5] monthly-mean hourly heat gain data through traditionally used walls at eight different orientations and roof at eight cities, namely, New Delhi, Mumbai, Calcutta, Lucknow, Jodhpur, Ahmedabad, Bhopal and Roorkee for the month of May are compared on the basis of SD and RSD [Eq. (14)] and the results are given in Table 2. Results show that average RSD for these eight cities varies from 6.5%-15.7% and average SD varies from 1.25 W/m^2 to 5.02 W/m^2.

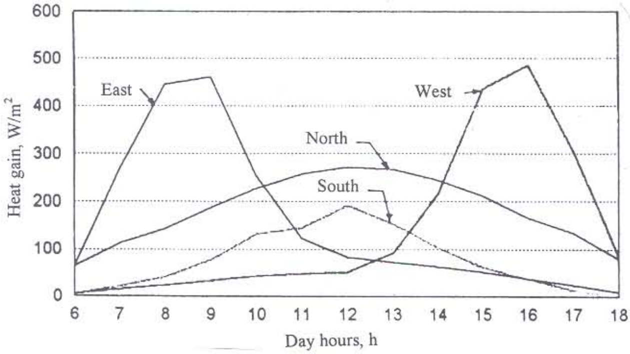

Fig. 2. Monthly-mean hourly solar heat gain through single-glazing windows in New Delhi for the month of May.

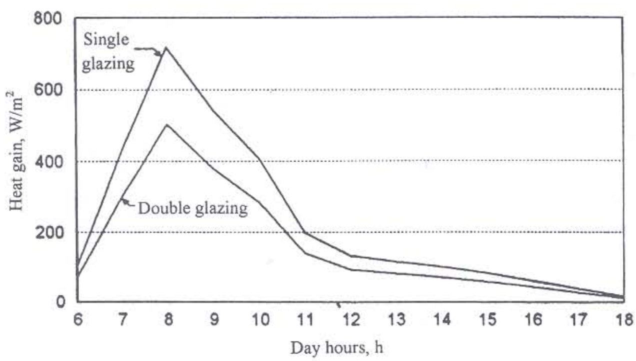

Fig. 3. Comparison of monthly-mean hourly solar heat gain through single and double glazing in New Delhi for the month of May.

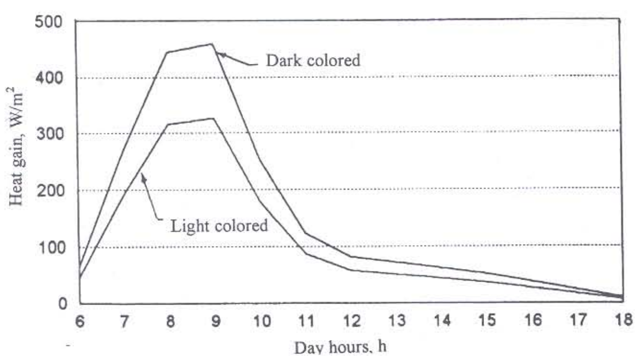

Fig. 4. Comparison of monthly-mean hourly solar heat gain through light and dark color of curtains.in New Delhi for the month of May.

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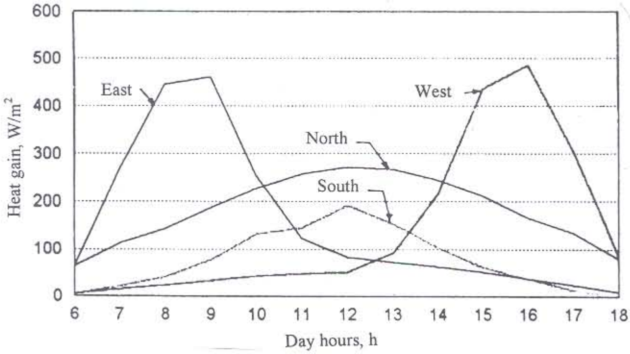

