EFFECT OF DISTRIBUTION PERCENTAGE OF RADIANT HEAT ON LOADS IN AN UPWARD DISPLACEMENT ROOM

Zhi-Wei Lian

Deptartment of Environmental Engineering, Xi'an University of Architecture & Technology, Xi'an 710055, P. R. China

Abstract

In the paper cooling loads are calculated and analysed under different distribution percentages of radiant heat sent out by indoor heat sources to the envelope of an upward displacement ventilation room with different constructions. It is found that the former approximate methods of distribution percentage will cause big errors when accurately calculating the cooling loads formed by radiant heat gains from indoor heat sources. The accurate method should be calculating the cooling loads based on the actual distribution percentage to each of the inside surfaces of the room.

Key words: *air-conditioning; upward displacement ventilation; cooling load; distribution percentage; radiant heat*

1. Introduction

It is well known that there is an attenuation and delay process for radiant heat sent out by a heat source before it becomes cooling loads of a room, no matter what kind the heat source is. And it is inevitable that the problem of distribution percentage of radiant heat would be encountered when air conditioning cooling loads are accurately calculated. Different envelopes cause different cooling loads when the radiant heat goes through them at any time. Therefore, distribution percentage of radiant heat on the envelopes directly influences the cooling loads of the room at each hour. A systematic study on this problem has not been made till now, however. Different solutions to this problem are used domestically and abroad, when calculating cooling loads of rooms. For example, as regard to indoor heat sources (including heat equipment, lighting fixture and occupant), radiant heat is generally evenly distributed, by area, on the inside surfaces of the envelope[1,2], and as to solar radiant heat, the same method as above is used[3,4], and another method is also applied in the computation, such as that 50% of the radiant heat is distributed on the floor and the other 50% is evenly distributed by area on the other inside surfaces[5]. What about the result differences when these methods are used to deal with the cooling loads of the same room? The authors of reference [4] think it is almost feasible to suppose the solar radiant heat evenly distributed by area to the envelope when dealing with the intermittent air conditioning cooling loads of an office building. Now it is discussed in the paper as regard to indoor heat sources inside an upward displacement ventilation room.

2. Calculation and analysis

Different constructions of a room cause different cooling loads at each hour as regard to the same affecting factor. A computer program is made to calculate cooling loads of a room through building a set of partial differential equations and solving them to obtain response factors of the envelope and through considering view factors of radiant heat transfer and considering the distribution percentage of the radiant heat to each inside surfaces of the envelope[6]. Table 1 shows the results of cooling loads in the occupied zone calculated by the program, when a unit step factor affecting the envelope of an air conditioned room with medium-weight type construction according to the following radiant heat distribution method:

1) radiant heat is evenly-distributed by area to each inside surfaces and the corresponding cooling load is expressed by CL_A;

2) 50% of the radiant heat is distributed on the floor and the other 50% is evenly distributed by area on the other inside surfaces. The corresponding cooling load is expressed by CL_D;

3) all of the radiant heat is distributed to an inner wall, outer wall, floor and ceiling, respectively. And the corresponding cooling load is expressed by CL_I, CL_O, CL_F, CL_C, respectively.

Thermal property data of material in each wall are obtained from reference [7].

Tab. 1 Effect of distribution percentage on the cooling load in an upward displacement ventilation room

Time(h)	CL_A(W)	CL_D(W)	CL_I(W)	CL_O(W)	CL_F(W)	CL_C(W)
1	0.1418	0.1321	0.1801	0.1727	0.1164	0.0190
3	0.1842	0.1764	0.2370	0.2152	0.1639	0.0323
5	0.2108	0.2059	0.2701	0.2400	0.1981	0.0433
10	0.2512	0.2514	0.3182	0.2761	0.2519	0.0639
20	0.2887	0.2912	0.3642	0.3112	0.2951	0.0856
40	0.3120	0.3129	0.3939	0.3382	0.3144	0.0987

It can be seen from table 1 that there are big differences among the methods. The maximum cooling load occurs when the affecting factor is only on the inner wall and the minimum on the ceiling. It is not difficult to explain through the two main factors causing the cooling load in an upward displacement ventilation room. One is the distribution percentage of radiant heat in occupied and non-occupied zone; The other is the coefficient of the convective heat transfer of each inside surface. According to reference [8], as regard to the room with upward displacement ventilation system, it can be got

$$\alpha_c(side\ wall) > \alpha_c(ceiling) > \alpha_c(floor)$$

Of course, the latter four methods are the limit situations which are supposed for analysis. It is very commonly seen, however, for the heat equipment to stand near the inner wall in practical engineering (eg. big computer room). Distribution percentage of the radiant heat of the equipment to the inner wall is much bigger at this time.

Now let's analyse a calculation example. According to the characteristics of a room with upward displacement ventilation, we divide the room into two sections: occupied zone and non-occupied zone. In this way, the envelope of the room consists of thirteen faces (as shown in figure 1). Faces 1, 2, 5 and 6 refer to the inside surfaces of the side walls and 7, 8 to the window and door in the occupied zone, respectively, and faces 9 ~13 stand for the inside surfaces of the envelope in non-occupied zone. Dimensions of an indoor heat source are 0.5 × 2.0 × 2.0m(H). Its temperature and emissivity are 60℃ and 0.94, respectively, standing on the floor of a room, shown in figure 1.

