ASSESSMENT AND OPTIMIZATION OF INDOOR ENVIRONMENT IN TERMS OF HYGRO-THERMAL MICROCLIMATE

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ABSTRACT

The contemporary construction, both new buildings and renovations, is characterized by the low air permeability of the building envelope. The high airtightness of the building envelopes reflects current energy-saving trends. However, saving energy is a contrast with hygienic conditions (supply of fresh air). The well-being of occupants is defined by the interaction of the physical, chemical and biological components of the internal environment of buildings. The basic factors of indoor air quality are indoor air temperature [°C] and relative humidity [%]. The paper includes an analysis of long-term (1-year) measurements in the apartment in terms of the thermal-humidity microclimate, including the optimization of the hygro-thermal parameters of the indoor environment. The measurements were carried out in a standard apartment in the residential prefabricated building after revitalization (new thermal insulation and new windows) located in Central European climatic conditions. This climate is typical of low relative humidity in the indoor environment of buildings in the winter (heating season).

Keywords: Indoor air quality, indoor air temperature, relative humidity, indoor environment, residential building

INTRODUCTION

In urbanized and industrialized areas, people spend up to 90% of their time indoors [1]. Ensuring thermal comfort is associated with considerable energy consumption [2]. The building sector consumes 40% of energy in the countries of the European Union. In this respect, more attention should be paid to the concentration of pollutants in the indoor environment than the external environment. Indoor air temperature and indoor air humidity affect comfort and health of occupants and safety and durability of constructions. There are many studies focused on indoor air quality (IAQ) related to the indoor air temperature and humidity, for example [3-7].

HYGRO-THERMAL MICROCLIMATE

Thermal comfort is one of the most important components of the indoor climate. Hygro-thermal microclimate is formed by flows of heat and water vapor in the air. Hygro-thermal microclimate is created by three essential parameters - indoor air temperature [°C], indoor relative humidity [%] and air velocity [m/s].

The optimum air temperature of the internal environment is in the range of 20 to 22°C. The acceptable summer range of indoor air temperature is 23 to 26°C [8]. However, long-term temperatures above 22°C may lead to the development of the symptoms of Sick Building Syndrome (SBS) [9]. Too high or low temperatures can pose a serious hazard to human health [10]. If the indoor air temperature is higher than 27 ° C, the productivity and efficiency decrease by 25%.

Humidity expresses the amount of water in the air. The relative humidity (RH) can be defined as the ratio of the partial pressure or water vapor in the air and water vapor to the saturated vapor pressure of water at a given temperature [11]. The ideal relative humidity of the indoor environment is between 40 and 50%. Relative humidity in the range of 30 to 70% is still acceptable. The acceptable limits for the indoor environment are based on considerations of respiratory infections, dry skin, eye irritation, occurrence of bacteria, virus, fungi, and other humidity related situations. High values of RH are characteristic for unused or unventilated rooms. High relative humidity levels create potential hazards for the occurrence of bacteria, viruses, fungi, mites associated with allergies and asthma. Vice versa, low humidity is associated with respiratory difficulties, allergies, asthma, and increased ozone formation. [8].

EXPERIMENTAL MEASUREMENTS

The experimental measurement of indoor temperature [T; °C] and relative humidity [RH; %] is carried out on revitalized prefabricated panel houses built in last century. The building is situated in the centre of Ostrava, Czechia, Central Europe. Ostrava falls into the warm climatic region. The average altitude is 210 meters above sea level. Ostrava is located in the climate with warm, humid summers and mild winters. Average annual temperature is 10.2°C (January: -1.2° C, July: 23.5°C) with an annual average precipitation of about 580 mm.

