RADIANT CEILING HEATING AND LOCAL THERMAL DISCOMFORT

Mária BUDIAKOVÁ

Slovak University of Technology, Bratislava, Slovak Republic

ABSTRACT

In the introduction of the paper are reasons presented, which cause local thermal discomfort. Currently the reasons of asymmetric thermal radiation are not clearly explained. Therefore I oriented my experimetal laboratory measurements, which were carried out in a special microclimatic laboratory on radiant ceiling heating. A special laboratory model of heating of interior was created. The measurements were performed with the help of a thermal mannequin that was used to measure the asymmetric radiation (that is asymmetry of perceived temperature). The analysis of the graphic results of measurements shows in radiant ceiling heating in their three important directions: direction I (from the front and the back), direction II (from the right and the left side), direction III (from the above and the underneath side). The IMPROVEMENT is for ceiling heating, as well as for all directions of sensing by the mannequin, stated in the study. By IMPROVEMENTS I mean improvements in heating system that reduce the local thermal discomfort. The improvements of heating system include the size of the heating surface, its location and its surface temperature.

KEYWORDS

Radiant ceiling heating, local thermal discomfort, asymmetric thermal radiation, experimetal laboratory measurements, asymmetry in directions of sensing I, II, III, IMPROVEMENTS in removal of asymmetric radiation.

1. INTRODUCTION

In majority of heated interior spaces the local thermal discomfort can be developed. That is caused by obscurity of the reasons of local thermal discomfort and by unclear possibilities of their elimination. Currently the least clarified and the most serious area of local thermal discomfort is asymmetric radiation. Asymmetric radiation is caused by a warm or cold wall, ceiling, floor or a cooling window. The measurements in experimental laboratory were done to analyse the problem of asymmetric radiation and find proper solution for its elimination.

2. METHODOLOGY OF EXPERIMENTAL LABORATORY MEASUREMENTS

Before I started the measurements, I created a laboratory model of room heating (Bánhidi 1968). I realized the laboratory model in the special microclimatic laboratory.

2.1 Laboratory Model of Room Heating

The aim of creating the laboratory model was to simulate thermal - humidity microclimate for radiant ceiling heating. The outdoor climate conditions were simulated too. The model had been mathematically defined with a system of equations by the air temperatures t_a = 18, 20, 22 °C for the room with one perimeter wall (1 PW, the room is in the middle location of a building) and with two perimeter walls (2 PW, the room is in the corner location of a building). After the substitution of other marginal parameters I calculated the following values for radiant ceiling heating.

TABLE 1
Values for Radiant Ceiling Heating

Air Temperature t_a	Surface Temperature of Ceiling $t_s^{ceiling}$		Surface Temperature of Floor t_s^{floor}	
	1 PW	2 PW	1 PW	2 PW
18	31,99	38,68	20,12	22,84
20	34,86	42,18	22,20	25,14
22	37,63	45,18	24,46	27,51

Ceiling HS (heating surface) covered 80 % from total heat loss and the remaining the floor HS 20 %. Heating surface sizes were with 1 PW and with 2 PW $S^{ceiling} = S^{floor} = 2{,}08\ m^2$.

2.2 Experimental Laboratory Measurements

The aim of measurements was to record parameters of the thermal mannequin by the designed laboratory model and by the basic measurement. Measurements took place in a measuring room of the special mikroclimatic laboratory in standpoints A, B, C, D, Figure 1.

Surface temperatures were simulated by aluminium panels (Figure 1) as follows: window panel a; sill panel b; wall panel c; floor panels d,e,f; ceiling panels g,h,i (locality as in the case of the floor). Other surfaces were kept at air temperature. Heating surfaces (HS) have been simulated in the following way:

at 1 PW (perimeter wall) and 2 PW — floor HS by parts of panels d, e
ceiling HS by parts of panels g, h

All surfaces of the measuring room were kept by **the basic measurement** at air temperature.

I used the following devices for the measurements:

– Thermal mannequin (1). It consisted of eighteen parts. Every part measured five parameters in every twenty seconds. The measuring accuracy unit of the thermal mannequin was connected to the computer and it computed additional four parameters. Thermal mannequin was dressed in a morning dress .

– Logger. It measured air temperatures and surface temperatures.