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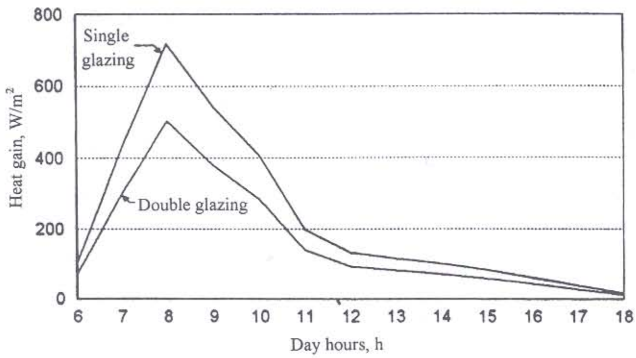

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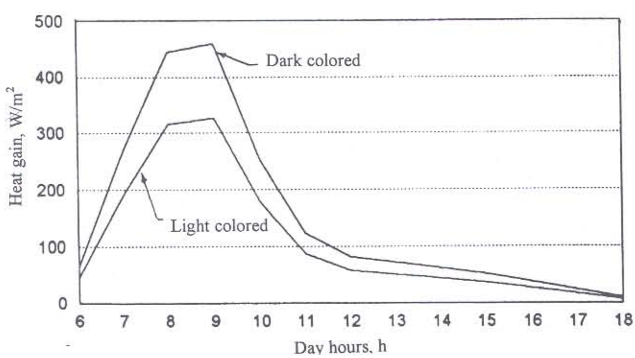

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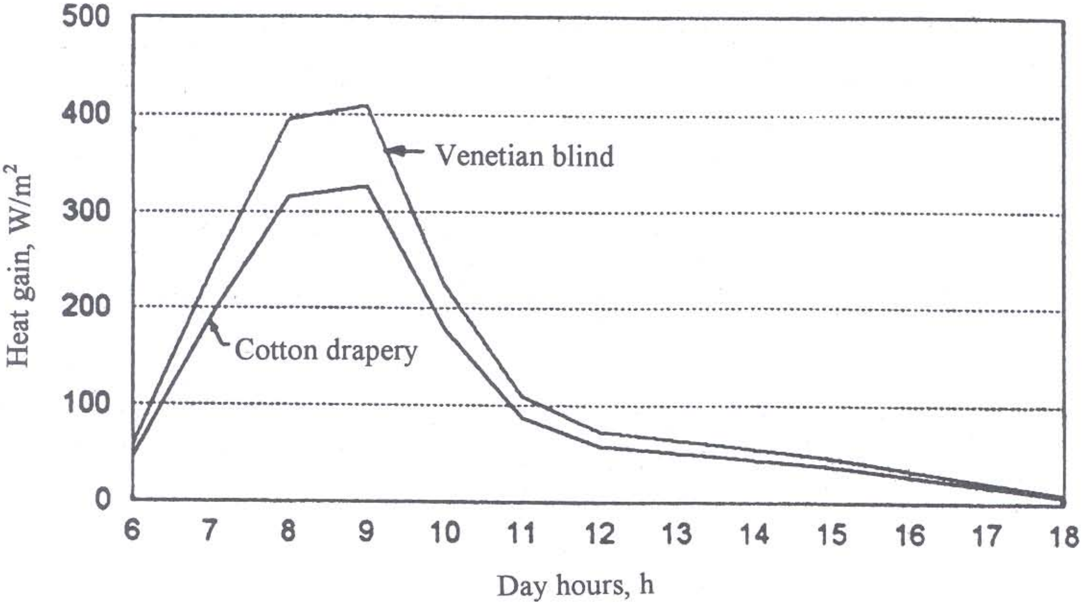

Fig. 5. Comparison of monthly-mean hourly solar heat gain through curtain and venetian blind in New Delhi for the month of May.

