INTRODUCTION OF HYBRID VENTILATION SYSTEMS OF DWELLING BUILDINGS IN LATVIA

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ABSTRACT

Until the end of 90-ties all dwelling buildings in Latvia were equipped with mandatory natural ventilation systems with stack effect. Nowadays in many cases in dwellings there are only exhaust mechanical ventilation but air tight windows prevent natural air intake. Such systems result in bad IAQ. The using of regular mechanical “inflow - outflow” ventilation systems in dwelling buildings is limited by different factors - such as high noise level during operation time, limited buildings’ area and high construction expenses. The operation of mentioned ventilation systems is complicated and inefficient.

In order to improve the existing situation with ventilation of dwelling buildings some of new modern technical decisions were introduced. One of these decisions is the implementation of hybrid ventilation.

The paper is devoted to the trial implementation of hybrid ventilation systems in dwelling buildings in Latvia. The comparison of indoor air in buildings equipped with hybrid ventilation system and in buildings with natural ventilation was done as well.

The paper gives theoretical principles of the hybrid ventilation system, describes advantages and shortcomings of the ventilation systems selected for the trial implementation.

KEYWORDS

Hybrid ventilation, indoor air quality, humidification

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 buildings which were constructed pursuant to Soviet buildings codes [SNiP 1986] took 75% of all buildings that is equivalent to 3.5 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. Use of mechanical ventilation systems in multi-storey apartment buildings was forbidden by Latvian Building Codes as previously it was forbidden in Soviet Union Building Codes because of their noise level.

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” [LBN 2002] 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

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ventilation systems that certainly reduces the positive energy saving effect of improvements of thermal performance of building structures.
The possible solution in order to overcome the shortcomings of installation of mechanical ventilation systems is introduction of hybrid ventilation systems in Latvia.
The hybrid ventilation combines features of both mechanical and natural ventilation. The hybrid ventilation systems may be quite different in configuration. By classification given in [P. Heiselberg 2000] hybrid ventilation systems include:
- alternating natural and mechanical ventilation;
- fan assisted natural ventilation;
- stack and wind supported mechanical ventilation.

The best economical effect of implementation of hybrid ventilation systems can be achieved when outdoor air could be delivered directly to the room without any additional heating or cooling.

LATVIAN CLIMATIC CONDITIONS

In general Latvian climate can be described by moderate temperatures with all year round high relative humidity.
The theoretical modeling of energy consumption for ventilation needs by apartments in Latvian climatic conditions is based on outside air statistical data for 10 year time period. The example of average temperatures and relative humidity of January for Latvian capital city Riga is given in table 1. This table shows monthly iteration of outside air parameters in three time zones of the day: from 0.00 till 8.00, from 8.00 till 16.00 and from 16.00 till 24.00 (Table 1). These data are especially useful when the supply air quantity and temperature is variable during the day depending on the utilization of premises.

Table 1. Number of hours in January when outside air has certain temperature and relative humidity for three daily time zones in Riga, Latvia (during 10 year monitoring period)

Temperature, ° C	Time	Relative humidity							
		0,2-0,3	0,3-0,4	0,4-0,5	0,5-0,6	0,6-0,7	0,7-0,8	0,8-0,9	0,9-1,0
+5:+10	0-8	-	-	-	-	-	2	8	-
	8-16	-	-	-	-	-	-	9	-
	16-24	-	-	-	-	-	4	5	-
0:+5	0-8	-	-	-	1	7	69	184	391
	8-16	-	-	1	-	22	95	297	379
	16-24	-	-	-	-	3	78	287	405
-5: 0	0-8	-	-	1	6	20	91	284	392
	8-16	-	-	5	12	44	105	331	389
	16-24	-	-	3	8	45	114	279	316
-10:-5	0-8	-	4	10	16	48	98	253	122
	8-16	1	2	9	24	62	127	189	85
	16-24	-	-	5	17	54	111	208	112
-15:-10	0-8	-	-	-	1	23	72	166	52
	8-16	-	-	4	-	34	97	136	22
	16-24	-	-	1	4	25	92	130	42
-20:-15	0-8	-	-	-	-	14	31	87	11
	8-16	-	-	-	-	11	39	29	12
	16-24	-	-	-	-	4	27	54	25
-25:-20	0-8	-	-	-	-	-	-	9	4
	8-16	-	-	-	-	-	-	2	2
	16-24	-	-	-	-	2	9	2	-
-30:-25	0-8	-	-	-	-	-	2	6	-
	8-16	-	-	-	-	-	2	-	-
	16-24	-	-	-	-	-	-	-	-

