Comfort assessment in an office building in Budapest, Hungary

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Abstract. A historical office building was refurbished in Budapest a few years ago. An energy audit was made in the renovated building. During the energy audit a comfort questionnaire was prepared in order to assess the occupants' opinion about comfort parameters. The questionnaire was filled out by 65 employees. Using the questionnaire the occupant opinion on comfort conditions, as well as operational information and complaints can be gathered. During the energy audit the air temperature was measured by dataloggers in different places to collect real temperature data. The paper presents the developed comfort questionnaire, the results of the occupant comfort survey and the temperature measurements and how these can be considered during the elaboration of recommended interventions.

1 Introduction of the building

The historical building is located in Budapest, Hungary. The function of the building is office and university educational building. The renovation of the building was completed in spring 2014. Considering the exterior walls of the building, it is made of solid brick with a traditional construction. The thermal insulation of exterior walls was not possible during the renovation due to monument protection of the building and its environment. Doors and windows of the building were changed to new structures with insulated glazing. The heat supply of the building is provided by six gas boilers. The total output of the boilers is 2.75 MW. One of the boilers is condensing boiler and the others are low temperature natural gas boilers. The nominal heating water temperature is 80/60°C. In the heating system there are new cast iron radiators with thermostatic radiator valve. Cooling system installed only in some building parts. The cooling energy demand of the building is served by compact liquid chillers, as well as VRV system and some split air conditioners. Artificial ventilation system operate only in the auditoriums. The offices have natural ventilation system.

We conducted an energy audit in the building. During the energy audit the heating, DHW, cooling, ventilation and also the lighting systems were assessed. The energy audit included a comfort assessment in order to take into consideration the occupants' opinion about indoor comfort.

2 The comfort questionnaire

A questionnaire was prepared to assess how the occupants perceive comfort parameters in the offices. The three-page questionnaire consisted of 17 questions. The questionnaire was filled out by 65 employees in the office

building part. The developed questionnaire includes eight topics:

1. Basic data: date, time, room, current indoor air temperature.
2. Winter thermal comfort: thermal sensation during the heating period, typical indoor temperature in the heating period, position of thermostatic radiator valve.
3. Summer thermal comfort, shading: thermal sensation during the cooling period, operation hours and set point temperature of the air conditioning system, occupant satisfaction on existing shading.
4. Ventilation: freshness of air during winter and summer periods.
5. Domestic hot water supply: hot water supply issues, hot water temperature.
6. Lighting: occupant opinion on artificial illumination.
7. Satisfaction / Dissatisfaction: what the comfort parameters the occupants are satisfied with and the comfort parameters the occupants are not satisfied with.
8. Other comments, suggestions, comments.

3 Comfort assessment

The questionnaires, filled out by office workers, were recorded in electronic form (excel sheet) for further analysis. Based on the completed questionnaires, several findings were summarized, which were related to comfort and energy fields and some of them referred to maintenance aspects.

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3.1 Winter thermal comfort

In winter, the majority are satisfied, since 74% of the respondents say that the temperature of the air is adequate during the heating season. 8% of the respondents feel slightly cold and 10% feels slightly warm at the offices. In some offices the employees feel cold (5%), while elsewhere feel warm (3%).

Fig. 1. Perception the air temperature in the heating season

The thermal comfort is subjective therefore there will never be 100% satisfied, as it is detailed in ISO 7730 standard [1]. 74% say that the indoor air temperature is appropriate in the heating period.

The thermal comfort of those people, whose answers were “slightly warm” or “warm”, can be improved by adjusting the thermostatic radiator valve to lower value. However in the offices where employees perceive the air temperature as “cold”, the thermostatic radiator valves were in IV and V position, so the thermal comfort cannot be improved by adjusting thermostatic valves. In these places further analysis is necessary to solve their problem.

3.2 Summer thermal comfort

The office workers’ opinions are very uniform in terms of thermal comfort in the summer season. In summer, 54% of respondents feel warm in the office, 34% feel slightly warm, while only 12% feel air temperature as appropriate. The average of the temperature values given by office workers in the non air-conditioned offices is 28.4 ° C, which explains the bad summer thermal comfort. According to workers answers’ in several offices the temperature is more than 30° C, which is very high and not comfortable and makes the work difficult.

Fig. 2. Perception the air temperature in summer

In the case of shading, 92% of respondents have textile roller blinds in the office, 3% has curtains, 2% has vertical blind and 3% has not any shading. 32% of office workers are dissatisfied with the existing shading. Almost all of the employees who wrote a text commentary noted that in summer in the offices the temperature increases very soon and the existing shading is insufficient.