The floorplan of the apartment is shown in Figure 1 [12]. This is a prefabricated panel construction with an external thermal insulation system and new plastic windows. Ventilation is natural through windows. The inner surface is made of plaster. Floors consist of a combination of laminate and ceramic tiles. The total living area of the apartment is 44 m^2. Living room of 15.7 m^2 floor area is used to the experimentation from October 2016 to September 2017. The apartment is commonly used by 2 people during the measurement period. Room plants and a 100-liter aquarium are part of the room's facilities. The water vapor from the aquarium is approximately 2 - 3 liters per week. The wireless indoor sensor Elgato Eve Room is used for experimental measurements. The indoor air temperature and relative humidity are measured in 10-minutes cycles.

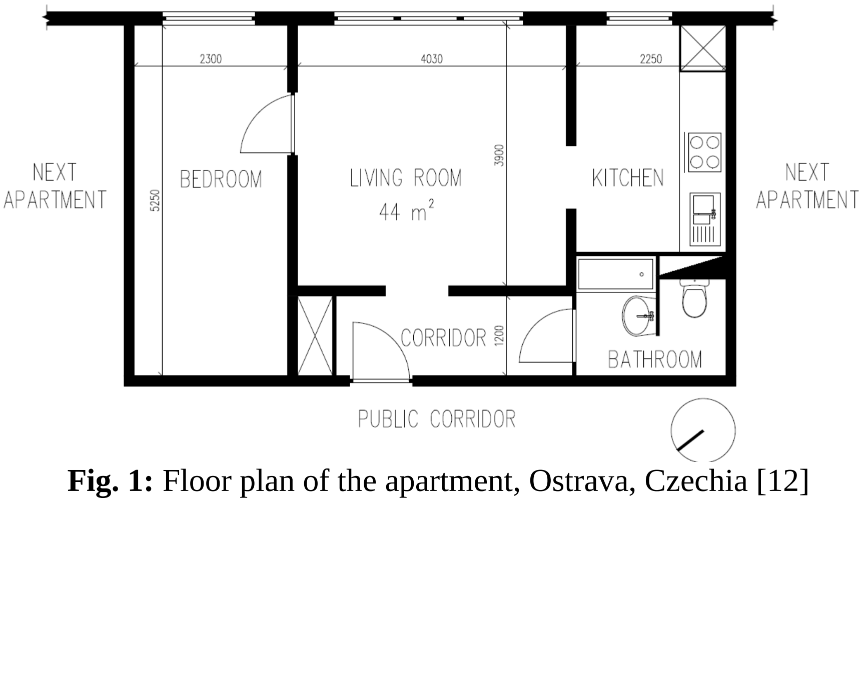

Fig. 1: Floor plan of the apartment, Ostrava, Czechia [12]

RESULTS AND DISCUSSIONS

The contribution follows the result of short-term measurements published in [8] and [12]. Figure 2 shows measured values of relative humidity throughout the year. It is obvious that relative humidity is low in winter and high in summer. Low humidity values are typical for the heating season. The lowest measured value of relative humidity is 14%. This value is significantly lower than the recommended minimum (30%). Relative humidity is held within acceptable limits outside the heating season. The highest of relative humidity reaches 70% in July 2017.

