American Journal of Environmental Sciences 1 (3): 209-212, 2005
ISSN 1553-345X

A Simple Approach for Building Cooling Load Estimation

F.A. Ansari , A.S. Mokhtar, K.A. Abbas and N.M. Adam
Faculty of Engineering, UPM, Serdang, Selangor Darul Ehsan, Malaysia

Abstract: The present work is to demonstrate how some very simple problems are made mathematically complex and seemingly tedious due to academic or business compulsions. There are some problems in which mathematical model are developed after making many simplifying assumptions. But, when it comes to solving these models, very sophisticated and complex schemes are applied. For such problems, dual policy does not make sense and in many cases the problem may be tackled in a simpler way to get comparable accuracy. The present paper reports one such example. It deals with the development and authentication of computer software for estimating building cooling load. The software is simpler to use, needs fewer input data and is more versatile compared to any other commercially available, exorbitantly costly and extensively used software. The effects of significant building parameters like orientation, window glass shade type, number of glass panes used, wall insulation, roof type and floor type can be easily investigated. Effects of all these parameters have been investigated for a typical building block to arrive at an intelligent decision. With any other software or method, it cannot be made so conveniently. All the above mentioned advantages are without sacrificing accuracy and reliability.

Key words: Buildings cooling load computations, empirical approach

INTRODUCTION

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. Step by step calculation procedure has been adequately reported in the literature[1-4]. It is a scientific and exact approach, but time consuming and lengthy. Overall heat transfer coefficients for all the components of building envelope are computed with the help of thermal properties of the building materials. 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. The requisite data of building material properties, climate conditions and ventilation standard are also established and reported[5-8]. First principle is applied to yields the rates of heat transfer through different building components. All these components, when added up, give the total cooling (or heating) load of a building. This lengthy procedure makes the theoretical approach more of academic interest, which quite often, the design engineers do not prefer.

A widely popular method is by using load estimation forms; standard or developed by the designer/company. This approach saves both effort and time. Although it is an approximate method, it gives quite acceptable results for selecting suitable capacity of air conditioning units. The Air Conditioning and Refrigeration Institute (ACRI) load estimation form is very popularly used. There are many similar commercially available forms, which consist of tabulated data as function of design temperature difference. All the probable loads are included in these forms. 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. Some times, big companies prepare there own load estimate forms.

A third method is by applying computer software, standard and commercially available or developed by the designer/company. Due to omnipresence of personal computers, the third method remains the most popular these days.

Present approach: The present authors first converted the ACRI load estimation form in SI units. 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. The factor F has been given for five arbitrary values of this temperature difference. For any given temperature difference the value of F is generally interpolated and multiplied with the area of the building envelope

Corresponding Author: K.A. Abbas, Faculty of Engineering, UPM, Serdang, Selangor Darul Ehsan, Malaysia,

Table 1: Modified cooling load estimation form

ITEM 1-10 Sensible Heat only	AREA, A m^2	FACTOR, F (Circle the factors applicable)			LOAD, F*A
1. Direct solar radiation: (Figure all windows for each exposure, but use only the exposure with the largest load)		For glass black reduce factor by 50%: for storm windows or double glass reduce factor by 15%.			
		No. Shading	Inside Shade	Outside Awn.	
North-east		190	79	63	
East		158	126	79	
South-east		237	95	63	
South		237	111	63	
South-west		347	142	95	
West		473	205	111	
North-west		379	158	95	
2. Window Transmission : (Total of all windows)		ΔT = (Outside T_{db} – Inside T_{db})			
Single glass		32.26136 +4.42684*ΔT			
Double glass of glass block		0.46241 + 3.025756*ΔT			
3. Walls:					
No insulation (brick, frame etc.)		8.3932 + 1.21465*ΔT			
1 in insulation		1.6405*ΔT – 1.2103			
2 in or more insulation		4.8094 + 0.43592*ΔT			
4. Partitions:		1.14461*ΔT – 0.179986			
5. Roofs:					
(a) With vented air space and:					
No insulation		48.82143 + 1.54762*ΔT			
No insulation with attic fan		12.68333 + 0.418599*ΔT			
2 in insulation		13.810 + 0.4350*ΔT			
4 in insulation		1.332 + 0.82311*ΔT			
(b) Flat with no air space and:					
No insulation		36.81435 + 1.37692*ΔT			
1 in insulation		73.67258 + 2.7099*ΔT			
1.5 in insulation		24.01056 + 0.708693*ΔT			
3 in insulation		16.80943 + 0.435918*ΔT			
6. Ceiling: (under unconditioned room only)		2.820 + 1.144611*ΔT			
7. Floor: (Omit if over Basement crawl space or slab)					
Over unconditioned room		0.984077 – 2.7099*ΔT			
Over open crawl space		0.470845 + 1.482207*ΔT			
8. Outside air:		20 frequent door usage			
Per m^2 of floor area		2.010575 + 0.708692*ΔT			
9. People:					
10. Light & Fixtures					
11. Sub-total					
12. Latent heat allowance	30 % of item 11				
13. Total cooling load	Sum of 11 and 12				
14. Cooling load recommended					

