Thermal Comfort Measurements In Large Window Offices

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***Abstract*—A growing number of office buildings have large window surfaces. The architects prefer this solution because of the building's beauty external appearance and because of the natural lighting. The greatly increased incoming direct solar radiation can adversely affect comfort sensation. For these reasons are essential the application of external shading devices. On-site measurements were made in summer in such an office building. We evaluated the thermal comfort under PMV, PPD and air quality based on carbon dioxide concentration. The measurement results were evaluated with scientific research methods, which results we present in this article. The thermal sensation may play important role in especially for office buildings because thermal discomfort deteriorates human productivity. The results of measurements give assistance to planning. Chilled beams were operated in the office building, the measurement results helped improve the regulation of HVAC.**

keywords: thermal sensation, measurement, PMV, PPD, solar radiation, draught

I. Introduction

In office buildings the thermal comfort and indoor air quality determine the comfort sensation and productivity of people. To be efficient at work needs to be essential to thermal sensation and indoor air quality. It could be possible to evaluate only on objective measurement method. The best indicators of the thermal sensation are the PMV, PPD and these values can definitely be measured in an operating office building. The requirements of CR 1752 were based on the evaluation of comfort.

The results of measurements were evaluated on the base of probability theory. The assumption was that the measurement results followed by distribution of the Gaussian distribution. The daily office work period was interpreted between 7 a.m. and 7 p.m. In every offices we determined by daily measurements the average value and standard deviation of measured data. The CR 1752 comfort categories were determined based on the double average absolute deviation ($\pm 2\times\sigma$) from the mean value (μ) of the measurements and calculations. It is reported corresponding safety because according to the probability theory based on Gaussian distribution the 95.44% of the results located into this range ($\mu \pm 2\times\sigma$).

II. Methods

The office building contained nine stairs, two of that located underground. In stairs of above-ground were found the offices and meeting rooms. These offices were single and landscaped offices. The total floor area was about 4000 m^2. The building consisted of two longitudinal sides: north and south facing. The window fronts were built without external shading. On the underground stairs were found the garages and technical rooms. The internal environment assessment was carried out according to CR 1752. We were evaluated the temperatures, thermal sensation, draught rates and the carbon dioxide concentration. The measurements results were determined in each compartment the comfort categories and the distribution of categories. Offices were air-conditioned by chilled beams. The total number of operating chilled beams was 562 pieces. The planned cooling water temperature was 15/18°C. The total performance of chilled beams was 660 kW. In the offices were working 750 persons and the planned specific fresh air volume was 45 m^3/h per person.

We were selected typically oriented rooms (9 pieces) to evaluate the comfort in offices. The continuous measures were done from May 10th to September 30th. The measured parameters and sampling frequencies are included in Table I.

The operating characteristics of the climate system is continuously measured, the measured characteristics and the sampling frequencies are shown in the Table II.

The instruments used for measuring temperatures and the thermal parameters were Testo instruments and for measuring the carbon dioxide concentration was Horiba equipment. The daily measured data was processed with an own developed computational program.

TABLE I.
COMFORT PARAMETERS

Measured parameter	Sign	Sampling frequency
Air temperature	t_i	5 min
Mean radiant temperature	t_r	5 min
Relative humidity	φ	5 min
Mean air velocity	w	12 sec
Carbon dioxide concentration	c_{CO2}	5 min

TABLE II.
SYSTEMS OF AIR CONDITIONING

System	Measured parameter	Sign	Sampling frequency
Chilled beam	Entering - cooling water temperature	t_{we}	5 min
	Leaving - cooling water temperature	t_{wl}	5 min
Air handling unit	Supply air temperature	t_{sa}	5 min
	Leaving - cooling water temperature	t_{wl}	5 min

III. RESULTS

The measuring results were registered steady by the data loggers. The data were processed with an own developed computational program and the following parameters were calculated from the data:

Predicted Mean Vote (*PMV*), Predicted Percentage of Dissatisfied (*PPD*), located mean air velocity, (*w*), Turbulence intensity (*Tu*), Draught rating (*DR*). The mean value and dispersion of the calculated and measured values were processed daily and we determined the characteristic of the distribution.

A. Thermal sensation

Figure 1 shows the daily changing of *PMV* values in the case of north and south-east oriented office rooms. The effect of solar radiation the maximum values of *PMV* were greater by 0.36 the case of south-east oriented office rooms. Figure 2 shows *PPD* values for the same day of these represented rooms. The selected diagram illustrates correctly the divergent thermal sensation north and south-east oriented office rooms. The maximum of the *PPD* value was 23.6% in the case of south-east oriented office room and 10.9% by the north oriented office room. The significant divergence caused by the lack of external shading.

