Indoor air quality in dwelling buildings after renovation

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ABSTRACT

The paper provides the results of monitoring on the specifics of indoor air quality in Latvian dwelling buildings. It will present the results of the evaluation of the ventilation system's operation in different working regimes in Latvian climatic conditions.
Until the end of 90-ties all dwelling buildings in Latvia were equipped with mandatory natural ventilation systems with stack effect. Installation of regular mechanical "inflow - outflow" ventilation systems in dwelling buildings was limited by such factors as high noise level during operation time, limited buildings' area and high construction expenses. At the beginning of 2007 the part of Latvian multi-storey apartment buildings which were constructed with natural ventilation systems took 75% of all buildings. The inflow of fresh air acquired through the gaps between window frame and window carcass. The exhaust of air acquired through the vents, which are situated in kitchens and bathrooms. Old multi-storey dwelling buildings in Latvia were mainly built using wooden window frames with low heat insulation quality. It was assumed that such constructive decision would provide sufficient air exchange rate without any mechanical devices.
Nowadays the PVC windows have got a great expansion at Latvian market due to their acceptable prices and high heat and noise insulation qualities. At the same time air tight windows require the introduction of mechanical ventilation systems that certainly reduces the positive energy saving effect of improvements of thermal performance of building structures.
In the scope of this paper the influence of ventilation on building energy performance was evaluated.

KEYWORDS

Ventilation, indoor air quality, humidification, CO_2 concentration.

INTRODUCTION

The main aim of any kind of ventilation systems is to ensure optimal comfort conditions of indoor air quality for inhabitants independently of outdoor air parametrs.
At the beginning of 2007 the part of Latvian multi-story apartment buildings which were constructed pursuant to Soviet buildings codes took 48% of all buildings that is equivalent to 26.4 millions m^2. All these buildings were equipped with mandatory natural ventilation systems with stack effect. The inflow of fresh air acquired through the gaps between window frame and window carcass. The exhaust of air acquired through the vents, which are situated in kitchens and bathrooms. Old multi-storey dwelling buildings in Latvia were mainly built using wooden window frames with low heat insulation quality. It was assumed that such constructive decision would provide sufficient air exchange rate without any mechanical devices. Since the end of 90ies the PVC windows have got a great expansion at Latvian market due to their

acceptable prices and high heat and noise insulation qualities. The new Latvian Building Code LBN 002-01 “Thermal performance of building envelopes”that entered into force on January 1, 2003 requires much higher thermal resistance of building structures than the previous normative.

The heat transfer coefficient for window in dwelling buildings must be not higher than 1.8 W/(m^2·K). Due to this requirement now it is not possible to build new buildings with simple wooden frames which could ensure necessary air exchange rate in apartments. The main expected benefit of the implementation of such LBN 002-01“Thermal performance of building envelopes” requirement is the reduction of building energy consumption for heating by 50% - from 140 kWh/m^2 per year to 70 kWh/m^2 per year due to better thermal characteristics of building structures including also windows. At the same time air tight windows require the introduction of mechanical ventilation systems that certainly reduces the positive energy saving effect of improvements of thermal performance of building structures.

The existing researches (Adrie van der Luijt 2007, Olli Seppanen 2000, and another) on indoor air quality have shown that optimal CO_2 concentration in indoor air is up to 1000 ppm. Although data (Eliseeva 1964) on CO_2 impact on human health has shown that negative impact on breath occurs when $C0_2$ concentration was above 5000ppm. The evaluation of indoor air quality in Netherlands (Wim Zeiler and Gert Boxem 2008) has shown that allowed $C0_2$ concentration level was 1000ppm with a maximum value 1200ppm. The recommendations (ASHRAE 2004) also provide that indoor CO_2 concentrations should be maintained at or below 1000 ppm in schools.

LATVIAN CLIMATIC CONDITIONS

In general Latvian climate can be described by moderate temperatures with all year round high relative humidity. The convergence of Latvian average climate parameters, the comfort zone of indoor air and possible working modes of ventilation system is shown in Figure 1.