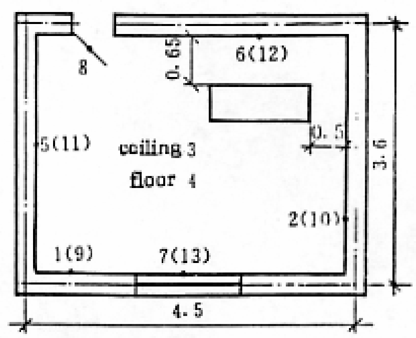

Fig. 1 Position of a heat source in a room in the calculation example

Distribution proportions of its radiant heat to each inner surface are obtained from references [9] and [10] as 0.0693, 0.1310, 0.1135, 0.1817, 0.0432, 0.1987, 0.0269, 0.0735, 0.0275, 0.0350, 0.0193, 0.0599, 0.0151. According to the proportions, cooling loads in the occupied zone of the room, CL_E, can be calculated as shown in figures 2 and 3 when the room is of heavy and light construction, respectively. The cooling loads are not shown in figures 2 and 3 when all the radiant heat affects the ceiling because they are much smaller compared with the others.

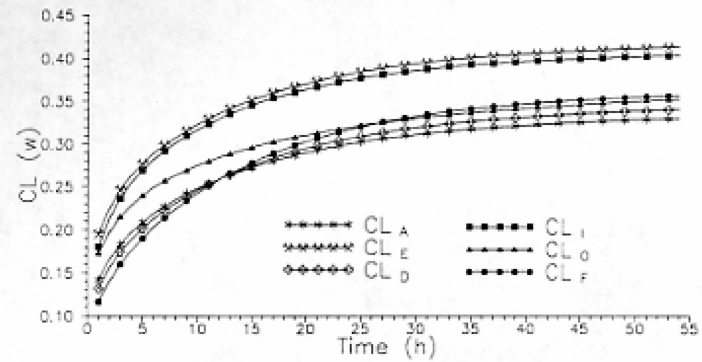

Fig. 2 Effect of different distribution percentages on cooling loads of a heavy construction room when the heat source is near the inner wall

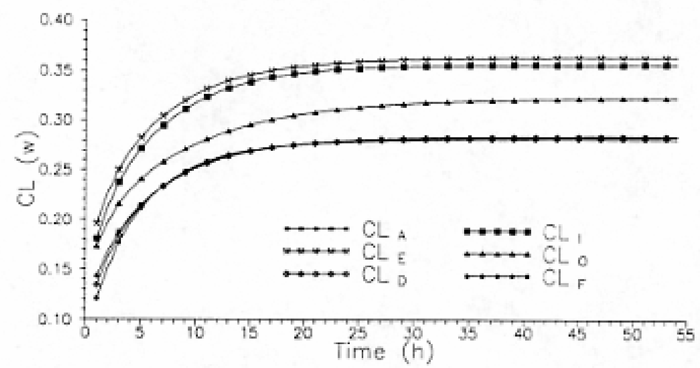

Fig. 3 Effect of different distribution percentages on cooling loads of a light construction room when the heat source is near the inner wall

It can be seen from figures 2 and 3 that there are big differences between the cooling loads calculated by each method and the calculation example, no matter what kind the room is, heavy, medium or light construction. The same conclusion can be got when the position of the equipment is changed to the center of the floor and other conditions are kept unchanged, shown as figure 4 (the distribution percentage is still obtained from reference [9] and [10]).

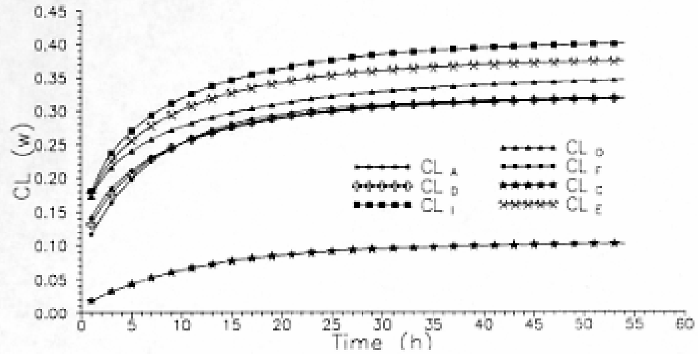

Fig. 4 Effect of different distribution percentages on cooling loads of a medium construction room when the heat source is at the center of the floor

3. Conclusion

It is found, from the analysis above, that the former approximate methods of the distribution percentage of radiant heat will cause big errors to the cooling load calculation, such as the method of evenly-distributed by area on inside surfaces of the envelope, when accurately calculating the loads formed by strong radiant heat from indoor heat sources, no matter what kinds the rooms are. The accurate method should calculate the cooling loads based on the actual distribution percentage of the radiant heat to each of the inside surfaces of the room in practical engineering.

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