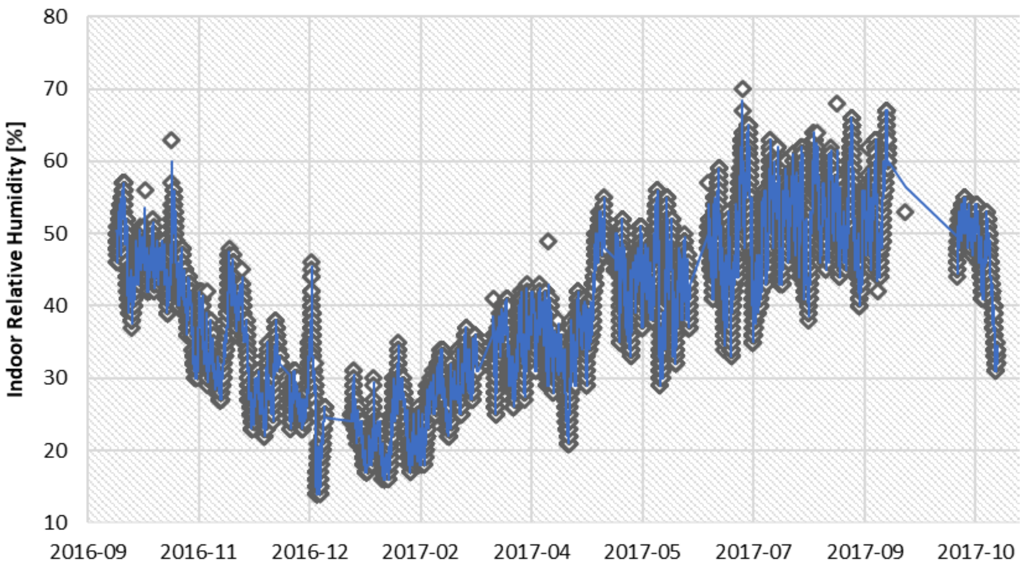

Fig. 2. Indoor relative humidity [%] during the entire year in the apartment located in Ostrava, Czechia

The mean of relative humidity in the whole year is represented by valued of 39.33 %. This value is in accordance with the specified range of optimum humidity of the indoor environment. The median is the middle point of the data set, in which 50% of the data is above the median and 50% is below. The median of RH is represented by value 40.00 %. Other characteristics of Exploratory Data Analysis (EDA) are presented in Table 1.

Table 1: Descriptive characteristic of RH [%]. The output of IBM SPSS Statistics.

			Statistic	Std. Error
RH	Mean		39.3325	.05172
	95% Confidence Interval for Mean	Lower Bound	39.2312	
		Upper Bound	39.4339	
	5% Trimmed Mean		39.3603	
	Median		40.0000	
	Variance		128.598	
	Std. Deviation		11.34010	
	Minimum		14.00	
	Maximum		70.00	
	Range		56.00	
	Interquartile Range		18.00	
	Skewness		-.072	.011
	Kurtosis		-.893	.022

