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Ventilation rates and CO_2-levels before and after energy retrofits in Finnish apartment buildings

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Abstract

This paper focuses on assessment of CO_2 concentrations and ventilation rates before and after energy retrofit. The majority of the studied apartment buildings were built between 1960 and 1980. Most typical retrofitting actions performed included installing new windows, adding heat recovery system for ventilation system, and / or adding thermal insulation on external walls. Majority of the buildings had mechanical exhaust ventilation system, where more efficient exhaust is typically turned on for two hours once or twice a day: in the morning between 6am and noon, and in the afternoon between 4pm and 8pm. The 24-hour average CO_2 concentration was 749 ppm before energy retrofits and 707 ppm after retrofits. The average CO_2 concentration between 5pm and 8am was 681 ppm and 658 ppm before and after retrofits, correspondingly. Therefore, CO_2 concentrations both before and after retrofits were relatively low. The average ventilation rates were 0.43 ACH before and 0.48 ACH after retrofits. Some correlations between ventilation rate and CO_2 concentrations can be found from measured data of case buildings equipped with mechanical exhaust ventilation. The CO_2 concentrations and ventilation rates were improved after retrofits in most cases. Pressure differences across envelope and inlet routes of supply air are expected to change as a result of a retrofit, especially if the airtightness of building envelope is improved. Therefore, it is important that the ventilation system is re-balanced after such retrofits. Measurements of CO_2-levels and ventilation rates before and after energy retrofits can be used to assess the situation.

Keywords - ventilation; energy retrofit; IEQ; apartment building (key words)

1. Introduction

The objective of the project (INSULAtE) was to demonstrate the effects of energy retrofits on indoor environmental quality (IEQ) and occupant satisfaction and wellbeing, and to develop a common assessment protocol [1]. The assessment protocol includes measurement of building related parameters (ventilation rate, pressure difference across envelope, thermal conditions), IEQ parameters (including carbon dioxide (CO_2) and carbon monoxide (CO) concentrations, and various indoor air pollutants), and questionnaires to the occupants. Assessments have been performed in 45 Finnish apartment buildings before and after energy retrofits. Also some control buildings (without retrofits) were included in the study. This paper focuses on assessment of CO_2 concentrations and ventilation rates.

2. Case study buildings

The age distribution and performed retrofitting methods are presented on Fig. 1. The majority of the buildings were built between 1960 and 1980. Most typical retrofitting actions performed included installing new windows, adding heat recovery system for ventilation system, and / or adding thermal insulation on external walls. The number of studied apartments was 130, including 10 apartments in Control buildings without any retrofit actions. Majority of the retrofitted buildings (119 apartments) had mechanical exhaust ventilation system, where more efficient exhaust is typically turned on for two hours once or twice a day: in the morning between 6am and noon, and in the afternoon between 4pm and 8pm.

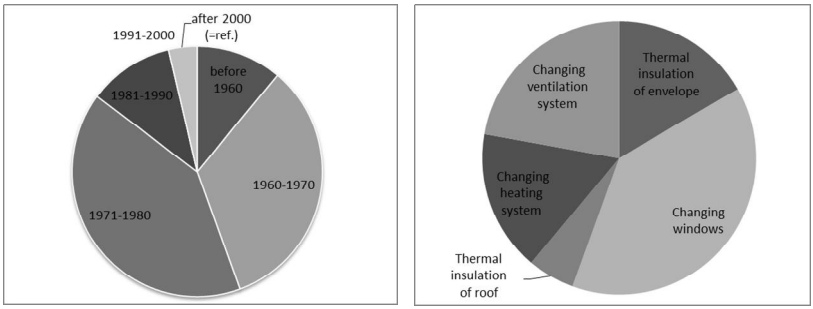

Fig. 1 The age distribution and performed retrofitting methods of the case study builings

3. Methods

Air flows were measured from the exhaust vents using rotating vane anemometer (Testo 417) with built-in 100mm vane and temperature probe, based on which the ventilation rates were calculated. Carbon dioxide (CO_2)

and carbon monoxide (CO) concentrations were measured every minute during a 24-hour period, usually in the living room, using portable meter (Delta OHM HD21AB/HD21AB17).

4. Results

The 24-hour average CO_2 concentration of Case buildings (retrofitted) was 749 ppm before energy retrofits and 707 ppm after retrofits. The 24-hour average CO_2 concentration of Control buildings (no retrofits) were about the same in both measurements, 628 and 625 ppm, respectively. The average CO_2 concentration between 5pm and 8am of the Case buildings was 681 ppm and 658 ppm before and after retrofits, correspondingly. The average CO_2 concentration between 5pm and 8am of the Control buildings was 657 ppm in 1st measurement and 590 ppm in 2nd measurement. The sample size of Control buildings was quite small, about 10 apartments, and therefore any deep conclusions could not be drawn. However, the CO_2 concentrations both before and after retrofits were relatively low. Also the CO_2 concentrations in Control buildings were low.

The average ventilation rates of Case buildings equipped with mechanical exhaust ventilation system were 0.44 ACH before (Pre) and 0.48 ACH after (Post) retrofits. The average ventilation rates of Case buildings which had natural ventilation were 0.25 ACH both before after retrofits. The average ventilation rates of Control buildings were 0.59 ACH in the first measurement and 0.45 ACH in the second measurement. The ventilation rates of Case buildings with mechanical ventilation varied between 0.02 … 1.04 ACH before retrofits and between 0.03 … 1.57 ACH after retrofits. The lowest values were measured when exhaust was off, obviously.

Table 1. Average ventilation rates, ACH.

	CASE_Mechanical		CASE_Natural		CONTROL_Mechanical	
	Before	After	Pre	Post	1st measur.	2nd measur.
N	119	71	11	8	10	8
Average	0.43	0.48	0.25	0.25	0.59	0.45
Max	1.04	1.57	0.45	0.41	1.00	0.64
Min	0.02	0.03	0.07	0.14	0.18	0.24

The average CO_2 concentrations of Case buildings which had mechanical ventilation during time of air flow measurement was 913 ppm and 834 ppm before and after retrofits.

5. Analysis

The CO_2 concentrations and ventilation rates were improved after retrofits in most cases, especially among buildings which had mechanical exhaust ventilation system. Weak correlations between ventilation rate and CO_2 concentrations can be found from measured data of Case buildings equipped with mechanical exhaust ventilation. The Pearson correlation value among measured data was -0.28 before retrofits and -0.19 after retrofits.

While in many cases the CO_2 concentrations and ventilation rates were improved, in some cases opposite trends were seen. Pressure differences across envelope and inlet routes of supply air are expected to change as a result of an energy retrofit, especially if the airtightness of the building envelope is improved. Therefore, it is important that the ventilation system is re-balanced after such retrofits. Measurements of CO_2-levels and ventilation rates before and after energy retrofits can be used to assess the situation.

6. Conclusions

The CO_2 concentrations and ventilation rates were assessed before and after energy retrofits in multi-family apartment buildings. The CO_2 concentrations and ventilation rates were improved after retrofits in most cases, especially among buildings which had mechanical exhaust ventilation system. However, in some cases opposite trends were seen. It is important that the ventilation system is re-balanced after such retrofits. Measurements of CO_2-levels and ventilation rates before and after energy retrofits can be used to assess the situation and also to assess IEQ.

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