Kravchenko, Ilia; Kosonen, Risto; Kilpeläinen, Simo

Comparison of IAQ in mechanical balanced and natural ventilated in apartment buildings

Published in:
Sisäilmastoseminaari 2021. Verkkoseminaari 9.3.2021

Published: 01/01/2021

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

Please cite the original version:
Kravchenko, I., Kosonen, R., & Kilpeläinen, S. (2021). Comparison of IAQ in mechanical balanced and natural ventilated in apartment buildings. In *Sisäilmastoseminaari 2021. Verkkoseminaari 9.3.2021* (pp. 189-194). (Sisäilmayhdistys raportti ; No. 39). SIY Sisäilmatieto Oy.

COMPARISON OF IAQ IN MECHANICAL BALANCED AND NATURAL VENTILATED IN APARTMENT BUILDINGS

Ilia Kravchenko[1,*], Risto Kosonen[1,2] and Simo Kilpeläinen[1]

[1]Department of Mechanical Engineering, School of Engineering, Aalto University
[2]Department of HVAC, College of Urban Construction, Nanjing Tech University, China

HANDOUT

The paper focuses on comparing the indoor climate in a modern apartment building with mechanical balanced ventilation system to a building with natural stack effect ventilation. The results of 9-month measurements of CO_2 concentration level, indoor air temperature and relative humidity are presented. Overall, the CO_2 concentration level in the building with the mechanical balanced ventilation is significantly lower in winter and comparable in the summertime. The indoor temperature in building with natural stack ventilation was lower during the cold period. The relative humidity level is closer to preferable in the building with stack induced ventilation most likely due to lower airflow rates.

INTRODUCTION

The Nordic climate combined with the tight energy requirements of the Finnish building code implicates strict requirements to the building's energy efficiency. Thus, envelope airtightness and thermal insulation for the residential buildings have been emphasized during the last years[1,2]. The majority of the residential ventilation systems are represented by mechanical exhaust or mechanical balanced ventilation in Finland. However, some old buildings or heritage buildings are equipped with natural stack ventilation with controllable air inlets and trickle vents[3]. Trickle vents are a ventilation device that transfers outdoor air to the inside[4,5]. Standard solutions control the inlet airflow rate by pressure difference, temperature difference or outdoor temperature to ensure the designed airflow rates[5]. However, it is reported that buildings with natural stack ventilation have issues with indoor air quality (IAQ) and cold draughts[6,7]. This paper is focused on the ventilation performance of the apartment building, that has been renovated after 2018 and equipped with natural stack ventilation with trickle vents with outdoor temperature control. The ventilation performance is compared with a building with mechanical balanced ventilation based on the 9-month temperature, relative humidity and CO_2 measurements.

METHODOLOGY

Two buildings in Helsinki, Southern Finland, were selected for the analysis. The building with mechanical balanced ventilation was built in 2019, further, it is called building A. The building with natural stack was built in 1951 and most recently renovated in 2019, further, it is called building B. Both buildings have several staircases, and one staircase in each building was chosen for the analysis. Both buildings' staircases have five floors with a floor height of 3 m. The first floor is non-residential, and the 4 above are residential. The mechanical balanced ventilation system supplies the air in the bedrooms and living rooms and exhausts it in bathrooms, kitchens and storage rooms. The average air change rate in apartments is 1 1/h with a minimum of 0.5 1/h on room level. The natural stack ventilation system is equipped with self-regulating inlet air terminal devices, also called trickle vents in the living rooms and bedrooms. The stack ducts are located in the bathroom and kitchen. The average air change rate apartments is 0.5 1/h with a designed airflow rate at 5 Pa pressure difference and outdoor temperature 15 ºC and higher. The windows are equipped with openable sections and the balcony doors are also openable. The overall structure is shown in Figure 1. For the analysis, the one-room and three-room apartments were chosen. The occupancy of one-room apartments and three-room apartments are 1 and 3 persons respectively.