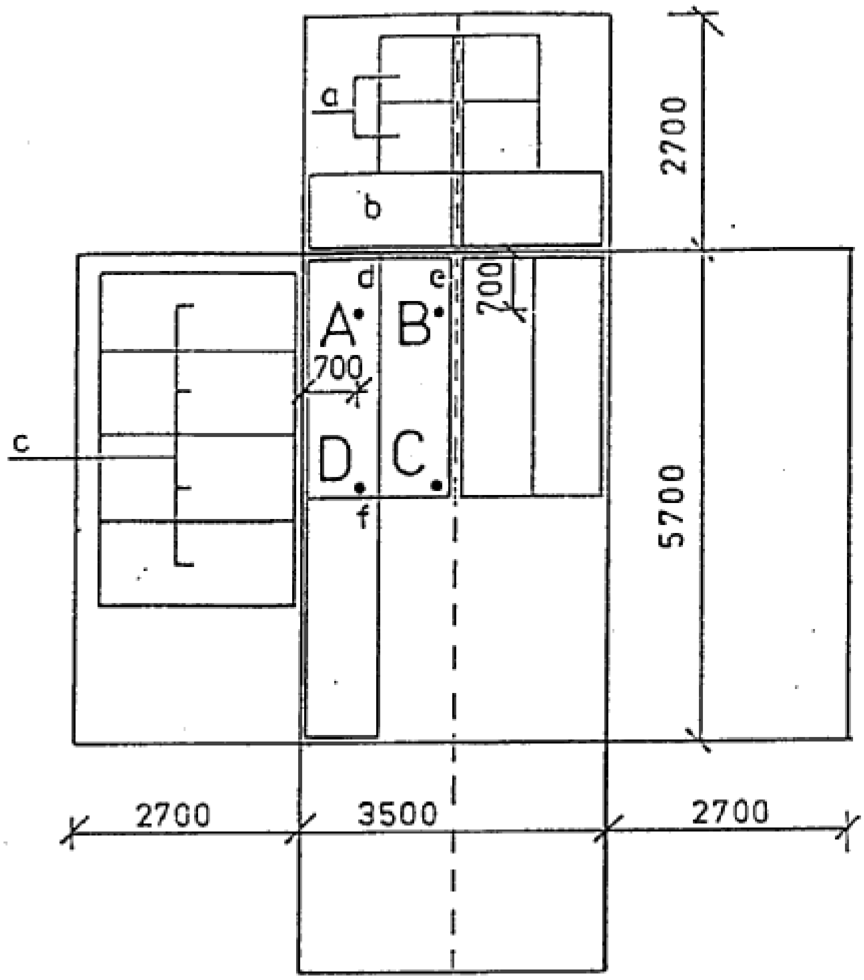

Figure 1: Measuring Room of Special Microclimatic Laboratory

3. RESULTS OF EXPERIMENTAL LABORATORY MEASUREMENT

I computed the asymmetric radiation (that is the asymmetry of perceived temperature – t_p) from measuring values t_p of all mannequin parts. In the first computation phase I ascertained the difference of perceived temperatures with the following arithmetical formula:

$$'t_p = t_p^{heating} - t_p^{basic}$$

Parameter $'t_p$ represents the perceived temperature of one part of the mannequin. This temperature was induced by the radiant thermal flow from the interior. Therefore this parameter is suitable for determination of asymmetric radiation. In the second computation phase I computed the Δt_{pe} difference from the $'t_p$ values of the opposite mannequin parts. The asymmetric radiation was developed in three directions of interior:

– direction I (from the front and the back),
– direction II (from the right and the left side),
– direction III (from the above and the underneath side).

Therefore I integrated the opposite mannequin parts to three different directions. In each directions of sensing (I, II, III) I summed up the Δt_{pe} differences by which I obtained the asymmetry of perceived Δt_p temperature. The Δt_p values are figured by 1 PW and 2 PW, in standpoints A, B, C, D, by t_a = 18, 20, 22 °C in directions of sensing I, II, III in Figure 2.