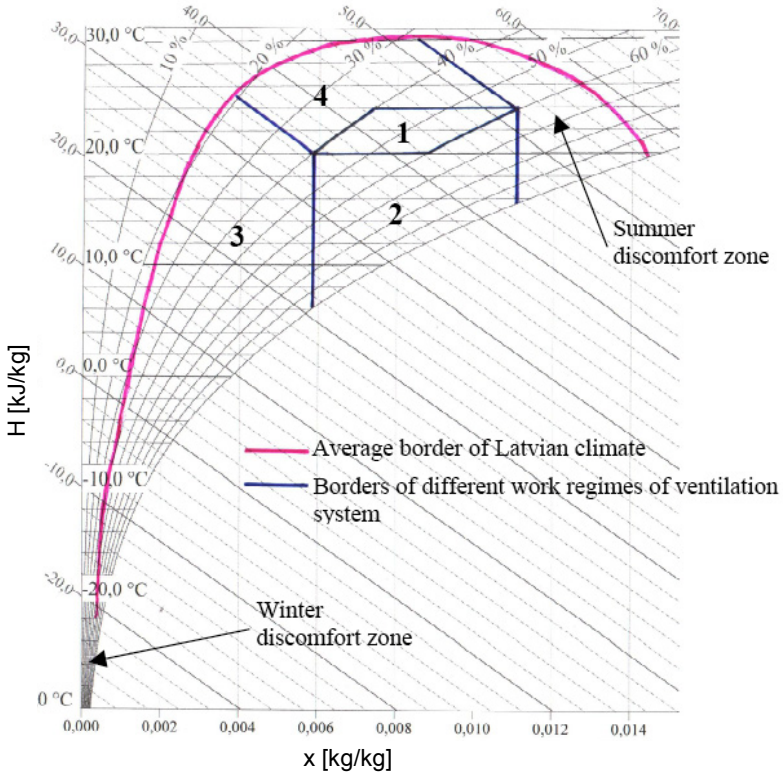

Figure 1. The convergence of Latvian average climate parameters, the comfort zone of indoor air and possible working regimes of ventilation system

The above shown Figure provides only four working regimes of ventilation system that are typically used in Latvia. In order to find out the operation time of the each ventilation regime the hourly Latvian outdoor parameters of 10 year time period were analyzed (Table 1).

TABLE 1: Latvian outdoor parameters sorted by ventilation working regimes

Outdoor air	Description	Number of hours during 10 years	Number of hours per average year	Number of days per average year
Winter discomfort zone	The capacity of heating system is not enough in order to ensure optimal air heating	305	30.5	1.3
1st zone	The outdoor air parameters are equal to comfort zone of indoor air, the outdoor air is supplied directly to apartments	2664	266.4	11.1
2nd zone	The outdoor air is heated by the convector till the minimal required temperature	29438	2943.8	122.66
3rd zone	The outdoor air is heated by the convector and then it is moisturized	51192	5119.2	213.3
4th zone	The outdoor air is only moisturized till the comfort zone's upper level	580	58	2.42
Summer discomfort zone	Formed when cooling systems are not used in multistory apartment buildings	3435	343.5	14.31

As it can be seen from the table 1 the average number of days per year when it is necessary to cool off the outdoor air is equal to 14.31 days per average year. This number shows that use of air cooling devices in common Latvian apartments is not quite efficient.

THEORETICAL MODELING OF VENTILATION SYSTEM'S ENERGY CONSUMPTION IN TYPICAL LATVIAN APARTMENT

For the theoretical calculation of ventilation system's energy consumption the typical Latvian apartment was chosen (Figure 2). The calculation were done in case that old wooden frame windows were replaced by PVC frame window. The calculation of energy consumption was done for two cases: first - when ventilations system ensures the optimal temperature and relative humidity during the winter time and second – when ventilations system ensures only optimal temperature parameters during the winter time. The air exchange rate was taken as 120m$^{3/}$h. This air exchange rate is optimal for typical Latvian apartment with occupancy level of four people per apartment [ABOK 2004].