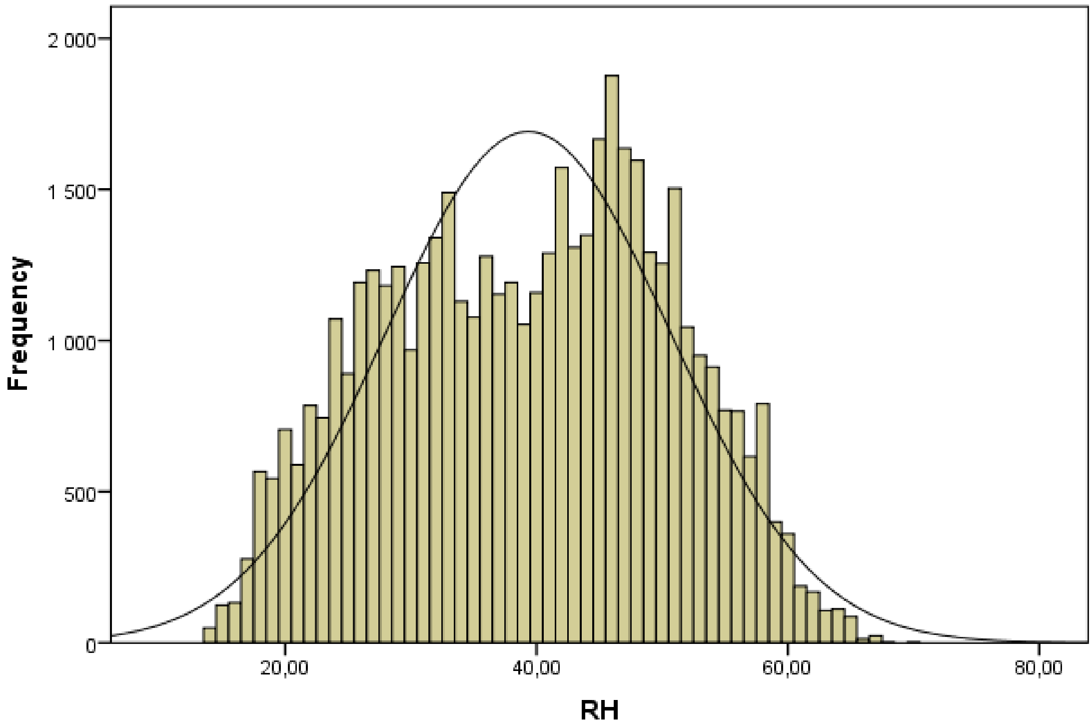

Fig. 3. Histogram of measured values of RH. The output of IBM SPSS Statistics.

Indoor temperatures throughout the year are shown in Figure 4. The indoor air temperature is kept within acceptable limits during autumn, winter and spring. The temperature exceeds acceptable values in the summer. The indoor temperature reflects the temperatures in the exterior. The mean indoor air temperature for the whole year is 23.73°C. The minimum measured temperature is 17.96°C, which can still be considered acceptable. Table 2 shows the results of the exploratory analysis of the measured data.

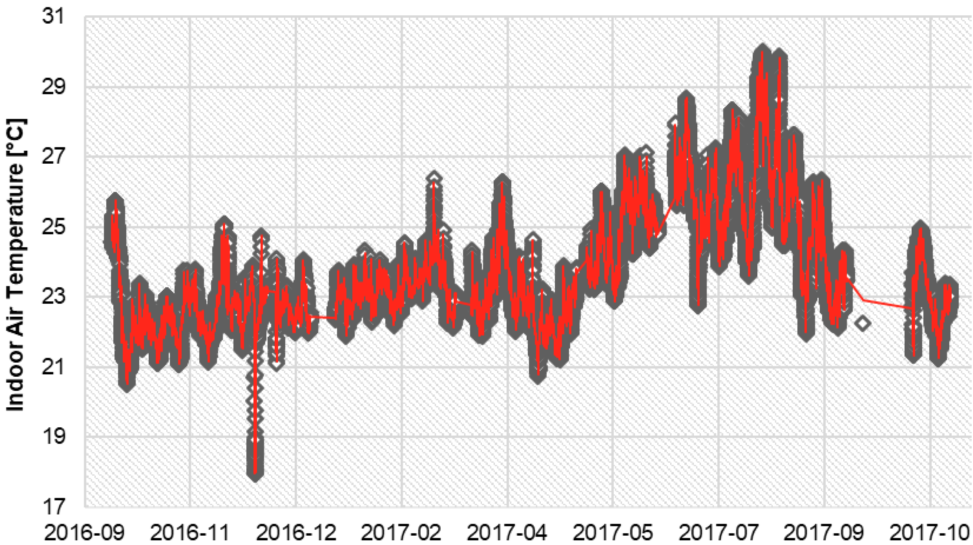

Fig. 4 Indoor air temperature [°C] during the entire year in the apartment located in Ostrava, Czechia.

Table 2. Descriptive characteristic of T [°C]. The output of IBM SPSS Statistics.

			Statistic	Std. Error
T	Mean		23.7302	.00745
	95% Confidence Interval for Mean	Lower Bound	23.7156	
		Upper Bound	23.7448	
	5% Trimmed Mean		23.6336	
	Median		23.2800	
	Variance		2.671	
	Std. Deviation		1.63435	
	Minimum		17.96	
	Maximum		30.02	
	Range		12.06	
	Interquartile Range		2.08	
	Skewness		.915	.011
	Kurtosis		.607	.022

The internal temperature even exceeds 30°C in the summer. The graph indicates that the temperature in July and August is greater than 27°C. Venetian blinds installed on the inside of the windows do not prevent overheating of the interior. In terms of thermal comfort, this condition is totally unacceptable and unsustainable in the long term. Heat discomfort reflects the reduced comfort of the indoor environment reduces performance and can lead to the collapse of the body.

