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Air pressure difference between indoor and outdoor or staircase in multi-family buildings with exhaust ventilation system in Finland

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Abstract

Pressure differences between outdoors and indoors influence indoor environmental quality (IEQ) and building physics of the building envelope. This paper focuses on measurements of pressure difference values of about 152 apartments from 26 multi-family buildings in Finland. Measured data include pressure differences between indoor spaces and both outdoors and staircases before and after renovation. In buildings equipped with mechanical exhaust, the pressure differences between indoors and outdoors before renovation varied from +10,1 to -95,0 Pa (average -7,8 Pa), and between indoors and staircases from -3,5 to -6,0 Pa (average -18,6 Pa), being lower than -5 Pa in 36% of the buildings. In naturally ventilated buildings, the pressure differences between indoors and outdoors were lower than -5 Pa in 44% of the buildings. The average pressure differences after renovation in nine buildings equipped with mechanical exhaust were slightly higher (-19,1 Pa against outdoor and -9,0 Pa against staircase). A possible reason for higher negative pressure could be that the airtightness of building was improved by renovation, but the ventilation system was not balanced accordingly. Improving energy efficiency (EE) could effect on pressure difference either positively or negatively. Measured pressure difference between indoors and outdoors or staircase before and after renovation could be a possible indicator when assessing the impacts of improving EE on IEQ and occupant satisfaction.

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1. Introduction

Due to high over pressure between outdoors and indoors, the moist indoor air could transfer into the structures and condensate on cold surfaces. On the contrary, high under pressure could result in decreased IEQ when impurities from the structures and surroundings (including radon from the beneath soil) could be sucked to indoor air. INSULAtE project (www.insulateproject.eu) has been developing a common protocol for assessment of IEQ and demonstrating the protocol in energy retrofit case study buildings in Finland and Lithuania. This paper focuses on measurements of pressure difference values of about 145 apartments from 27 multi-family buildings in Finland. Also some data will be presented on pressure differences after energy efficiency (EE) of the buildings is improved.

Stack effect (temperature gradient), wind, and ventilation affect pressure differences over building envelope. Also distributions of air leakage sites influence the air pressure differences. Pressure difference is a driving force for the airflows transporting water vapour and gaseous contaminants through the envelope. In cold climate, if the air pressure is higher indoors, air with high moisture content could flow to the cold envelope structures and condensate, causing possible mold growth, reduction of thermal insulating properties, or structural deterioration. If the air pressure is lower indoors, impurities from ground, outdoors and envelope structures flows indoors, causing deterioration of IEQ [1].

According to the National Building Code of Finland [2], the buildings should be maintained under negative pressure conditions (under pressure) related to outdoor, in order to avoid moisture damage to the building envelope. Higher negative air pressure could cause infiltration of airborne gaseous and particulate outdoor or crawl-space or ground floor contaminants (for instance radon), if the buildings envelope is not airtight. Special attention should be paid into floor-wall, wall-roof and other joints.

The Ministry of Social Affairs and Health of Finland has given guidelines (Table 1) for pressure difference between indoor and outdoor as well as indoor and staircase depending on ventilation systems [3].

Table 1. Guidelines for pressure difference [3] (Guide for Occupational Health, 2009).

Ventilation system	Pressure difference
Natural	0…-5 Pa against outdoor
	0 Pa against staircase
Mechanical exhaust	-5…-20 Pa against outdoor
	0…-5 Pa against staircase
Mechanical inlet and exhaust	0…-2 Pa against outdoor
	0 Pa against staircase
Note: Pressure differences vary a lot enclosed to weather	

2. Case study buildings and methods

Case studies were a part of INSULAtE project (Improving energy efficiency of housing stock: impacts on indoor environmental quality and public health in Europe). Case study buildings include 26 multi-storey residential apartment buildings (152 apartments) in Finland. The buildings were selected among volunteers where some actions influencing the energy efficiency have been performed during duration of the project (2010-2015). Most typical retrofitting actions performed were installing new windows, installing heat recovery system for ventilation system, and / or adding thermal insulation on external walls.

Measurements were performed inside apartments of the case study buildings. The number of measured apartments within a case building varied from one to eleven. Fig 1 shows the distribution of construction decades of the case study buildings. Majority of the apartments (137) were in buildings equipped with mechanical exhaust ventilation system, while the rest (15) had natural ventilation. 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.