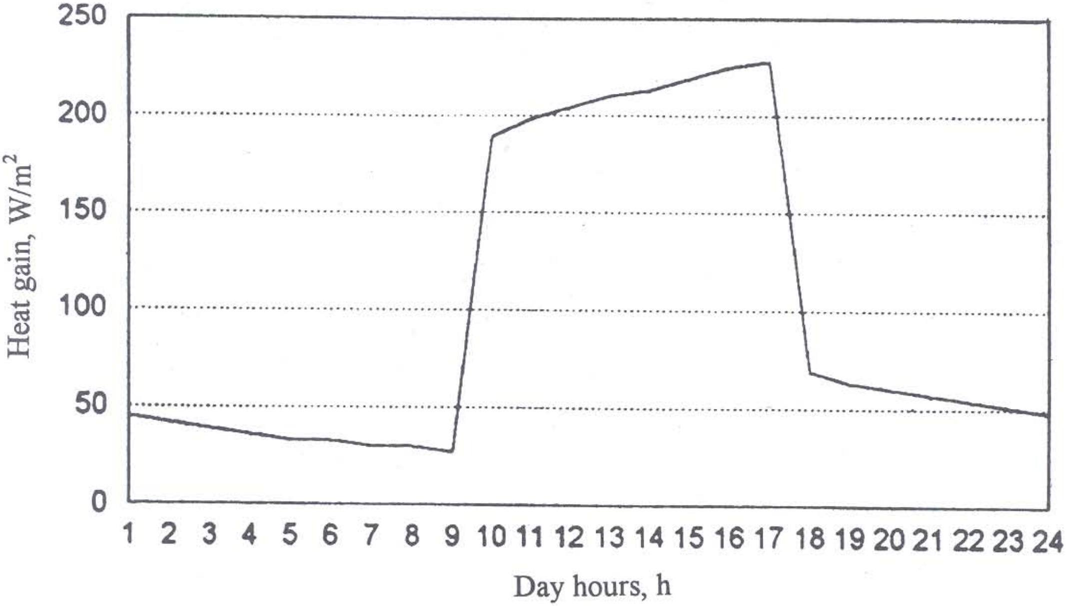

Fig. 6. A sample variation of heat gain due to 300 W lights at an office if lights are switched on during 0900 hours to 1700 hours in New Delhi for the month of May.

Table 2 Comparison of estimated and available [5] monthly-mean hourly heat gain data through traditionally used walls and roof in eight cities namely, New Delhi, Mumbai, Calcutta, Lucknow, Jodhpur, Ahmedabad, Bhopal, and Roorkee for the month of May, compared on the basis of SD and RSD [Eq. (14)]

Orientation	Delhi		Roorkee		Jodhpur		Bhopal		Mumbai		Lucknow		Ahmedabad		Calcutta	
	SD	RSD (%)	SD	RSD (%)	SD	RSD (%)	SD	RSD (%)	SD	RSD (%)	SD	RSD (%)	SD	RSD (%)	SD	RSD (%)
E	0.74	9	6.6	23	3.48	11	3.45	10.9	2.8	9	1.45	9	1.4	7	3.2	10
N	1.87	9	1.1	3	0.82	3	1.74	6	3.48	22	3.87	11	2.8	19	2.65	16
S	1.77	7	2.7	9	4.5	15	3.5	13	4.3	24	1.76	7	2.4	13	3.75	8
W	4.24	11	1.73	5	2.39	7.7	1.36	5	6.3	25	3.4	18	2.7	17	2.51	6
NE	3.2	6	2.5	16	1.42	13.1	3.12	15.9	2.9	16	4.9	15	3.3	6	3.46	16
SE	1.3	9	1.6	7	1.76	13.1	1.23	8.4	1.3	9	1.9	7	1.36	9	5.42	6
SW	1.89	7	2.98	12.8	1.75	13	1.98	7.1	3.2	13	4.4	16	6.41	16	4.45	6
NW	1.56	7.5	1.67	8.6	1.11	9.8	1.21	6.8	1.12	7.5	4.4	17	4.61	13	3.96	6
ROOF	3.4	12	2.11	15	1.08	8	1.85	9	2.78	16	1.6	7	3.4	12	3.12	15
Average	**2.21**	**8.6**	**2.55**	**11**	**2.03**	**10.4**	**2.16**	**9**	**3.13**	**15.7**	**3.07**	**12**	**3.15**	12	3.61	10