component to get heat load through that component in Watts. It was envisaged by the present authors to write a computer program on the basis of this cooling load estimation form and compare the results with the commercially available software. The tabulated data in the form would not be suitable for writing a computer program. It would be more convenient if a single formula is known for each case. With this in view, a linear equation was developed for each load type. Thus the modified load estimation form looks as shown in Table 1.

With this new table, it was quite easy to write a computer program. The only data in tabular form to be incorporated into the program was that for direct solar radiation. The input data for this program consisted of the dimensions of all the conditioned spaces and the internal load components read from appropriate data tables. In each category of the building envelope, the type will be chosen by the program itself by an integer specified for a particular type in the conditional GO TO statement. The program can be executed in a single stretch to give printout of cooling loads of individual spaces, total sensible load of the building as well as it gross cooling load.

RESULTS AND DISCUSSION

First of all, the validity of the software was checked by making cooling load calculation for a typical building block shown in Fig. 1. The Carrier software was also used to calculate the cooling load for the same building. The building block had a height of 3 m and all the dimensions shown in Fig. 1 are in meters. The estimate by the present software was found to be 5.2% higher than that obtained from Carrier software. The present software has potential of investigating the effects of significant building parameters on the cooling load, which may be treated as its unique feature.

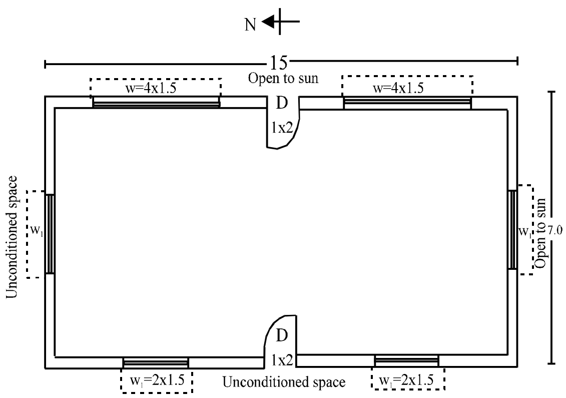

Fig. 1: A typical building block

The effect of building orientation, or the direction of transparent glass surfaces, has been shown in Table 2. The cooling load will be minimum when all the transparent surfaces are kept facing east. Load for other building orientations have, therefore been compared with this minimum load. Percent increase in each case has also been shown in this table. It is observed that the west facing glass surfaces result into maximum cooling load, which is 26.43 % higher than the minimum.

Table 2: Effects of building orientation on gross cooling load

Orientation with respect to sun	Gross cooling load, CL (kW)	% Increase with minimum, (CL-CL2)x100/CL2)
1. N-E facing glasses	15.20	6.29
2. East facing glasses	14.30	0.00
3. S-E facing glasses	15.24	6.57
4. South facing glasses	15.24	6.57
5. S-W facing glasses	16.56	15.80
6. West facing glasses	18.08	26.43
7. N-W facing glasses	16.95	18.53

The effect of shade type on the window glass is also investigated and has been shown in Table 3. As expected, the minimum cooling load was needed when there was outside awning. If no shading is provided, the gross cooling load will increase by 18.25%.