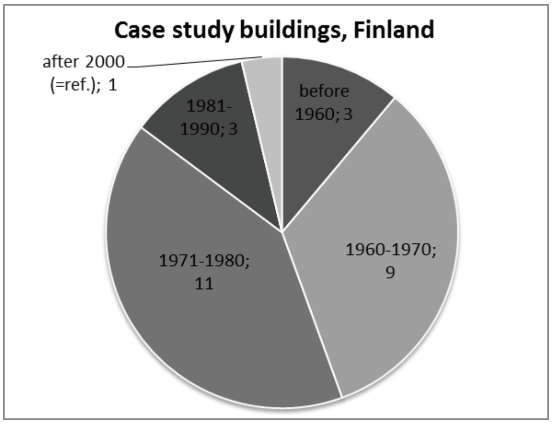

Fig. 1. Distribution of construction decades of the cases.

Air pressure differences were measured with calibrated Testo 512 differential pressure meter. The pressure range of this device is 0 to 2 hPa, pressure resolution 0,001 hPa, pressure overload 10 hPa, and accuracy ±05%. Operating temperature range of the device is 0 to 60°C and temperature resolution is 0,1°C. The pressure difference was measured at two sites, if possible. Pressure differences between apartments and staircases were measured through mailbox by installing measuring outlet tube through the mailbox. Pressure differences between apartments and outdoors were measured through a window or balcony door opening by installing measuring flexible metal outlet tube outdoors and closing the window or door carefully, while avoiding blocking the airflow.

3. Results

Pressure difference values between both apartment and staircase and outdoor before renovation have been presented in Fig. 2 and 3.

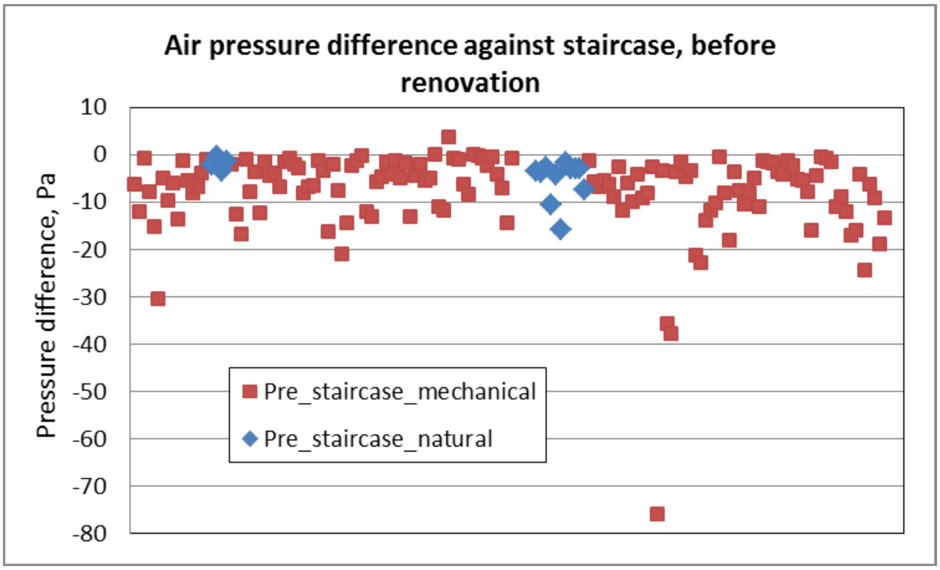

Fig. 2. Measured pressure difference values against staircase, before renovation.