THE COMFORT PARAMETERS OF INDOOR AIR AND TECHNICAL PROBLEMS OF ENSURING THEM IN LATVIAN CLIMATIC CONDITIONS

The assumed optimal comfort parameters (comfort zone) of indoor air are the following: temperature between +20 and +24 and relative humidity between 40% and 60%.

In order to ensure such optimal comfort conditions of indoor air quality in dwelling buildings the hybrid ventilation system has to consist of the following parts: natural or mechanical air outlet with regulation possibilities, convector placed immediately after the intake air opening in the wall, other heating devices located in the room, heat sources for heating devices with maximal capacity, air humidifier, control equipment for the automatic regulation of heating devices and air humidity.

For the optimal system performance all parts of the system should have the regulation possibility. Natural or mechanical air outlet ventilation system has to ensure the maximal of the following air quantities: minimal required by norms outdoor air intake *L* kg/s or air quantity required by CO_2 sensor measurements or air quantity required by air humidity sensor measurements.

For the comfortable air conditions the supply air temperature has to be in the *comfort zone* confined in area of temperatures $\theta_{Smin} \ldots \theta_{Smax}$ and air humidity $\varphi_{Smin} \ldots \varphi_{Smax}$. This zone is shown at the *H-x* diagram (Figure 1) and represents the calculated climatic conditions that can be ensured by the previously mentioned regulation facilities of the hybrid ventilation system.

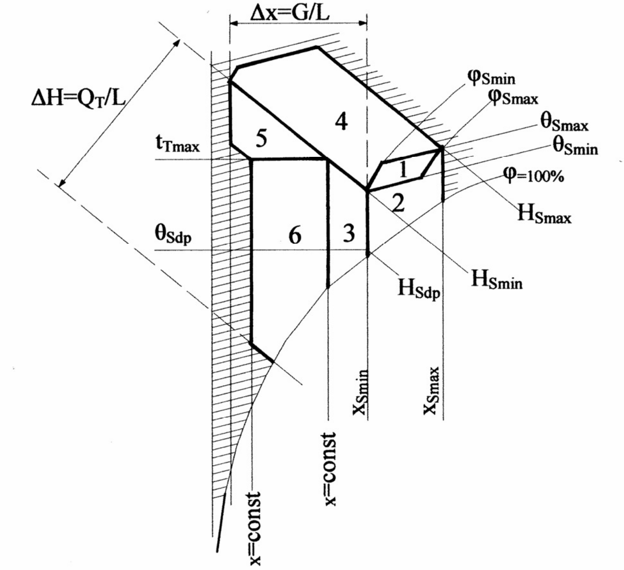

Figure 1. The indoor air comfort zone and regulation regimes on H-x diagram
(H – enthalpy, kJ/kg; x – moisture content, g/kg; θ – temperature, ºC; φ – relative humidity; Q_T – heat source capacity, kW; G – humidifier capacity, g/s; L - air quantity, kg/s)

There are six system regulation regimes depending on the conditions of the outdoor air and required indoor air parameters:

- in the 1st zone the outdoor air parameters match required indoor air parameters so the heating devices and air humidifier are switched off;
- in the 2nd zone the air is heated by the convector till the minimal required temperature θ_{Smin} if $\varphi_{Smin} \ldots \varphi_{Smax}$ or till maximal relative humidity φ_{Smax} if $\theta_{Smin} \ldots \theta_{Smax}$;

- in the 3rd zone the air is heated by the convector till enthalpy is H_{Smin} and then it is moisturized till φ_{Smax};
- in the 4th zone the air is only moisturized till the comfort zone upper level - till φ_{Smin} if θ_{Smin} ... θ_{Smax} or till θ_{Smax} if φ_{Smin} ... φ_{Smax} ;
- in the 5th zone the air is moisturized till moisture content is x_{Smin} and then additionally heated by other heating devices till θ_{Smin};
- in the 6th zone the air is heated by the wall mounted convector with intake air supply till the maximal possible temperature $\theta_{Tmax} = t_{Tmax}$; moisturized till moisture content is x_{Smin} and then additionally heated by other heating devices till θ_{Smin}.

In the systems that do not have immediate heating of outside air at the intake point it is still possible to ensure required air treatment in 2nd zone and in zones 3 and 4 by other heating devices if outdoor air enthalpy is higher than the supply air dew point enthalpy H_{Sdp}.
The convergence of Latvian average climate parameters, the comfort zone of indoor air and possible working modes of ventilation system is shown in Figure 2.

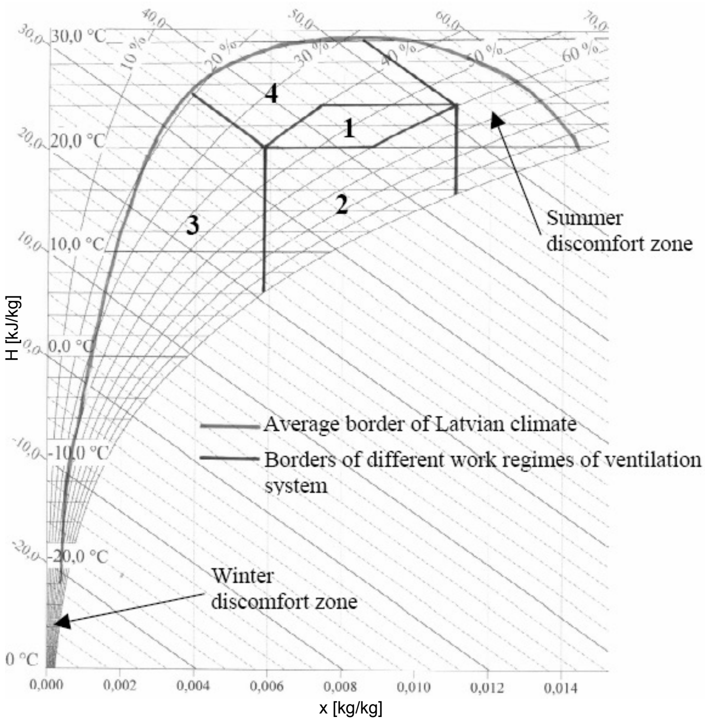

Figure 2. The convergence of Latvian average climate parameters, the comfort zone of indoor air and possible working regimes of ventilation system

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 2).

Table 2. 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 3 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 HYBRID VENTILATION SYSTEM'S ENERGY CONSUMPTION IN TYPICAL LATVIAN APARTMENT

For the theoretical calculation of hybrid ventilation system's energy consumption the typical Latvian apartment was chosen (Figure 3). 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^oC 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^oC.

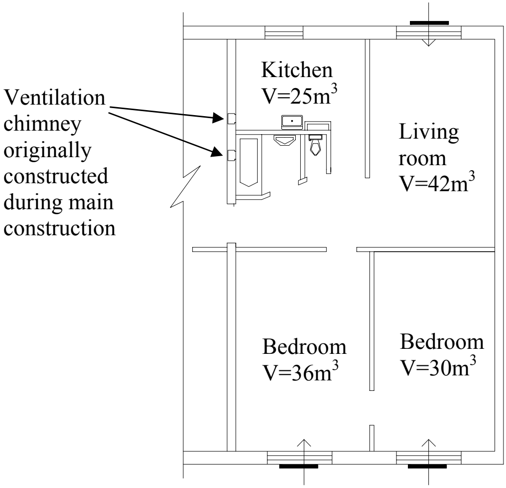

Figure 3. The typical Latvian apartment

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 3. 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 3. 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.

THE PRELIMINARY RESULTS OF PRACTICAL IMPLEMENTATION OF HYBRID VENTILATION SYSTEM IN LATVIA

The analysis of practical implementation of hybrid ventilation in Latvia was done. For that purpose two apartments were chosen. One of them (Studied Building) was equipped with ventilation system and one (Control Building) left without any special ventilation system.

The studied ventilation system consisted of special air supplying devices which were placed in the window frame. The amount of air supplied through the ventilation system into the apartment depends on humidity rate of indoor air.

Examples of monitoring results are shown in Figure 4 and Figure 5.

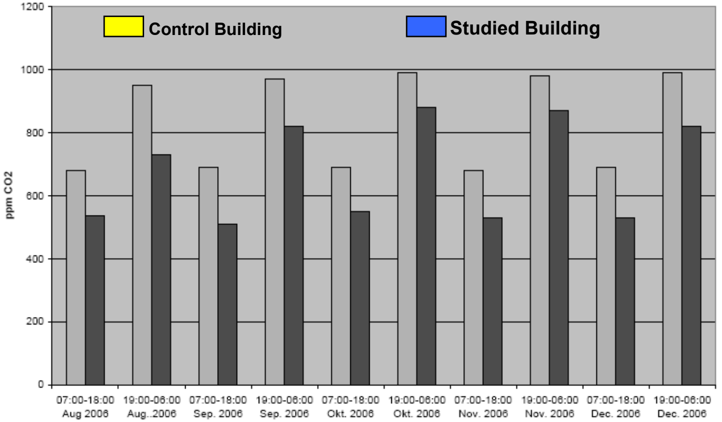

Figure 4. Average CO_2 emission per month

From the Figure 5 it can be seen that CO_2 emission level is much better in the building equipped with the hybrid ventilation. The CO_2 concentration there is up to 20% smaller than in the Control Building.

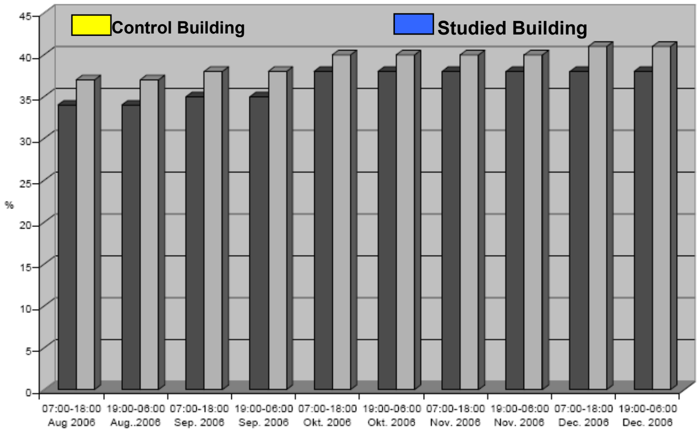

Figure 5. Average humidity rate per month

The comparison of humidity rate in both buildings had shown that the difference in that area between two buildings is not significant. In general the humidity parameters of indoor air in the Control Building are better than in the Studied Building.

In order to improve the humidity rate in the Studied Building in Latvian climatic conditions it is necessary to supplement the simple ventilation system with the humidifier.

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CONCLUSIONS

1. Hybrid ventilation systems are preferable type of ventilation systems in new and refurbished dwelling buildings in Latvia as they may ensure both good indoor air quality and efficient energy use.
2. The average number of days per year in Latvia 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 generally in common Latvian apartments is not quite efficient.
3. 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.
4. The ventilation system, where ventilation rate is dependent on humidity rate of indoor air, is not efficient in Latvian climate. Although this kind of ventilation system provides the smaller CO_2 emission level of indoor air in comparison with classic natural ventilation system.

ACKNOWLEDGEMENTS

The monitoring of hybrid ventilation was done in the scope of EC LIFE project. The analysis of 10 years monitoring of Latvian climate was implemented with the support European Social Fond.

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