B. Draught

The characteristic of the draught was favourable irrespective of the orientation by the case in that office building. The changing of the *w*, *Tu*, *DR* values can be seen on Figure 3 for the same chosen day seen on the previous figures. There was no significant difference in shaded and sunlit offices for *w*, *Tu*, and *DR* values. It is fully visible that the chilled beams supply favourable draught sensation. The maximum of *DR* value was 5.25% and the local mean air velocity was less than 0.1 m/s in the occupied zone.

C. Indoor air quality

Figure 4 shows the daily change of the carbon dioxide concentration in the comfort zone of a represented office room for a chosen day. After the starting of work the carbon dioxide concentration in the comfort zone increased significantly because of the breathing of people. It can be seen the reduction of the carbon dioxide concentration in the lunchtime.

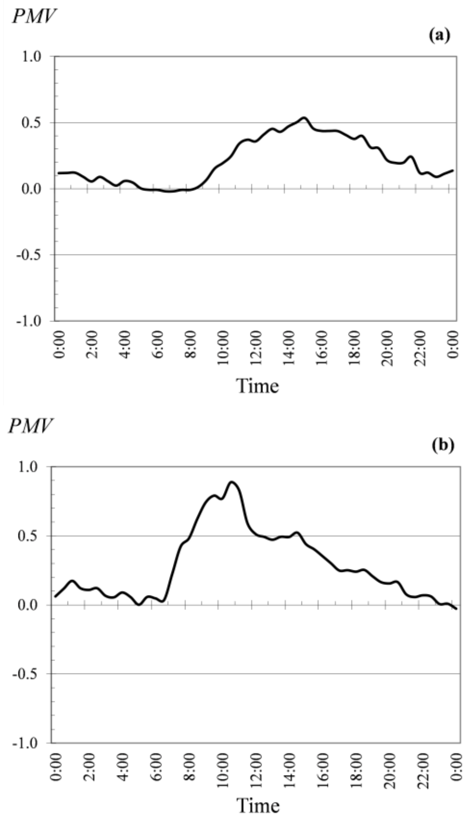

Figure 1. *PMV* values of calculations.
a) North oriented office, b) South-east oriented office

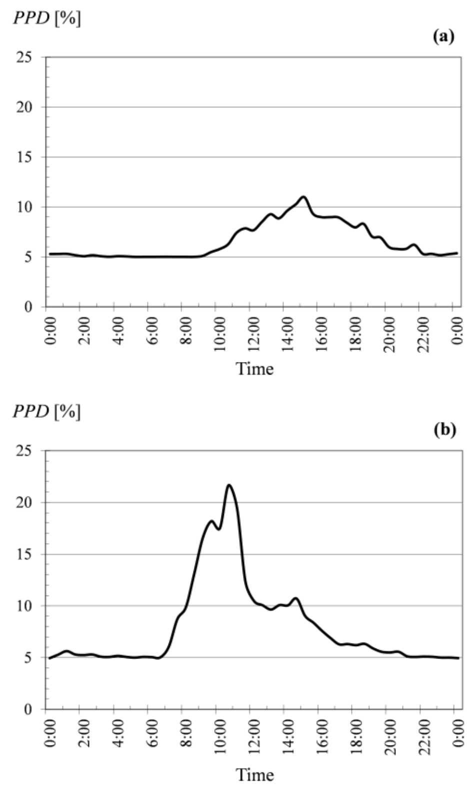

Figure 2. *PPD* values of calculations.
a) North oriented office, b) South-east oriented office