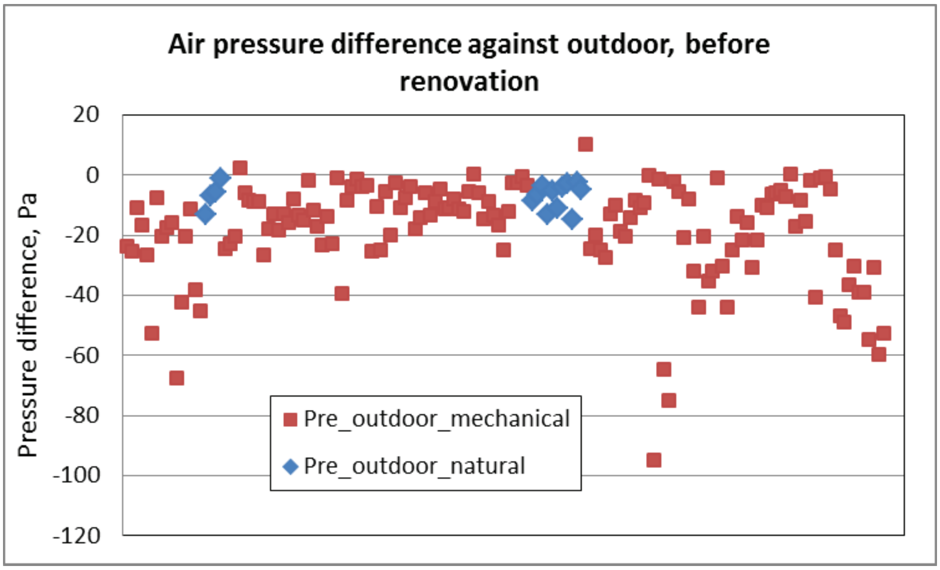

Fig. 3. Measured pressure difference values against outdoor, before renovation.

Average pressure difference against staircase was -7,8 Pa and against outdoor -18,6 Pa for buildings with mechanical exhaust ventilation. Pressure differences against staircase varied from +3,5 to -76,0 Pa and against outdoor from +10,1 to -95,0 Pa. There were higher than -5 Pa negative pressure against staircase in 52% of the apartments, exceeding the guideline values. Negative pressure against outdoor was higher than -20 Pa, exceeding the guideline values, in 36% of the apartments.

Average pressure difference against staircase was -4,5 Pa and against outdoor -7,0 Pa for buildings with natural ventilation. Pressure difference against staircase varied from -0,4 to -15,9 Pa and against outdoor from -1,0 to -15,0 Pa. Guideline values for buildings with natural ventilation are more strict (0 Pa against staircase and 0 to -5 Pa against outdoor). Negative pressure against staircase in all apartments exceeded guideline value (0 Pa). Also there was higher negative pressure than -5 Pa against outdoor in 60% of apartments.

Data on pressure differences after renovation are available from nine buildings (43 apartments). Fig 4 shows measured pressure differences before and after renovation. Only two of the apartments had natural ventilation (marked into chart, Fig.4). In buildings with mechanical exhaust ventilation, average pressure difference against staircase after renovation was -9,0 Pa and against outdoor -19,1 Pa. Higher negative pressure than -5 Pa against staircase was now measured in 70% of apartments. Negative pressure against outdoor was higher than -20 Pa in 44% of apartments, respectively.