5. CONCLUSIONS

The developed software is useful to estimate heat gains through individual building components as well as total cooling load and it will be a useful tool to study the effect of various building components on the cooling load. The estimated heat gain data through walls at eight orientations were compared with that of available for eight cities, distributed well over India. Results show that average relative standard deviation for these eight cities for the month of May varies from 6.5% to 15.7%.

This work will be useful to air-conditioning design engineers, researchers, engineering students and academicians.

6. ACKNOWLEDGMENTS

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7. REFERENCES

1. Kreider, J.F., and Rabl, A. 1994. *Heating and Cooling of Buildings - Design for Efficiency*. Singapore: McGraw-Hill Inc.
2. Ding, G.D.; Pederson, C.O.; Mc cully, M.T.; and Rao, K.R. 1982. Simulation studies of building energy performance in warm and humid climates. In *Proceedings of Energy Conservation in the Design of Multi-Storyed Buildings*, pp. 41-59 .
3. Sullivan, R.; Nozari, S.; Johnson, R.; and Selkowitz, S. 1985. Commercial building energy performance analysis using multiple regression. *ASHRAE Transactions*, Paper No. 2911, (91): 337-353.
4. Sharma, M.R.; Chandra, M.; and Sharafat Ali. 1970. Climatic data and computation of cooling load, *Climate Control* 3(3): 31-41.
5. Sharma, M.R.; Chandra, M.; and Sharafat Ali. 1972. Computation of peak or average cooling loads for Indian cities- Part I-IV. *Climate Control* 5(2): 45-55, 5(3): 33-42, 5(4): 23-37, 5(5): 25-40.
6. Mitalas, G.P. 1972. Transfer function method of calculating cooling loads, heat extraction rate, and space temperature. *ASHRAE Journal* 14(12): 52-59.
7. Rudoy, W., and Duran, F. 1975. Development of an improved cooling load calculation method, *ASHRAE Transactions*. (81): 19-28.
8. American Society of Heating, Refrigeration and Airconditioning Engineers. 1989. *ASHRAE Handbook of Fundamentals*-1989, Atlanta: American Society of Heating, Refrigeration and Airconditioning Engineers,Chapter 23-28.
9. Mani, A., and Mooley, D.A. 1983. *Wind Energy Data for India*.. New Delhi: Allied Publishers.
10. ISO/TC-59-160-162-163/WG2. 1988. Thermal insulation-windows-calculation rules for determining the thermal transmittance. *International Standards Organization*.
11. Parishwad, G.V.; Bhardwaj, R.K.; and Nema, V.K. 1998. Prediction of monthly-mean hourly relative humidity, ambient temperature, and wind velocity for India. *Renewable Energy*, UK (in press).

12. Rao,K.R. 1971. Building and air-conditioning loads. *Climate Control* 4(4): 13-20.
13. Parishwad, G.V.; Bhardwaj, R.K.; and V.K.Nema. 1997. Estimation of hourly solar radiation for India. *Renewable Energy*, UK. (12):303-313.
14. Parishwad, G.V.; Bhardwaj, R.K.; and Nema, V.K. 1998. A theoretical procedure for the estimation of solar heat gain factor for India. *Architectural Science Review* 41(1): 11-15.
15. Down, P.G. 1966. *Heating and Cooling Load Calculations.* London: Pergamon Press.
16. Mitalas, G.P. 1973. Calculating cooling load caused by lights. *ASHRAE Journal* 15(6): 37-44.
17. Chandrasekaran, J., and Kumar, S. 1994. Hourly diffuse fraction correlation at a tropical location. *Solar Energy* 53(6): 505-510.