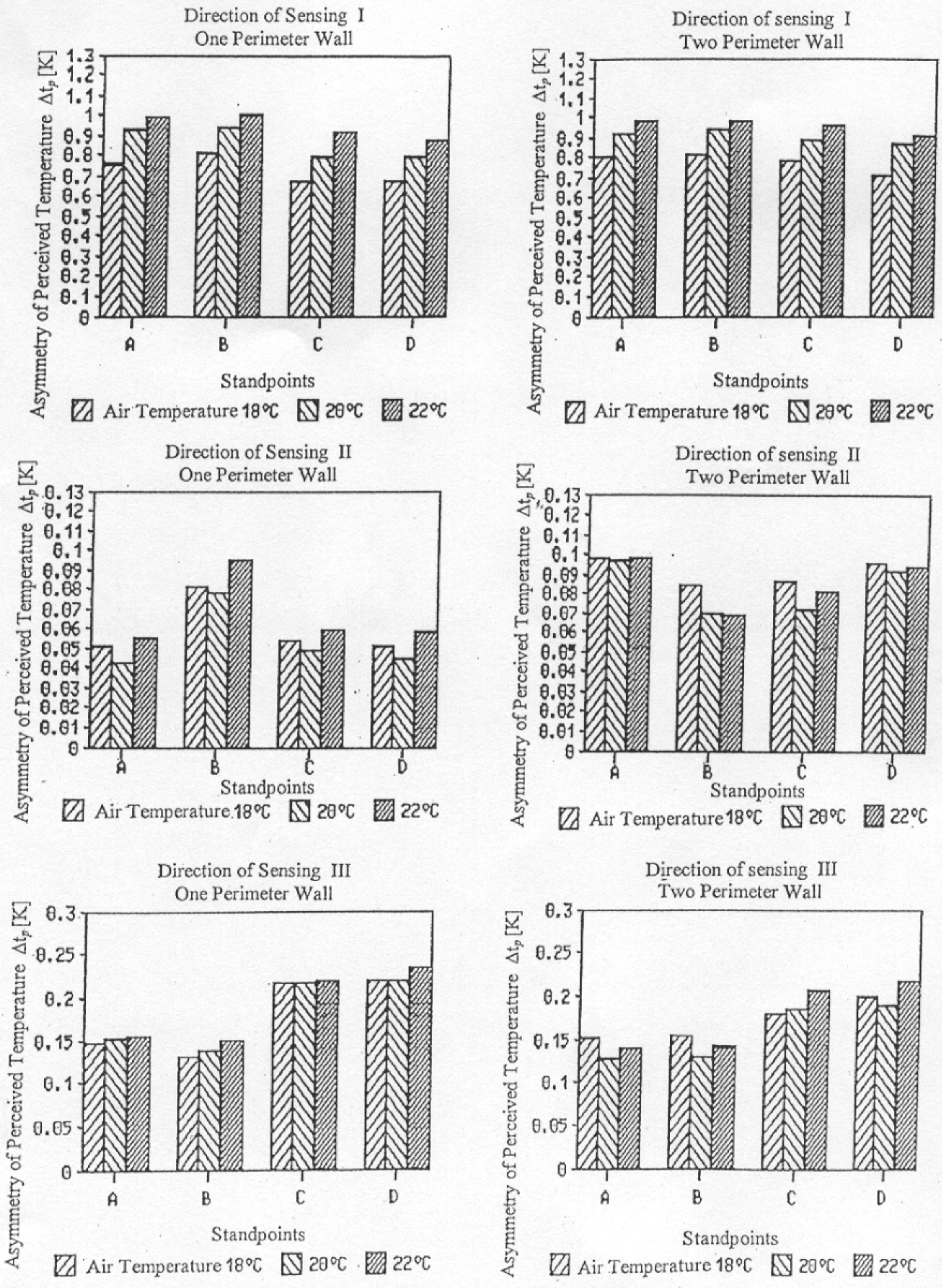

Figure 2: Comparison of Δt_p Values by 1 PW and 2 PW in Directions of Sensings

4. RESULTS OF THE ANALYSIS OF THE EXPERIMENTAL LABORATORY MEASUREMENTS

4.1 Direction of Sensing I

Direction of sensing I represents the direction of incidence radiant heat flow at the mannequin from front and the back.

Small asymmetry was caused from the equivalent quantity of incidence radiant heat flow at the front and at the back. With 2 PW in standpoints C, D more asymmetry was caused by the second PW and the absence of incidence radiant heat flow at the back of the mannequin. IMPROVEMENT: asymmetry in standpoints C, D can be reduced by using ceiling HS outside of the cooled surface, too. In this case the second part of ceiling HS has got low $t_s^{ceiling}$ value.

4.2 Direction of Sensing II

Direction of sensing II represents the direction of incidence radiant heat flow at the mannequin at the right and the left side.

With 1 PW in standpoint B asymmetry was small. In standpoint B asymmetry was caused by bigger incidence warm heat flow at the mannequin from the left than from the right side. With 2 PW in standpoints A, B, C asymmetry was increased. IMPROVEMENT: another part of ceiling HS with low $t_s^{ceiling}$ value has to be located into the middle and into the back part of the interior.

4.3 Direction of Sensing III

Direction of sensing III represents the direction of incidence radiant heat flow at the mannequin from the above and underneath side.

With 1 PW and 2 PW in standpoints A,B the asymmetry was small but in standpoints C, D the asymmetry was bigger. In standpoints C, D warm incidence radiant heat flow wasn´t compensated in the level of the head. IMPROVEMENT: another part of ceiling HS with low $t_s^{ceiling}$ value has to be located in the middle and into the back part of interior. In higher buildings from the entire heat flow needed for thermal comfort in interior 70 % should be covered by ceiling HS and 30 % by floor HS (i.e. the ceiling HS of the lower floor).

5. CONCLUSIONS

a./ The described analysis created the image of the asymmetric radiation. For the respectable asymmetry (i.e. respectable local thermal discomfort) I consider such value of asymmetry, which is developed by index PPD = 20 % (i.e. 80 % of persons will perceive local thermal discomfort as respectable). If this specified value of asymmetry is not fulfilled, the suggested IMPROVEMENTS have to be used to eliminate the local discomfort.

b./ Creation of single sided big radiant heat flow in direction I, II, III can be avoided, i.e. it is possible to remove the local thermal discomfort by keeping the following REQUEST: the size of HS and their value of surface temperature have to be chosen and located in a way, that the amount of the heat flow from all directions is equal.

c./ The removal of local discomfort with keeping the REQUEST and with the application of IMPROVEMENTS is most necessary in direction of sensing I. This is the cardinal direction of all three directions of sensing as it influences 43,7 % from total effective area of man. Direction of sensing II is the second cardinal direction, because it influences 31,2 % from the total effective area of man. Direction of sensing III is the least significant direction, because it influences only 25,1 % from total effective area of man. It proves the little difference between single standpoints in direction of sensing III. Therefore this direction of sensing of asymmetry causes the smallest discomfort for a person in sitting position.

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