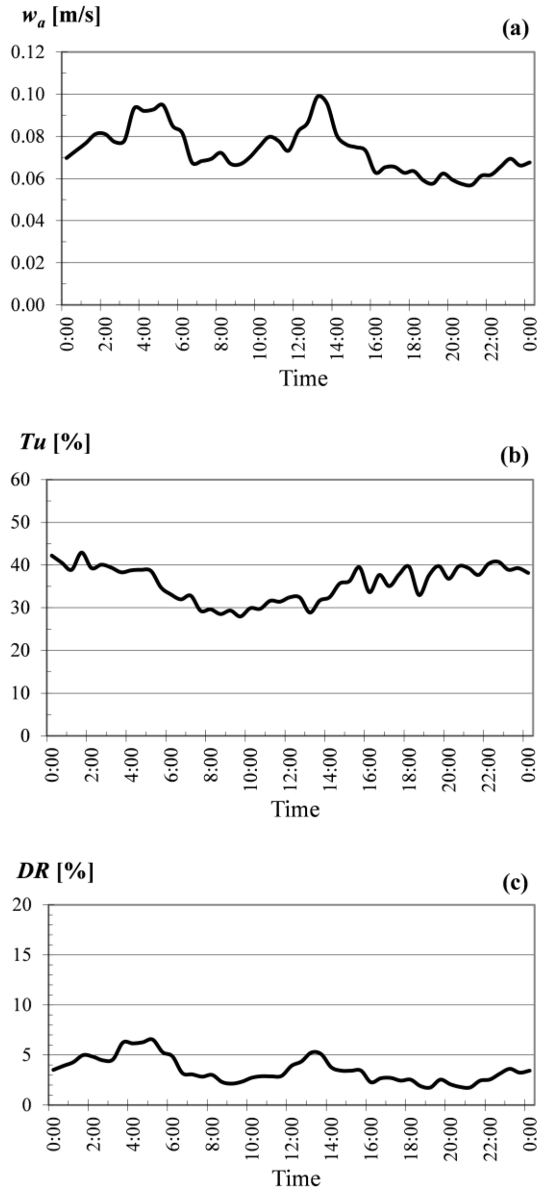

Figure 3. Specifics of draught
a) Local mean air velocity,
b) Turbulence intensity,
c) Draught rating.

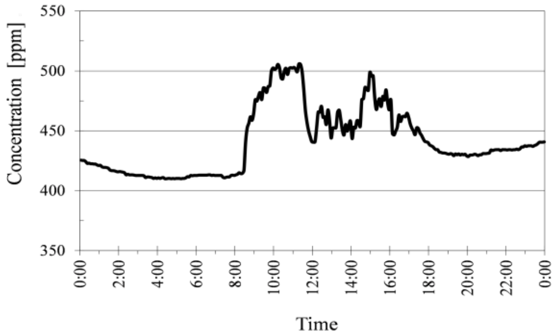

Figure 4. Measurement of the carbon dioxide concentration

IV. Discussion

The sample frequencies and the instruments accuracy made possible the exact calculation and evaluation of the comfort parameters. All measured and calculated parameters were evaluated with the method of probability theory. During the evaluation the Gaussian distribution was taken based on the double average absolute deviation ($\pm 2\times\sigma$) from the mean value (μ) of the measurements and calculations. With the probability theory we determined the category (CR 1752: “A”, “B”, “C” and “>C”) according to the 95.44% confidential range of the parameter value.

V. Conclusions

During the evaluation we made the distribution of the comfort parameters by comfort categories. Figure 5 shows the significant difference between the distributions of the thermal comfort, air temperature, draught sensation and carbon dioxide concentration. The examined rooms filled the category „A” requirements in the case of the draught sensation with 90.3%, carbon dioxide concentration with 73.7% and air temperature 37.4%. According to thermal comfort there was no result for category “A”.

This conclusion of the comfort sensation caused by the lack of shadowing in south oriented rooms. The external shading could improve the thermal comfort and reduced significant the cooling energy consumption. Based on the results of the measurement’s evaluation will be built external shading devices on the facade of the office building and the regulation of the HVAC systems will be optimized.

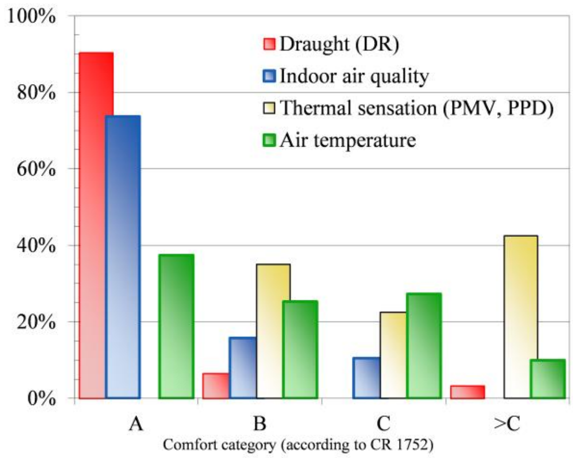

Figure 5. The distribution of measured results by category

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