In case when it is necessary to provide comfort temperature as well as comfort humidity level, the outdoor air should be heated up at least till 36^{o}C and after that it should be humidified till comfort temperature. Although in case when it is possible to ensure only comfort temperature parameters it is enough to heat the outdoor air only till 22^{o}C.

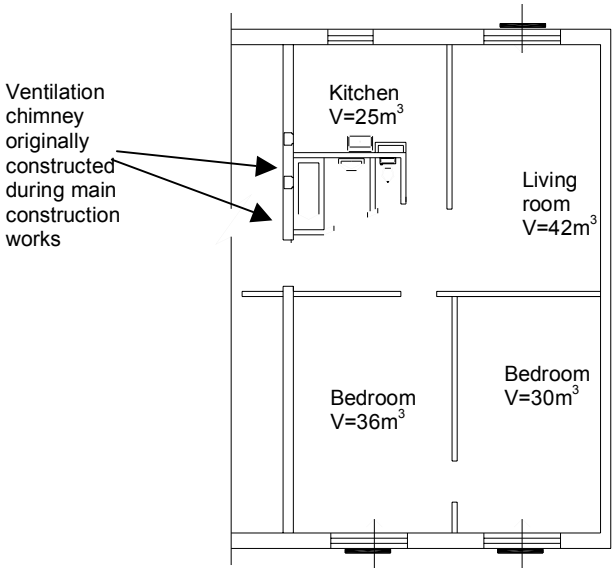

Figure 2. The typical Latvian apartment

The comparison between heat consumption for ventilation needs in order to ensure comfort parameters of indoor air (including temperature and humidity) and in order to create only comfort temperature is shown in table 2. This table also provides the data on the part of heating energy for ventilation needs in comparison with total heat consumption including space heating and ventilation.

TABLE 2. The comparison between heat consumptions for ventilation needs in order to ensure comfort parameters of indoor air and in order to ensure only comfort temperature

	kWh/m^2 per average year	% of total heat consumption
Annual heat consumption in order to ensure comfort parameters of indoor air	166.1	71.3%
Annual heat consumption in order to ensure only comfort temperature of indoor air	99.74	60%
Annual heat consumption for apartment's space heating	66.72	28.7/40

The energy consumption in case when it is necessary to ensure comfort parameters (both temperature and humidity level) of indoor air is by 66% higher than in case when it is possible to ensure only comfort temperature.

EVALUATION OF INDOOR AIR QUALITY

The monitoring of IAQ wav done for similar apartments as is shown in figure 3. The analyzed apartment was equipped with mechanical exhaust in kitchen and natural air intake vents in the wall in each bedroom. The area of intake vents 0.022m^2. In each room the PVC windows are installed.

The monitoring of IAQ was done during the time period form January till May 2009. The Figure 3 presents the measurement results of IAQ in bedroom with 2 adult person and outdoor air parameters for 1th and 2nd of April 2009. The outdoor air temperature during this time period varied from -1^{0}C till +9^{0}C. The average CO2 concentration in outdoor air near the analyzed building was 690ppm.