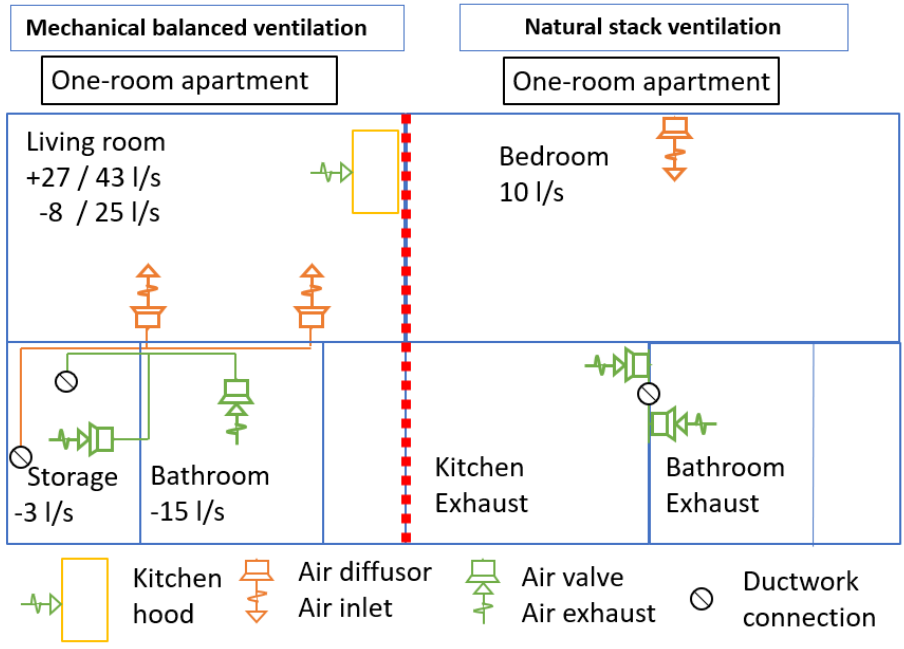
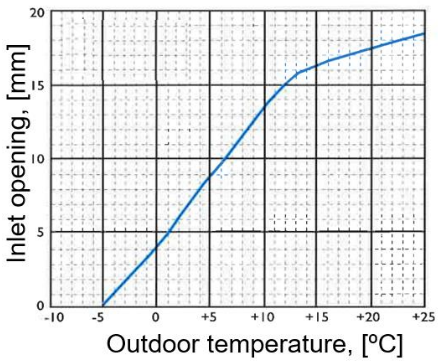


Figure 1. The apartment ventilation system of the building with mechanical balanced ventilation on the left and natural stack ventilation on the right.

The trickle vents are controlled by the outdoor temperature and have a linear dependency with damper opening. The damper is 4 mm open at -5 ºC and 20 mm open at +15 ºC. based on the manufacturer’s product data. The opening and airflow rate as a function of outdoor air temperature are presented in Figure 2. The performance of the self-regulating air inlet is presented in Figure 3.



Living room

Flow rate, [l/s]				
Pressure, [Pa]				Opening, [mm]
5	10	20	30	
3,2	4,9	7,5	9,5	4
4,5	6,9	11	13	8
4,9	7,5	12	14	12
5,1	7,8	12	15	16

Bedroom

Flow rate, [l/s]				
Pressure, [Pa]				Opening, [mm]
5	10	20	30	
4,5	6,6	9,5	13	4
7,0	11	16	21	8
8,5	13	20	25	12
9,3	14	22	28	16

Figure 2. The air inlet thermostat opening characteristics on the left and inlet airflow characteristics on the right

The vents are adjusted to supply 10 l/s and 5 l/s for bedrooms and living rooms respectively at a pressure difference of 5 Pa with outdoor temperature 15 ºC and higher according to the product data.

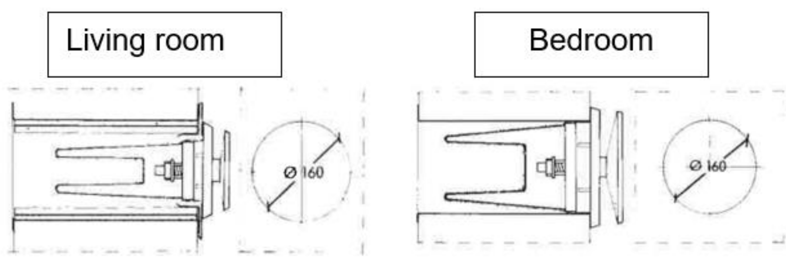


Figure 3. The self-regulating air terminal devices for living rooms and bedrooms.