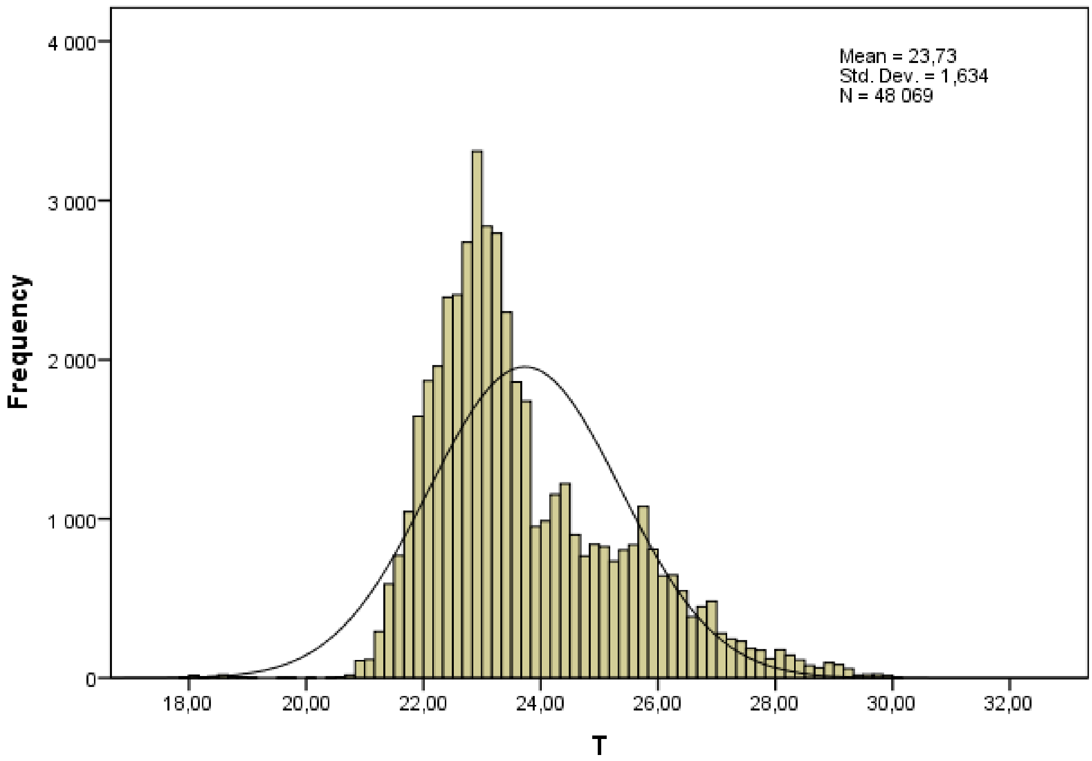

Fig. 5. Histogram of measured values of T. Output of IBM SPSS Statistics.

CONCLUSION

In the contribution, attention is paid to the quality of the indoor environment in terms of indoor temperature and relative humidity. The current construction is characterized by low air permeability through the building envelope due to energy savings. This state of affairs is not only about new buildings, but also about the reconstruction and revitalization of existing buildings. The ambient air temperature and relative humidity should be kept within certain limits in summer and winter to achieve suitable conditions of the indoor environment. According to the long-term monitoring, it is clear that maintaining a good relative humidity is a problem, especially in winter. Indoor relative humidity in the winter is below 20%. It is necessary to pay attention to adjust the relative humidity in residential buildings. In particular, it is the addition of water vapor to the air in the winter season (heating season). Ordinary human activities (showering and cooking), indoor flowers, or 100-liter aquarium do not have an effect on the provision of acceptable relative humidity. Installation of individual indoor air humidifiers is a good option in terms of cost-optimum level.

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