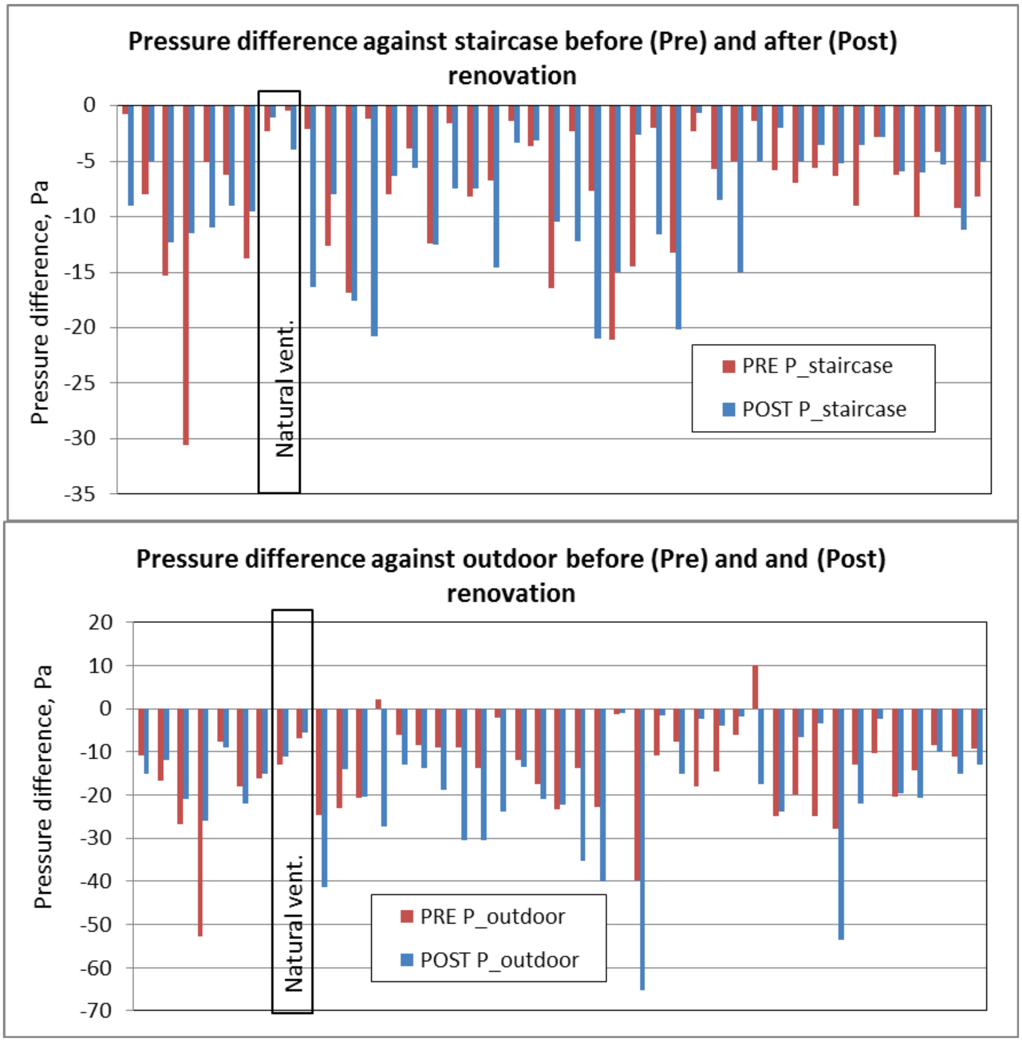

Fig. 4. Measured pressure difference values against staircase and outdoor before (Pre) and after (Post) renovation.

4. Discussion

Measured average pressure differences are quite similar than in a long-term (about one month) measurement of two apartment buildings, reported by Kalamees [4]. In their study the pressure differences of all four apartments were negative almost whole measurement period. The daily average air pressures at the first floor were -11 Pa and -7 Pa. At the fourth floor the averages were -2 Pa in both buildings, respectively. Based on moisture convection simulation it was suggested that air pressure difference across the building envelope, against outdoor, should be close ±10 Pa [4].

While the pressure differences reported in this paper are one-off measurements, there are some uncertainties concerning climate conditions (wind and indoor-outdoor temperature differences) and operating time of exhaust system. Especially in buildings with natural ventilation, the pressure difference is closely related to wind and indoor-outdoor temperature difference (stack effect).

The average pressure difference levels after renovation were slightly higher than before renovation or there is higher negative pressure. However, the pressure difference values in some buildings were improved. The reason for higher negative pressure could be that the airtightness of building was improved by renovation, but the ventilation system was not balanced, or there are no designed routes of compensation air for exhaust ventilation. It is reported [4] that the air pressure difference may increase up to ±30 Pa.

Pressure difference between outdoor and indoor influences indoor environmental quality (IEQ) and building physics of building envelopes. Improving EE could effect on overall pressure difference positively or negatively. Measured pressure differences between apartment and outdoor or staircase before and after renovation could be a possible indicator for impact of improving EE on IEQ, and also related to occupant satisfaction.

5. Conclusions

Air pressure differences between indoors and staircase and outdoors have been measured before and after improving EE of multi-family buildings in Finland. Average pressure difference against staircase was -7,8 Pa and against outdoor -18,6 Pa for buildings with mechanical exhaust ventilation (137 apartments). Average pressure difference against staircase was -4,5 Pa and against outdoor -7,0 Pa for buildings with natural ventilation (15 apartments). Data on pressure differences after renovation are available from nine buildings (43 apartments In buildings with mechanical exhaust ventilation, average pressure difference against staircase after renovation was -9,0 Pa and against outdoor -19,1 Pa. The average pressure difference levels after renovation were slightly higher than before renovation or there is higher negative pressure.

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