Measurements

The measurements were carried out from January to September 2020. The sensors have been placed on the windowsills opposite the openable windows side in bedrooms. The data with information about pressure difference, absolute pressure, temperature, relative humidity and CO_2 level have been recorded every 5 minutes using devices Miranlink IAQ. Sensor accuracy is: temperature ± 0.3 °C, relative humidity ± 2.5% (20 - 80% RH), barometric pressure ± 1.0 mbar (abs.) and ± 0.12 mbar (rel.), CO_2 ± 50 ppm

Data analysis

The analysis has been carried out with the help of python 3.0 libraries: NumPy, Pandas and Plotly.

The following data processing was applied[8]:

- filtering missing points
- identifying outliers and inconsistency correction
- hourly averaging

The mean hourly sensor reading has been calculated for relative humidity, temperature and CO_2 level. For the duration curve figures, the time period was normalized.

RESULTS

The results are presenting the data measured for one-room and three-room apartments of building A and B. The box plot figures present the dependency in the outdoor air temperature and indoor CO_2 level, room air temperature and relative humidity (Figure 5). The duration curve figures represent the overall time spent in different indoor climate level conditions according to EN 15251 (Figure 4). The data is divided into two time periods: January to April and May to September, to show the influence of the additional window opening ventilation in the building with natural stack ventilation in the warm period.

The performance of ventilation in one-room apartments is acceptable for both buildings and has a warning level in three-room apartments of building B.

In the cold period in one-room apartments, occupants spent about 99% of time in IDA 1 conditions with mechanical balance ventilation, and with natural stack ventilation occupants spent about 60% in IDA 1, 30% in IDA 2 and 10 % in IDA 3 conditions. In three-room apartments, occupants spent about 90% of time in IDA 1 and 10 % in IDA 2 conditions with mechanical balance ventilation, and with natural stack ventilation occupants spent only about 20% in IDA 1, 20% in IDA 2, 40 % in IDA 3 and 20% in IDA 4 conditions, shown in Figure 3

In the warm period performance of the building, A is on the same level, but the performance of building A is higher than in cold period due to additional ventilation via windows opening. In one-room apartments with natural stack ventilation occupants stays in the same conditions with slight changes within IDA category. In three-room apartment ventilation performance improved significantly with about 40% in IDA 1, 20% in IDA 2, 30 % in IDA 3 and 10% in IDA 4 conditions with overall more than 60% of the time under 1000 ppm. The additional windows opening ventilation has a significant effect on indoor conditions, shown in Figure 3

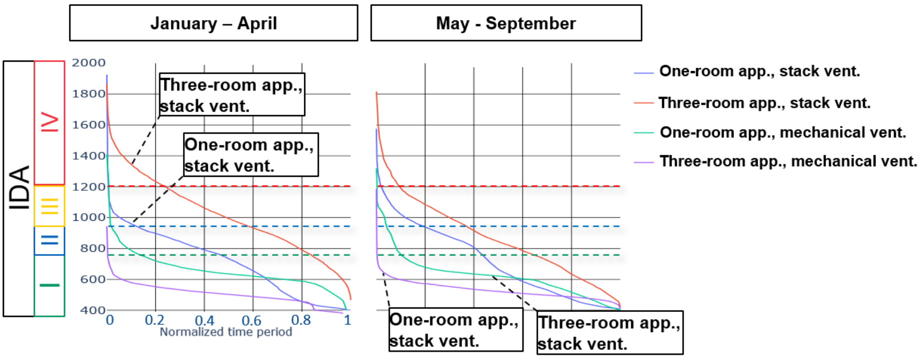


Figure 4. The duration CO_2 curves of the buildings with natural stack and mechanical balanced ventilation

The overall air temperature trend shows the normal heating systems' performance in both buildings. The low temperature readings in the building B are due to the sensor placement and periodic windows opening. CO_2 level shows that trickle ventilation is not able to maintain CO2- concentration in the target level below 1000 ppm during the cold period. The relative humidity has a preferable level in the building with stack ventilation due to the lower ventilation rates and lower moisture extraction.

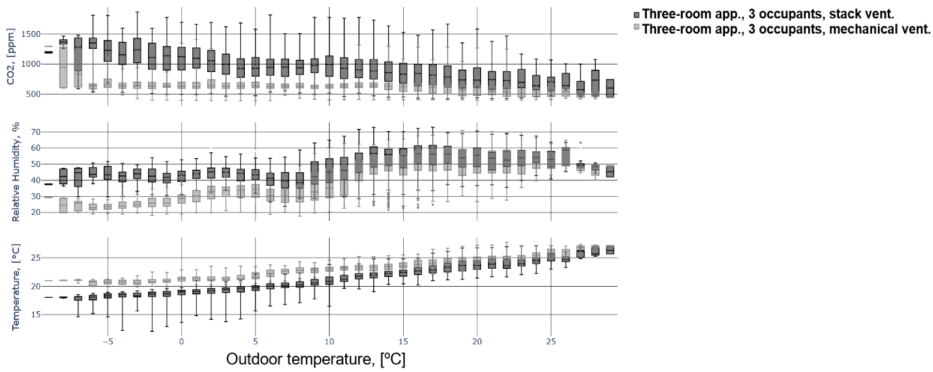


Figure 5. Comparison of three-room apartment CO_2 level, humidity and temperature with mechanical and natural ventilation

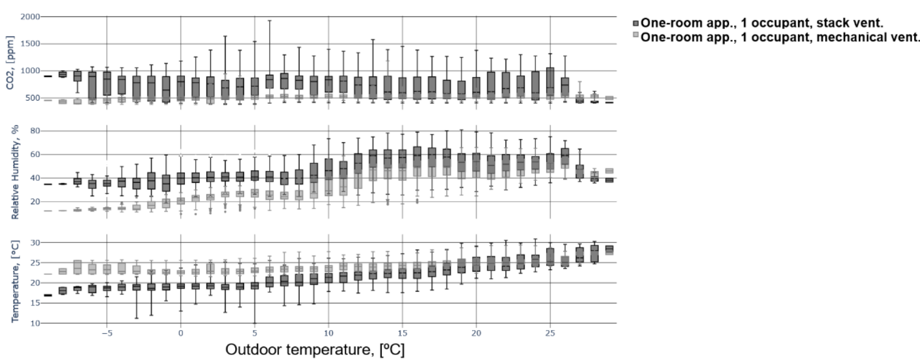


Figure 6. Comparison of one-room apartment CO_2 level, relative humidity and temperature with mechanical and natural ventilation

CONCLUSION

This paper assesses the IAQ of the new apartment building with mechanical balanced ventilation and renovated old apartment building with modern natural stack ventilation with trickle vents, where the ventilation was controlled based on the outdoor temperature. Based on conducted 9-month measurements, the CO_2 concentration level in building with the mechanical balanced ventilation was significantly lower during the whole observed period. Performance of the natural stack ventilation combined was better in a warm period than in the cold due to additional ventilation with windows opening. The indoor temperature with natural stack ventilation was lower during the cold period. The relative humidity level was closer to preferable in the building with stack ventilation due to lower airflow rates. Overall, indoor climate was better in the building with a mechanical balanced ventilation system.

BIBLIOGRAPHY

1. Brelih N, Seppanen O. Ventilation rates and IAQ in European standards and national regulations. Proc 32nd AIVC Conf 1st TightVent Conf Bruss. January 2011.
2. The National Building Code of Finland. Ympäristöministeriö. https://ym.fi/en/the-national-building-code-of-finland. Accessed November 11, 2020.
3. Rämö A. Statistics Finland - Building stock 2019. http://www.stat.fi/til/rakke/2019/rakke_2019_2020-05-27_kat_002_en.html. Accessed November 5, 2020.
4. Willems L, Janssens A. Performance prediction of dwelling ventilation with self-regulating air inlets. :6.
5. Biler A, Unlu Tavil A, Su Y, Khan N. A Review of Performance Specifications and Studies of Trickle Vents. Buildings. 2018;8:152.
6. Pinto M, Viegas J, de Freitas VP. Air permeability measurements of dwellings and building components in Portugal. Build Environ. 2011;46:2480–2489.
7. Ramos NMM, Almeida RMSF, Curado A, Pereira PF, Manuel S, Maia J. Airtightness and ventilation in a mild climate country rehabilitated social housing buildings – What users want and what they get. Build Environ. 2015;92:97–110.
8. Han J, Pei J, Kamber M. Data Mining: Concepts and Techniques: Concepts and Techniques. Elsevier; 2011.