The high indoor temperature and insufficient shading results the dissatisfaction of employees in summer. On one hand installing air conditioning system would increase the energy consumption, but on the other hand the thermal comfort, the working efficiency and the concentration of the workers would be greatly improved, therefore a new central cooling system in non-air-conditioned offices has to be considered by the decision makers.

3.3 Ventilation

32% of respondents feel the air quality as relatively good, 30% of respondents consider the air freshness as neutral, 17% of respondents feel it as slightly bad and the same respondents (17%) feel it as bad. This is probably related to the fact that occupants cannot adequately ventilate in the summer, because of high outdoor temperatures and the draught.

Fig. 3. Perception the air quality in summer

The offices have natural ventilation, so fresh air can only be provided in the rooms by opening the windows. Regular ventilation should be provided in order to ensure the appropriate indoor air quality.

3.4 Domestic hot water

According to 84% of respondents, the DHW temperature is correct and 74% of them say when the hot water tap is opened, the hot water – with adequate temperature – flows within seconds. 40% of office workers experience that after the cold water tap has been opened, slightly warm water was flowed. This is due to insufficient thermal insulation of cold and hot water pipelines.

3.4 Lighting

Nearly half of the respondents (47%) answered that the artificial light is appropriate, 29% feel as slightly bright and 15% feel it as too bright. Only 6% feel the illumination as slightly dark and 3% of the respondents say there is dark in the office. At next lighting renovation,

it is recommended to design more lighting zones in larger offices, which can be switched independently from each other, and also to install illumination sensors. This intervention will result energy saving and improve occupant's opinion on illumination.

4 Temperature measurements

The indoor temperatures were measured by dataloggers both in the heating and in the summer season. Data loggers measured and recorded the indoor temperature values in every 10 minutes. The measured data was downloaded to computer for further analysis. In the summer season the temperatures in the non air-conditioned offices were very high which is related to the results of the occupants' comfort questionnaire. In several offices the measured indoor temperatures are over 30°C during daytime due to the high outdoor temperature and the internal heat load. In the air-conditioned offices the most of the measured temperatures were between 24 and 27°C, which are met with requirement of the EN 15251 standard [2].

In the heating season overheating was observed. The average of measured temperatures was over 23°C, but in some places it was even higher. During the day, the temperatures in the offices were typically between 23 and 25 °C, while the library was even warmer (25-28°C). In the library, the thermostatic radiator valves were in positions IV and VI which partly explains the high indoor air temperature, because they were set too high and therefore did not regulate the radiator valves.

Fig. 4. Overheating in an office

Based on the measurement results in the heating season it can be stated that the indoor temperature is too high and there is no adequate temperature reduction at night and on weekends when there is nobody in the offices. We suggested setting the indoor temperature to 22°C during daytime in the heating period, which will result in adequate thermal comfort. As for the radiator valves this usually corresponds to the position III and IV, so it is recommended to set radiator valves to these positions. In the energy audit, we proposed the development of the existing building management system, because in the current status the central heating reduction cannot be implemented at night and on weekends.

5 Conclusion

Comfort parameters can be measured directly, but this can often be complicated, costly and long-lasting. However, with a properly compiled questionnaire, we can measure office workers' opinions on comfort parameters, which in many cases provide more substantiated results, as we also get feedback from the occupants on the current state. The questionnaire can be used to survey winter and summer thermal comfort, operation of the heating and the air conditioning system, the lighting, the domestic hot water supply, and other information that we need. With the help of the questionnaire, we can collect and evaluate occupants' opinion, complaints and suggestions on existing status, which is very useful when developing the existing system in defining the required intervention areas. In the analyzed building, the questionnaire survey showed there are high indoor temperatures in the offices during the summer, the existing shading is inadequate and the office workers' summer thermal comfort is very poor.

Office workers can only make opinion on data during working hours, therefore it is recommended to measure indoor temperature values after working hours by temperature dataloggers. By evaluating the measured temperatures, it is easy to show whether there is adequate heating reduction in the heating season or whether they switch off the air conditioning system after working hours in summer. In the analyzed building, datalogger measurements revealed during the heating season there is too high indoor temperature during working hours, however, there is no heating reduction at nights and weekends.

References

1. ISO 7730:2005 Ergonomics of the thermal environment - Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria
2. EN 15251:2007 Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics