CLIMA 2016 - proceedings of the 12th REHVA World Congress

volume 10

Heiselberg, Per Kvols

Publication date:
2016

Document Version
Publisher's PDF, also known as Version of record

Indoor Climate and Energy Standard of School Buildings with Different Ventilation Strategy

Maciej Mijakowski[#1], Piotr Narowski[*2]

[#]*National Energy Conservation Agency*
Warsaw, Poland

[1]mmijakowski@nape.pl

[*]*Warsaw University of Technology*
Warsaw, Poland

[2]piotr.narowski@is.pw.edu.pl

Abstract

Indoor climate quality as well as energy standard of school buildings is very important subject. In this context it seems obvious that mechanical ventilation with heat recovery (HR) is better solution than natural/hybrid ventilation. However, data collected within RenewSchool Project showed that in some cases natural ventilation provides better indoor climate than mechanical ventilation with HR. At this point the question arises whether it is possible to provide required indoor climate and similar energy consumption in school classrooms with natural/hybrid ventilation as in buildings with balanced mechanical ventilation with HR?

The paper presents comparison of energy performance and indoor climate in typical school classroom with two different ventilation strategies: mechanical balanced ventilation with heat recovery (HR) and natural/hybrid ventilation. For both types of ventilation the model of energy performance as well as calculation of indoor climate were carried out. The primary energy consumption (heating energy and electricity used for ventilation) in rooms with similar ventilation rate and thermal comfort were analysed and commented.

It was showed that providing thermal comfort is not problematic, but energy performance and indoor air quality can vary a lot between different ventilation strategies. In analysed cases the classroom equipped with mechanical ventilation with HR, for heating and ventilation, consumed about 40% of primary energy less then the one with natural/hybrid solution. In a moderate climate (Europe, Poland) it is possible to meet requirements of indoor climate and keep energy consumption on reasonably level in classrooms with mechanical ventilation with HR as well as in classrooms with natural/hybrid ventilation.

Keywords – school building, energy performance, indoor air quality

1. Introduction

Indoor climate (thermal environment and indoor air quality) has a significant influence on users comfort, health and performance. High quality of indoor climate is especially important in educational buildings given the magnitude and density of the school population as well as vulnerability of school users.

The energy standard of large number of schools needs to be improved. Many of school buildings in Europe were built between 1950s and 1980s and are presently in high need of renovation. It seems crucial while retrofitting to improve both indoor climate and energy standards. Complex modernization of school buildings is a subject of RenewSchool Project co-financed by European Union. Among other activities within the project, data on key indoor air parameters were collected in selected schools across Europe. Monitoring was performed in school buildings with natural ventilation as well as in ones with mechanical balanced ventilation with heat recovery (HR). Although generally better indoor air quality was observed in school buildings with mechanical balanced ventilation (which is in accordance with the conclusions made by other researchers, for example [5], (Fig. 1 a)), there are some exceptions where natural ventilation provided better indoor air quality than mechanical systems (Fig. 1 b).

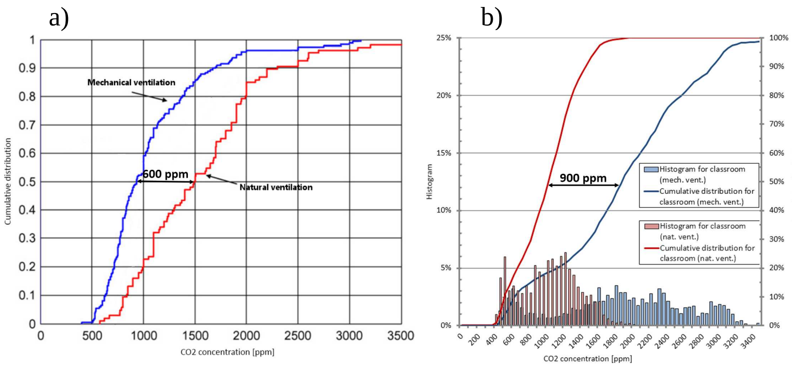

Fig. 1. a) typical results of monitoring CO_2 concentration in schools [5], b) sample of monitoring identifying better indoor air qulity in naturally ventilated classroom then in mechanical ventilated clasroom

In this context the question arises whether it is possible to provide required indoor climate and similar energy consumption in school classrooms with natural/hybrid ventilation as in classrooms with balanced mechanical ventilation with HR? To answer the question we simulated and compared energy performance and indoor climate in typical school classroom with two different ventilation strategies: mechanical balanced ventilation with heat recovery (HR) and natural/hybrid ventilation. This paper presents analysis and comments the primary energy consumption (heating energy and electricity used for ventilation) for similar ventilation rate and thermal comfort in classroom with mechanical balanced ventilation with heat recovery (HR) and the one with natural/hybrid ventilation.

2. Methods

To simulate the energy performance, we used the 6R1C model developed at Warsaw University of Technology [3]. The 6R1C tool integrates building energy simulation (based on hourly method described in EN ISO 13790:2007 [2]) with component of ventilation (air handling unit (AHU)) (based on EN 15241 [1]). To model the indoor climate we used regression techniques and data on indoor temperature, relative humidity, and CO_2 concentration collected through measurements performed in real schools during a heating season. Thereby we included in our calculations controlled air flows caused by ventilation as well as air change rate caused by stochastic in nature windows opening.

These models were applied to a classroom in pre-school building located in Warsaw, Poland. Calculations were performed for two ventilation systems: natural/hybrid ventilation and mechanical balanced ventilation with HR. Both systems were designed to provide similar indoor air quality and thermal comfort. Fig. 2 presents schemes of the classroom with two ventilation solutions.

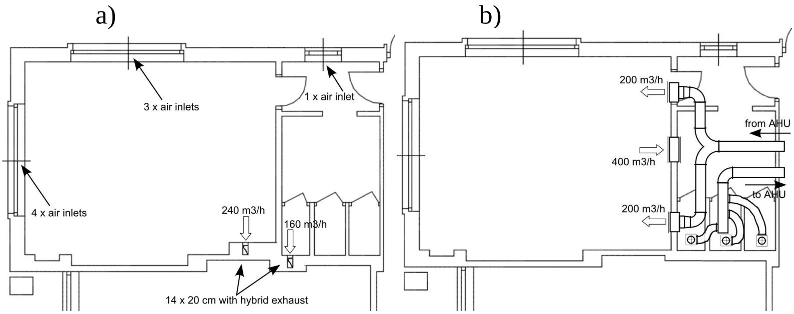

Fig. 2 Analysed clasroom equiped with (a) natural ventilation; (b) mechanical balanced ventilation with heat recovery

Main assumptions for the classroom and ventilation systems are given in the Table 1.

Table 1 Description of simulation cases

	mechanical ventilation with HR	natural/ hybrid ventilation
Outdoor climate	Warsaw, Poland	
Hours of operating	7.00 – 17.00	
Area of classroom	40 m^2	
Volume of classroom	120 m^3	148 m^3

<table>
<tr><td>Number of children in the classroom</td><td colspan="2">18</td></tr>
<tr><td>Limit of CO_2 concentration</td><td colspan="2">1250 ppm</td></tr>
<tr><td>Design indoor temperature for winter</td><td>21°C</td><td>22°C</td></tr>
<tr><td>U- value (roof, walls. floor)
windows</td><td colspan="2">0.20 – 0.30 W/m^{2}K
1.30 W/m^{2}K</td></tr>
<tr><td>Heat gains (lighting, equipment, people)</td><td colspan="2">time profile, max 34.6 W/m^2</td></tr>
<tr><td>Solar heat gain</td><td colspan="2">calculated</td></tr>
<tr><td>Heating system</td><td>hydronic, floor heating</td><td>hydronic, radiators</td></tr>
<tr><td>Design air flow</td><td colspan="2">400 m^3/h</td></tr>
<tr><td>Air inlets</td><td rowspan="2">¼ central AHU with HR</td><td>8 window frame air inlets</td></tr>
<tr><td>Air outlets</td><td>two 14x20 cm ducts with hybrid exhaust</td></tr>
<tr><td>Max electricity power for ventilation</td><td>¼ x 770 W</td><td>14 + 18 W</td></tr>
<tr><td>Max HR efficiency</td><td>87%</td><td>-</td></tr>
<tr><td>Control of ventilation</td><td>time profile and CO_2 concentration</td><td>time profile and stack effect control</td></tr>
<tr><td>Heating energy source</td><td colspan="2">natural gas boiler</td></tr>
<tr><td>Electricity source</td><td colspan="2">national grid</td></tr>
</table>

As results the hourly heating and electricity energy consumption, as well as indoor temperature were calculated.

3. Results and Discussion

Calculated energy consumption for each variant of ventilation system is presented on Fig. 3 (heating energy) and Fig. 4 (electricity).

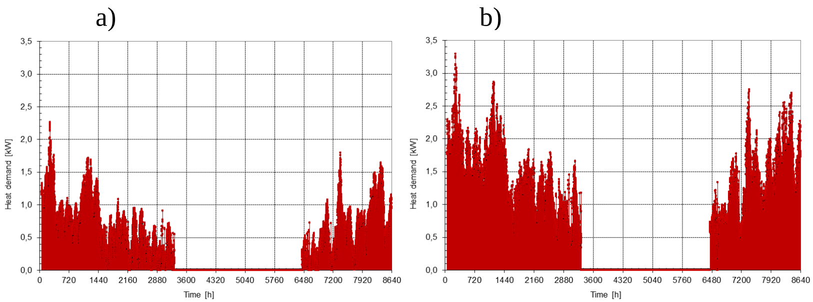

Fig. 3 Heating energy consumption for classroom with mechanical ventilation with HR (a) and with hybrid ventilation (b)

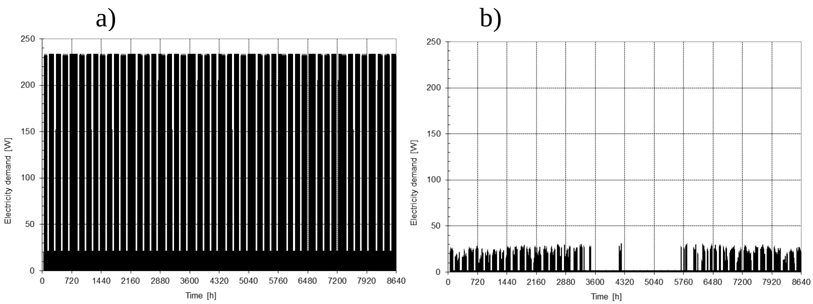

Fig. 4 Fans electricity consumption for classroom with mechanical ventilation with HR (a) and with hybrid ventilation (b)

These results were obtained for similar ventilation rate and indoor temperature provided by central heating system (fig. 5)

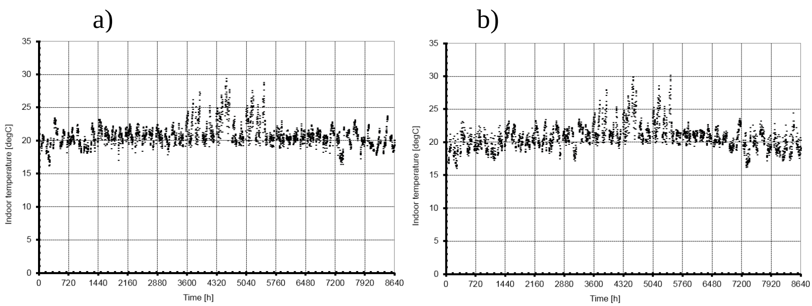

Fig. 5 Indoor temperature (only hours of oparating time) for classroom with mechanical ventilation with HR (a) and with hybrid ventilation (b)

It is obvious that mechanical ventilation with heat recovery consumes less energy than ventilation without HR. At the same time mechanical ventilation needs more electricity for fans (and sometimes for anti-frosting procedure) than hybrid ventilation. Fig. 6 and Fig. 7 present heating and electric energy consumption in a function of outdoor temperature. According to these results it may be observed that more heating energy is consumed during winter time and maximum heating energy demand for a room with mechanical ventilation reaches almost 2.5 kW, and 3.5 kW for hybrid ventilation. Heating season starts at 6-14°C for HR ventilation and about 14°C for hybrid ventilation.

a) b)

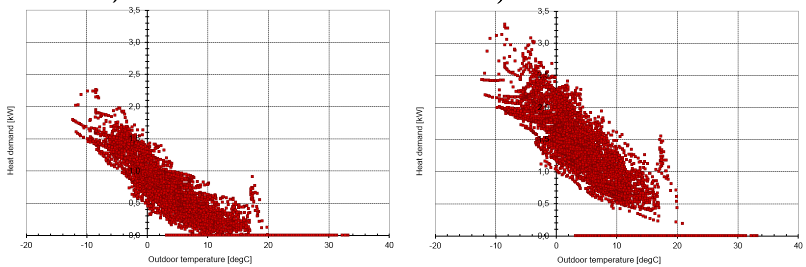

Fig. 6 Heating energy consumption as a function of outdoor temperature for classroom with mechanical ventilation with HR (a) and with hybrid ventilation (b)

a) b)

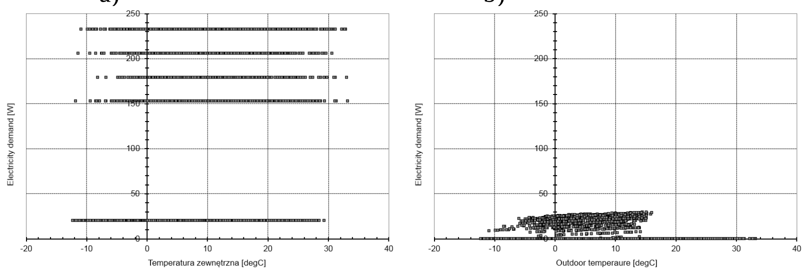

Fig. 7 Fans electricity consumption as a function of outdoor temperature for classroom with mechanical ventilation with HR (a) and with hybrid ventilation (b)

Electric energy consumption profile is more complex. It depends mainly on occupancy in rooms with mechanical ventilation which is controlled with CO_2 concentration. In rooms with hybrid ventilation electric energy consumption is reduced during winter, when stack effect is enough for driving the air and during summer time when opening windows is the main ventilation strategy.

As mechanical balanced ventilation with HR needs less heating energy and more electric energy, and hybrid ventilation quite opposite, better comparison can be possible for primary energy. In Poland according to the national law, primary energy conversion factor is 1.2 for natural gas boiler and 3.0 for electricity [4]. Fig. 8 presents energy profiles of the two analysed cases.

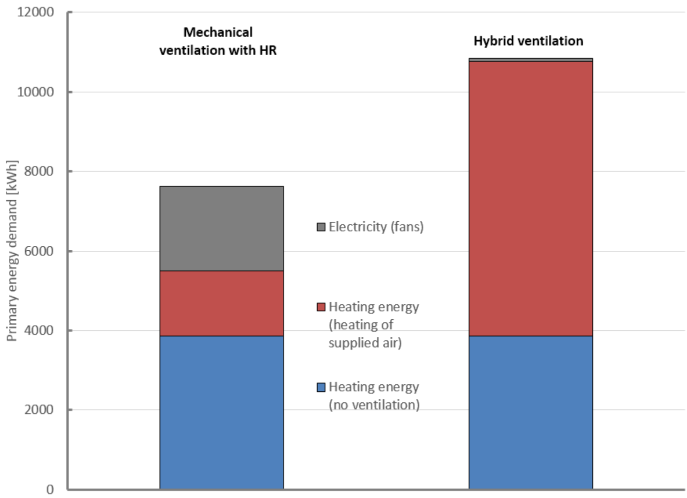

Fig. 8 Comparison of primary energy consumption for classroom with mechanical ventilation with HR and with hybrid ventilation

4. Conclusions

Mechanical ventilation with HR in our specific case consumed about 40% less primary energy (for heating and ventilation) than hybrid ventilation when for both cases the indoor comfort was quite similar. Ventilation rate was controlled in both cases. In rooms with mechanical ventilation with HR ventilation rate was controlled according to CO_2 concentration, and in rooms with hybrid ventilation it was controlled as time profiled constant ventilation and additionally, accordingly to stack force. As during cold period outdoor air is supplied to a room without any preheating it was necessary to increase designed indoor temperature to 22°C for hybrid ventilation to provide similar thermal comfort in both cases.

The higher primary energy consumption of hybrid ventilation may be compensated with easier service of the system and lower investment costs at the beginning. Hybrid ventilation may be successful strategy as it can provide required comfort, but only if energy consumption is not crucial.

Acknowledgments

The paper was written due to the support of RENEW SCOOL Project co-funded by the Intelligent Energy Europe Programme of the European Union.

Co-funded by the Intelligent Energy Europe Programme of the European Union

References

[1] EN 15241 Ventilation for buildings – Calculation methods for energy losses due to ventilation and infiltration in commercial buildings.
[2] ISO-FDIS 13790: *Energy performance of buildings - Calculation of energy use for space heating and cooling*, ISO/TC 163/SC 2, 2007.
[3] Narowski P., Mijakowski M., Panek A., Rucińska J., Sowa J., Integrated 6R1C energy simulation method – principles, verification and application, CLIMA 2010, 11th REHVA World Congress "Sustainable Energy Use in Buildings", 9th – 12th May 2010, Antalya, Turkey, ISBN 978-975-6907-14-6
[4] Ordinance of Ministry of Infrastructure on methodology of energy certification calculation, Polish Government, 2015
[5] Santamouris M., Synnefa A., Assimakopoulos M., Livada I.,Pavlou K., Papaglastra M., Gaitani N.,Kolokotsa D, Assimakopoulos V., Experimantal investigation of the air flow and indor corbon dioxide concentration in classrooms with intermittent natural ventilation, Energy and Building 40 (2008 1833-1843