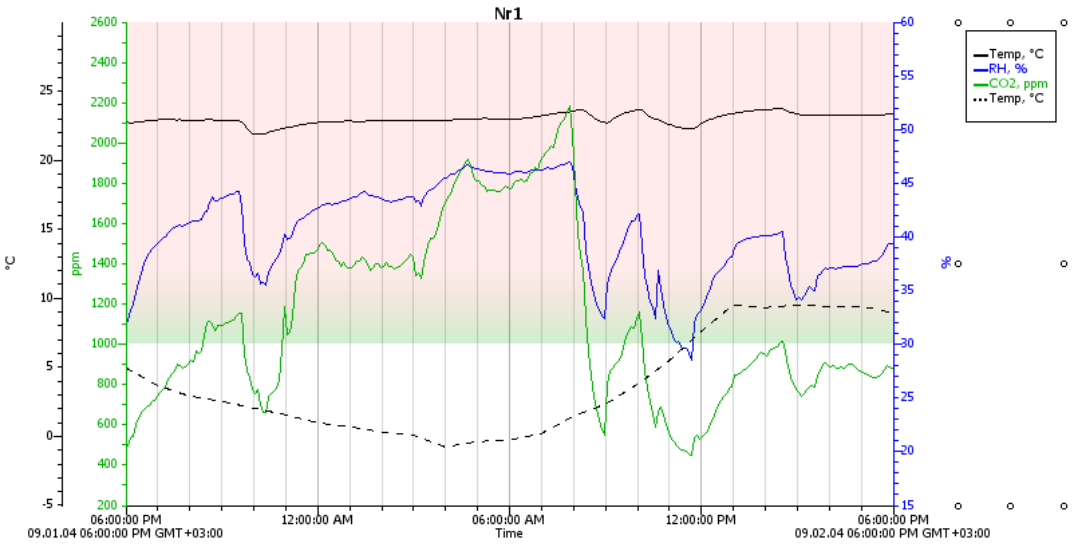

Figure 3. IAQ in bedroom with 2 adults (F=13m^2 ;V=33.2m^3)

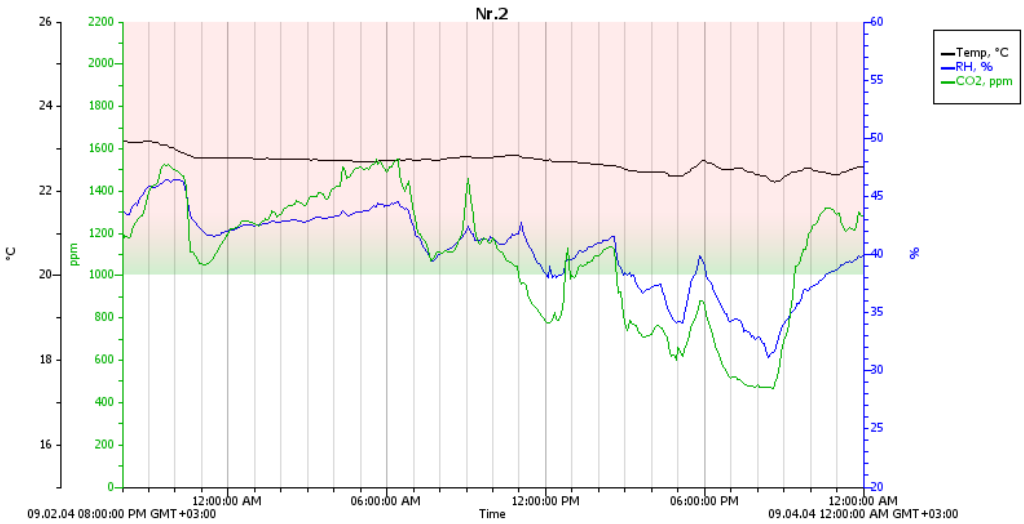

Figure 4 IAQ in bedroom with 1 child (F=14m^2 ;V=35.7m^3)

As it could be seen from Figure 3 CO_2 concentration in room with two adults during the night time is up to 2200ppm. Situation becomes better after opening the windows during the day but at the same time indoor air relative humidity drops up to 30% and the additional air moisturizing is necessary. The situation in children's room is also not in conformity with the requirements of normative - the level of CO_2 emission in room is up to 1600ppm during the night time and rises up to 1100 during the day. The ventilation by means of opening the windows is limited due to the high infiltration of cold outdoor air which can cause colds. The analysis of indoor air parameters in typical Latvian apartment has shown that such kind of ventilation system could not insure optimal IAQ in the small rooms.

CONCLUSIONS

The average number of days, when it is necessary to cool off the supplying outdoor air in Latvia, is 14.31 days per average year. This number shows that use of air cooling devices generally in common Latvian apartments is not quite efficient.
The energy consumption in case, when it necessary to ensure indoor air's comfort parameters of both temperature and humidity level, is by 66% higher than in case, when it is possible to ensure only comfort temperature.
The ventilation systems with mechanical exhaust in kitchen and natural air supply in rooms can be recommended for large rooms where beds or children's playing area could be placed far from the windows and intake vents.

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