Table 3: Effect of shades on window glass

Shade type	Gross cooling load, CL (kW)	% increase with min. CL, (CL-CL3)x100/CL3)
1. No shading	16.91	18.25
2. Inside shading	14.73	2.30
3. Outside awning	14.30	0.00

Table 4 shows the effect of type of window glass pane on the gross building cooling load. With single glass pane, the load is 8.9 % more than that with double glass pane windows.

Table 4: effect of type of window glass pane

Glass pane type	Gross cooling load, CL (kW)	% Increase with min. CL, (CL-CL2)x100/CL2
1. Single glass pane	15.57	8.88
2. Double glass pane	14.30	0.00

Table 5: Effect of wall insulation on cooling load

Wall insulation	Gross cooling load, CL (kW)	% Increase with min. CL, (CL-CL2)x100/CL2
1. No insulation	15.23	6.50
2. 1 in insulation	15.03	5.10
3. 2 in insulation	14.30	0.00

The effect of wall insulation has been shown below in Table 5. Without insulation, the gross cooling load was found to be 6.5 % higher than that when heavy 2 in insulation were used. This comparatively smaller increase necessitates having a comparative economic analysis before going for insulation of the walls.

The effect of roof type on the building cooling load was thoroughly investigated for all the roof types included in Tables 1. The findings of these investigations have been shown in the Table 6 shown below. Pitched flat roof with vented air space and 4 in insulation gives minimum gross cooling load. Flat roof with no air space and no insulation gives maximum gross cooling load, which is 80.8 % more than the minimum value. A large variation can be observed in the cooling loads with different types of roof. Special care is therefore, needed for designing the most suitable roof for an air conditioned building.

Table 6: Effect of roof type on cooling load

Roof type	Gross CL (kW)	% Increase with min. CL(CL-CL4) X 100/CL4
1. Flat with air space & no insulation	20.92	46.29
2. Flat with air space, attic fan & no insulation	20.92	46.29
3. Pitched flat with vented air space & 2 in insulation	14.93	4.41
4. Pitched flat with vented air space & 4 in insulation	14.30	0.00
5. Flat with no air space & no insulation	25.85	80.77
6. Flat with no air space & with 1 in insulation	19.24	34.55
7. Flat with no air space & with 1.5 in insulation	16.61	16.15
8. Flat with no air space & with 2 in insulation	15.25	6.64
9. Ceiling under un-conditioned space	15.25	6.64

Table 7: Effect of floor type on cooling load

Floor type	Gross CL (kW)	% Increase with min. CL, (CL-CL1)x100/CL1
1. Over un-conditioned space	14.30	0.00
2. Over open crawl space	15.35	7.34

The effect of floor type has been shown in Table 7. Floor over open crawl space gives 7.34 % higher cooling load than that over un-conditioned space.

CONCLUSION

The cooling load calculation described in the present paper is simply based on the rule of thumb. It may be called a computer version of cooling load estimation form. But surprisingly enough it gives very reliable results, which are almost the same as those obtained by the sophisticated and costly commercial software developed and marketed by the renowned MNCs. It is very easy to use and requires quite few number of data input. It is also capable of being used as a good tool to make thorough investigations of different building parameters and its orientation before starting the construction.

REFERENCES

1. Stoecker, W.F. and J.W. Jones, 1982. Refrigeration and Air Conditioning. McGraw Hill, Int. Edn.
2. McQuiston, F.C. and J.D. Parker, 1982. Heating, Ventilating and Air Conditioning, Analysis and Design. John Wiley and Sons, New York.
3. Threlkeld, J.L., 1970. Thermal Environmental Engineering. 2nd Edn., Prentice Hall, Englewood Cliff, N.J.
4. Rudoy, W., 1979. Cooling and Heating Load Calculation Manual. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Ga.
5. ASHRAE Handbook, Fundamentals Volume, 1981. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Ga.
6. Thermal Environmental Conditions for Human Occupancy, ASHRAE Standard 55-81, 1981. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Ga.
7. Standard for Ventilation Required for Minimum Acceptable Indoor Air Quantity, ASHRAE Standard 62-81, 1981. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Ga.
8. Prasad, M., 1989. Refrigeration and Air Conditioning Data Book. Wiley Eastern Limited, New Delhi.